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Horticultural Studies 2003

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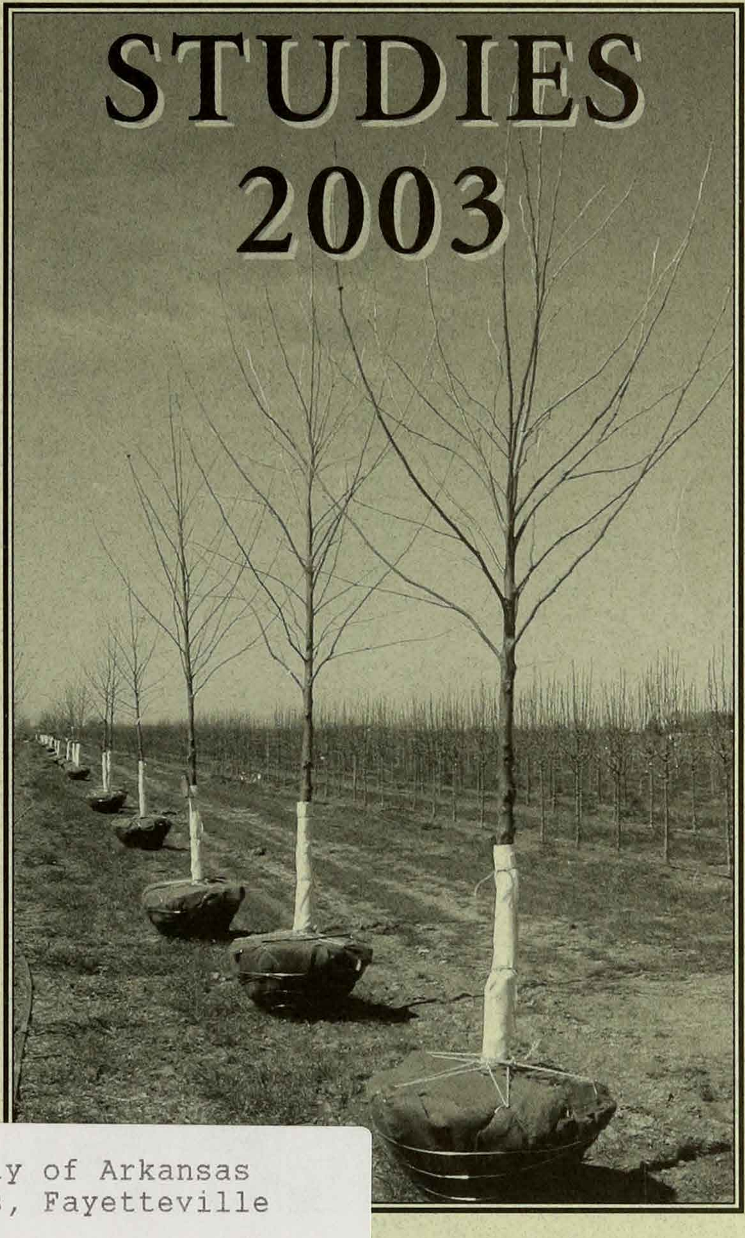
HORTICULTURAL STUDIES 2003



**Edited by James A. Robbins,
Brad Murphy,
and Mike Richardson**

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HORTICULTURAL STUDIES 2003

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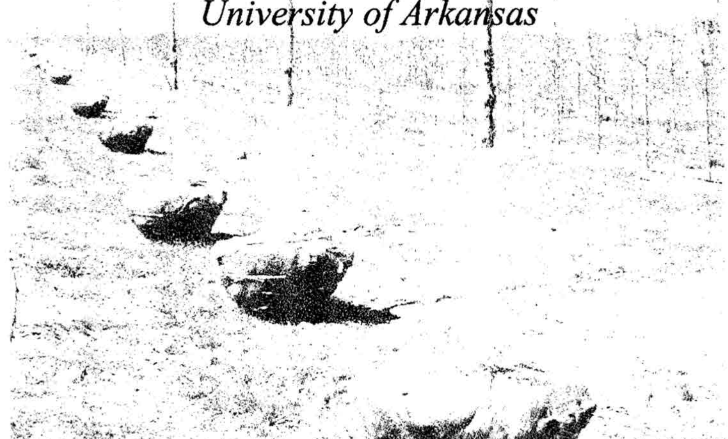

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PREFACE

We are pleased to bring you the sixth 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 in the Agricultural Communications Unit for the technical editing, design, and printing of this document.

We hope you find value in *Horticultural Studies 2003*. Contact us with any comments or questions!

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FRUITS

Propagation of Thornless Arkansas Blackberries by Hardwood Cuttings

M.M. Bray, C.R. Rom, and J.R. Clark[1]

Additional index words: *Rubus* sp., Floricane stem cuttings

Summary. Affects of auxin application and cutting location on canes on adventitious root development in hardwood cuttings of three Arkansas thornless blackberry cultivars were studied. Dormant canes were collected from one-year-old plants of 'Apache', 'Arapaho', and 'Navaho' and stored in a cold room until February. Two- or three-node cuttings were taken from the canes at apical, mid, and basal locations along the cane and were placed under intermittent mist in a perlite-filled greenhouse bed. Cuttings were either untreated or treated with auxin indole-3-butyric acid (IBA), applied as a liquid quick dip at 0.3%. In general, cutting diameter was greatest for basal, and smallest for apical cuttings. Significant interactions were observed for cultivar and cutting location, and cultivar and auxin treatment for rooting. 'Apache' with auxin treatment had the highest rooting percentage, and 'Arapaho' and 'Navaho' with auxin the lowest. For cuttings that rooted, auxin treatment increased the root rating, representing root system development, for 'Apache' and 'Navaho' but had no affect on 'Arapaho'.

Improvements in blackberry cultivars from the University of Arkansas fruit breeding program have contributed significantly to the expansion of commercial blackberry production (Clark, 1999). Thornless blackberry cultivars released from the University of Arkansas breeding program that have contributed to this expansion include 'Apache' (Clark and Moore, 1999), 'Arapaho' (Moore and Clark, 1993), and 'Navaho' (Moore and Clark, 1989). With this expansion the demand for plants has increased along with a need for improved methods of propagation (Busby and Himelrick, 1999).

Nurseries have utilized various propagation techniques and types of vegetative material to propagate desirable genotypes. Common methods of propagating blackberries include: tip layering, leaf-bud cuttings, tissue culture, and root cuttings (Caldwell, 1984). Each method has its disadvantages. Tip-layering involves excessive hand labor to separate canes, few propagules are produced per plant, and weeds are difficult to manage. Successful propagation by tip-layering is also difficult to achieve with erect-cane genotypes. The leaf-bud softwood cutting method has been utilized for high production with some success. Leaf-bud location along cane was observed to affect rooting; consequently, this method has not been widely adopted (Caldwell, 1984). The disadvantage of the tissue culture method is the large initial investment of high tech expensive propagation equipment. Therefore, the use of this method may not be appropriate for small nurseries. Indubitably, growers will choose the method of propagation that most greatly reduces production costs (Caldwell, 1984).

Hardwood cutting propagation is not used commercially but might be of value since the cane material utilized with this method is traditionally pruned and discarded. The advantages of propagating by hardwood cuttings would be the production of more propagules per plant, the utilization of excess cane material, and a reduction of the spread of virus infections. Propagation techniques that generate an increased number of propagules per plant, from otherwise useless, excess plant material would reduce propagation costs for nurseries and could reduce plant costs for growers. In addition to reduced costs, another benefit for growers would be a possible solution to virus transmission among plants. By mass propagating from virus-indexed stock, growers would reduce the rate at which virus infections are spread (Ahrens, 1991). Furthermore, this method of propagation could be useful to plant breeding for timely pollen collection or manipulated pollination procedures (Lopez-Medina and Moore, 1997).

Propagation of blackberries by hardwood and softwood stem cuttings has been successfully achieved without the use of auxin rooting hormone. However, the application of auxin when propagating *Rubus* sp. by stem cuttings has proved valuable for root system enhancement (Busby and Himelrick, 1999; Williams and Norton, 1959). Busby and Himelrick (1999) reported that root development increased on 'Navaho' softwood cuttings treated with 0.3 and 0.8% K-IBA quick dip. Lopez-Medina and Moore (1997) reported that the application of 0.3% IBA improved the volume of roots formed in Arkansas erect-cane blackberries propagated by floricane dormant stem cuttings. Our experiment further studied the propagation of thornless erect-cane blackberries by dormant hardwood cuttings. The purpose was to evaluate a mass propagation system that is simple and efficient for commercial production of several thornless Arkansas blackberries. Specific objectives were to evaluate the effects of cultivar, auxin, and cutting location on rooting of hardwood cuttings.

Materials and methods

On 9 Dec. 2002, at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, one-year-old canes of 'Apache', 'Arapaho', and 'Navaho' were removed from plants grown in cold-frame growing beds and placed in sealed plastic bags. Then the canes were placed in cold storage at 7°C for approximately 2 months to satisfy chill requirement. Two- to three-node hardwood cuttings 4-5 in. (10-12 cm) long were taken on 12 Feb, 2003. The cuttings were taken

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from three locations on the cane; apical, mid, or basal sections. The basal cut on each cutting was made at approximately 0-5 in. (1.5 cm) below the basal node. Cuttings were treated with either no hormone treatment (control) or treated with rooting hormone. The rooting hormone treatment consisted of a commercial auxin (0.3% IBA solution) with a quick dip of 1-3 s. Cuttings were immediately inserted approximately 2 in. (5 cm) deep into propagation beds consisting of a perlite rooting medium. The propagation beds were equipped with heating cables for bottom-heat at 22-25°C, and a mist system. The automatic intermittent mist system was set to mist for approximately 16 s every 10 min during daylight hours. Cuttings remained under mist for 45 d, and then were removed for evaluation of root systems. Propagation beds were located in a heated greenhouse with daily minimum temperature of 15°C and a daily maximum of 25°C. No supplemental lighting was provided. Rooted cuttings were potted in soil-less medium for plant establishment.

The experimental design was a three-by-two factorial design (three cultivars and two auxin treatments) arranged in a randomized complete block design with seven replications of three cuttings for each cultivar and auxin treatment. Treatments were blocked by location in mist beds. Data collected were cutting diameter, number of cuttings that rooted, and rooting rating. The number of cuttings that rooted was expressed as percentage of rooted cuttings. The rating system was a subjective rating of zero to five; where zero represented the absence of roots or a dead cutting, and five an extensive root system. Data were analyzed by analysis of variance using Statistical Analysis System (SAS), and means separated by t-test.

Results and discussion

Analysis of cutting diameter indicated significant ($P \leq 0.05$) sources of variation were cutting location on cane, cultivar and the cultivar by location interaction. For rooting percentage, significant effects were auxin treatment and the cultivar by auxin treatment interaction. Rooting rating sources of variation that were significant were cultivar, auxin, and the cultivar by auxin interaction. Due to significant interactions of all variables, the interaction means will be presented.

Average diameters for apical cuttings of all three cultivars were similar (Table 1). Cuttings taken from mid sections of canes for 'Apache' and 'Navaho' were similar. However, mid-section cuttings of 'Arapaho' averaged 0.8 mm larger in diameter than 'Apache' mid-section cuttings, and 0.6 mm larger in diameter than for 'Navaho'. Furthermore, the average diameters of basal cuttings for all three cultivars were different. 'Arapaho' cuttings were the largest, averaging 0.8 mm larger in diameter than 'Apache', and 0.4 mm larger than 'Navaho'. Although there were some significant differences for cutting diameter, in general the diameter differences for the cuttings were negligible for potential rooting. A Pearson Product Moment Correlation was conducted on the cutting diameter and rooting percent data. The results of the correlation were not significant ($P < 0.05$) and the r value = 0.15. These findings indicate that cutting diameter had no relationship to rooting in the study.

Significant auxin by cultivar interaction for rooting percentage was observed (Table 2). Within the no-auxin treatment, there were no significant differences among cultivars. However, within the auxin-applied treatment, there were significant differences among cultivars. Percent rooting for 'Arapaho' was greatly reduced (47.5% to 14.2%) with the application of auxin. The cultivar with the highest percent rooting was 'Apache' with auxin treatment (47.6%). However, auxin treatment reduced rooting percentage for 'Arapaho' and 'Navaho' compared to control. These findings indicate that with the auxin concentration used (0.3%), these three cultivars responded differently to auxin treatment.

For cuttings that rooted, root rating had significant differences for cultivar and auxin treatment (Table 2). Root ratings for 'Apache' and 'Navaho' with auxin treatment were greater compared to non- treated control. 'Arapaho' cuttings that rooted showed no difference in rooting rating with auxin treatment compared to control.

Several studies on the propagation of *Rubus* sp. by stem cuttings have been reported with inconsistent performance records. Bobrowski et al. (1996) reported that propagation by hardwood stem cuttings is simple but rooting is not always satisfactory. Similarly, we observed that less than 50% of hardwood cuttings established roots. Zimmerman et al. (1980) reported that node position on the cane had no significant effect on rooting of 1-node softwood cuttings, and that softwood cuttings rooted better than one-node, and much better than three-node hardwood cuttings for cultivars 'Smoothstem' and 'Dirksen Thornless'. Zimmerman also reported that IBA had little effect on rooting of softwood and hardwood cuttings for cultivars 'Smoothstem' and 'Black Satin'. Lopez-Medina and Moore (1997) reported that significant differences in percentage of cuttings rooted occurred only for 'Arapaho' and 'Shawnee' but not 'Navaho'. In contrast with Zimmerman's findings, Lopez-Medina and Moore also reported that cultivar by position interaction effect was evident and IBA improved volume of roots formed (Lopez-Medina and Moore, 1997). Busby and Himelrick (1999) reported that thornless blackberry cultivars rooted easily from softwood cuttings in mist beds without the application of auxin, but that with auxin (0.3% and 0.8% IBA) root system development was enhanced for 'Navaho'. However, no specific auxin concentration consistently improved rooting for the cultivars tested. They suggested that a liquid quick dip in 0.3% to 0.8% IBA would enhance the rooting response in a range of blackberry cultivars.

Conclusions

The objective of this study was to determine the effects of auxin treatment and cutting location along canes of three Arkansas thornless blackberry cultivars. The findings suggest that propagation of thornless erect blackberries by hardwood cuttings is feasible, and may have some utility. However, the results indicate that there are differing responses among cultivars with IBA rooting hormone. The findings indicated that although the quality of root systems may be enhanced with the use of rooting hormone, the percentage of rooted plants might be cultivar dependent. With this variation, one could speculate that different concentrations of rooting hormone may have variable effects on the rooting success of thornless erect blackberries. More research is necessary to achieve guidelines for propagating blackberries by hardwood cuttings.

Further studies of related interest may include research on plant establishment with regard to plant precocity and growth habits of blackberries propagated by hardwood cuttings. Blackberries are traditionally perennial plants that produce biennial canes. The first year primocanes are vegetative, whereas the second year floricanes are reproductive. We observed an interesting phenomenon of the blackberries growth habit that deviates from the traditional perennial plant/biennial cane system. We observed a morphological reversion of the floricane cuttings to juvenile plants after the plants rooted and flowered. As anticipated, the majority of cuttings that rooted subsequently produced flowers. However, after the reproductive cycle of the plant was completed the canes did not die as expected. The plants continued to live and produce new vigorous shoots. We observed lateral shoots developing from vegetative buds along canes, as well as new shoots originating from the base of the plants. In concept, propagating by hardwood cuttings has enabled a blackberry plant to complete its efflorescence, but also revert to the vegetative growth period. These observations suggest that propagating blackberries from hardwood cuttings may be of significant value and that more research of blackberry hardwood propagation is warranted.

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Table 1. Interaction means for cutting diameter (mm) of blackberry cultivar and cutting location along canes.

Cultivar	Apical	Mid	Basal	Main effects of cv.
Apache	4.2aC[zy]	4.7bB	5.5cA	4.8b
Arapaho	4.2aC	5.5aB	6.3aA	5.3a
Navaho	4.1aC	4.9bB	5.8bA	4.9b
Main effect of location	4.2C	5.1B	5.9A	-

[z] Means in columns followed by different lowercase letters are significantly different (P< 0.05).
[y] Means in rows followed by different uppercase letters are significantly different (P< 0.05).

Table 2. Interaction means of blackberry cultivar by auxin treatment for percent rooting and root rating (1 to 5 rating with 5 = extensive root system) after 5 weeks.

	Percent rooted			Root rating		
Cultivar	- Auxin	+ Auxin	Main effect of cv.	- Auxin	+ Auxin	Main effect of cv.
Apache	38.1aA[zy]	47.6aA	42.8A	2.1bB	3.5aA	2.8a
Arapaho	47.5aA	14.2bB	30.9A	2.1bB	2.1bB	2.1b
Navaho	38.1aA	26.9bA	32.5A	2.6bB	4.2aA	3.4a
Main effect of auxin	41.3A	29.5B	-	2.3B	3.3A	-

[z]Means in columns followed by different lowercase letters are significantly different (P< 0.05).
[y]Means in rows followed by different uppercase letters are significantly different (P< 0.05).

Early Performance of Peach Cultivars in Southwest Arkansas

M. Carter[1], *C.R. Rom*[2], *and R.K. Striegler*[3]

Additional index words: peaches, late-blooming cultivars

Summary. Peaches (*Prunus persica* (L.) Batsch.), both fresh market and processing, is a major fruit crop in Arkansas. However, production is limited in many years by spring frosts that result in crop loss, and by diseases and insect pests. Selection of late-blooming cultivars in order to avoid frosts with superior resistance to pests and diseases is vital for a successful crop in southwest Arkansas. A peach cultivar evaluation trial containing 29 fresh market cultivars was established in 1999 at the University of Arkansas Southwest Research and Extension Center. Data collection began in the third growing season (2001). The cultivars were evaluated for bloom and harvest dates, yield, fruit size, fruit quality, and susceptibility to selected diseases. Preliminary results indicated significant differences in early productivity. During the 3 seasons, 12 of the cultivars bloomed prior to the last average frost including PF23, PF27, PF24, PF7, and PF15A. Ripening dates ranged from 8-June ('PF1') to 0-Aug ('Encore'). Average fruit size, after uniform hand thinning ranged from <100 g ('Jayhaven') to >200 g ('Glohaven', 'Loring', 'Contender', PF 24). There was no significant correlation of average fruit size and yield, or average fruit size and days from bloom to harvest among the cultivars evaluated. Based on bloom characteristics, yield, and fruit quality, the cultivars Bellaire, Contender, PF-1, PF-15A, and Surecrop are suitable for this location. 'Canadian Harmony', 'Ernie's Choice', 'Jon Boy', 'PF-17', 'PF-23', 'PF-24', 'Redhaven' and 'Winblo' were high-yielding but their poor fruit quality make them a questionable choice for this location. 'Bounty' was also high yielding, but its early blooming character and the significant flower abortion observed in 2003 raises some doubt as to the reliability of 'Bounty' at this location. Continued evaluation of these cultivars is necessary to substantiate these initial findings.

Materials and methods

Three trees of each cultivar (Table 1.) were planted adjacent to each other on raised beds in 1999, at a spacing of 6' between trees and 20' between rows. The trees were trained to a 2-scaffold perpendicular-V. The trees were fertilized with a complete fertilizer each spring, and drip-irrigated during the summer months. A commercial fungicide and pesticide spray program was employed during the growing season. Data were collected beginning in the third growing season (2001). Dates of first and full bloom, and first and peak harvest were recorded. Visual ratings of bloom amount and amount of thinning required were done on a scale of 1 to 5 where 1=little and 5=most. At harvest, fruit and drops from each tree were weighed, and the average fruit weight was calculated. The fruit were rated for incidence of peach scab, scale, brown rot, split pits, cracks, bacterial spot and leaf curl. The data were analyzed as a randomized complete block with individual trees as replications, under the assumption that field conditions were uniform and tree position in the field was a negligible source of error. The results for 2003 only are presented.

Results and discussion

The cultivars with the earliest average first bloom date were Bounty, PF-23, PF-27A, PF-7 and Sentry (9-Mar and 10-Mar) (Table1.). 'Contender', 'Ernie's Choice', and 'Harcrest' were last to bloom (15-Mar). The first cultivars to reach full bloom were 'Bounty', 'Jon Boy', 'PF-23', 'PF-27A' and 'Sentry' (15-Mar and 16-Mar). The last to reach full bloom were 'Contender', 'Cresthaven', 'Ernie's Choice', 'Glohaven', 'Harcrest', 'Jayhaven', 'Jefferson', 'Redhaven', 'Surecrop', and 'Winblo' (22-Mar to 24-Mar). 'Bounty', 'Bellaire', 'Encore', 'Ernie's Choice', 'Harcrest', 'Jefferson', and 'Winblo' were the most prolific bloomers (data not shown). 'Contender', 'Cresthaven', 'Encore', 'PF-15A', 'PF-23', and 'Redhaven' had the highest thinning requirement indicating the highest fruit set (data not shown). Significant flower abortion occurred for 'Bounty', 'Sentry' and 'Winblo' in 2003 although there were no killing frosts during bloom.

The earliest fruiting cultivar was 'Bounty' (3-July) and the latest was 'Encore' (29-July). Overall, the cultivars had statistically similar yields (Table 2.). However, Gala and Sureprince had significantly lower yields than the other cultivars. A storm with high winds on 11-June resulted in many dropped fruits. 'Gala' and 'SurePrince' had a high weight of dropped fruit which contributed to their low yield. 'Bellaire', 'Jayhaven', and 'Sentry' had the lowest weight of drops (Table 2.).

Average fruit size, after uniform hand thinning ranged from <100 g ('Jayhaven') to >200 g ('Glohaven', 'Loring', 'Contender', PF 24). There was no significant correlation of average fruit size and yield, or average fruit size and days from bloom to harvest among the cultivars evaluated in 2003 (data not presented). A traditional minimal acceptable fruit size for commercial use is a diameter of 6.35cm (2.5") which requires that a fruit have a weight of approximately 125 g or more.

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Cultivars that did not achieve that average size in 2003 were Jayhaven, SurePrince, Encore, Cresthaven, Jim Dandee, PF-23, PF-15A, and Redhaven. However, 'Redhaven' and had relatively large yield and may not have received sufficient thinning for fruit to attain their size potential. In other Ark. field observations at the Fruit Research Substation, Clarksville, Ark. (Rom, et al., 2000) it was reported that 'Encore' produces small fruit, 'Redhaven' was typically slightly larger than observed this year, and 'Cresthaven' and 'Jim Dandee' produced both heavy crops and large fruit size. Differences in the observed fruit sizes may be due to both the condition of the trees being young and early crops, and due to location.

No incidence of bacterial spot or peach leaf curl was observed in any year of data collection (data not shown). 'Bounty', 'Ernie's Choice', Jon Boy', 'Loring', 'PF-27A', 'PF-24', and 'Winblo' were susceptible to scale infestation although levels were low (20-40%) (Table 3.). Cracking of fruit was negligible (data not shown). Peach scab was observed on all cultivars except 'Encore', 'PF-1', 'PF-15A', 'Ruston Red', 'Sentinel', 'Sentry', 'Surecrop', and 'Sureprince' (Table 3.). Fruit of 'Bellaire' and 'Gala' had low levels of scab (less than 10%). Fruit of 'Canadian Harmony', 'Cresthaven', 'Harcrest', 'Jayhaven', 'Loring', 'PF-17', 'Redhaven' and 'Winblo' had the highest incidence of scab (40 - 90%). Incidence of brown rot in the fruit was highest for 'Ernie's Choice', 'Gala', 'Sentinel', and 'Surecrop'(30-45%) (Table 3.). 'Canadian Harmony', 'Glohaven', Jon Boy', 'Jim Dandee', 'Jayhaven', 'Loring', 'PF-7', 'PF-17', 'PF-23', 'PF-24', 'Redhaven', 'Sureprince', and 'Winblo' had a high incidence of brown rot in dropped fruit (40-93%). 'Bounty', 'Canadian Harmony', 'Ernie's Choice' and 'Jayhaven' had significantly more split pits than the other cultivars (Table 3.).

Conclusion

Significant differences in productivity and fruit quality were observed in the cultivars evaluated. Although some cultivars appeared very promising, continued observation is necessary before definitive recommendations can be made. When recommending or selecting appropriate cultivars key characteristics to evaluate would be long-term record of average bloom date, average harvest date, cropping reliability, fruit size, and fruit disease susceptibility.

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Table 1. Cultivar date of release, fruit type, and average dates of bloom and harvest.

			Bloom		Harvest	
Cultivar	Year released	Type[z]	1st	Full	1st	Peak
Bellaire	1985	FS, M	Mar. 11	Mar. 18 (±2.4)	27-Jun	June 29 (±2.7)
Bounty	1988	FS, F	Mar. 10	Mar. 16 (±1.6)	3-Jul	July 8 (±1.5)
Canadian Harmony	1968	FS, M	Mar. 14	Mar. 20 (±7.4)	8-Jul	July 15 (±1.0)
Contender	1988	FS, M	Mar. 15	Mar. 24 (±4.5)	14-Jul	July 15 (±1.0)
Cresthaven	1963	FS,M	Mar. 13	Mar. 22 (±4.9)	19-Jul	July 22 (±3.6)
Encore	1996	FS, M	Mar. 11	Mar. 21(±5.7)	29-Jul	Aug. 2 (±4.2)
Ernie's Choice	1990	FS, M	Mar. 15	Mar. 24 (±2.2)	9-Jul	July 10 (±0)
Gala	1977	FS, M	Mar. 11	Mar. 18 (±3.2)	21-Jun	June 23 (±4.2)
Glohaven	1963	FS, F	Mar. 14	Mar. 22 (±4.9)	13-Jul	July 14 (±1.0)
Harcrest	1983	FS, M	Mar. 15	Mar. 22 (±4.6)	25-Jul	July 27 (±3.1)
Jon Boy	1981	FS, F	Mar. 11	Mar. 15 (±2.5)	28-Jun	July 3 (±1.5)
Jayhaven	1976	FS, M	Mar. 14	Mar. 22 (±4.9)	2-Jul	July 4 (±1.2)
Jefferson	1960	FS, F	Mar. 14	Mar. 22 (±4.9)	24-Jul	24-Jul
Jim Dandee	1980	FS, M	Mar. 14	Mar. 21(±6.5)	5-Jul	July 7 (±2.9)
Loring	1946	FS, M	Mar. 12	Mar. 19 (±3.5)	14-Jul	July 15 (±1.0)
PF-1	1995	SF, F	Mar. 11	Mar. 20 (±4.0)	5-Jun	June 9 (±3.6)
PF-15A	1994	FS, F	Mar. 12	Mar. 19 (±4.7)	26-Jun	June 27 (±0.6)
PF-17	1993	FS, F	Mar. 12	Mar. 21 (±6.5)	7-Jul	July 12 (±3.8)
PF-23	1993	FS, F	Mar. 9	Mar. 15 (±3.6)	11-Jul	July 14 (±2.0)
PF-24-007	1997	FS, F	Mar. 11	Mar. 17 (±2.2)	10-Jul	July 15 (±4.5)
PF-27A	1997	FS, F	Mar. 10	Mar. 16 (±3.6)	24-Jul	July 26 (±2.0)
PF-7	1998	SF, F	Mar. 10	Mar. 18 (±6.0)	19-Jun	June 21 (±4.9)
Redhaven	1940	SF, M	Mar. 13	Mar. 22 (±4.9)	27-Jun	June 30 (±3.8)
Ruston Red	1982	FS, M	Mar. 13	Mar. 21 (±4.4)	15-Jul	July 19 (±0.6)
Sentinel	1958	SF	Mar. 11	Mar. 18 (±3.2)	16-Jun	June 19 (±1.7)
Sentry	1980	C,M	Mar. 10	Mar. 16 (±3.6)	10-Jun	June 12 (±3.0)
Surecrop	1973	C,M	Mar. 14	Mar. 22 (±4.9)	14-Jun	June 17 (±1.7)
Sureprince	1998	SF, M	Mar. 13	Mar. 19 (±4.7)	23-Jun	June 25 (±3.5)
Winblo	1972	FS, M	Mar. 13	Mar. 22 (±4.9)	5-Jul	July 7 (±2.5)

[z]F=firm flesh, M=melting flesh, FS=freestone, SF=semi-freestone, C=cling stone

Table 2. Peach cultivar yield per tree, weight of drops, average fruit weight, & % brown rot in drops, Southwest Research/Extension Center-Hope,Ark.,2003

Variety	Yield/ tree (kg)	Wt of drops (kg)	Avg. fruit wt. (g)	Brown rot in drops (%)
Bellaire	18.6 b[z]	2.3 hi	191 bc	13 e
Bounty	21.3 b	4.1 f-i	182 b-d	23 de
Canadian Harmony	30.9 a	5.4 d-i	163 b-g	50 b-d
Contender	18.6 b	5.9 c-i	104 h-j	13 e
Cresthaven	6.1 d-g	7.6 c-g	86 ij	0 e
Encore	4.8 fg	6.1 c-h	104 h-j	0 e
Ernies Choice	19.3 b	4.5 e-i	177 b-e	30 de
Gala	1.9 g	4.2 f-i	141 d-h	30 de
Glohaven	5.4 d-g	3.3 g-i	245 ab	47 c-e
Harcrest	6.7 c-g	4.3 e-i	145 c-h	30 de
Jon Boy	14.9 b-d	4.0 f-i	177 b-e	60 ab
Jim Dandee	2.9 fg	8.8 b-e	100 h-j	80 a-c
Jayhaven	6.1 d-g	2.3 hi	104 h-j	40 c-e
Jefferson	5.3 e-g	5.8 c-i	132 e-i	0 e
Loring	5.9 d-g	5.0 e-i	263 a	58 ab
PF-15A	14.9 b-d	5.4 d-i	91 ij	30 de
PF-17	17.6 b	9.6 b-d	118 g-j	53 ab
PF-23	12.0 b-f	16.8 a	114 h-j	80 a-c
PF-27A	7.3 c-g	12.8 ab	127 f-j	0 e
PF-7	4.0 fg	4.4 e-i	177 b-e	60 ab
PF-1	17.5 b	3.8 g-i	173 b-f	30 de
PF-24-007	14.6 b-e	5.5 d-i	277 a	93 a
Redhaven	16.0 bc	6.1 c-i	77 j	50 b-d
Ruston Red	7.7 c-g	10.0 bc	186 b-d	0 e
Sentinel	6.1 d-g	4.4 e-i	141 d-h	0 e
Sentry	5.1 fg	1.0 i	250 a	0 e
Surecrop	18.9 b	8.2 c-f	123 g-j	0 e
Sureprince	1.8 g	1.7 hi	100 h-j	90 ab
Winblo	19.2 b	6.9 c-g	200 b	40 c-e
LSD	9.5	4.4	50	43

[z]Numbers followed by the same letter are not significantly different as determined by LSD ($P < 0.05$).

Table 3. Peach fruit quality: percent scab, scale, split pits and brown rot in fruit, Southwest Research and Extension Center, Hope, Ark., 2003.

Variety	Scab (%)	Scale (%)	Split pits (%)	Brown rot in fruit (%)
Bellaire	7 gh[z]	0 c	0 b	0 e
Bounty	20 f-h	37 a	18 a	12 c-e
Canadian Harmony	40 d-g	7 b	22 a	7 de
Contender	37 e-h	0 c	1 b	0 e
Cresthaven	83 ab	0 c	0 b	0 e
Encore	0 h	0 c	0 b	0 e
Ernies Choice	57 a-e	27 ab	23 a	43 a
Gala	6 gh	2 c	0 b	45 a
Glohaven	35 e-h	0 c	2 b	0 e
Harcrest	50 b-f	0 c	0 b	0 e
Jon Boy	18 f-h	38 a	0 b	0 e
Jim Dandee	17 f-h	2 c	0 b	0 e
Jayhaven	80 a-c	0 c	27 a	0 e
Jefferson	25 e-h	0 c	0 b	0 e
Loring	73 a-d	30 a	0 b	0 e
PF-15A	0 h	0 c	0 b	0 e
PF-17	47 c-f	3 c	3 b	0 e
PF-23	37 e-h	0 c	0 b	0 e
PF-27A	23 e-h	22 a-c	0 b	0 e
PF-7	28 e-h	0 c	0 b	2 e
PF-1	0 h	0 c	3 b	0 e
PF-24-007	28 e-h	20 a-c	0 b	10 c-e
Redhaven	43 d-f	2 c	0 b	0 e
Ruston Red	0 h	0 c	0 b	0 e
Sentinel	0 h	0 c	0 b	30 a-c
Sentry	0 h	0 c	0 b	23 b-d
Surecrop	0 h	0 c	0 b	40 ab
SurePrince	0 h	0 c	0 b	3 de
Winblo	90 a	40 a	5 b	5 de
LSD	35	22	13	21

[z] Numbers followed by the same letter are not significantly different as determined by LSD ($P<0.05$).

Evaluation of Post-Harvest Disease Resistance in Blackberry Cultivars

J.P. Kidd[1], J.R. Clark[1], P. Fenn[2], and B.J. Smith[3]

Additional index words: *Rubus*, small fruits, *Botrytis cinerea*

Summary. Seventeen blackberry cultivars were evaluated for post-harvest fruit-rot resistance in June and July, 2003. Fully mature, undamaged berries were harvested on two dates for each genotype at the University of Arkansas Fruit Substation, Clarksville. After transporting in chilled coolers to the Plant Pathology Department in Fayetteville, two replications of 10 berries of each genotype were placed in a high humidity chamber for 3 d (21-23°C; 16-h daylength). This provided a total of four replications for each entry across the two harvest dates. Natural inoculum from the field provided the post-harvest pathogens, and no additional inoculations were conducted. Berries were evaluated after 3 d in the chambers for the presence of postharvest rot. Berries free from any rots were counted, and if rot was present, then a rating scale of 1 to 3 (1-very little mycelial growth present; 3=berry totally covered by mycelia) was used to quantify rot. The fungal growth was examined visually and microscopically to identify the causal pathogen. There was a wide range of post-harvest fruit rot responses among the genotypes. The cultivars with the least rot were 'Kiowa' and 'Navaho', with near 80%, and 70% berries free of any rots, respectively. *Botrytis cinerea* was identified on all berries that had any presence of rot and was the most important pathogen that contributed to berry decay. *Colletotrichum* spp. was found less frequently on rotted berries. Results indicate that substantial fruit-rot resistance existed among genotypes and variation for resistance could likely be used in breeding. *Botrytis cinerea* is the primary pathogen to target in post-harvest fruit rot breeding resistance at this location.

Blackberry (*Rubus* subgenus *Rubus*) production is important in Arkansas, other states in the U.S., and many countries around the world. The University of Arkansas is one of the leading institutions in the world for blackberry improvement. Eleven cultivars have been released from the Arkansas program through 2003.

Although blackberries are resistant to most diseases, fruit rots do occur in some years. Recent observations in the southern U.S. indicated that fruit rot occurrence varied in blackberry genotypes (B. Smith, personal communication). The development of post-harvest disease resistant cultivars of blackberries is now becoming more of a focal point for researchers due largely to the expansion of shipping of blackberries. *Botrytis cinerea*, the fungus causing gray mold, is likely the primary disease-causing post-harvest rot of ripe blackberries (J. R. Clark, personal communication). It is the most important pathogen affecting blackberry production and marketing worldwide (Jarvis, 1962). Since previous research on the susceptibility of small fruits to *Botrytis* has been focused primarily on raspberries and strawberries, there are practically no publications related to the genotypic variance of blackberries and their relative levels of resistance or susceptibility to post-harvest pathogens.

Current fungicides recommended for *Botrytis* control suggest application to berries three or four times a season. These materials are expensive and may be ineffective in wet seasons (Jarvis and Hargreaves, 1973). The marginal disease control achieved with fungicides and a rise in public concern of the health hazards associated with chemical use has prompted the scientific community to search for alternative, perhaps more effective, means of disease control. Scientists are attempting to improve the effectiveness of disease control through genetic resistance in order to reduce fungicide dependency. If cultivars can be developed that have both good gray mold resistance and high quality berries, the marketing of fresh fruit to places distant from the centers of production could expand and production costs be reduced.

The main objective of this research project was to evaluate multiple blackberry genotypes for resistance to post-harvest decays and confirm which pathogen causes these losses. Then, if differences could be established, these may provide insight into the genetic variability of fruit-rot resistance and could also be useful in identifying resistance for use in breeding.

Materials and methods

Berries were harvested from 17 blackberry cultivars growing at the University of Arkansas Fruit Substation, Clarksville. The genotypes selected for evaluation included 11 Arkansas-developed cultivars and six cultivars developed elsewhere. The plants sampled were sprayed once with an application of liquid lime-sulfur at bud-break in March for anthracnose control, but no further sprays were applied to control fruit rots. Berries were not washed after being picked. All inoculum provided was that which occurred naturally on the berries from the field. Samples were collected from late May to late July, 2003. Twenty fully ripe berries with no visible signs of disease or injury were selected at two harvest dates for each genotype. The berries were transported to the

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Plant Pathology Department at the University of Arkansas, Fayetteville, in coolers. Two replications of ten berries of each cultivar at each harvest date were then placed into two small trays lined with dry paper towels. These trays were then placed onto large black flats (six trays per flat) in a completely random design. These flats were then placed into inverted, clear propagation domes that were lined with moist paper towels to keep the relative humidity near 100% without the fruit being in direct contact with moisture. The flat was then covered with another clear dome and sealed with tape to provide a tight, high-moisture chamber. The clear cover allowed observation of fruit rot development without opening the container. Fruit was incubated at 21°C-23°C with a 16 h daylength (Smith et al., 1996). This environment provided optimum conditions for disease development on the fruits. Berries with no presence of rot were counted 3 d after beginning of incubation. If rot was present, it was rated on a scale of 1-3: a value of 1 = slight fungal presence, 3 = berry totally consumed by fungal growth, and the pathogen was identified. Evaluation of the fungi causing the fruit rot was determined by visual examination. The main fungi that were expected to be seen were *Botrytis cinerea* and *Colletotrichum* spp., (Barbara J. Smith, personal communication). However, the fruits were examined for other pathogens and their presence was recorded. A microscope viewed at 40x was used to identify and differentiate the pathogens. After all ratings were completed, the data were analyzed by analysis of variance using SAS (release 8.2, SAS Institute, Cary, N.C.) Proc GLM program. Mean separation was by LSD (P=0.05).

Results and discussion

There was a wide range of responses for the genotypes for all variables measured. None of the genotypes evaluated displayed complete resistance to any of the post-harvest rots. The genotypes with the highest resistance to fruit rots expressed as the percentage of fruit without evidence of rot included 'Kiowa' (near 80%), 'Navaho' (73%), and 'Triple Crown' (near 60%) (Fig.1). The most susceptible cultivars to post-harvest rot included 'Comanche', 'Rosborough', and 'Cheyenne'.

Results of the pathogen identification indicated that *Botrytis* contributed more than *Colletotrichum* to total rot of the berries. *Botrytis* was observed on berries of all cultivars in the study, while *Colletotrichum* was found on 12 of 17 cultivars. However, the percentage of berries in each sample infected with *Colletotrichum* was much lower than *Botrytis*. Thus, *Botrytis* can be assumed to be the primary causal pathogen of the post-harvest rot. Average post-harvest rot ratings for the cultivars for *Botrytis* ranged from a low of near 0.2 for 'Kiowa' to an average high of near 2.0 for 'Comanche' and 'Rosborough' (Fig. 2). Other pathogens found were *Rhizopus* spp. and *Pestalotia*. Although their presence was recorded, their occurrence was too minute to contribute to fruit decay of any importance.

Conclusions

These data are from a single season, thus repeated observations for additional years would be advantageous to verify the year-to-year stability of the fruit-rot resistance responses. This would further verify and allow the identification of superior genotypes for breeding, and increasing the fruit-rot resistance character.

The evaluation method used appeared to work very well, in that the fruits had a very stable environment for pathogen development, and also the natural inoculum was assumed to be uniform enough among genotypes and sample dates to provide a good pathogen pressure.

These data may prove helpful to growers who have high occurrences of fruit rots. Growers with these fruit rots could consider planting the more resistant genotypes on their farms and avoid growing others with high occurrences of fruit rots. This could lead to higher profits and lower production costs.

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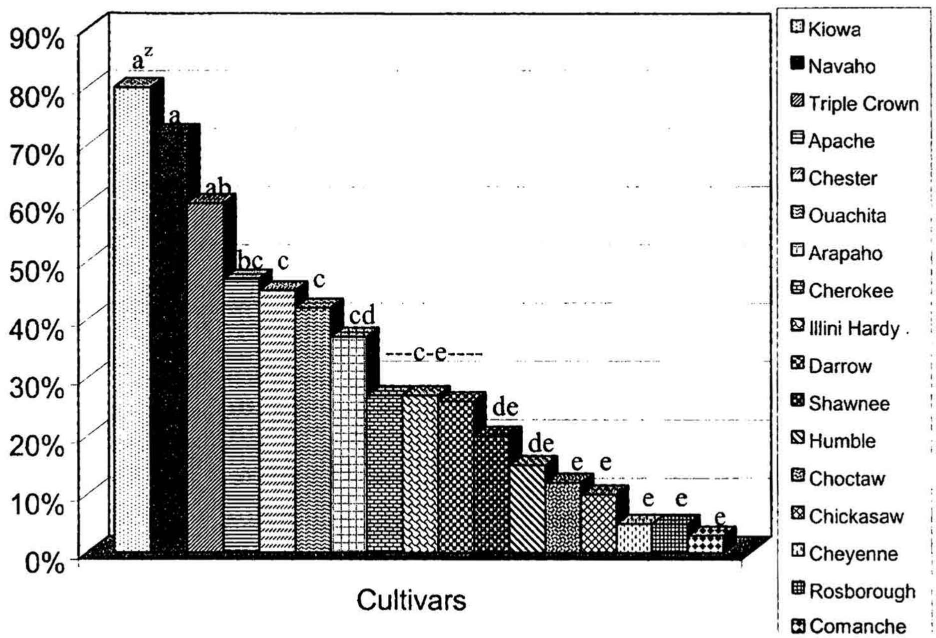

Fig. 1. Percentage of berries of 17 blackberry cultivars with no evidence of post-harvest fruit rots after storage for 3 d. Means not followed by the same letter differ significantly (P< 0.05) as determined by LSD.

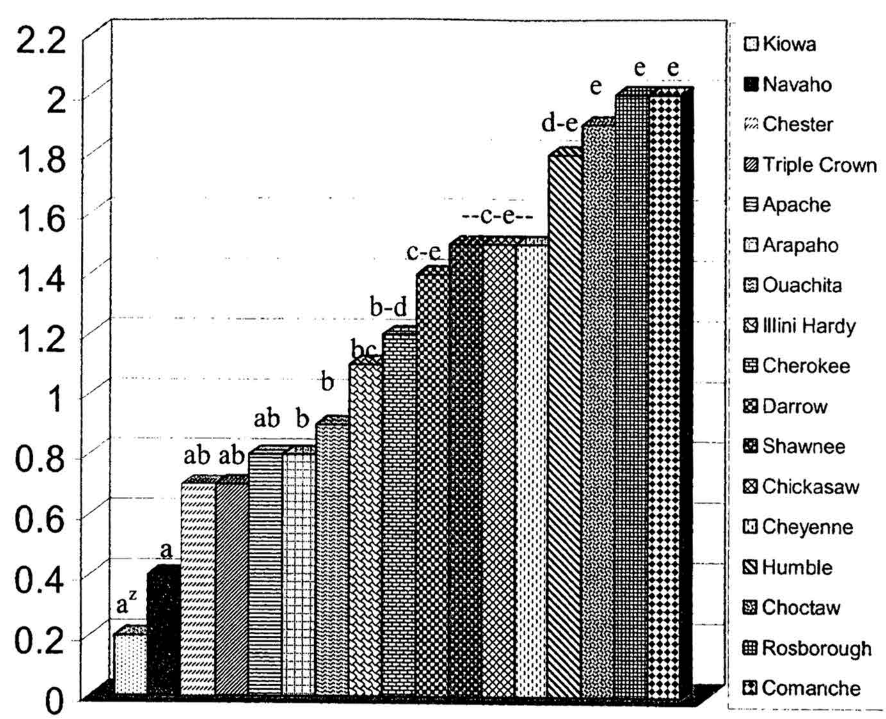

Fig. 2. The average disease rating of 17 blackberry cultivars for *Botrytis cinerea* on a disease severity scale of 1 to 3 with 1= slight fungal presence; 3 = berry totally consumed by fungal growth following storage for 3 d. Means not followed by the same letter differ significantly (P< 0.05) as determined by LSD.

Evaluation of Size-Controlling Apple Rootstocks for High-Density 'Gala' Apple Orchards in Arkansas: Final Year Results of the 1994 NC-140 Uniform Apple Rootstock Trial

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Additional index words: Dwarfing rootstocks, high-density orchard, *Malus domestica*

Summary. Growth and productivity of 'Gala' apple on 17 size-controlling rootstocks were studied in a 10-year trial in Arkansas as part of the NC-140 cooperative project. During the study, 70% of trees on the rootstocks 'Mark', M.27 E MLA, and Ott.3 died, while the overall survival average was 60%. Trunk cross-sectional area (TCSA) and height were largest on V.1 rootstock. 'Mark', M.27, and P.16 rootstocks produced the smallest trees. No significant difference was observed for tree performance among six M.9 clones for TCSA, shoot height, shoot spread, fruit yield efficiency, and fruit size. Nic.29, M.26, Pajam 1, Ott.3, and V.1 had significantly greater yields compared to other rootstocks. Trees on Nic.29 had significantly higher yields per tree compared to other M.9 clones. Nic29 and Pajam 1 were the largest M.9 clones with the greatest yields, and significantly more root suckers than other clones. No significant differences were observed for tree size between M.26 EMLA and M.9 EMLA. Fruit size was significantly smaller for M.27 EMLA and 'Mark' compared to all other rootstocks. Tree yield efficiency was significantly higher in M.9 and Ott.3 rootstocks. Cumulative yield was highest for B.9 and Ott.3. Cumulative yield was significantly correlated to tree size variables TCSA, shoot height, and spread estimated canopy volume and surface area. Cumulative yield was highly correlated with estimated canopy volume and surface area/volume ratio.

For Arkansas orchards to be economically sustainable, the system must be productive, both early in its life and annually, and easily manageable. Rootstocks, because of effects on orchard precocity, productivity, and size, have a profound influence on sustainability. Previous research at the University of Arkansas Agricultural Experiment Station has shown that high-density orchards in the range of 600-800 trees per acre maximize production and minimize labor using the central leader training systems such as vertical axis. Rootstock cultivars are important for the grower in developing specific tree characteristics for early production and good fruit quality. Therefore, it is important that rootstock varieties be tested locally for characteristics of survival, precocity, and fruit size. The objective of this long-term project was to test, in Arkansas conditions a range of size controlling rootstocks for high-density systems. Reported here are final results of the 10th season of the trial.

Materials and methods

A trial of 'Gala' apple on 17 size-controlling rootstocks was established at the University of Arkansas, Agricultural Experiment Station, Fayetteville, in 1994, as part of the NC140 uniform cooperative tree fruit research project (NC-140, Marini, 2001; Marini et al., 2000). The trial was also established at 24 additional North American locations in (19 states and 3 Canadian provinces). The Arkansas planting site consisted of Captina silt loam soil with a soil pH at planting of 5.5-5.8. Soil was deep-ripped and tree rows were cultivated prior to planting. 'K-31' fescue was planted in tree row middles. Tree spacing was 2.5 x 4.5m (8' x 15'). The vertical axis system was used to train each tree. A single wire trellis was 3m (9.5') was placed on each row. A single bamboo pole was attached at the wire and each tree trunk for support. Annual applications of residual and contact herbicides were used to maintain a 1.5m (5') strip under the trees in each row. Trees received supplemental trickle irrigation, annual applications of lime and fertilizer, and standard pest control management. Trees did not crop the first two seasons (1994, 1995), but were allowed to crop in following years.

Rootstocks used in the trial were representative of commercially available stocks which may be useful for high-density orchards. These included B.9, B.469, B.491, Ott.3, V.1, P.2, P.16, P.22, M.26 EMLA, M.27 EMLA, and 'Mark.' There were a number of M.9 clones including M.9 EMLA, Nic.29, Pajam 1, Pajam 2, NAKBT.337 (T.337), and Fl.56. Trees were measured annually for tree height, spread (average in-row and across-row), and trunk cross-sectional area (TCSA) at 25cm (10") above graft union. Beginning in the third season, fruit were harvested to determine total yield and average fruit size (25 fruit sample). Annual and cumulative yield efficiencies were calculated using total yield and TCSA. The trial was planted as a random complete block, blocked in two row blocks by orchard position (east to west), with 10 replications. All data were analyzed using SAS (Cary, NC) PROC GLM procedure, with mean separation by LSD if significant at the 0.05 level.

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Results and discussion

Weather and Survivability. In some years, weather had a significant impact on this trial. A record cold temperature in March 1996 resulted in bud damage and lighter bloom than anticipated. A bloom-time frost in April 1997 resulted in moderate to poor fruit set and no fruit thinning was required. Warm spring conditions in 1998 resulted in flowering one week earlier than normal. Severe heat and drought followed from July-September. Subsequently, sunburn and summer rots on fruit were prevalent in 1998. A bloom-time frost occurred in 2000 followed by near record precipitation during May-June. Trees showed some flood stress during this period. However, this was followed by severe drought and heat during July-September resulting in sunburn and severe summer fruit rots which limited cropping. In 2002, bloom and post bloom conditions were cool and wet. A frost occurred during bloom followed by severe infection by fire blight which limited tree growth and cropping. In 2003, a frost limited cropping and no fruit thinning was practiced. Survival and growth was not good in this trial over the 10-year period.

Over the 10-year period survival was less than 60% due to the following conditions: poor site and soil (result of fuel-oil tainted ground), lightening strike (1996), and strong winds that broke trees in several rows in two different seasons. However, some notable observations can be made. Trees on 'Mark', Ott.3, and P.16 had only 30% survival during the 10-year trial. Low survival of these three rootstocks during this 10-year trial is consistent with observations in other research trials at the University of Arkansas. Ott.3 appeared to die due to severe fire blight and other root rots. 'Mark', which is known for poor heat and drought tolerance, suffered during the seasons of severe drought and heat stress. Surviving trees were stunted and non-productive. Therefore, these rootstocks are cannot be recommended for this region. Fl.56 resulted in the best overall survivability followed by B.9, B.491, and Pajam 1 (Table 1). Trees on M.9 EMLA and its clones had average survival of approximately 70% which is better than average in this trial.

Growth. The largest trees based upon TCSA, shoot height and spread, were grown on rootstocks V.1, Ott.3, M.26 EMLA, Fl.56, Pajam 1, Pajam 2, T.337, and M.9 (Table 1). Trees on Fl.56, M.26, M.9, Nic.29, Ott.3, Pajam 1, Pajam 2, T.337, and V.1 were the tallest while trees on M.27 were the shortest (Table 1). Trees grown on M.26 were widest, and trees grown on M.27 were narrowest (Table 1). TCSA is a good measure of total aerial vegetative growth of a tree (Westwood, 1993). Pajam 1, V.1, and Nic.29 had the largest TCSA while trees grown on M.27 were smallest for TCSA (Table 1). Annual increase in TCSA was greatest for V.1 and Nic.29 and least for M.27 (Table 1). Root suckers occurred most on Nic.29 rootstock while all other rootstocks (not significant) had lower occurrence of root suckers. Generally, root suckering was not a problem in this trial.

Tree Cropping: Yield and Fruit Size. Trees exhibited biennial bearing pattern with larger yields in 1997, 1999, 2001, and 2003 than the years prior or succeeding. In 2000, yields were very light due to the large amount of sunburn, summer fruit rots, and early fruit drop due to the high temperatures experienced that year. Yields were suppressed in 2002 due to severe epidemic of fire blight and poor codling moth control. Tree yield was significantly correlated to TCSA and canopy volume/surface area ratio (data not shown). Trees on Nic.29, M.26, Pajam 1, Ott.3, and V.1 had the greatest yield (Table 1). Trees on P.22, Mark, M.27, B.469, and B.491 had the lowest yields (Table 1). The M.9 clones had similar yields, however, Nic.29, T.337, Pajam 1 and Pajam 2 had yields greater than M.9 EMLA. Trees on Fl.56 had yields less than M.9 EMLA (Table 1). Over the 10-year study, trees on V.1, Nic.29, and Pajam 1 had the greatest cumulative yields, while M.27 had the least cumulative yields (Table 1). Trees on B.9 produced a cumulative yield 35% less than trees on M.9 EMLA. M.9 clonal rootstocks Nic.29 and Pajam 1 had the largest cumulative yields per tree. This represents a significant production potential for these rootstocks. Fruit size was largest on M.26 EMLA, Nic.29, Pajam 1, and Pajam 2 (Table 1). Trees on P.16 produced large fruit but had a large annual variation and small yields.

Yield efficiency (Yield/TCSA) compares the amount of fruit relative to the amount of vegetative growth of the tree (Westwood, 1993) and is an indicator of physiological partitioning efficiency. Over the 10-year study, cumulative yield efficiency was highest for Nic.29 while 'Mark' and Fl.56 had the lowest cumulative yield efficiency (Table 1). Trees on 'Mark' were relatively non-productive while trees on Fl.56 grew vigorously and partitioned more resources into vegetative growth. Cumulative yield efficiency was highest for B.9 and Ott.3 (Table 1). There was little difference observed among the M.9 clones for yield efficiency (Table 1).

Conclusion

Most rootstocks included in this study are useful in high-density orchards for this region. Potential rootstocks and planting densities are recommended in Table 2. M.26 EMLA and M.9 EMLA are recommended for moderate density orchards. Trees on M.9 EMLA can be planted up to a density of 800 trees per acre. Higher density orchards trained to a vertical axis system will require rootstocks such as B.9, B.469, and P.22. M.9 EMLA is adaptable in other regions of the country for super-spindle, high-density plantings of 1500-3000 trees per acre. However, this high density planting system has not been studied in this region and is not recommended at this time.

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Table 1. Summary of 10 years growth and production of 'Gala' apple on 17 dwarfing rootstocks in the 1994 NC-140 Uniform Cooperative Trial, Fayetteville, Ark.,1994-2003. [z]

Rootstock	Survival %	Shoot height (m)	Shoot spread (m)	TCSA (cm^2)	2002-2003 Increase in TCSA (cm^2)	2003 Annual root suckers	2003 Total fruit yield (kg)	2003 Average fruit size (g)	2003 Fruit yield efficiency (kg/cm^2)	Cumulative fruit yield (kg)	Cumulative fruit yield efficiency (kg/cm^2)
B469	60	2.6 bc	1.99 efg	47.9 e	8.5 defg	0 b	24.5 f	121 de	0.52 cde	129 efg	2.7 abcd
B491	60	2.7 bc	2.41 def	48.1 e	9 cdefgh	0 b	22.4 f	149 abcde	0.53 cde	120 fg	2.9 abcd
B9	80	3.1 bc	2.26 def	52.4 de	6.4 gh	0.5 b	39.3 cdef	140 abcde	0.74 abcd	173 def	3.3 a
FL56	50	3.7 a	2.62 bcd	83 bc	13.8 bcdefg	1 ab	54.1 bcde	167 abcd	0.65 abcde	204 d	2.5 cd
M26	50	3.9 a	3.19 a	96.3 ab	15.5 abcdef	0.5 b	78.7 ab	180 a	0.85 ab	289 abc	3.1 abc
M27	60	1.8 d	1.36 h	23.4 f	3.7 h	0 b	15.9 f	143 abcde	0.73 abcd	59 h	2.6 bcd
M9	50	3.7 a	2.91 abc	89.1 ab	18.3 abcdef	0.4 b	66.4 bcd	135 abcde	0.75 abcd	268 bc	3.1 abc
Mark	30	2.6 bc	1.77 gh	46.6 e	7.1 fgh	0.1 b	17.3 f	126 cde	0.4 e	92 gh	2.2 d
NIC29	80	3.7 a	3.01 ab	106 a	22.9 a	1.8 a	98.9 a	110 e	0.94 a	340 a	3.2 ab
OTT3	30	4 a	2.96 abc	83.9 bc	16.6 abcd	0.7 b	76.6 ab	171 abc	0.91 a	283 bc	3.4 a
P16	40	2.3 cd	2.06 efg	35.6 ef	7.8 efgh	1 ab	29.3 ef	145 abcde	0.73 abcd	117 g	2.9 abc
P2	70	2.9 b	2.48 cde	67 cd	7.4 fgh	0.6 b	38.9 def	132 abcde	0.59 bcde	182 de	2.8 abcd
P22	50	2.6 bc	1.99 fg	44.4 e	5.6 gh	0.2 b	19.5 f	167 abcd	0.45 de	97 gh	2.6 bcd
PAJAM1	70	3.8 a	2.93 abc	101.4 a	17.6 abc	0.6 b	80.2 ab	153 abcde	0.8 abc	307 abc	3.1 abc
PAJAM2	70	3.7 a	2.95 abc	94.1 ab	16.3 abcde	0.4 b	69.3 b	152 abcde	0.72 abcd	277 bc	2.9 abc
T337	90	3.7 a	2 bcd	89.3 ab	16.3 abcde	0.9 ab	66.9 bc	129 bcde	0.75 abcd	262 c	2.9 abc
V1	50	3.9 a	2.97 ab	102.6 a	23.5 a	0.2 b	79.6 ab	177 ab	0.74 abcd	321 ab	2.9 abc

[z] Analysis using SAS GLM procedure. Means are least square means. Means separation by LSMEANS/PDIFF. Mean within a column followed by the same letter not significantly different (P = 0.05).

Table 2. Approximate planting density, spacing, and their appropriate apple rootstocks for use in high-density vertical axis planting in Arkansas.

Trees/acre	500-700	600-800	800-1000	1000-1200
Row spacing (ft)	15--10	12--8	8--10	8--10
Tree spacing (ft)	6	6--5	5--4	4--3
Rootstocks recommended	M.26 EMLA	Pajam 1	P.2	P.22
	Ott.3	M.9 EMLA	P.16	Mark
	V.1	Fl.56	P.22	M.27
	M.9 EMLA	NAKBT.337	B.9	
	Nic.29	P.2	B.469	
	Pajam 1	B.9	NAKBT.337	
	Pajam 2	P.16		
	Fl.56	B.469		
	B.491	P.22		
	B.9			

Do Students Learn in the Introductory Principles of Horticultural Science Class?

C.R. Rom[1]

Additional index words: education, test results

Summary. Principles of Horticultural Science (HORT 2003) is a core course for Horticulture majors and is required of all students as a prerequisite for most other upper-level horticulture courses. The class has no prerequisites and enrollment is open to non-majors both from within the College of Agricultural, Food and Life Sciences (AFLS) or other colleges. The course is designed to introduce students to the principles and practices of horticulture. During the course, students are exposed to important horticultural crop plants, how they are grown and utilized. The learning objectives for the class include an introduction to the history, mythology, and importance of horticulture to Arkansas, the US, and our societies; introduction to plant classifications, structures, and functions of horticultural plants as a means of understanding how to produce them; introduction to the principles underlying the technologies involved in horticultural crop production such as propagation, use of plant-growth regulators, physical manipulation of the plant, and controlling the plant growth environment; and introduction to various commodities and disciplines of horticulture. The course is taught with two 50-minute lectures and one two-hour lab each week.

A common question asked by instructors is whether or not students learn or acquire knowledge based upon instruction during a course. The means by which this question is typically answered is by evaluating grade performance of students at the end of the semester. However, grades alone may not account for previous knowledge or experience class participants may have. Therefore, it is important to account for preexisting knowledge and evaluate the change in knowledge from the first day of a course until the last day of the course based upon changes in performance of students enrolled in the course during the past two years on the pre- and post- tests, the final exam grades, and course final grades. Scores on pre-tests, indicating preexisting horticultural knowledge, were not related to performance on a final exam or the students' final grades. However, scores of a post-test using the same questions as the pre-test revealed the score difference between the pre- and post-tests was highly correlated to students' final grades. Thus, it is believed that students learn the key concepts for the course related to the course objectives.

Materials and methods

This study included all students enrolled in the course during the past 4 semesters. During the first day of class, students were given a thorough syllabus, instructions for accessing materials on the internet using WebCT, and instructions to purchase a required textbook. The course description objectives were verbally reviewed with the students.

To determine if students gain knowledge and information during the duration of the course, a pre-test comprised of 20 answer-recognition questions is given during one of the first two sessions of the class. Each question is a statement or question followed by an array of four choices which may complete the statement or answer the question. Students were instructed in writing and orally to select the "best" answer, solution, or completion that they could recognize for each question. The questions represented key concepts of the course presented in the class presentations, during the labs, or through the assigned readings and relate specifically to the objectives of the course. Students were allowed 15 minutes to complete the pre-test and it was explained that this exam was given to understand students pre-course knowledge of the subject matter. Students were allowed to guess answers or not respond; a non-response was recorded as an incorrect answer. The pre-test was recorded for each student but did not count as part of their grade record for the class. Students received notification of their pre-test grade and the class average but the test was not returned to the students. The course comprehensive final exam was comprised of 200 answer-recognition questions within which the 20 pre-test questions were imbedded. During final exam grading, these questions were scored separately as the post-test.

Final grades for the course were comprised of the composite of ten weekly quizzes, lab reports, lab quizzes, three unit exams, three to five homework assignments, and a comprehensive final (20% of the total final grade). Students were allowed to submit up to 3% of the total course points in extra credit assignments to improve their grades.

Means and standard errors of the pre- and post-test scores, the final exam scores, and final grades were calculated based upon various demographic groups of the class including students within or outside of AFLS, HORT majors and non-majors, and class standing. Correlation coefficients were calculated for the relationship among the variables of pre-test score, post-test score, final exam score, and final grade.

Results and discussion

During the four semesters of evaluation, class enrollment averaged 21 students. Of the total enrolled, nine students either withdrew from the class or did not complete the final exam for the course. Of the class par-

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ticipants, 76% were enrolled in AFLS and 61% of the class participants were majors from within the Horticulture (HORT) Department (Table 1). Two-thirds of the class were freshman and sophomores while one-fifth were seniors. The majority of non-majors were either juniors or seniors while horticulture majors were typically sophomores or freshman. Enrollment in the spring semester was larger than in the fall semester.

The pre-test and post-test questions were constructed as a measure of knowledge related to subject areas to be covered in the course in order to accomplish the course objectives. Therefore, the answers given on a pre- and post-test are indicators of previous knowledge of subject matter related to the course objectives during the first week of the course and at the conclusion of the course. Changes in scores would be an indicator of a change in knowledge during the course.

On average, students in the class recognized appropriate answers to approximately 38% of the pre-test questions and were able to answer approximately 78% of the post-test questions correctly (Table 1). Thus, the average student doubled their measured performance on the same set of questions or moved approximately 4-grade points up a 10 percentage-point grade scale. The average final exam grade was approximately 80% and students on average received 75% of the points achievable in the course. Grade distribution was roughly normally distributed but skewed towards "B" grades and fewer failing grades (data not presented). This was not unexpected. Most student who received early progress reports of failing grades or were failing on the last day of the semester withdrew from the course (data not presented). Further, students could achieve extra credit points. Both of these would result in shifting the class mean performance and grade distribution upward.

Non-major students both from within AFLS and outside the College scored above the class mean on the pre-test and post-test compared to horticulture majors (HORT and TURF) who scored lower than the class mean on both. There was no significant difference between pre-test and post-test mean scores among the horticulture majors as both groups performed similarly. The mean final exam score and final score for the class were similar for all student groups.

As may be expected, scores on the pre-test and post-test increased with the increase in class standing as freshman scored lowest and seniors scored highest. Likewise, the mean final course grades were higher for upperclassmen compared to lower-level students although not statistically different due to a high level of variance within the classes. There were no significant differences between the spring and fall term classes. Likewise, there was no significant difference among the years evaluated (data not presented).

No strong correlation existed between the scores on the pre-test and post-test scores ($r = .44$), the pre-test and the final exam ($r=.41$), and the pre-test and the final grade ($r=.18$) for the class. Thus, pre-existing knowledge of horticulture was not a determinant of either what was learned during the class or the final grade in the class, and test results or knowledge at the end of the course were independent of knowledge of horticultural subject matter at the beginning of the course. Therefore, any change in performance from the pre-test to the post-test would be due to knowledge gained or from learning during the course. Post-test scores were highly significantly correlated to the final exam scores ($r=.77$) and the final course grade ($r=.62$). The final exam (approximately 1/5th of the final grade) and the final grade were correlated ($r = 0.81$). The difference between pre-test and post-test scores was highly significantly correlated ($f < 0.01$) to the final grade but only explained 32% of the class grade variation.

Conclusion

There was no significant difference in pre-existing knowledge among students regardless of college or major at the beginning of the course, or in achievement in the course. However, upperclassmen tended to score higher on tests than lowerclassmen. The pre-test was not a predictor of how students would perform either on the final exam or in the class overall. The post-test exam, however, indicates final achievement in the class and accounts for more than half of the variance of student performance. From these data, it can be concluded that students do learn and have achievement towards the objectives of the course during their term of enrollment.

Table 1. Average grades on pre-tests, post-tests, and final grades in HORT 2003 Principles of Horticultural Science 2002-2003.

		Mean Grade Score of 100% (±s.e.)			
Group	n	Pre-Test	Post-Test	Final Exam	Final Grade
Total	84	38.3	78.3	79.6	75.4
	College and Major				
AFLS	64	37.6 (1.6)	76.7 (1.8)	79.1 (1.0)	76.7 (1.8)
Non AFLS	20	42.6 (2.9)	81.1 (3.0)	81.6 (1.7)	74.7 (3.1)
		ns	ns	ns	ns
	Major				
HORT	20	37.8 (2.9)	74.1 (3.0)	76.9 (1.7)	76.0 (1.6
TURF	35	36.8 (2.2)	75.9 (2.4)	79.7 (1.4)	76.4 (1.6)
Non Major	29	42.1 (2.1)	83.0 (2.6)	81.8 (1.4)	77.2 (1.9)
		ns	*	ns	ns
	Class Standing				
FR	22	35.5 (2.6)	71.2 (2.9)	76.0 (1.7)	70.3 (3.1)
SO	34	35.6 (2.1)	76.4 (2.4)	79.4 (1.4)	74.8 (2.6)
JR	12	39.5 (3.6)	82.0 (3.8)	81.7 (2.1)	80.1 (2.6)
SR	16	49.1 (3.0)	85.3 (3.1)	83.1 (1.8)	78.1 (3.4)
		**	**	*	ns
	Term of Enrollment				
Fall	34	38.1 (1.9)	77.6 (2.2)	79.2 (1.2)	74.1 (2.3)
Spring	50	39.5 (2.0)	78.2 (2.2)	80.3 (1.2)	76.2 (2.3)
		ns	ns	ns	ns

* - significant, 0.05 level; ** - significant, 0.001 level; ns - not significantly different.

A Short Retrospective of Blackberries in Arkansas

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Additional index words: Breeding, *Rubus*

Summary. Blackberries (*Rubus* subgenus *Rubus* Watson) have been grown in Arkansas for more than one hundred years. In the late 19th century and early 20th century, cultivars such as 'Early Harvest', 'Lawton', and 'Snyder' were of great importance. A canning industry enhanced the opportunities for blackberry growers in the first half of the 20th century, particularly in the northwest portion of the state. By 1940, Arkansas had greater than 10% of the total acres of blackberries east of the Rocky Mountains. Following World War II the production of blackberries declined significantly. However, efforts through the University of Arkansas blackberry breeding program have aided in resurrecting production of blackberries in the state. By the end of the 20th century nearly 250,000 lb of blackberries were being produced in Arkansas each year and the fresh market production has expanded significantly in the first years of the 21st century. To date, 13 blackberry cultivars have been released by the University of Arkansas.

Domestication of North American blackberry species began in the late 1820s (Hedrick, 1925). Yet improved, named cultivars did not become popular until the 1840s and 1850s when 'Dorchester' and 'Lawton' became widely grown. Throughout the 19th century, blackberry cultivation grew along with the burgeoning population and westward expansion of the United States. Since blackberries are native to Arkansas, it was only a matter of time until production was established. The first report of blackberries being grown in Arkansas occurred in 1880 (Moore, 1979). The first reported cultivar released in the state of Arkansas was named 'Bauer', after C.P. Bauer, who discovered it in 1890 (Hedrick, 1925) (Table 1). 'Bauer' was a wild selection of *R. trivialis* L. In 1896, J. Stinson, horticulturist at the University of Arkansas, reported that the primary cultivars grown in Arkansas were 'Early Harvest', 'Lawton', and 'Snyder' (Stinson, 1896). 'Early Harvest' was a derivative of *R. laudatus* Berger, which was also known as the "plains blackberry." Its adaptation to the central plains region of the United States contributed to its success in Arkansas. 'Lawton' was imported from New York with the background of *R. allegheniensis* Porter x *R. frondosus* Bigel. (Hedrick, 1925) Both are common eastern North American blackberry species and are widely adapted to this region. The hybridization of *R. allegheniensis* and *R. frondosus* also gave rise to 'Snyder' (Hedrick, 1925).

By 1900, more than 750 acres of blackberries were being grown in Arkansas, which yielded greater than 1.4 million lb (Table 2) (USDC, 1900). By comparison, Missouri, Texas, and Kansas all produced more blackberries in total, but Arkansas had the greatest average yield at 1,891 lb/acre (USDC, 1900). Production declined slightly by 1910, but then more than doubled over the next decade. By 1914, the Arkansas Agricultural Experiment Station was recommending 'Early Harvest', 'Kittatinny', 'Snyder', and 'Taylor' as blackberry cultivars and 'Mayes' and 'Lucretia' as dewberry varieties (Truax, 1914). 'Kittatinny' also played an important role in shaping blackberry production in the eastern U.S. It was derived from *R. argutus* L. or *R. pergratus* Blanch. x *R. frondosus*. *Rubus argutus*, one of the major North American blackberry species, is also known as the "tall blackberry" or "highbush blackberry," and exhibits a number of major traits such as cane erectness (Hedrick, 1925). *Rubus pergratus* is widespread throughout the eastern U.S. and is known for having big clusters, large fruit, and sweet and juicy berries. 'Taylor' was a derivative of *R. allegheniensis* x *R. argutus* originating in Indiana. It was very hardy and was considered to have some of the highest quality blackberry fruit (Hedrick, 1925). The dewberries were trailing and incorporated different species. Both 'Mayes' and 'Lucretia' had *R. baileyanus* Britton in their genetic background that contributed large fruit size. Moore (1979) stated that around this time the 'Lavaca' blackberry was widely grown in the area of Lavaca, Ark., but no other information is available about this genotype.

Throughout the 1920s and 1930s, blackberry production in Arkansas continued to increase, as was also the case in Oklahoma. However, surrounding states Kansas and Missouri experienced major declines in production. A cultivar named 'Austin Thornless' was discovered in Oklahoma in 1918 and released in Fayetteville, Ark., in 1924 by J.M. Parker and Son (Hedrick, 1925) (Table 1). It descended from an open-pollination of the cultivar Mayes (synonymous with 'Austin', sometimes called 'Austin-Mayes'). The new cultivar was thornless, had a dominant thornless gene, and was an octoploid.

In 1936, the Arkansas Agricultural Experiment Station began to formally conduct testing of blackberry cultivars supervised by J.E. Vaile (Strausberg,1989). Most of the observations focused on cold hardiness. However, breeding endeavors were not started until 1957 under the direction of J.W. Hull (Moore, 1979).

Blackberry production peaked in Arkansas according to the 1940 agricultural census (USDC, 1940). At that time, almost 2,650 acres of blackberries were grown in the state and production exceeded 1.8 million lb (Table 2). More than 10% of the total acreage of blackberries east of the Rocky Mountains was being grown in Arkansas at that time. Throughout the early decades of this century, canneries in the northwest

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portion of the state processed the blackberries, thus lending to the strong industry (Moore, 1979). By the 1950 census, acreage of blackberries in Arkansas had declined to 1084 acres (USDC, 1950). The steep post-World War II decline continued until 1964, when only 7 acres were being grown in the state, which produced a mere 8,000 lb (USDC, 1964). At the nadir of blackberry production in Arkansas, J.N. Moore greatly expanded the blackberry breeding program. Under his leadership, the new blackberry breeding program at the University of Arkansas spurred a renewed interest in production. Acreage began a slow increase in the late 1960s due to desire for mechanically harvested processing berries and fresh market pick-your-own (PYO) operations (Moore, 1979).

In 1974, Moore released 'Comanche' and 'Cherokee', followed by 'Cheyenne' in 1977, initiating the Native American namesake series of blackberry cultivars (Table 1). These cultivars were products of a cross between 'Darrow' and 'Brazos'. 'Darrow' was a cultivar from New York released in 1958. It was known to be vigorous, cold hardy, very erect, and a heavy producer. It also produced fruit early with good flavor and quality. It was borne out of two main early cultivars, Eldorado and Brewer. 'Eldorado' was a hybrid between *R. allegheniensis* and *R. argutus*, whereas 'Brewer' incorporated *R. pergratus* and *R. frondosus*. 'Brazos' was a Texas A&M Univ. release in 1959 that had 'Nessberry' as a male parent. 'Nessberry' was a cross between a southeastern U.S. blackberry species, *R. trivialis*, and the 'Brilliant' red raspberry (*R. strigosus* Michx.).

By the early 1980s nearly 75% of all blackberries in Arkansas were being mechanically harvested (Moore, 1983) due to the success of 'Comanche', 'Cherokee', and 'Cheyenne'. Yet, double blossom (rosette), caused by the fungus *Cercosporella rubi*, was a prevalent disease that limited wide adaptations of those cultivars. The Arkansas blackberry breeding program continued to be productive throughout the 1980s releasing 'Shawnee', 'Choctaw', and 'Navaho'. 'Shawnee', again, relied heavily on 'Darrow' and 'Brazos' in its background, but also incorporated new species through 'Merton Thornless', a European blackberry. The two European blackberry species present in 'Merton Thornless' are *R. ulmifolius* var. *inermis* Focke and *R. procerus* Muell. *Rubus ulmifolius* var. *inermis* was the source of the recessive thornless gene and *R. procerus* contributed large berry size. 'Shawnee' was the first blackberry cultivar to be patented at the University of Arkansas. 'Choctaw' was a product of 'Darrow', 'Brazos', and another cultivar from Texas, 'Rosborough'. A great program breakthrough was realized in 1988 with the release of 'Navaho', the first thornless Arkansas cultivar.

Success at the University of Arkansas continued through the early to mid-1990s with the releases of 'Arapaho' in 1993 and 'Kiowa' in 1996. 'Arapaho' was similar in background to 'Navaho', but also had a little known cultivar from Virginia in its background named 'Hillquist'. This fortuitous inclusion of 'Hillquist' would pay dividends later on in the evolution of Arkansas blackberry breeding. Like 'Navaho', 'Arapaho' was also thornless with a high quality berry. Unlike the new thornless releases, 'Kiowa' was a thorny, semi-erect to erect cultivar with a low chilling requirement. This probably stemmed from its parentage of Texas-based cultivars, 'Brazos', 'Rosborough', and 'Wells Beauty'.

In 1996, J.N. Moore retired and J.R. Clark was hired to direct the small-fruit breeding program. Clark had been the Director of the Fruit Research Substation in Clarksville, Ark., since 1983, where the majority of the blackberry program activities were conducted. Under the new stewardship of Clark, along with the continued collaboration with Moore, the program released 'Apache' and 'Chickasaw' in 1998 and 'Ouachita' in 2003. Both 'Apache' and 'Ouachita' are thornless, and produce large high-quality berries. 'Ouachita', like 'Apache', 'Arapaho', and 'Navaho', is nearly immune to double blossom. 'Chickasaw' is a thorny variety that produces large berries with a unique flavor. By the end of the century, with the aid of the new cultivar releases from the University of Arkansas blackberry breeding program, production had risen to 178 acres and nearly 250,000 lb (USDC, 1997), the highest number since the 1950 census (Table 2). Near the beginning of the 21st century, production further expanded for fresh-market shipping based entirely on the Arkansas thornless cultivars, which proved to be among the best in the world for postharvest handling (Table 2).

Currently, two new cultivars, Prime-JanTM (APF-8) and Prime-JimTM (APF-12), are being released. In both genotypes, 'Arapaho' is a parent. As mentioned previously, the propitious inclusion of 'Hillquist' in the Arkansas breeding program paid dividends with 'Prime-JanTM' and 'Prime-JimTM'. The hybridizations that produced these genotypes were made in the mid-1990s by Jose Lopez-Medina, then a doctoral student in the Horticulture Department. The selections were nurtured along after his departure and now the new genotypes are the first primocane-fruiting cultivars to be released since 'Hillquist' in 1949. However, 'Hillquist' was a wild selection that had significant problems and limited its widespread production, thus diminishing its usefulness as a cultivar. Both 'Prime-JanTM' and 'Prime-JimTM' are thorny, display a reliable expression of the primocane fruiting trait, and have good fruit size. They are primarily recommended for home garden production. Currently, new primocane-fruiting selections are being evaluated for cane erectness, high yield, and superior fruit quality.

Conclusions

Throughout the last 100 years, blackberry production in Arkansas has cycled through boom and bust cycles. The first half of the 20th century saw many acres worth of blackberries being planted, even during the Depression-era economic downturn. However, the post-World War II years saw the industry bottom out. A rebound was observed throughout the later decades due to mechanical harvesting and fresh market potential. With the continued development of improved cultivars through the University of Arkansas blackberry breeding program, the outlook for Arkansas blackberry production appears promising.

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Table 1. Blackberry cultivars released in Arkansas.

Year	Cultivar	Female parent	Male parent	Releasing entity
1890	Bauer	*R. trivialis*	*R. trivialis*	C.P. Bauer
1924	Austin Thornless	Mayes	O.P.	J.M. Parker
1974	Comanche	Darrow	Brazos	University of Arkansas
1974	Cherokee	Darrow	Brazos	University of Arkansas
1977	Cheyenne	Darrow	Brazos	University of Arkansas
1985	Shawnee	Cherokee	Ark.586	University of Arkansas
1988	Choctaw	Ark.526	Rosborough	University of Arkansas
1988	Navaho	Ark.583	Ark.631	University of Arkansas
1993	Arapaho	Ark.631	Ark.883	University of Arkansas
1996	Kiowa	Ark.791	Ark.1058	University of Arkansas
1998	Apache	Ark.1007	Navaho	University of Arkansas
1998	Chickasaw	Ark.842	Ark.1242	University of Arkansas
2003	Ouachita	Navaho	Ark.1506	University of Arkansas
2004	Prime-Jan™ (APF-8)	Ark.1836	Arapaho	University of Arkansas
2004	Prime-Jim™ (APF-12)	Arapaho	Ark.830	University of Arkansas

Table 2. Arkansas blackberry production in acres, pounds, and lbs/acre from 1900-2004.[z]

Year	Acres	Lb	Lb/acre
1900	769	1,453,935	1,891
1910	525	881,966	1,680
1920	1,269	1,328,309	1,047
1930	1,824	1,404,657	770
1940	2,646	1,855,737	701
1945	2,575	1,734,341	674
1950	1,084	810,243	747
1954	159	56,486	355
1959	75	70,857	945
1964	7	8,000	1,143
1969	94	216,349	2,302
1974	99	93,070	940
1978	65	119,933	1,845
1982	53	81,337	1,535
1987	94	219,960	2,340
1992	68	95,377	1,403
1997	178	246,579	1,385
2004	500	2,000,000	4,000
Total	12,084	12,677,136	--
Average	--	--	1,428

[z] All data from the U.S. Dept. of Commerce, Census of Agriculture 1900-1997, except the 2004 data which was an estimate contributed by John R. Clark.

Genetic Similarity Among Arkansas Blackberry Cultivars Based on Pedigree Analysis

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Additional Index Words. *Rubus* subgenus *Rubus*, fruit breeding

Summary. Blackberries have been an understudied crop in terms of genetic relationships and analysis. The University of Arkansas maintains one of the largest blackberry breeding programs in the world and thus, in-depth knowledge of the cultivars released from the program can aid in future breeding endeavors. Pedigrees of 13 cultivar releases were traced to their founding clones. Genetic contribution (GC) and maximum potential similarity (MPS) were calculated for all cultivars. Sixteen founding clones contributed to 13 cultivars, ranging from <1% to 19%. Calculations for MPS ranged from complete similarity for 'Cherokee'/ 'Cheyenne'/ 'Comanche' to 0.3594 for 'Comanche', 'Cherokee', and 'Cheyenne' / 'Ouachita'. The MPS calculation provided some similarity to those of other molecular studies, especially for the cultivar Choctaw.

Blackberry breeding has existed for well over 150 years, and in 1909, the first public blackberry breeding program was started in Texas (Moore, 1984). The University of Arkansas blackberry breeding program was initiated in 1964 and has since released 13 cultivars, of which 10 are patented. Some of the major objectives of this program are to develop superior genotypes that contain the following traits: improved thornless character, erect canes, fruit firmness, large fruit size, high yield, and, recently, primocane fruiting (Clark, 1999).

The Arkansas program has relied heavily on genotypes derived from *Rubus allegheniensis* Porter, *R. argutus* Link., and *R. frondosus* Bigel. Cultivars that were exploited at the beginning of the program were 'Darrow', 'Brazos', and 'Thornfree', among others. The current practice of intensive crossing among selections within the program has led to important discoveries with economic potential within the blackberry genome, such as thornless canes and primocane fruiting.

Molecular studies to determine genetic relatedness have been reported in *Rubus*, however few have dealt directly with blackberry cultivars (Nybom et al., 1989; Stafne et al., 2003). Even though the advent of molecular techniques has made genetic similarity results more robust, it is still of interest to determine how established pedigrees of blackberry genotypes relate to each other and what the potential ramifications are for future breeding objectives.

Blackberry is a highly heterozygous organism and many current cultivars are tetraploid. Because of the varied reproductive strategies of polyploid blackberries (sexual, facultatively apomictic, and obligately apomictic; Hall, 1990), cytological conditions (auto- and allo-polyploidy), and inheritance strategies (disomic and tetrasomic), it is difficult to accurately portray genetic contribution through pedigree records. However, since eastern North American blackberries for the most part are not apomictic (Hall, 1990), sexual recombination can be assumed and an equal segregation of genes from parent to progeny will also be assumed in this study because allopolyploidy is more prevalent in Eubatus than autopolyploidy (Ourecky, 1975), thus leading to bivalent chromosome pairing. Even though in blackberries both auto- and allopolyploidy are recognized (Ourecky, 1975), pedigree analysis still provides a basis for comparison of genotypes.

The objectives of this study were to determine genetic similarity among the Arkansas blackberry genotypes using maximum potential similarity (MPS) coefficients derived from the genetic contribution (GC) of the founding clones.

Materials and methods

Thirteen University of Arkansas blackberry genotypes were included in this study (Table 1). The pedigrees for these genotypes were entered into a specialized program called PediTrack (Stafne and Clark, 2004) using Microsoft Access® 2000 which traced all pedigrees back to their founding clones. All parentage information was gained from the original published pedigree or internal University of Arkansas blackberry breeding program parental records.

Genetic contribution was calculated as $GC = \sum(1/2)^{n}_{1...x}$, where n is equal to the number of generations between the founding clone and the cultivar, and x is the number of generational pathways between the founding clone and the cultivar. Open-pollinated genotypes were considered to have an unknown male parent and were not included in the statistical comparisons due to their unknown parentage.

Maximum potential similarity takes into account pair-wise comparisons between genotypes for each founding clone they share. Unshared founding clones were ignored in this comparison, as were unknown or open-pollinated (OP) clones. When the shared founding clones were compared, the lesser of the two values was selected and totaled for all shared founding clones. This total was attributed the name MPS because it determined how much potential genetic contribution one genotype could share with another.

Dendrograms were derived from the application of the unweighted pair-groups method average (UPGMA) to the similarity matrices in

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NTSYS-pc in the TREE program in the Numerical Taxonomy and Multivariate Analysis System for PC (NTSYS-pc, version 2.1) (Rohlf, 2000). A cophenetic correlation was used to determine the goodness of fit of the MPS similarity matrices to the resulting UPGMA cluster dendrograms using ultrametric distances with the Mantel test (Mantel, 1967) in the COPH and MXCOMP programs.

Results and discussion

A total of 15 founding clones contributed to the 13 Arkansas cultivars in this study. *Rubus allegheniensis*, *R. frondosus*, *R. argutus*, *R. strigosus* Michx., *R. rubrisetus* Rydb., and *R. pergratus* Blanch. had the greatest frequencies and were present in all 13 genotypes (Table 2). *R. allegheniensis* had the highest mean GC of 18.93%, indicating that according to pedigree records, it comprised nearly 20% of the total genetic makeup in all of the 13 Arkansas cultivars in this study. At the opposite end of the spectrum, *R. occidentalis* L., a raspberry species, contributed only 0.12%, having been in only 'Prime-Jan™' (APF-8). Eight of the 15 founding clones had a frequency of 10 or more and five of 16 had a frequency of six or less. Overall, the top six founding clones for mean GC conferred over 75% to the 13 cultivars in this study, suggesting a somewhat narrow genetic base.

Maximum potential similarity was used to calculate the similarity among genotypes. The MPS ranged from a high of 1.0 (complete similarity) for 'Cherokee' / 'Cheyenne' / 'Comanche' to a low of 0.3594 for 'Comanche', 'Cherokee', and 'Cheyenne' / 'Ouachita' (data not shown). Due to the approximate nature of the MPS calculation, clones with identical parentage were not discernible. Overall mean MPS for all genotypes was 0.6899 and ranged from 0.4496 for 'Ouachita' to 0.7683 for 'Shawnee' (data not shown).

Cluster analysis was performed for the MPS similarity matrix and a dendrogram was produced using the UPGMA method. The MPS method was meant to give a relative measure of relatedness, and because of it's lack of precision, was not able to distinguish between 'Cherokee', 'Cheyenne', and 'Comanche', which all have the same parentage (Fig. 1). The MPS dendrogram did reflect what is known of the Arkansas cultivars, showing close relationships between parents and offspring [such as 'Navaho' / 'Apache' and 'Arapaho' / 'Prime-JimTM'(APF-12)]. The matrix correlation derived from the Mantel (1967) test was 0.9211, suggesting a very good fit of the matrix to the resulting dendrogram (Rohlf, 2000). The dendrogram consisted of three clusters, with one being 'Ouachita' by itself.

As for comparison with molecular studies, MPS tended to overestimate relatedness, though in some cases the similarity coefficients were very close. In several instances the minisatellite data from Nybom et al. (1989) and the RAPD data from Stafne et al. (2003) were within 0.05 of the MPS, especially in relation to comparisons dealing with 'Choctaw'. Even though MPS is an imprecise method of estimation, it appears to have some validity for gauging similarity between blackberry cultivars. However, any assessment should be backed by other methods of estimation, such as molecular studies.

Conclusion

Recovering recessive alleles and a dependence on a somewhat narrow genetic base in the early years of the program have led to high similarity coefficients among the 13 Arkansas blackberry cultivars in this study. Yet, as the background of 'Ouachita' can attest, there is still a wide diversity of genes to explore within the program. New germplasm could infuse genes for cold hardiness, disease resistance, and other useful traits for future breeding endeavors, thus widening the genetic base of blackberry. However, the University of Arkansas blackberry breeding program maintains an extensive variety of genes from which to continue its production of improved blackberry cultivars.

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Table 1. Parentage of 13 Arkansas blackberry cultivars.

ID	Genotype	Parentage
Ap	Apache	(SIUS 68-6-15 x Comanche) x Navaho
A08	Prime-Jan™ (APF-8)	Ark.1836 x Arapaho
A12	Prime-Jim™ (APF-12)	Arapaho x Ark.830
Ar	Arapaho	(Ark.550 x Cherokee) x Ark.883
Ce	Cherokee	Darrow x Brazos
Cy	Cheyenne	Darrow x Brazos
Ck	Chickasaw	(Comanche x Ark.516) x Ark.1246
Ct	Choctaw	(Darrow x Brazos) x Rosborough
Cm	Comanche	Darrow x Brazos
K	Kiowa	(Ark.586 x Comanche) x (Ark.628 x Rosborough)
N	Navaho	(Thornfree x Brazos) x (Ark.550 x Cherokee)
Ou	Ouachita	Navaho x Ark.1506
S	Shawnee	Cherokee x (Thornfree x Brazos)

Table 2. Frequency of occurrence and mean genetic contribution (GC) of founding clones in 13 Arkansas blackberry cultivars.

Clone	Frequency	Mean GC (%)
Rubus allegheniensis Porter	13	18.93
Rubus frondosus Bigel.	13	17.07
Rubus argutus Link.	13	12.02
Rubus strigosus Michx.	13	10.16
Rubus rubrisetus Rydb.	13	10.04
Rubus pergratus Blanch.	13	7.03
Unknown (OP)	6	5.41
Rubus thyrsiger Banning & Focke	9	3.73
Rubus ulmifolius var. *inermis* Focke	9	3.73
Georgia Mammoth	10	3.49
Rubus procerus Muell.	10	3.49
Wells Beauty	3	2.88
7433	1	0.96
SIUS 68-1-8	1	0.96
Rubus occidentalis L.	1	0.12

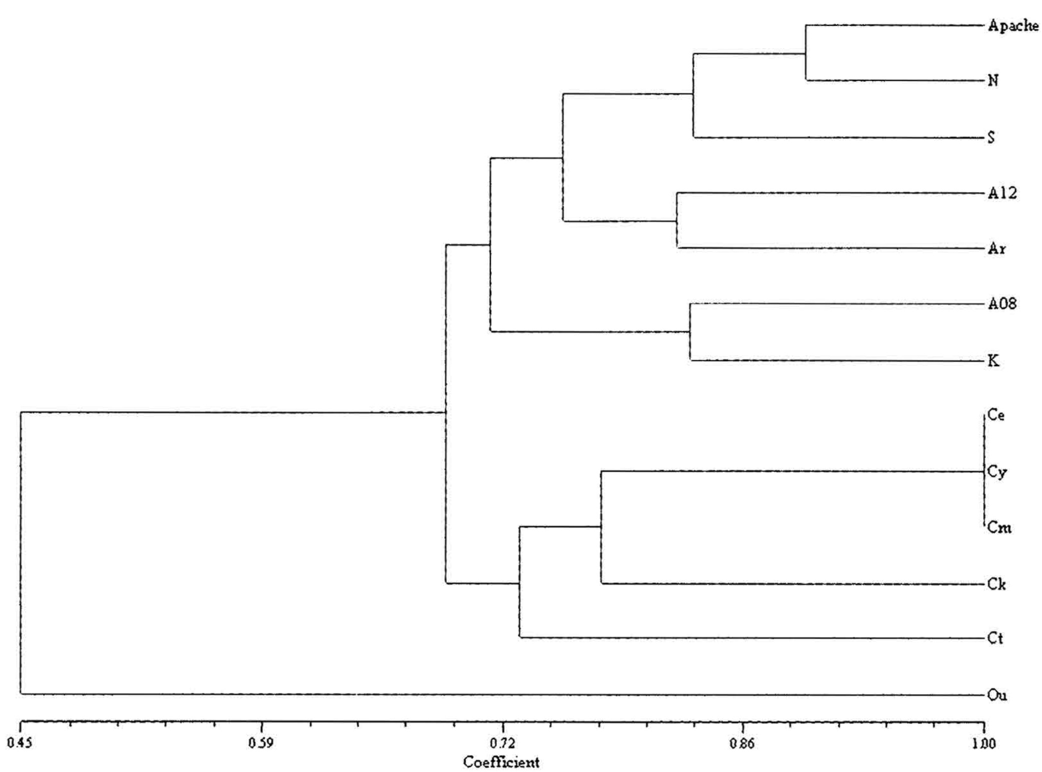

Fig. 1. Maximum potential similarity (MPS) dendrogram of 13 Arkansas cultivars.

Evaluation of Resistance to *Erwinia amylovora* and *Botryosphaeria dothidea* in Eastern U.S. Blackberry Cultivars

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Additional Index Words. Disease resistance, fire blight, *Botryosphaeria* cane canker, *Rubus.*

Summary. In order to gauge the level of resistance available, eleven blackberry cultivars were inoculated with two different pathogens, the bacterium *Erwinia amylovora* and the fungus *Botryosphaeria dothidea.* Primocanes on 1-year-old plants were greenhouse inoculated with *E. amylovora* by injecting a sterile water suspension of the pathogen into the shoot-tips. Ten days after inoculation, these plants were rated for severity of symptoms on a scale of 0 to 5. Primocane cuttings 7 in. (18 cm) in length, taken from mature field plots, were inoculated with *B. dothidea* by placing a 1/8th in. (3 mm) square of mycelia into an incision, and incubating them at high humidity on a lab bench. Ten days following inoculation, the resulting lesions, if any, were measured and the area computed. Both resistant and susceptible cultivars were identified for each of the two diseases. The most resistant cultivars to *E. amylovora* were 'Kiowa', Prime-Jim™ and 'Arapaho', while 'Triple Crown' and 'Arapaho' were the most resistant to *B. dothidea.*

Blackberries (*Rubus* subgenus *Rubus*) are a crop of growing importance in Arkansas and the United States, and the University of Arkansas breeding program is among the largest in world. While blackberries are generally considered a relatively disease-free crop and most blackberry diseases are infrequent problems, some have on occasion caused significant damage. As blackberries continue to be planted in varied climates and in increasing numbers, the possibility exists that currently minor diseases may become serious issues. Prompted by an unexplained outbreak of shoot-tip blight in 'Apache', which was observed in research plots in 2001, inoculation studies were conducted in order to gauge resistance of important cultivars of eastern U.S. blackberries to two cane blight pathogens: the bacterium *Erwinia amylovora* Burr. (Winsl. et al.), and the fungus *Botryosphaeria dothidea* (Moug. Ex Fr.) Ces. & de Not.

Erwinia amylovora causes fire blight, a bacterial disease affecting many Rosaceous species, with apple (*Malus* sp.) and pear (*Pyrus* sp.) being of the greatest economic significance (Bonn and van der Zwet, 2000). Outbreaks in *Rubus* species, while less common, do occur, including incidents on blackberries in eastern Oklahoma (S. von Broembsen, personal communication), and Illinois (Ries and Otterbacher, 1977). Fire blight has been reported on red raspberries (*Rubus idaeus* L.) in Wisconsin (Heimann and Worf, 1985) and Canada (Braun et al., 1999; Evans, 1996), where it has become a significant problem in some years. Although the strain of *E. amylovora* responsible for fire blight in *Rubus* species is generally considered to be different than that responsible for the disease in all other hosts, at least one incident of infection by an apple isolate in raspberry has been reported (Evans, 1996). While Ries and Otterbacher (1977) found several resistant raspberry cultivars, including 'Fall Red' and 'Heritage', none of the nine blackberry cultivars included in their study demonstrated any resistance to the pathogen.

Botryosphaeria dothidea is the causal agent of *Botryosphaeria* cane canker, a fairly uncommon disease of thornless blackberries (Maas and Uecker, 1984). It is a common facultative parasite on dead and dying tissue in many woody species, and a pathogen on several important species, including apple, peach (*Prunus persica* (L.) Batsch), and blueberry (*Vaccinium* sp.), in addition to blackberries. In blackberries, it causes dark, spreading lesions at wound sites on mature tissue, sometimes girdling canes entirely. In severe cases, removal of entire plantings has been necessary (Maas and Uecker, 1984). Maas and Uecker (1984) compared both lengths of lesions and subjective ratings of six cultivars, and found significant differences among genotypes using both measurements. However, little is known about most of the cultivars currently important in the eastern United States.

Materials and methods

Fire Blight Resistance Study: An isolate of *E. amylovora* bacterium taken from affected blackberry plants in eastern Oklahoma was obtained in 2002 from S. von Broembsen at Oklahoma State University, Stillwater, Okla. This was streaked on *Erwinia* selective medium (Crosse and Goodman, 1973) and confirmed as *E. amylovora* by colony morphology, then grown on liquid 523 medium (Kado and Heskett, 1970) and stored in 15% glycerol solution at -20°C. Two days before inoculation, this solution was streaked on plates of 523 medium and incubated at 28°C until immediately before inoculation. Two loopfulls of bacteria were taken from the plate and placed in 10 ml of sterile distilled water and mixed vigorously to provide a uniform liquid suspension.

Dormant root cuttings (~10 cm or 4 in. in length) were taken from mature research plantings at the University of Arkansas Agricultural

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Research and Extension Center, Fayetteville, and the University of Arkansas Fruit Substation, Clarksville, in December 2002. Twelve to 15 cuttings of each cultivar were potted in Sunshine Mix LC1 (SunGro Horticulture Inc., Bellevue, Wash.) potting mix amended with 50 ml of Osmocote Vegetable & Bedding Slow Release Plant Food (The Scotts Company, Marysville, Ohio) fertilizer (14-14-14) per 0.03 m^3 of soil in February 2002, and grown in the greenhouse. Of the resulting plants, five were selected of 'Apache', 'Arapaho', 'Navaho', 'Chester Thornless', 'Triple Crown', 'Illini Hardy', and and 'Prime-Jim'™ for the first trial, and six plants of each these cultivars, as well as 'Kiowa', 'Chickasaw', 'Ouachita', and 'Shawnee', were selected for the second trial. Both trials were conducted according to a randomized complete block design in the greenhouse. Greenhouse temperature was maintained at 24° day /22°C night, and plants were kept humid with misting at 9 AM and 4:30 PM each day. The first trial began 5 May 2003, while the second began 1 June 2003.

Plants were inoculated by inserting a No. 30-gauge hypodermic needle completely through the stem just below the first fully unfolded leaf. Sufficient liquid was ejected to completely fill the wound and leave a droplet on either side (Norelli et al., 1988). Additionally, two plants each of 'Arapaho', 'Apache', and 'Navaho' were injected with sterile water as controls. Ten days following inoculation, plants were rated on a scale of 0 to 5 based on the severity of their reaction, with 0 being no visible symptoms, and 5 being complete necrosis from the point of inoculation to the tip of the shoot. Ratings data were analyzed using t-test and analysis of variance functions of the JMP 5.0 statistical software package (SAS Institute, Cary, N.C).

Botryosphaeria Cane Canker Resistance Study. An isolate of the *B. dothidea* fungus was obtained from a research planting of 'Apache' blackberries in Fayetteville, Arkansas in September of 2001. Cultures were maintained at room temperature on plates of potato dextrose agar (PDA) medium with streptomycin (75 mg/L).

Cuttings of primocanes were taken from 11 cultivars of blackberry: 'Arapaho', 'Apache', 'Navaho', 'Ouachita', 'Chickasaw', 'Kiowa', 'Shawnee', 'Illini Hardy', 'Triple Crown', 'Chester Thornless', and 'Prime-Jim'™ . Cuttings were 7 in. (18 cm) in length and averaged 1/3 in. (7.5 mm) in diameter, and were taken from the woody portion of the main stem. After collection in the field, cuttings were transported within an ice-filled cooler to the laboratory, where ends of the fresh cuttings were sealed by dipping 1/2 in. (1 cm) of each end in molten wax held at 100°C. After sealing they were briefly surfaced sterilized by submersion in a 1.5% sodium hypochlorite solution, wiped dry, and rinsed with water. Cuttings were then stored in a walk-in cooler overnight until inoculation the next day. The trial was repeated four times, with material collected on 10 and 24 Aug. 2002 and 18 July and 15 Aug. 2003.

Squares of media (~3 mm square or 13 in.) containing fungal mycelia were cut and placed in an incision 3 mm (1/8 in.) wide and 12 mm (1/2 in.) long made near the middle of each cutting. Incisions were deep enough to penetrate the epidermis and expose the underlying tissue without causing major vascular damage. After placing the inoculum, the wound was wrapped gently with a small piece of Parafilm® (American Can Company, Greenwich, Conn.) to hold the media in place and prevent desiccation of the incision. In each trial, two additional cuttings of each cultivar received uninoculated squares of PDA with streptomycin as controls.

The inoculated cuttings were placed in perforated plastic trays with clear plastic covers, suspended above water at a depth of approximately 1 in. (2 cm) to maintain humidity. The tray covers were misted with water once daily. Cuttings were placed diagonally on test tube racks in the center of the tray, and arranged according to a completely random design. The number of cuttings (replications) of each cultivar varied among trials. The 10 Aug. 2002 trial included eight of each genotype, the 18 July 2003 trial included 10 of each, and the 24 Aug. 2002 and 15 Aug. 2003 trials each had 12 of each cultivar.

Ten days following inoculation, the length and width of each resulting lesions was measured, and an area estimated by assuming an elliptical shape. The data were then transformed by taking the square root of this area, to compensate for skewness. Pair-wise student's t-test for mean separation and analysis of variance were performed using the JMP 5.0 statistical software package (SAS Institute, Cary, N.C).

Results and discussion

Fire Blight Resistance Study. Analysis of variance indicated that cultivar was the primary source of variance in the study, and that neither trial date nor replication had a significant effect. As such, data were summarized across trials. Significant differences were noted among many of the cultivars evaluated, indicating a wide range of resistances to the fire blight pathogen (Table 1). The cultivars Triple Crown, Arapaho, Prime-Jim™, and Kiowa all appeared highly resistant, with average disease severity ratings of less than 1. 'Navaho' was the most susceptible, with an average rating of 3.9. 'Navaho' is also a parent of two other susceptible cultivars, 'Apache' and 'Ouachita'. No symptoms were observed on any of the control plants.

Differences in genetic resistance to fire blight in blackberry were not unexpected. Studies have revealed both resistant and susceptible individuals in many host species of *E. amylovora*, including apple (Gardner et al., 1980), pear (Oitto et al., 1970) and red raspberry (Ries and Otterbacher, 1977). However, this study may be the first to document resistance to the pathogen in blackberry.

Botryosphaeria Cane Canker Resistance Study. Cultivar was shown by analysis of variance to be the only significant factor affecting lesion area, with no significant effects of trial or trial by genotype interaction. Significant differences in mean transformed lesion area were noted among the cultivars in the study (Table 2), on all trial dates. 'Chickasaw' was the most susceptible and was significantly greater than 'Ouachita', the second most susceptible. 'Arapaho' and 'Triple Crown' were once again among the most resistant, but 'Kiowa' was among the most susceptible cultivars. Most cuttings of 'Arapaho' and 'Triple Crown' showed no symptoms at all (data not shown).

It would seem likely, though not necessarily certain, that the differences observed in this detached cane assay would extend to intact plants. Smith (1988), working with rabbiteye blueberries (*V. ashei* Reade), found that a similar technique yielded the same ratings in both cuttings and potted plants. This detached-cane assay seems to confirm the resistance observed in both greenhouse and field plantings of 'Chester Thornless' noted by Maas (1986) and Maas and Uecker (1984).

Conclusions

Resistance to both *E. amylovora* and *B. dothidea* existed among the blackberry cultivars used in this study. Because both of these diseases have previously received relatively little study in blackberry, this information may prove useful for growers and researchers in the future. As the cultivation of blackberries expands to new regions and larger acreages, the potential exists for both these diseases to become more serious issues, and this study may help in the management of such problems.

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Table 1. Mean disease severity rating (0-5[z]) of blackberry genotypes 10 d after inoculation with *E. amylovora* .

Genotype	Mean rating
Navaho[y]	3.9 a[w]
Apache[y]	2.6 b
Ouachita	2.0 bcd
Shawnee	1.8 bcde
Chickasaw	1.5 cdef
Illini Hardy[y]	1.4 cdef
Chester Thornless[y]	1.1 def
Triple Crown[y]	0.9 ef
Arapaho[y]	0.8 ef
Prime-Jim™[y]	0.8 ef
Kiowa	0.1 f

[z] Ratings scale: 0=no symptoms, 5=severe necrosis.

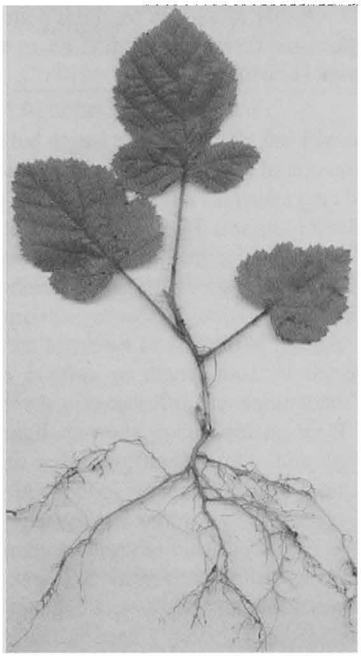
[y] Cultivar included in both trial 1 and trial 2 (n=11). All others included in trial 2 only (n=6).

[w] Means followed by the same letter do not differ significantly ($P \leq 0.05$) according to the pair-wise student's t-test method.

Table 2. Mean of square-roots of *B. dothidea* lesion areas (cm^2) and mean areas for blackberr cuttings of different genotypes collected and inoculated on all dates.

Genotype	Mean area (transformed)	Mean area (cm2)
Chickasaw	2.49 a[z]	7.9
Ouachita	1.89 b	4.9
Kiowa	1.65 bc	4
Shawnee	1.65 bc	4
Prime-Jim™	1.63 bc	4.2
Navaho	1.59 bc	4.3
Apache	1.41 cd	3.4
Illini Hardy	1.40 bcd	2.8
Chester Thornless	1.07 d	2.4
Arapaho	0.31 e	0.6
Triple Crown	0.29 e	0.4

[z] Means followed by the same letter do not differ significantly ($P \leq 0.05$) according to the pair-wise student's t-test method.



Propagation of Thornless Blackberries Utilizing Adventitious Shoots from Root Cuttings

E. Thompson, J.R. Clark, and C.R. Rom[1]

Additional Index Words. Small fruits, *Rubus.*

Summary. Studies were conducted in early 2003 to determine the effect of root source and length on yield of adventitious shoots and plant yield from root cuttings of Arkansas-developed thornless blackberries. In the first study, roots from 'Arapaho' and 'Apache' plants grown in an aboveground bed containing commercial potting soil were compared to field-grown roots. Bed-grown roots averaged 6.9 shoots per 15 cm root cutting while field-grown roots averaged 3.4 shoots per root. 'Apache' produced more shoots/root cutting compared to 'Arapaho', (5.9 vs. 4.4 shoots/root cutting, respectively). In a comparison of 15- and 30-cm-long root cuttings of 'Apache', 'Arapaho', and 'Ouachita', shoot yield of 30-cm roots was higher than that of 15 cm roots, but total yield of shoots per unit root was not increased by the longer root cuttings. Rooting of adventitious shoots neared 100% in both studies, and resulting quality of plants from these shoots was very good. This minor modification to the traditional method of using root pieces to yield individual plants could lead to a more efficient and productive yield of propagules. The use of adventitious shoots from root cuttings for blackberry plant propagation appears to be a viable method for growers to consider.

Traditional methods of blackberry (*Rubus* subgenus *Rubus* Watson) propagation include tip layering, softwood cuttings, root cuttings, and tissue culture (Caldwell, 1984). While all are successful, some methods require lengthy establishment and growing periods and do not meet virus-tested stock demands when virus-tested stock plant material is limited or when propagation must be conducted in enclosed structures with very limited space. These methods are commonly used due to familiarity and cost efficiency. Root cuttings are the most widely practiced type of propagation for Arkansas-developed cultivars (John R. Clark, personal communication). However, modifications in the use of root cuttings could lead to a more efficient yield of propagules. The forcing of multiple adventitious shoots and subsequently rooting them to produce individual plants would allow propagators to yield more plants from a single, longer root cutting. This method has been used in raspberry production as a successful means to increase propagule yield (Jennings, 1988). Also, a nursery in Switzerland that propagates and grows Arkansas-developed cultivars has found this method to be efficient for both raspberries and blackberries (Markus Kobelt, Rhein-Baumschulen, Buchs, Switzerland, personal communication).

Cultivar and source of root cuttings have been regarded as possible sources of variation in resulting plant stand and quality. Observations involving bed-grown root cuttings indicated they varied in performance compared to field-grown root cuttings (Charles Boyd, Cedar Valley Nursery, Centralia, Wash., personal communication). Arkansas-developed blackberry cultivars have also been shown to vary in the percent sprouting of root cuttings (Clark and Moore, 1999), therefore, an evaluation of cultivar effects is needed in the evaluation of root cutting feasibility for plant production.

The objectives of our studies were to: 1) compare field-grown roots to soil-less, bed-grown roots in adventitious shoot production for two blackberry cultivars, and 2) determine if root cutting length affects resulting adventitious shoot number, plant size, and quality for three blackberry cultivars. Our goal is to provide blackberry nurserymen with information to maximize propagation potential of Arkansas-developed blackberries.

Materials and methods

Experiment I: Cultivar and Root Source Study

In Dec. 2002, thirty field-grown roots of the thornless blackberry cultivar Arapaho were collected from the University of Arkansas Agricultural Research and Extension Center, Fayetteville. The same number of 'Apache' roots was collected from the University of Arkansas Fruit Substation, Clarksville. The diameter of the roots was measured and root pieces cut to 15 cm and placed in sealed, moist plastic bags in cold storage at approx. 3°C (37°F). The average diameter of the bed-grown roots was 2.4 mm (0.9 in.), while the field-grown roots averaged 4.7 mm (2.18 in.). On 19 Jan. 2003 (approximately 1 month storage), the root cuttings were removed from storage and placed in drained, plastic tubs containing soil-less potting mix Promix® (Sun-Gro Horticulture, Bellevue, Wash.) to a depth of 6 cm (3.4 in.). The roots were maintained in the containers until mid-June. The containers were kept in a greenhouse with a daily minimum temperature of ≈18°C (64°F) and a daily maximum temperature of ≈25°C (76°F). Roots were placed in the containers in a randomized complete block design with 10 replications, with three roots of each cultivar/root source per replication. Adventitious shoots were removed each 7-10 d as they emerged and average length of shoots at removal was 3 to 5 cm. Harvested adventitious shoots were

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then inserted into peat pellets (Jiffy Co., Batavia, Ill.) and placed under an intermittent mist system until rooted. Adventitious shoots generally rooted within 7 to 12 d. Up to 10 rooted shoots were potted in 10 cm pots containing soil-less potting mix Promix® (Sun-Gro Horticulture, Bellevue, Wash.), maintained in the greenhouse, grown, and later evaluated for quality in May, 2003. Each 0.8 cubic meter bag of potting media was mixed with 50 g of sulfur-coated fertilizer (Osmocote) 14-14-14 (The Scotts Co., Marysville, Ohio) per 0.03 cubic meter of soil. Data collected included the following: 1) date of adventitious shoot collection, 2) total number of adventitious shoots yielded, 3) plant establishment and survival percentage, and 4) overall resulting plant quality rating from 1 to 5 with 1 equal to excellent plant health and 5 = poor plant health.

Experiment II: Cultivar and Root Length Study

Field-grown roots of 'Arapaho' and 'Ouachita' were collected from the same Fayetteville location, and 'Apache' from Clarksville in Dec. 2002. Roots of each cultivar were cut into lengths of 15 and 30 cm and placed in plastic containers containing soil-less medium as described in Experiment I. Roots were evaluated for quality in May 2003, and all roots were maintained in the containers until mid June 2003. Roots and harvested adventitious shoots had received the same greenhouse environment as in Experiment I. The study was arranged as a randomized complete block design with four replications of each treatment, with three roots of each cultivar and length per replication. Data were collected as described in Experiment I.

Data for both studies for shoot yield, plant survival, and plant quality were analyzed by analysis of variance using JMP (JMP, version 4, SAS Institute Inc. Cary, N.C.) and treatment means compared using t-tests ($P<0.05$).

Results and discussion

Experiment I

There were significant effects for root source and cultivar for adventitious shoot production per root cutting, but not for the interaction of root source and cultivar. 'Apache' averaged 5.9 adventitious shoots per root, compared to 'Arapaho' with 4.4 (Table 1). This observation agrees with a study by Clark and Moore (1999), in which adventitious shoot yield from 'Apache' root cuttings was higher than that of 'Arapaho.' Bed-grown roots produced on average 6.9 adventitious shoots per root, significantly greater than field-grown roots, which averaged only 3.4 adventitious shoots per root (Table 1). Adventitious root collection began approximately 4 weeks after placement of roots in the medium. Overall, adventitious shoot harvest was greatest in the first 7 weeks after first shoot emergence, but was greatly reduced thereafter (Fig.1). For bed-grown roots, there was a tendency for earlier shoot development and subsequent adventitious shoot harvest particularly in the first 2 weeks after first emergence (data not shown). Eleven weeks after initial planting, 75% of 'Apache' and 72% of 'Arapaho' bed-grown shoots had been harvested. Field-grown adventitious shoot yield was also greatest in the first 11 weeks of the study, however in comparison to bed-grown sources, shoot development in field-grown sources was somewhat delayed. Adventitious shoot yield decreased greatly after 11 weeks from initial root planting for both bed-grown and field-grown sources (data not shown).

The percent survival for the adventitious shoots was approximately 100% (data not shown), indicating near complete success of rooting and subsequent plant survival using this method. Once potted, the plants grew vigorously and did not show any signs of nutrient deficiencies or further weaknesses. Quality ratings on resulting potted plants indicated excellent performance and there were no differences among cultivars or root sources (data not shown).

Experiment II

There were significant effects for root length but not cultivar in this study and the interaction of root length and cultivar was not significant. A root length of 30 cm yielded 6.1 adventitious shoots per root, while the average for the 15 cm roots was 3.4 adventitious shoots per root (Table 2). The overall plant yield, in a practical sense, was not different in that longer roots simply yielded about the same number of adventitious shoots as two of the shorter roots. Similar to Experiment I, adventitious shoot harvest was greatest in the first 11 weeks of the study, and did not appear to be affected by root length or cultivar (data not shown). Cultivars showed small numerical differences in shoot number, but none were significant. Plant quality ratings showed slight numerical differences for root length and cultivar, but none were significant (data not shown). Overall, plant quality was very good for all cultivars and root lengths.

The major objective of our studies was to determine if propagation of thornless blackberries utilizing adventitious shoots from root cuttings proved to be a more efficient and higher-yielding method than traditional root cutting propagation commonly used in the industry. We were equally interested in ensuring that plant quality using this method is as good as that produced from other, more traditional methods. The survivability of plants using this method was excellent. Once the adventitious shoots rooted and were potted, they grew vigorously and could quickly be grown into a marketable plant.

The increased number of plants yielded per root using this method would be much less than the more common yield of one plant per root cutting. This could be of particular value if nurserymen grew plants for root cuttings in enclosed structures, such as beds in screenhouses that excluded virus vectors, and subsequently used the roots to force adventitious shoots. Growers using this method could expect significantly higher adventitious shoot production in the thornless cultivar 'Apache', although this method is also useful for the other cultivars. Growers could also expect to double adventitious shoot yields if bed-grown roots were used.

Further studies on this topic might include the evaluation of rooting hormone on adventitious shoot production. Evaluating the use of shorter bed-grown roots in greater quantities and comparing the resulting number of adventitious shoots may result in an even greater yield of propagules.

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Table 1. Number of adventitious shoots per root resulting from bed- and field-grown roots of 'Apache' and 'Arapaho' blackberries.

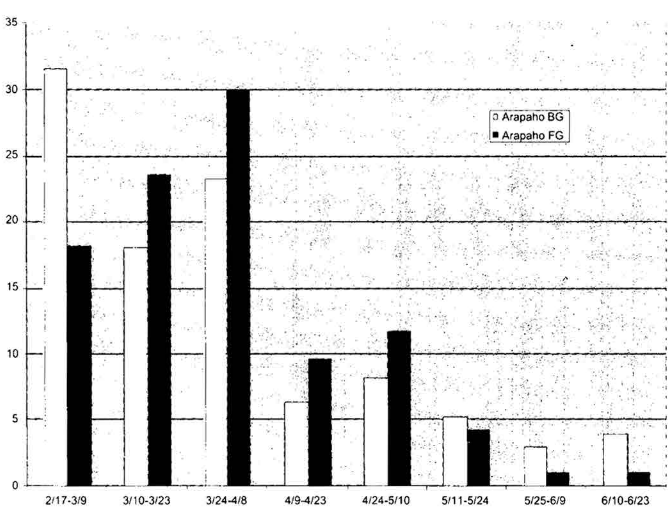
Cultivar	Bed-grown	Field-grown	Cultivar main effects
Apache	8	3.8	5.9a[z]
Arapaho	5.8	2.9	4.4b
Root source main effects	6.9 A[z]	3.4 B	

[z] Upper case letters represent a significant main effect difference for root source; lower case letters represent a significant difference for cultivar (P<0.05). The interaction of cultivar by root source was not significant in the data analysis.

Table 2. Number of adventitious shoots per root at two root lengths among three cultivars.

	Root length		
Cultivar	15 cm	30 cm	Cultivar main effects
Apache	2.5	5.8	4.2
Arapaho	4.6	5.3	5.0
Ouachita	3.1	7.2	5.2
Root length main effects	3.4 A[z]	6.1 B	

[z] Upper case letters represent a significant difference among root lengths, (P<0.05).



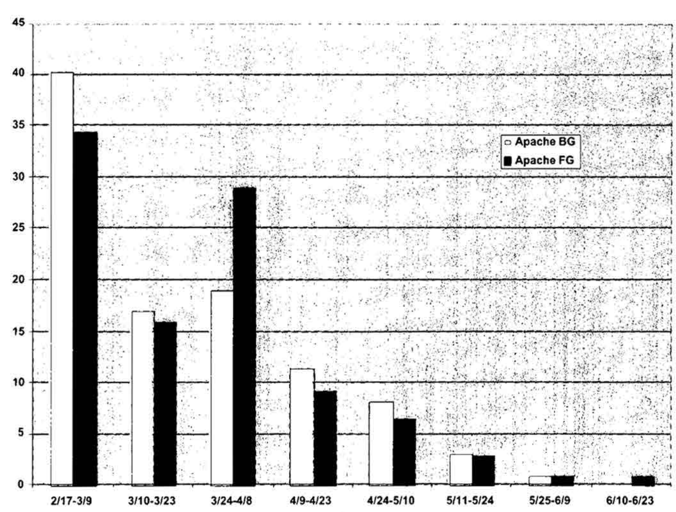


Fig. 1. Dates of adventitious shoot collection from 'Arapaho' and 'Apache' blackberry roots from bed- (BG) or field-grown (FG) sources.

TURFGRASSES
&
ORNAMENTALS

Early Field Performance of Ornamental Birch Taxa (*Betula* spp.) at Fayetteville and Hope

M. Gu, J. A. Robbins, and C. R. Rom[1]

Additional index words: trees, environmental stress

Summary. Nineteen birch taxa (*Betula* spp.) were planted in the field at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, and the Southwest Research and Extension Center, Hope, Arkansas, in 2002 to evaluate survival, growth rate, and leaf gas exchange. After two seasons of replicated field observation at two sites, taxa are differentiating themselves for survival and potential landscape use. Of the taxa tested, *B. populifolia*, and *B. nigra* L., the only birch taxa native to Arkansas, and their 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. suffered significant tree death and appear to be poorly adapted to southern climate landscapes.

Birch trees, especially white-barked taxa, are a popular ornamental tree in urban landscapes. Most birch species are naturally distributed in regions or geographical settings typified by high soil moistures in the northern United States (Atkinson, 1992). In general, white-barked birches, the most highly desirable landscape form, do not grow well in the southern landscape due to environmental stresses, among which water deficit stress and heat stress are major problems. Environmental stresses increase birch susceptibility to bronze birch borer, a secondary cause of decline and dieback of trees in the landscape.

There has been significant research conducted on various birch taxa in northern Europe, Canada, and the US. Similarly, there have been significant field trials of *Birch taxa* in northern climates. However, there has not been intensive landscape performance evaluation of birch in the southern regions.

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The objective of this study was to evaluate survival and growth of birch taxa at two locations in Arkansas, and study the interaction of water deficit on birch performance under Arkansas conditions.

Materials and methods

Nineteen birch taxa were planted at the University of Arkansas Research and Extension Center, Fayetteville, Ark., and the Southwest Research and Extension Center, Hope, Ark., as previously described by Gu et al. (2003). Trees were evaluated for survival and measured for growth of height and trunk caliper on 29 Oct. and 17 Oct., 2002, and 4 Dec. and 13 Nov., 2003, at Fayetteville and Hope, respectively. Gas exchange of single leaves was measured on multiple days in July and Aug., 2003 using a portable gas exchange system (CIRAS-1, PP Systems, Inc.) as described by Gu et al., 2003.

The study in Fayetteville was established as a split-plot for soil water status with each taxon receiving either adequate water or a water deficit during the growing season. In order to limit the infiltration of precipitation and control soil water status of the rhizosphere, the soil under trees within the rows was covered with polyethylene mulch 54 in. (1.2m) wide under which irrigation lines with trickle-emitters were installed. One inch (2-3cm) layer of hardwood mulch was applied to cover the plastic mulch in spring 2003. In May 2003, soil-water tensiometers (Irrometer Company, Inc., Riverside, CA) were installed at 12 inch (30cm) depth close to the trunk of two randomly selected birches from each row (block) and soil water tension recorded daily. Beginning in July 2003 and continuing through Aug. 2003 water deficits were applied to one-half of the study. Four blocks were watered so that the daily soil water tension was maintained below 10 kPa while four blocks were maintained at a water deficit only receiving irrigation when the soil-water tension exceeded 40 kPa. All trees received similar water before July and after August. The experimental design was a two-factor, completely randomized block design with two factors of taxa and irrigation regime, at Fayetteville, and completely randomized design with one factor, taxa, at Hope. Each study had four blocks of each factor studied.

Results and discussion

At Fayetteville, water deficit did not affect tree height or caliper (data not shown), and there was no interaction between taxa and water deficit treatments. Therefore, only the main effects of taxa will be presented. The lack of effect of water deficits on growth and survival of trees is likely attributed to the fact that water deficit treatments were imposed after the spring flush of growth and growth had likely stopped for the summer dormancy period. In addition, the summer of 2003 was cooler than normal for that site with higher precipitation.

The birch taxa studied had higher survival in Fayetteville than at Hope after two years (Table 1). Average survival for all birch taxa was 67% at Fayetteville and 33% at Hope. Birch taxa with the best survival at both locations include *B. nigra* 'Dura-Heat', *B. nigra* 'Heritage', and *B. populifolia*. Birch taxa with the highest mortality (>70%) at both locations include *B. albosinensis*, *B. ermanii*, and *B. pendula* 'Trost's Dwarf'.

At the end of the second growing season, the tallest trees at Fayetteville (>300 cm) were *B. pendula* 'Laciniata' and *B. nigra* 'Heritage' (Table 2). Birch taxa with the greatest percent increase (>200%) in shoot height from 2002 include *B. papyrifera*, and *B. platyphylla* 'Fargo' at Fayetteville, and *B. davurica* and *B. pendula*, at Hope. It is interesting to note that while *B. papyrifera* had a large increase in growth during 2003 at Fayetteville (226% increase), it had a very small increase in growth at Hope (29%). *Betula maximowicziana* grew poorly (<70% increase) in 2003 at both locations. *B. nigra* had the largest (>6 cm) trunk diameter at Fayetteville and Hope at the end of 2003.

All birch taxa, except *B. nigra* and its cultivars, exist in the cooler regions of northern hemisphere (Kozel and Toth, 1975). Some birches, such as *B. papyrifera*, are not considered adaptable to regions outside of their natural habitat (Santamour Jr., 1982). Although not statistically comparable, trees at the Fayetteville location tended to have better growth than those at Hope. It is assumed that this was due to temperature differences among the two sites.

Water deficit significantly reduced net CO_2 assimilation, evapotranspiration, and stomatal conductance (data not shown). Well-watered and water-stressed trees of different taxa had similar order according to values of their gas exchange although birch taxa expressed different stress tolerance indicated by lesser or greater effects on gas exchange of water deficit compared to well-watered trees. Gas exchange values of well-watered and water-stressed trees of each taxon were combined and presented in Table 3. *Betula nigra* 'Heritage', *B. nigra* 'Dura-Heat', *B. platyphylla* 'Fargo', and *B. populifolia* 'Whitespire' had highest net CO_2 assimilation under water stress, while *B. alleghaniensis* and *B. ermanii* were among the lowest. Evapotranspiration and stomatal conductance showed similar results as net CO_2 assimilation except that *B. utilis* var. *jacquemontii* had highest evapotranspiration but relatively low net CO_2 assimilation, which might indicate that this species struggled with high-level water loss and low level of CO_2 uptake.

There appeared to be little relationship between gas exchange observations and growth. Again, this was likely due to the fact that growth had stopped prior to the onset of water deficits. However, the trees did physiologically respond to the water-deficit treatments on the days of gas exchange measurements.

Conclusions

After two years of field growth in Fayetteville and Hope, Ark., differences in growth rates, survival, and gas exchange were observed for the various birch taxa. Most of the trees evaluated at both locations grew and survived better in Fayetteville than in Hope. These preliminary data provide a first indicator of birch taxa that are adapted to Arkansas landscape conditions.

Acknowledgements

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Table 1. Survival of birch taxa evaluated at Fayetteville and Hope, Ark., during 2002 and 2003.

	Fayetteville			Hope		
	# trees planted	Survival		# trees planted	Survival	
		2002	2003		2002	2003
Taxa		(%)			(%)	
B. albosinensis	14	71	0	6	0	--
B. alleghaniensis	14	79	36	6	17	0
B. davurica	14	100	79	6	33	16
B. ermanii	14	64	28	6	0	--
B. lenta	14	71	0	6	50	50
B. maximowicziana	14	79	36	6	17	17
B. nigra	28	79	79	12	25	8
B. nigra 'Dura-Heat'	14	93	93	6	100	100
B. nigra 'Heritage'	30	97	97	12	92	92
B. papyrifera	15	93	86	6	17	17
B. papyrifera 'Renaissance Upright'	14	86	86	6	50	50
B. papyrifera 'Renaissance Reflection'	14	93	86	6	0	--
B. pendula	33	88	85	6	50	50
B. pendula 'Trost's Dwarf'	14	64	7	6	0	--
B. pendula 'Laciniata'	14	93	93	6	0	--
B. platyphylla 'Fargo'	16	75	62	6	33	16
B. populifolia	14	93	93	6	83	83
B. populifolia 'Whitespire'	14	93	72	6	67	50
B. x 'Royal *Frost*'	14	100	93	6	50	50
B. utilis var. jacquemontii	14	79	50	6	17	17

Table 2. Change in shoot height and trunk caliper of birch taxa planted at Fayetteville and Hope, Ark., in 2003.

	Shoot Height				Trunk Caliper			
	Fayetteville		Hope		Fayetteville		Hope	
Taxa	Final Shoot Height [z] (cm)	Change in Height (%)	Final Shoot Height (cm)	Change in Height (%)	Final Trunk Caliper [z] (cm)	Change in Trunk Caliper (%)	Final Trunk Caliper (cm)	Change in Trunk Caliper (%)
B. albo-sinensis	--	--	--	--	--	--	--	--
B. alleghaniensis	204 e-h[y]	101	--	--	2.8 ef	172	--	--
B. davurica	182 f-i	134	173 c-f	276	3.3 def	214	1.4 d	180
B. ermanii	144 i	97	--	--	1.9 gh	212	--	--
B. lenta	--	--	155 d-g	132	--	--	1.9 d	133
B. maximowicziana	164 hi	69	121 e-h	38	3.4 de	233	1.9 d	19
B. nigra	225 def	173	219 bcd	73	4.5 b	222	4.6 abc	203
B. nigra 'Dura-Heat'	318 ab	95	278 ab	110	6.5 a	126	6.1 ab	155
B. nigra 'Heritage'	345 a	120	337 a	113	5.8 a	179	6.8 a	259
B. papyrifera	285 bc	226	62 h	29	3.8 bcd	291	0.8 d	60
B. papyrifera 'Renaissance Reflection'	249 cde	114	--	--	3.5 de	154	--	--
B. papyrifera 'Renaissance Upright'	267 cd	95	139 efg	73	2.5 fg	146	1.9 d	175
B. pendula	263 cd	149	238 bc	234	3.8 bcd	244	4.5 bc	364
B. pendula 'Laciniata'	338 a	98	--	--	3.8 bcd	133	--	--
B. platyphylla 'Fargo'	228 de	206	--	--	2.9 ef	193	--	--
B. populifolia	234 de	83	187 cde	109	3.7 cd	227	2.9 cd	206
B. populifolia 'Whitespire'	213 efg	63	101 fgh	123	2.8 ef	156	1.5 d	101
B. 'Royal Frost'	324 ab	120	265 ab	147	4.3 bc	126	4.2 bc	146
B. utilis var. jacquemontii	157 i	133	80 gh	36	1.7 h	193	0.9 d	50

[z] Change from fall 2002 to fall 2003

[y] Numbers within a column followed by the same letter are not significantly different separated by LSD ($P \leq 0.05$).

Table 3. Gas exchange measurements of all trees of each birch taxon planted at Fayetteville, Ark., in July and August 2003.

Taxa	Evapotranspiration ($mmol\ m^{-2}s^{-1}$)	Stomatal conductance ($mmol\ m^{-2}s^{-1}$)	Net CO_2 assimilation ($\mu mol\ m^{-2}s^{-1}$)
B. alleghaniensis	3.52 de[y]	164 g	10.13 i
B. davurica	4.44 bc	284 ef	15.80 ef
B. ermanii	3.30 e	194 g	12.13 h
B. lenta	3.29 e	205 g	10.58 i
B. maximowicziana	3.91 b-e	288 ef	14.06 g
B. nigra	4.43 bc	368 bcd	18.50 ab
B. nigra 'Dura-Heat'	4.44 bc	424 a	18.39 ab
B. nigra 'Heritage'	4.46 bc	418 ab	18.71 a
B. papyrifera	3.78 cde	336 de	17.10 b-e
B. papyrifera 'Renaissance Upright'	4.48 b	360 cd	17.63 a-d
B. papyrifera 'Renaissance Reflection'	4.14 bcd	364 cd	17.62 a-d
B. pendula	4.03 bcd	363 cd	18.05 abc
B. pendula 'Laciniata'	3.86 b-e	295 ef	15.29 fg
B. platyphylla 'Fargo'	3.96 b-e	362 cd	18.89 a
B. populifolia	4.32 bc	281 f	16.20 def
B. populifolia 'Whitespire'	4.41 bc	395 abc	18.92 a
B. x 'Royal Frost'	4.05 bcd	327 def	15.99 ef
B. utilis var. jacquemontii	5.36 a	327 def	16.86 cde

[y] Numbers within a column followed by the same letter are not significantly different separated by LSD ($P \leq 0.05$).

Wetting Agents Decrease Wilt Symptoms and Water Repellency on a Sand-Based Putting Green

D.E. Karcher and J.W. Landreth[1]

Additional Index Words. *Agrostis palustris*, turfgrass, turf quality, localized dry spot

Summary. Localized dry spot (LDS) continues to be a management problem on sand-based golf course putting greens throughout the southern range of creeping bentgrass (*Agrostis palustris* Huds.) adaptation. The commercially available wetting agent, 'Primer Select', applied at label rate, and an experimental product, 'ACA 1820,'applied at three rates, were examined for their effects on reducing LDS symptoms on a sand-based putting green during the 2003 growing season. All wetting agent treatments improved turf quality and reduced wilt symptoms compared to a control treatment. Application of the experimental wetting agent, 'ACA 1820', resulted in slightly less turfgrass wilt and water repellency compared to 'Primer Select'.

Since the 1970s, construction of new golf course putting greens has included sand-based rootzones, primarily because of compaction resistance and rapid drainage. A management problem that has increased with the use of sand-based putting greens is the phenomenon called localized dry spot (LDS). LDS tends to occur within a few years following turfgrass establishment and is characterized by random patches of wilting turf on the surface of the putting green, with water-repellent sand immediately below the wilted turf. At this time, there is no known cure for LDS. Historically, the most effective treatment for LDS has been the application of wetting agents (surfactants), which act as a chemical bridge between hydrophobic sand particles and water. The effectiveness of wetting agents is variable and usually temporary, as they are broken down by microbial action while the water-repellent sand remains. The objective of the following study was to determine the effectiveness of a commercially available wetting agent, 'Primer Select' (Aquatrols Corp., Cherry Hill, NJ), and an experimental product, 'ACA 1820' on treating LDS symptoms.

Materials and methods

Experimental area. The experiment was conducted during the 2003 growing season at the University of Arkansas Research and Extension Center (Fayetteville, Ark.) on an 'SR-1020' creeping bentgrass putting green established in spring 2001 and constructed according to USGA recommendations (USGA, 1993). The green was mowed 6 times per week at a one-eighth inch (3.2 mm) height. The area was fertilized using biweekly foliar applications to apply approximately 0.5, 0.1, and 0.5 lb. of N, P_2O_5, and K_2O, per 1000 ft^2 (0.5 lb per 1000 ft^{-2} = 2.4 $g \cdot m^{-2}$, 0.1 lb per 1000 ft^{-2} = 0.48 $g \cdot m^{-2}$), respectively, per month during active growth. Other nutrients were applied according to soil test recommendations. Irrigation was applied as needed throughout the experiment, typically every 5 to 7 days. To encourage the development of localized dry spots, syringe irrigation was limited during the study. Occasional curative pesticide applications were made to the experimental area to minimize disease and insect damage.

Treatments. Twenty plots measuring 8 by 5 ft (2.43 by 1.52 m) each were arranged in four blocks of five plots each within the experimental area. Each of five wetting agent treatments was applied monthly to four replicate plots, beginning on 10 May. Treatments consisted of ACA 1820 at 2, 4, and 6 oz per 1000 ft^2 (0.64, 1.28, and 1.72 $L \cdot ha^{-1}$), Primer Select applied at a label rate of 6 oz per1000 ft^{-2} (1.72 $L \cdot ha^{-1}$), and a water-only control. Each treatment was applied using a CO_2 powered sprayer in 2.4 gal. water per 1000 ft^{-2} (978 $L \cdot ha^{-1}$). The final treatment applications were made on 10 September.

Evaluations. Turf quality, leaf wilt, and soil moisture were evaluated weekly on each plot, beginning on 8 May and concluding on 17 September, except for soil moisture evaluations, which concluded on 2 October. Turf quality was rated on a 1 to 9 scale, with 9 representing ideal, dark green, dense, uniform turf, 6 representing minimum acceptable quality, and 1 representing dead turf. Leaf wilt was evaluated by visually estimating the percent wilt occurring within each plot. Soil moisture was evaluated with a TDR probe (Model TRIME FM, Mesa Systems Co, Medfield, MA) by averaging five readings that were sampled randomly within each plot. Water drop penetration times were evaluated on soil cores extracted from each plot immediately prior to each monthly treatment application. Five soil cores per plot were collected, air-dried at room temperature for two weeks, and sectioned into 0, 1, 2, 3, 4, 5, and 6 cm rootzone depths for water drop penetration testing. A 40 μL water droplet was placed on each sample at each depth and the time elapsed until complete penetration into the rootzone was recorded. Water droplets still remaining after 600 sec. were recorded and discarded.

Statistical analysis. For each evaluation parameter, an analysis of variance was computed to determine if wetting agent, date, and wetting agent x date effects were significant ($P < 0.05$). When significant, means were separated according to Fisher's least significant difference test ($P < 0.05$). Since multiple measurements were taken on each plot over time, the data were analyzed as a repeated measures experiment, using PROC MIXED of SAS v. 8.02.

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Results and discussion

Turf Quality. Turf quality data during the 2003 growing season are summarized in Fig 1. The main effects of wetting agent and rating date were both significant in 2003. When averaged across evaluation dates, all wetting agent treatments had equal turf quality and significantly better turf quality than the control (data not shown). Significant differences among treatments were present on 21 August, and 11 and 17 September. On 21 August, 'ACA 1820' (6oz/1000ft^2) and 'Primer Select' had significantly higher quality than 'ACA 1820' (2oz/1000ft^2) and the control. On 11 and 17 September, all wetting agents treatments did not differ in quality, but had significantly higher quality than the control.

Turf Wilt. Turf wilt data during the 2003 growing season are summarized in Fig 2. Treatment, date, and treatment x date effects were all highly significant. From 3 July to 21 August, there were significant treatment differences in turf wilt on all but two rating dates (10 and 24 July). Before and after this period, there were no differences among treatments with regard to turfgrass wilt. On dates where significant wilting was present, the control treatment consistently had the highest amount of wilt, while 'ACA 1820' (6oz/1000ft^2) was the only wetting agent treatment that always had significantly less wilt than the control. When averaged across rating dates, all wetting agent treatments had equal turf wilt, but significantly less wilt than the control (data not shown).

Soil Moisture. Soil moisture was not significantly affected by wetting agent treatments during the 2003 growing season, however, there was a significant date effect. Soil moisture values ranged from an average low of 7.4 percent on 17 September to an average high of 13.1 percent on 5 June.

Water Drop Penetration Time. The effects of depth, date, treatment x date, and depth x date were all significant regarding water drop penetration time (WDPT). The thatch/soil interface was the only depth at which wetting agent treatments significantly affected water drop penetration time. Water drop penetration time data at the thatch/soil interface are summarized in Fig 3. At this depth, there were significant differences among wetting agents on 9 Aug. and 9 Sept. On 9 August, the control and 'ACA 1820' (2oz/1000ft^2) treatments had significantly longer water drop penetration times than the other three wetting agent treatments. By 9 September, all wetting agent treatments had significantly lower WDPT than the control.

Conclusions

All wetting agent treatments improved the overall quality of putting green turf during the 2003 growing season. Although the commercially available product, Primer, decreased turf wilt and water repellency at the thatch/soil interface when compared to the control, the experimental product, 'ACA 1820', when applied at 4 or 6 oz per 1000 ft^2 (1.28, and 1.72 L•ha^{-1}) reduced these symptoms associated with localized dry spot even further. Currently, it has not been determined when this product will become commercially available. The treatment and cure of localized dry spot will continue to remain a central focus for the University of Arkansas turfgrass research program.

Literature cited

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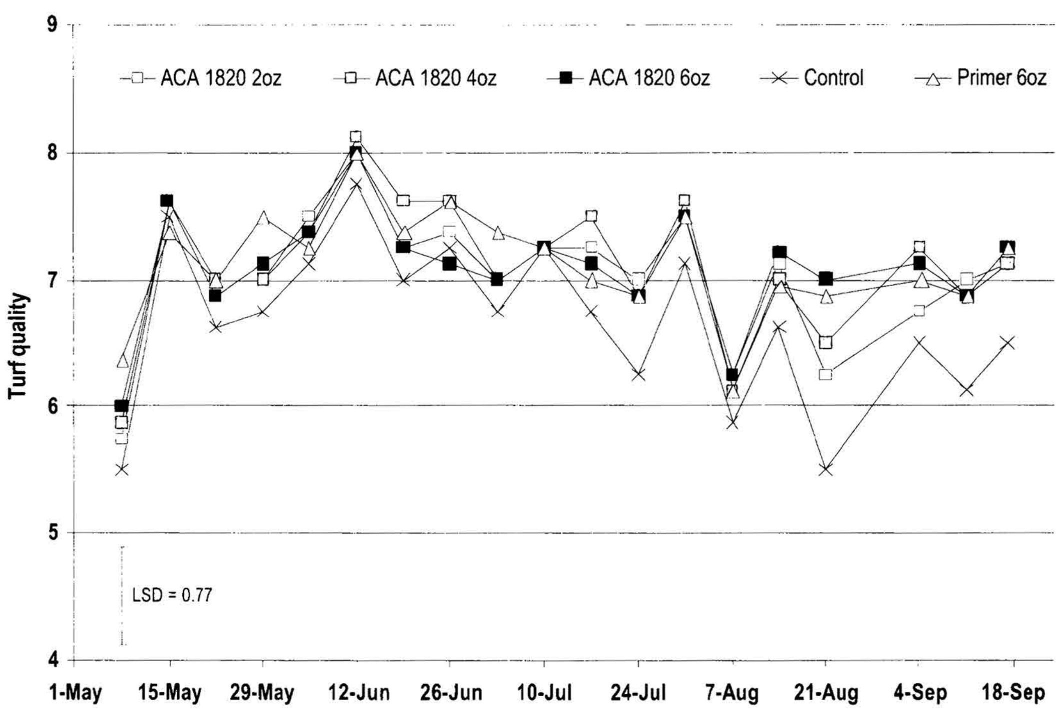


Fig. 1. Turfgrass quality ratings during the 2003 growing season as effected by wetting agent treatment. 9 = ideal, dark green, dense, uniform, fine-textured turf, 1 = dead turf.

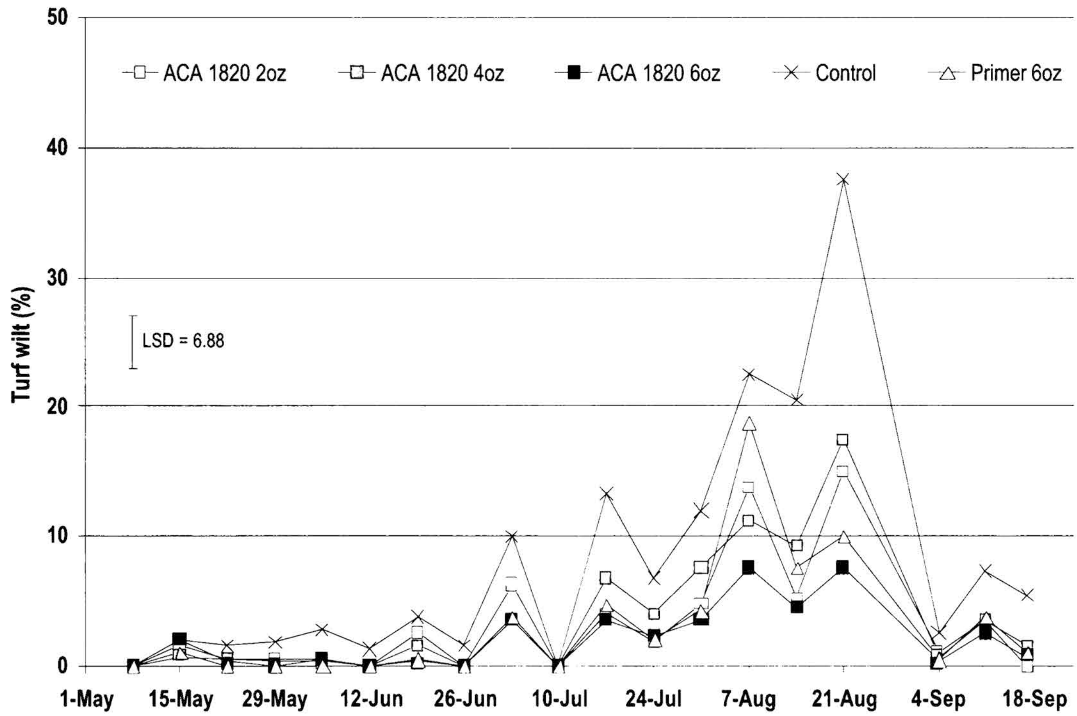


Fig. 2. Percent turf wilt during the 2003 growing season as effected by wetting agent treatment.

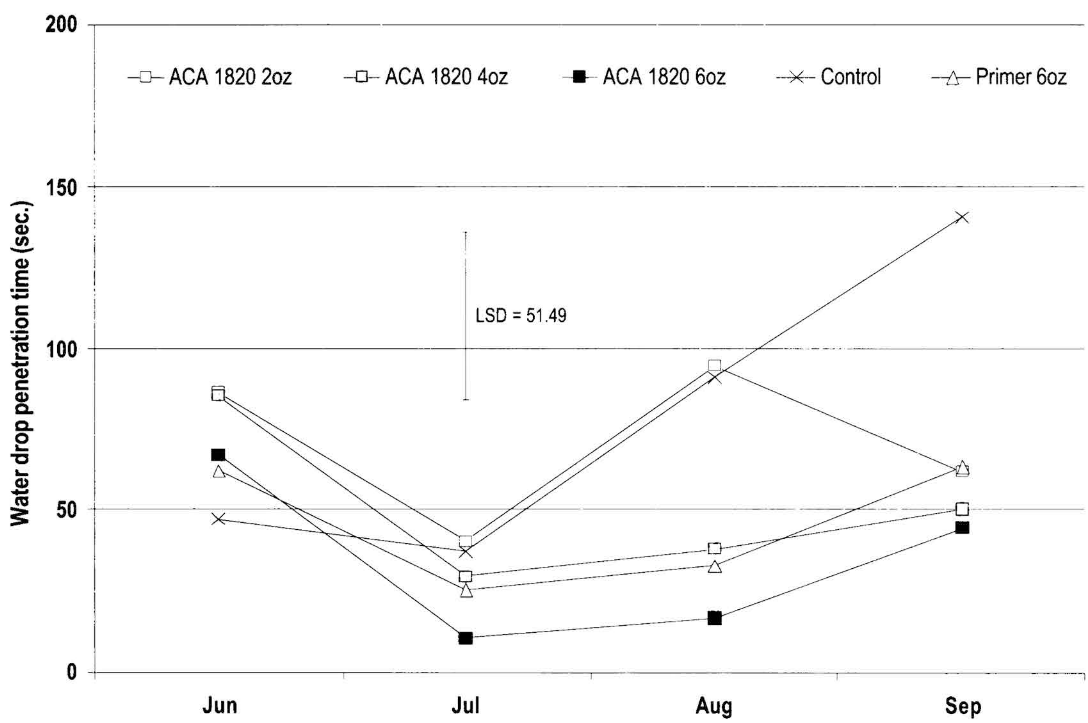
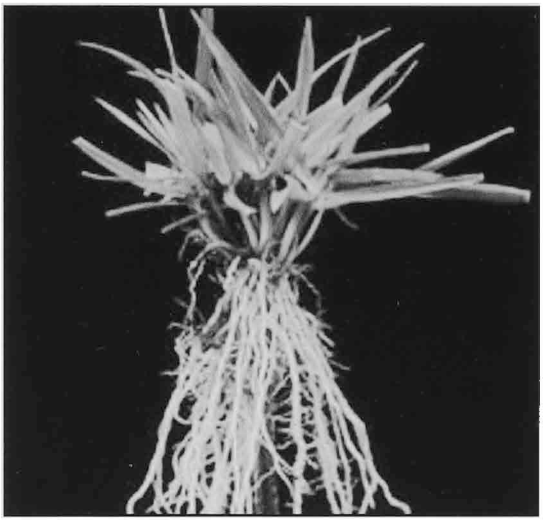


Fig. 3. Water drop penetration times at the thatch/soil interface during the 2003 growing season as effected by wetting agent treatment.



Report from the 2001 NTEP Tall Fescue Trial – 3rd Year Data

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Additional index words: *Festuca arundinacea*, turfgrass, turf quality, turf color, brown patch

Summary. Tall fescue (*Festuca arundinacea* Schreb.) 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 fall of 2001 at Fayetteville, Ark. During the 2003 growing season, cultivars were rated for overall turf quality, turf color, and incidence of brown patch disease. The cultivars, '2nd Millennium', 'Inferno', 'Finesse II', 'Quest', and 'Turbo' were consistently rated high for overall turf quality throughout the growing season and were among cultivars with the darkest green color on a 1 May rating date. 'Kentucky 31' and 'Elisa' averaged poor rating values for both turf quality and color. There were no significant differences among cultivars in brown patch incidence during a disease outbreak on 28 August.

Tall fescue 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 its 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 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 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 third-year performance data, including overall quality, turf color, and brown patch resistance, 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 have been maintained under lawn conditions throughout the duration of the study. Mowing height is varied during the year from 1.5 in. (3.8 cm) from October to May, and then raised to 2.5 in. (6.3 cm) for the summer season. Three nitrogen applications have been made 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 has been supplied as needed to prevent stress and maintain vigorous growth.

Overall turf quality was evaluated monthly from March through November in 2003. Quality was visually assessed on a 1 to 9 scale, with 9 representing ideal dark green, uniform, fine-textured turf and 1 representing dead turf. Turf color was visually evaluated on 1 May 2003 on a scale of 1 to 9, with 9 representing ideal, dark green turf and 1 representing tan or brown turf. Brown patch incidence was evaluated on 28 Aug. 2003 on a scale of 1 to 9, with 9 representing a completely diseased turf stand and 1 representing no disease.

For each evaluation parameter, an analysis of variance was computed to determine if the effect of cultivar was significant ($P < 0.05$). When significant, means were separated according to Fisher's least significant difference test ($P < 0.05$).

Results and discussion

Significant differences in turf quality were present among varieties on every rating date in 2003 except 5 November (Table 1). On average, the cultivars with the highest turf quality throughout the growing season were '2nd Millennium', 'Turbo', 'Cochise III', 'Rebel Exeda', 'Inferno', 'Finelawn Elite', 'Biltmore', 'Magellan', 'Blackwatch', 'Finesse II', 'Riverside', 'Plantation', 'Avenger', 'Cayenne', 'Endeavor', 'Picasso', 'Quest', 'Forte', and 'Mustang 3'. The cultivars with the worst overall quality throughout 2003 were 'Elisa' and 'Kentucky 31'.

There were significant differences in turf color among cultivars on the 1 May rating date (Table 1). 'Finesse II' and 'Turbo', each with an average rating value of 7.0, were rated darkest for color. Statistically, '2nd Millennium', 'Inferno', 'Plantation', 'Quest', 'SR 8550', 'Tahoe', and 'Tomahawk RT' were also rated among the darkest green cultivars. 'Kentucky 31' and 'Elisa' had the lightest green color with average color

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rating values of 2.3 and 2.7, respectively.

When brown patch disease was active across the experimental area on 28 August, average rating values for disease incidence for cultivars ranged from 1.3 to 4.7 (Table 1). However, differences among cultivars were not statistically significant due to inconsistent disease incidence among replications within cultivars.

Conclusions

There have been significant differences among tall fescue cultivars with regard to overall turf quality, turf color, and brown patch incidence through the 2003 growing season. Data will continue to be collected on these cultivars throughout the 2004 growing season and will be published by NTEP.

Table 1. Turf quality, turf color, and brown patch incidence means for tall fescue cultivars during the 2003 growing season.

	Turfgrass quality[z]										Color[y]	patch[x]
	Evaluation date										Evaluation date	
Cultivar[w]	3/25	4/25	5/21	6/26	7/29	8/28	9/21	10/25	11/05	Avg.	5/01	8/28
	rating value											
2nd Millennium	6.3	7.0	6.3	7.7	7.0	6.3	7.0	7.3	6.7	6.9	6.0	1.3
Avenger (L1Z)	5.0	5.7	6.0	6.3	5.7	5.7	6.3	6.3	6.3	5.9	5.3	3.0
Barlexas	4.7	4.7	4.3	4.7	4.0	4.7	4.7	4.7	5.3	4.6	4.0	3.3
Barlexas II	4.7	5.0	5.0	5.3	5.7	4.0	5.3	5.3	4.7	5.0	5.0	3.3
Barrera	5.0	5.0	5.7	6.3	5.0	5.0	6.0	6.3	5.7	5.6	5.3	3.3
Barrington	4.7	5.0	5.0	5.7	4.3	5.0	5.3	5.3	5.3	5.1	5.0	2.7
Biltmore	5.3	6.7	6.7	6.7	5.7	5.3	6.3	7.0	5.3	6.1	5.7	3.0
Bingo	5.3	6.0	6.0	6.7	5.0	5.3	6.3	6.7	5.3	5.9	5.3	2.0
Blackwatch (Pick-OD3-01)	6.0	6.0	6.0	7.3	6.3	4.3	6.3	7.0	5.0	6.0	5.7	3.7
Bonsai	3.3	3.7	4.7	4.3	4.3	4.3	4.7	4.7	4.3	4.3	4.3	3.0
Bravo	5.0	4.3	5.0	4.7	4.7	3.7	4.7	5.0	4.3	4.6	4.0	4.3
Cayenne	5.3	6.0	5.7	6.0	7.0	5.3	6.7	6.0	5.3	5.9	5.3	2.7
Cochise III (018)	6.0	6.3	6.7	6.7	6.3	5.3	6.7	6.7	6.7	6.4	4.7	2.7
Constitution (ATF-593)	5.0	5.7	6.0	6.3	5.7	5.3	6.0	6.3	6.0	5.8	5.7	1.7
Covenant (ATF 802)	4.3	4.0	5.0	4.7	5.3	4.7	5.3	5.0	4.7	4.8	5.0	3.7
Coyote	4.7	5.3	6.0	5.7	5.0	4.7	5.7	6.0	5.0	5.3	4.7	2.7
Davinci (LTP-7801)	5.0	5.3	5.7	5.7	5.3	4.3	5.7	6.0	5.7	5.4	5.3	3.7
Daytona (MRF 23)	4.3	5.0	5.0	5.0	4.3	4.7	5.3	5.3	5.0	4.9	4.7	3.3
Dominion	5.0	4.7	5.7	6.0	5.7	5.0	6.0	6.0	5.0	5.4	4.7	2.0
Dynasty	4.7	5.3	5.7	6.0	5.3	5.0	6.0	6.0	5.3	5.5	4.7	2.7
Elisa	4.0	3.3	3.7	4.0	3.7	4.3	4.7	4.0	4.3	4.0	2.7	3.3
Endeavor	5.3	6.0	6.0	6.3	6.0	5.3	6.3	6.3	5.7	5.9	4.3	2.0
Falcon II	5.7	4.7	4.7	4.7	4.7	4.3	5.0	5.0	5.0	4.9	4.0	3.0
Falcon IV (F-4)	4.7	5.0	5.0	5.7	5.7	5.0	5.7	5.7	5.3	5.3	5.3	3.0
Finelawn Elite (DLSD)	6.3	6.0	6.3	6.7	5.7	5.3	6.3	7.0	6.3	6.2	4.7	3.3
Finesse II	5.7	6.7	6.3	6.3	5.3	5.0	6.0	6.7	6.3	6.0	7.0	2.7
Five Point (MCN-RC)	5.3	5.7	5.7	6.0	5.3	5.0	5.7	6.0	5.7	5.6	5.7	2.7
Focus	5.0	5.7	5.7	5.7	5.7	5.3	5.7	5.7	6.3	5.6	4.7	2.3
Forte (BE-2)	5.7	5.7	6.7	6.0	5.7	5.0	6.0	6.7	5.7	5.9	5.7	3.3

Table 1. Turf quality, turf color, and brown patch incidence means for tall fescue cultivars during the 2003 growing season, continued...

	Turfgrass quality[z]										Color[y]	Brown patch[x]
	Evaluation date										Evaluation date	
Cultivar[w]	3/25	4/25	5/21	6/26	7/29	8/28	9/21	10/25	11/05	Avg.	5/01	8/28
	rating value											
Grande II	5.7	5.7	5.7	6.0	5.0	4.7	5.3	6.0	5.3	5.5	5.3	3.3
Gremlin (P-58)	5.3	6.0	6.0	5.7	5.7	4.3	6.0	6.0	5.7	5.6	5.7	3.7
Guardian-21 (Roberts DOL)	5.3	5.3	6.0	6.0	5.7	4.7	6.0	6.3	5.7	5.7	5.7	2.7
Inferno (JT-99)	5.3	6.7	6.7	6.7	6.7	5.3	6.7	6.7	5.7	6.3	6.0	3.0
Jaguar 3	4.7	4.3	4.7	5.0	5.0	5.3	5.7	5.0	5.0	5.0	4.0	2.7
Justice (RB2-01)	5.3	5.3	5.7	6.7	5.0	5.3	6.0	6.7	6.0	5.8	5.7	3.3
Kalahari	5.7	6.3	5.0	6.3	6.0	5.0	6.3	6.0	5.7	5.8	5.3	2.7
Kentucky 31	3.3	3.3	3.0	2.7	3.3	3.3	3.3	3.0	3.3	3.2	2.3	1.3
Kitty Hawk 2000	4.7	5.3	4.3	5.3	4.3	4.3	5.0	5.3	5.0	4.9	5.7	3.0
Lancer	5.0	4.3	4.7	4.3	4.0	4.0	4.3	4.7	5.0	4.5	4.3	3.3
Laramie	4.3	5.0	5.0	5.0	4.7	4.7	5.3	5.3	5.3	5.0	6.0	3.3
Legitimate	4.3	4.3	4.7	4.7	4.3	5.0	4.7	4.7	5.3	4.7	5.0	2.3
Magellan (OD-4)	5.3	6.3	6.0	6.7	6.3	5.3	6.7	6.7	5.7	6.1	5.3	1.7
Masterpiece	6.3	5.7	5.7	6.0	5.7	4.7	6.0	6.0	5.3	5.7	4.0	2.7
Matador	5.3	5.7	4.7	5.3	5.0	5.0	5.7	5.3	5.3	5.3	5.3	4.7
Millennium	5.7	6.0	5.7	6.0	5.7	6.0	6.3	6.0	5.0	5.8	5.0	1.7
Mustang 3	5.7	6.0	6.0	6.3	6.3	5.0	6.0	6.3	5.3	5.9	5.0	2.3
Olympic Gold	5.0	4.7	5.3	6.0	5.7	5.7	6.0	6.0	5.3	5.5	4.3	2.0
Padre (NJ4)	5.3	5.7	5.7	6.0	5.7	5.0	6.0	6.0	5.7	5.7	5.3	2.0
Picasso	6.0	6.3	6.0	6.3	5.0	5.7	6.0	6.3	5.7	5.9	5.3	2.3
Plantation	6.0	5.7	6.3	6.3	5.0	6.0	6.3	6.3	5.7	6.0	6.3	1.7
Prospect	4.3	4.3	5.0	4.7	5.3	5.7	5.7	5.0	5.7	5.1	5.3	2.3
Pure Gold	4.3	5.0	4.7	5.0	5.3	4.7	5.3	5.0	5.0	4.9	5.7	2.3
Quest	5.3	6.3	5.7	6.7	5.3	6.0	6.0	6.3	5.7	5.9	6.7	1.7
Raptor (CIS-TF-33)	4.3	5.7	6.0	6.0	5.0	5.0	5.7	6.3	5.7	5.5	6.3	3.3
Rebel Exeda	5.7	6.7	6.7	7.0	6.3	5.3	6.3	7.0	6.0	6.3	5.7	3.0
Rebel Sentry	4.3	5.3	5.7	5.7	5.7	5.7	5.7	5.7	5.3	5.4	5.3	2.3
Rembrandt	5.0	4.7	5.3	5.7	5.3	5.0	6.0	6.0	5.3	5.4	5.3	2.7
Rendition	4.3	5.7	6.3	6.3	6.0	4.7	6.0	6.3	5.3	5.7	5.3	2.7
Riverside (ProSeeds 5301)	4.7	6.0	6.0	6.7	5.3	6.3	6.7	6.7	5.7	6.0	5.0	2.0
Scorpion	4.0	4.7	5.3	5.7	4.7	4.7	5.3	5.7	5.0	5.0	4.3	2.7
Signia	4.3	5.3	5.3	6.0	5.7	5.3	6.0	6.0	5.7	5.5	6.3	2.7
Silverado II (PST-578)	4.7	5.7	5.3	5.0	5.7	4.7	5.7	5.3	5.0	5.2	5.7	2.7
Silverstar (PST-5ASR)	5.0	5.3	5.3	6.7	5.0	5.0	5.7	6.0	5.3	5.5	5.3	3.0
South Paw (MRF 24)	4.7	5.7	6.3	6.0	5.3	4.7	5.7	6.3	5.3	5.6	5.3	3.3
Southern Choice II	5.3	5.0	5.3	6.0	5.3	5.7	5.7	6.0	5.7	5.6	5.0	2.3
SR 8250	6.0	6.0	6.0	6.3	6.7	4.0	6.0	6.3	5.0	5.8	4.0	3.3
SR 8550 (SRX 8BE4)	4.0	4.7	4.7	5.0	4.7	5.0	5.3	5.0	5.0	4.8	4.7	2.0
SR 8600	4.3	5.0	5.7	5.7	5.0	5.3	5.7	6.0	5.0	5.3	5.3	2.0
Stetson	4.0	4.0	4.7	4.3	4.3	5.3	5.0	4.7	4.3	4.5	3.7	3.0

Table 1. Turf quality, turf color, and brown patch incidence means for tall fescue cultivars during the 2003 growing season, continued.

	Turfgrass quality[z]										Color[y]	Brown patch[x]
	Evaluation date										Evaluation date	
Cultivar[w]	3/25	4/25	5/21	6/26	7/29	8/28	9/21	10/25	11/05	Avg.	5/01	8/28
	rating value											
Tahoe (CAS-157)	4.0	5.0	5.3	5.7	5.3	5.0	5.7	5.7	5.0	5.2	6.3	2.3
Tar Heel	5.0	5.0	5.7	5.3	5.7	5.3	6.0	5.7	5.0	5.4	4.7	2.3
Tar Heel II (PST-5TR1)	5.7	5.3	5.7	5.7	5.7	5.0	5.7	5.7	5.3	5.5	4.3	2.0
Tempest	4.7	4.7	5.3	5.7	5.0	5.7	5.7	6.0	5.3	5.3	5.0	1.7
Titan Ltd.	5.3	5.3	4.7	5.0	4.7	4.3	5.0	5.0	5.3	5.0	4.7	3.7
Titanium (SBM)	5.0	5.3	5.0	5.7	6.0	4.7	5.7	5.7	5.7	5.4	4.3	3.0
Tomahawk RT	4.0	5.3	5.0	6.0	5.7	5.3	6.0	6.0	5.3	5.4	6.7	2.7
Tracer	5.0	5.3	6.0	6.3	4.7	4.7	5.3	6.3	5.3	5.4	5.7	3.3
Tulsa II (ATF 706)	4.7	4.3	4.3	5.0	4.3	4.3	4.7	5.0	5.0	4.6	4.0	3.3
Turbo (CAS-MC1)	5.3	6.0	6.7	7.3	6.3	6.7	7.0	7.3	6.3	6.6	7.0	1.3
Watchdog	5.3	5.7	5.7	6.3	5.3	3.7	5.3	6.3	5.3	5.4	4.7	4.3
Wolfpack	5.0	4.7	5.7	5.7	5.7	5.0	5.7	6.0	5.0	5.4	4.0	1.7
Wyatt	4.0	4.7	5.0	5.3	4.7	4.3	5.0	5.3	5.0	4.8	3.7	2.7
LSD0.05[v]	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	—	0.97	1.25	—
Significance[u]	***	***	***	***	***	**	**	***	NS	***	***	NS

[z] Quality was rated on a scale of 1 to 9 (9 = ideal dark green, uniform, dense, fine-textured turf, 1 = dead turf).

[y] Color was rated on a scale of 1 to 9 (9 = ideal dark green turf, 1 = brown/tan turf).

[x] Brown patch was rated on a scale of 1 to 9 (9 = severe brown patch, 1 = no disease).

[w] Experimental names of recently registered cultivars are in parentheses.

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

[u] **,*** Significant at the 0.01, 0.001 probability levels, respectively. NS = not significant.

Report from the 2002 NTEP Zoysiagrass Trial – 2nd Year Data

D.E. Karcher, M.D. Richardson, J.H. McCalla, and J.W. Landreth[1]

Additional index words: *Zoysia japonica*, *Zoysia matrella*, turfgrass, turf quality, turf color, spring green up, leaf texture, frost damage

Summary. **Zoysiagrass (*Zoysia* spp.) continues to increase in popularity in transition-zone environments due to its excellent turfgrass quality, persistence under adverse conditions, and low maintenance requirements. The National Turfgrass Evaluation Program (NTEP) is the predominant means by which cultivars are tested throughout North America. A zoysiagrass cultivar trial was planted in the summer of 2002 at Fayetteville, Ark. This trial has been maintained under golf course fairway conditions, and data on spring green-up, overall turf quality, leaf color, leaf texture, and frost damage were collected during the 2003 growing season. 'Cavalier' and 'Emerald' had the most spring green-up on 3 March, 'Zorro' and 'Emerald' had the best average overall quality throughout the growing season, 'Zorro', 'El Toro', and 'Emerald' had the darkest color on 6 June, 'Cavalier', 'Zorro', and 'Emerald' had the finest leaf texture on 28 July, and 'Emerald', 'Zorro', and 'Cavalier' had the least frost damage on 6 November.**

Zoysiagrass has become an increasingly popular turfgrass for golf courses and home lawns in the transition zone. The popularity of the species is due to its enhanced cold tolerance, slow growth rate, and competitiveness against weeds. Until recently, most of the zoysiagrass used in the United States has been the cultivar Meyer. However, in the past twenty years, new germ plasm has been collected and released and is starting to be used more frequently in the turfgrass industry. An integral part of the turfgrass research program at the University of Arkansas is the testing of new and improved cultivars of turfgrass for adaptation to this geographic region. The following report summarizes a zoysiagrass cultivar evaluation trial sponsored by the National Turfgrass Evaluation Program.

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Materials and methods

The cultivar experiment was established on 2 July 2002 at the University of Arkansas Research and Extension Center in Fayetteville on a silt-loam soil. The plot size was 2.4 x 2.4 m (8 x 8 ft) and there were three replications of each cultivar. The vegetative cultivars were planted as 5 cm (2 in.) diameter plugs on 30 cm(12 in.) spacings within the plots, while the seeded cultivars were broadcast planted at a seeding rate of 48 $kg \cdot ha^{-1}$ (1.0 lb / 1000 ft^2). Plots were maintained under golf course fairway or sports field conditions, with a mowing height of 12 mm (0.5 in.), and monthly applications of 24 $kg \cdot ha^{-1}$ (0.5 lb N / 1000 ft^2) during the growing season. Irrigation was applied as needed to promote germination and establishment and to prevent stress.

Cultivars were visually evaluated for spring green-up on 25 March 2003 using a scale of 1 to 9, with 9 representing complete green color and 1 representing a completely dormant turf stand. Overall turf quality was evaluated monthly from May through October in 2003. Quality was visually assessed on a 1 to 9 scale, with 9 representing ideal dark green, uniform, fine-textured turf and 1 representing dead turf. Turf color was visually evaluated on 25 June 2003 on a scale of 1 to 9, with 9 representing ideal, dark green turf and 1 representing tan or brown turf. Leaf texture was visually evaluated on 28 July 2003 on a scale of 1 to 9, with 9 representing extremely fine turf texture and 1 representing extremely coarse texture. On 6 Nov. 2003, cultivars were visually assessed for frost damage using a 1 to 9 scale, with 9 representing no frost damage and 1 representing complete leaf kill.

An analysis of variance was computed for each evaluation and cultivar effects were considered to be significant if $P < 0.05$. Cultivar means were separated using Fisher's protected least significant difference test ($\alpha = 0.05$).

Results and discussion

There were significant differences in spring green-up among cultivars on 25 March 2003 (Table 1). 'Emerald' and 'Cavalier' had the most green turf cover with average ratings of 4.7 and 4.0, respectfully. 'Himeno' and 'Chinese Common' had the least green-up with average ratings of 1.0 and 1.3, respectively.

There were significant differences in turf quality among cultivars on each rating date in 2003 (Table 1). 'Zorro' and 'Emerald' had the best average turf quality throughout the growing season with average rating values of 8.2 and 7.6, respectively. On 20 May 2003, 'GN–2', 'Himeno', and 'Zenith' were among the best cultivars with regard to turf quality and on 28 July 2003, 'Cavalier' was among the best cultivars with regard to overall quality. 'Chinese Common', 'Palisades', and 'Companion' were consistently rated lowest for turf quality with average values of 4.6, 5.1, and 5.2, respectively.

There were significant color differences among cultivars on 25 June 2003 (Table 1). 'Zorro', 'El Toro', and 'Emerald' were rated highest, with average rating values of 8.0, 7.7, and 7.7, respectively. All cultivars had acceptable turf color as the lowest average rating value was 6.0, belonging to both 'Chinese Common' and 'Companion'.

There were significant leaf texture differences among cultivars on 28 July 2003 (Table 1). 'Cavalier', 'Zorro', and 'Emerald' had the finest leaf texture, averaging rating values of 9.0, 9.0, and 8.7, respectively. 'Crowne', 'Palisades', 'Chinese Common', and 'El Toro' had the coarsest leaf texture with average rating values of 5.0, 5.3, 6.0, and 6.0, respectively.

On 6 Nov. 2003, there were significant differences among cultivars in frost damage (Table 1). 'Emerald', 'Zorro', and 'Cavalier' had the least frost damage with average rating values of 6.3, 6.3, and 6.0, respectively. 'Chinese Common', 'Himeno', 'Meyer', and 'Palisades' had the most visible frost damage as all these cultivars averaged rating values below 4.0.

Conclusions

There have been significant differences among zoysiagrass cultivars with regard to spring green-up, overall turf quality, turf color, leaf texture, and susceptibility to frost damage through the 2003 growing season. Data will continue to be collected on these cultivars throughout the 2005 growing season and will be published by NTEP.

Table 1. Spring green-up, turf quality, color, leaf texture, and frost damage ratings for the commercially available cultivars from the 2003 growing season of the 2002 NTEP Zoysiagrass Trial.

	Spring green-up[z]	Turf Quality[y]							Turf Color[x]	Leaf Texture[w]	Frost Damage[v]
		Evaluation date							Evaluation date		
Cultivar	3/25	5/20	6/25	7/28	8/21	9/16	10/04	Avg.	6/25	7/28	11/06
	rating value										
Cavalier	4.0	4.7	7.0	8.3	7.0	7.7	7.7	7.1	7.0	9.0	6.0
Chinese Common	1.3	4.3	4.7	5.0	5.0	4.7	4.0	4.6	6.0	6.0	3.0
Companion	3.0	4.7	5.3	5.7	5.3	5.0	5.0	5.2	6.0	6.3	4.3
Crowne	2.7	4.0	5.3	5.7	5.7	6.3	6.3	5.6	7.0	5.0	4.7
El Toro	3.0	4.3	6.0	6.0	6.0	6.7	7.0	6.0	7.7	6.0	5.0
Emerald	4.7	6.0	8.0	8.7	7.7	7.7	7.3	7.6	7.7	8.7	6.3
GN-2	3.3	5.3	6.0	7.7	7.0	7.0	7.3	6.7	7.0	7.7	5.3
Himeno	1.0	5.3	6.0	6.7	6.3	5.7	5.0	5.8	6.7	7.0	3.0
Meyer	2.3	5.0	6.3	6.3	6.0	5.3	4.3	5.6	7.0	6.7	3.7
Palisades	3.3	4.7	5.3	6.0	5.7	5.0	4.0	5.1	6.7	5.3	3.7
Zenith	2.3	6.0	6.0	6.7	6.3	5.7	4.7	5.9	6.0	7.3	3.7
Zorro	3.3	6.0	8.0	9.0	8.7	8.7	9.0	8.2	8.0	9.0	6.3
$LSD_{0.05}$[u]	0.76	0.99	0.99	0.99	0.99	0.99	0.99	0.69	0.90	1.07	0.74
Significance[t]	***	***	***	***	***	***	***	***	**	***	***

[z] Spring green-up rated on a scale of 1 to 9 (9 = complete green turf, 1 = complete dormant turf).

[y] Quality rated on a scale of 1 to 9 (9 = ideal dark green, uniform, dense, fine-textured turf, 1 = dead turf).

[x] Color rated on a scale of 1 to 9 (9 = ideal dark green turf, 1 = brown/tan turf).

[w] Texture rated on a scale of 1 to 9 (9 = very fine texture, 1= very coarse texture).

[v] Frost damage rated on a scale of 1 to 9 (9 = no frost damage, 1 =complete leaf kill).

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

[t] ***, ** significant at the 0.001 and 0.01 probability level, respectively.

Evaluations of postemergence herbicides on seedling zoysiagrass

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Additional index words: *Zoysia japonica*, Acclaim, MSMA, Confront, Trimec, Monument, flazosufuron, Revolver, Drive, Lontrol, *Cynodon*

Summary. Zoysiagrass is traditionally planted using vegetative methods such as sprigging or sodding. There have been several new seeded cultivars introduced into the market that are adding alternatives to the industry vegetative standards. The major issue with establishing any grass is weed control during establishment. An experiment was conducted at the University of Arkansas researching the herbicide tolerance of newly seeded zoysiagrass. Herbicide treatments were applied 2 weeks after emergence and visual injury ratings were taken several times following treatment application. Herbicide injury was most severe during the first ten days after treatment. Turfgrass cover was only affected by a few treatments when compared to the untreated control. Several of the treatment combinations offer great broad-spectrum control of weeds and caused minimal injury to the seedling turf.

Zoysiagrass has become a major turfgrass species for transition zone environments, where it is used primarily for golf course fairways and tees and home lawns. The major zoysiagrass cultivars that have been used for these applications are vegetatively propagated clones that have been selected for improved turfgrass performance. Recent efforts by turfgrass breeders have led to the development of seed-propagated cultivars of zoysiagrass. These seeded zoysiagrasses have the potential to greatly expand the use of this desirable turfgrass species.

One of the major challenges with the propagation of any species from seed is the control of weeds during establishment. There have been no studies that investigate the use of herbicides during establishment of seeded zoysiagrass. The objective of this study was to determine the tolerance of seedling zoysiagrass to a range of postemergence herbicides.

Materials and methods

In this trial, a single herbicide application date (2 weeks after emergence) was tested. The research plots were established at the University of Arkansas Research and Extension Center in Fayetteville, Ark. Prior to the initiation of this study, the plot area was fumigated using methyl bromide. 'Zenith' seeded zoysiagrass was seeded at 48.8 kg PLS ha^{-1} (1.0 lb PLS / 1000 ft^2) on 15 June 2003. Individual plots were 1.22 x 1.52 m (4 x 5 ft.). Herbicides were applied using a CO_2 propelled single nozzle sprayer in association with a high walled framed spray shield to prevent drift between plots. The herbicides were applied at a spray volume of 280 l ha^{-1} (30 gpa). The herbicides tested and their rates are listed in Table 1. Visual herbicide injury ratings (0-9, 0= no injury and 9= completely dead) were taken periodically following herbicide application. Turfgrass establishment rates were determined at 7, 14, and 21 days after treatment (DAT) using digital image analysis (Richardson et al., 2001).

Results and discussion

The majority of injury observed in this study consisted of yellowing or other discoloration of the leaves. In addition, some of the treatments resulted in a significant loss of turfgrass cover when compared to the untreated control. At 3 DAT, most of the herbicide combinations tested caused significant injury to the seedling turf (Table 1). The combination of Confront + MSMA caused the most severe injury on this date but all combinations caused significantly more injury than the control with the exceptions of both Drive treatments (Table 1). Over the duration of the rating period the most severe injury was from the Acclaim+ Confront treatment which was as high as 8.0 at the 10 DAT rating date. Other treatments that caused significant injury to the seedling turf included Manor + MSMA, Confront + MSMA, flazosulfuron + MSMA, and Revolver + MSMA (Table 1). Herbicide injury peaked within the first 10 days following application for all treatments (Table 1). Injury was still evident at 14 DAT on most plots but had subsided to acceptable levels by 28 DAT (Table 1).

Even though turf injury was high after the application of many of the herbicide combinations, turfgrass cover was only affected by a few of the treatment combinations at the 14 and 21 DAT evaluation dates (Table 2). The plots treated with the Acclaim + Confront combination showed significantly less cover than all other combinations tested at both 14 and 21 DAT while control plots showed near full cover, 96.3% and 97.8%, on both dates (Table 2). In addition, the Manor + MSMA treatments also significantly reduced turfgrass coverage at 14 and 21 DAT compared to the controls (Table 2).

Other herbicide combinations caused various levels of turfgrass injury, but did not significantly reduce the cover on the plots. These included the Trimec Classic + MSMA and Confront + MSMA combinations (Table 2). These two different treatments will offer a broad-spectrum weed control combination that should eliminate any problem weeds during establishment. Trimec and Confront are commonly used broad leaf herbicides while MSMA is a good postemergence grass control herbicide. Drive would also be an excellent treatment to use during establishment for goosegrass and crabgrass control and these treatments caused little to no injury on the seedling zoysiagrass.

With the introduction of improved seeded zoysiagrass cultivars, weed control during establishment will be a significant issue for turfgrass managers. This study demonstrates that several good postemergence herbicide treatments can be safely used during establishment to control problematic weeds in seedling zoysiagrass turf.

Literature cited

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Table 1. Tolerance of 'Zenith' seedling zoysiagrass to several postemergence herbicides applied at 2 weeks after emergence.

		Turfgrass injury due to herbicide†							
Herbicide	Rate	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	21 DAT	28 DAT	Avg. Injury
		---------- Herbicide Injury rating ----------							
Acclaim + Confront	28 oz / acre + 1.0 pt / acre	3.75	3.75	5.00	8.00	7.00	6.25	2.50	5.18
Manor + MSMA	0.33 oz / acre + 2.0 lb. ai / acre	4.25	4.75	4.50	6.50	5.75	5.50	3.25	4.90
Confront + MSMA	1.0 pt / acre + 2.0 lb. ai / acre	5.75	6.75	5.75	3.25	1.50`	0.00	0.00	3.28
Flazosulfuron + MSMA	3.0 oz / acre + 2.0 lb. ai / acre	3.25	4.00	5.00	5.25	3.25	1.50	0.75	3.20
Revolver + MSMA	17.4 oz / acre + 2.0 lb. ai / acre	5.25	5.00	4.25	4.25	2.25	0.75	0.25	3.10
Monument + MSMA	0.56 oz / acre + 2.0 lb. ai / acre	4.50	4.00	3.25	3.25	1.50	0.25	0.00	2.40
Drive + MSMA	0.75 + 2.0 lb. ai / acre	4.75	4.00	1.75	2.75	1.25	0.25	0.25	2.14
Lontrol + MSMA	0.38 + 2.0 lb. ai / acre	4.50	4.75	2.75	1.25	0.50	0.25	0.00	2.00
Trimec Classic + MSMA	3.5 pints / acre + 2.0 lb. ai / acre	3.00	2.25	1.25	2.75	1.25	0.00	0.00	1.50
Drive	0.75 lb. ai / acre	1.25	1.25	2.00	1.00	0.25	0.00	0.00	0.82
Drive fb Drive	0.5 fb 0.5 lb. ai / acre	1.00	1.00	2.00	1.25	0.25	0.00	0.00	0.78
Control	Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD (0.05)		1.60	1.40	2.50	1.40	1.10	0.90	0.70	0.70

† - injury ratings were made on a 0-9 scale, with 9 = dead turf and 1 = no injury

Table 2. Turfgrass coverage of 'Zenith' seedling zoysiagrass, as affected by several postemergence herbicides applied at 2 weeks after emergence.

		Turfgrass Coverage†		
Herbicide	Rate	7 DAT	14 DAT	21 DAT
		------------------------------	% cover	------------------------------
Acclaim + Confront	28 oz / acre + 1.0 pt / acre	28.10	31.90	44.90
Manor + MSMA	0.33 oz / acre + 2.0 lb. ai / acre	34.70	61.90	61.20
Confront + MSMA	1.0 pt / acre + 2.0 lb. ai / acre	53.50	87.80	93.00
Flazosulfuron + MSMA	3.0 oz / acre + 2.0 lb. ai / acre	50.10	74.80	82.40
Revolver + MSMA	17.4 oz / acre + 2.0 lb. ai / acre	56.20	83.80	91.10
Monument + MSMA	0.56 oz / acre + 2.0 lb. ai / acre	56.00	86.80	90.30
Drive + MSMA	0.75 + 2.0 lb. ai / acre	65.50	94.40	96.40
Lontrol + MSMA	0.38 + 2.0 lb. ai / acre	79.20	96.20	97.90
Trimec Classic + MSMA	3.5 pints / acre + 2.0 lb. ai / acre	56.20	89.50	93.60
Drive	0.75 lb. ai / acre	76.20	91.10	94.30
Drive fb Drive	0.5 fb 0.5 lb. ai / acre	77.00	95.80	97.50
Control	Control	84.40	96.30	97.80
LSD (0.05)		16.60	9.90	10.70

† - turfgrass cover was measured using digital image analysis

Report from the 2002 NTEP Bermudagrass Trial – 2nd Year Data

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Additional index words: *Cyndodon dactylon*, *Cynodon dactylon x C. transvaalensis*, turfgrass, cultivars, turf color, spring green-up, leaf texture, seedheads

Summary. Bermudagrass (*Cynodon dactylon*, *C. dactylon x C. transvaalensis*) continues to be the prevailing 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 though out North America. A bermudagrass cultivar trial was planted in the summer of 2002 at Fayetteville, Ark. This trial has been maintained under golf course fairway conditions and data on spring green-up, overall quality, leaf color, leaf texture, and seedhead formation were collected during the 2003 growing season. 'Aussie Green' had the most spring green-up on 13 April and consistently had the highest turf quality during the growing season. On 25 June, 'GN-1' had the darkest green color and on 28 July 'Ashmore' had the finest leaf texture. 'Ashmore', 'Aussie Green', and 'Patriot', were the only cultivars producing no seedheads on the 25 June evaluation date.

Bermudagrass remains the most commonly used turfgrass for golf, sports, 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 that 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 data from the 2003 growing season of 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 2.4 x 2.4 m (8 x 8 ft) and there were three replications of each cultivar. Vegetative cultivars were planted as 5 cm (2 in.) diameter plugs on 30 cm (12 in.) spacings within the plots, while seeded cultivars were broadcast planted at a seeding rate of 48 $kg{\bullet}ha^{-1}$ (1.0 lb / 1000 ft^2). Plots were maintained under golf course fairway or sports field conditions, with a mowing height of 12 mm (0.5 in.), and monthly applications of 48 $kg{\bullet}ha^{-1}$ (1.0 lb N / 1000 ft^2) during the growing season. Irrigation was applied as needed to promote germination and establishment and to prevent stress.

Cultivars were visually evaluated for spring green-up on 13 April 2003 using a scale of 1 to 9, with 9 representing complete green cover and 1 representing a completely dormant turf stand. Overall turf quality was evaluated monthly from May through October in 2003. Quality was visually assessed on a 1 to 9 scale, with 9 representing ideal dark green, uniform, fine-textured turf and 1 representing dead turf. Turf color was visually evaluated on 25 June 2003 on a scale of 1 to 9, with 9 representing ideal, dark green turf and 1 representing tan or brown turf. Leaf texture was visually evaluated on 28 July 2003 on a scale of 1 to 9, with 9 representing extremely fine turf texture and 1 representing extremely coarse texture. The presence of seedheads was visually evaluated on 25 June 2003 on a scale of 1 to 9, with 9 representing complete seedhead coverage and 1 representing no seedheads.

An analysis of variance was computed for each evaluation and cultivar effects were considered to be significant if $P < 0.05$. Cultivar means were separated using Fisher's protected least significant difference test ($\alpha = 0.05$).

Results and discussion

There were significant differences in spring green-up among cultivars on 13 April 2003 (Table 1). 'Aussie Green' had the most green-up with an average rating value of 3.0. Statistically, 'Midlawn', 'Patriot', 'Riviera', Sundevil', 'Tifway', 'Transcontinental', and 'Yukon' had as much green-up as 'Aussie Green'. 'Arizona Common', 'Celebration', 'GN-1', 'Mohawk', 'NuMex Sahara', 'Panama', 'Princess 77', and 'Sunstar' had no green cover.

There were significant differences in turf quality among cultivars on each rating date in 2003 (Table 1). Across rating dates, 'Aussie Green' had the highest average quality rating, 8.0, although 'Celebration', 'GN-1', 'Midlawn', 'Patriot', and 'Tifsport', statistically, were rated equal to 'Aussie Green'. 'Arizona Common', 'Ashmore', 'Mohawk', 'NuMex Sahara', 'Panama', 'SR 9554', 'Southern Star', 'Sundevil', 'Sunstar', and 'Transcontinental' were all consistently rated low, with regard to quality, throughout the 2003 growing season.

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There were significant color differences among cultivars on 25 June 2003 (Table 1). 'GN-1' had the darkest green color with an average rating value of 9.0. 'Aussie Green', 'Celebration', 'MS-Choice', 'Midlawn', 'Patriot', 'Tifsport', and 'Yukon' were also rated high for color, statistically equal to 'GN-1'. Conversely, 'Arizona Common', 'Ashmore', Mohawk', 'SR 9554', and 'Sunstar' were rated lowest for dark green color.

There were significant leaf texture differences among cultivars on 28 July 2003 (Table 1). 'Ashmore' and 'Tifway' had the finest leaf texture, averaging rating values of 9.0 and 8.3, respectively. 'Arizona Common', 'Mohawk', 'NuMex Sahara', 'Panama', 'SR 9554', 'Southern Star', 'Sundevil', 'Sunstar', and 'Transcontinental' had the coarsest leaf textures with average rating values of 6.0 or below.

On 25 June 2003, there were significant differences among cultivars with regard to the presence of seedheads (Table 1). No seedheads were present among 'Ashmore', 'Aussie Green', 'Patriot', although statistically, 'Celebration', 'Midlawn', 'Tifsport', 'Tifway', and 'Yukon' had as few seedheads. 'Arizona Common', 'Mohawk', 'NuMex Sahara', 'Sunstar', and 'Transcontinental' were the most prolific seedhead producing cultivars.

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

Conclusions

There have been significant differences among bermudagrass cultivars with regard to spring green-up, overall turf quality, turf color, leaf texture, and seed head formation through the 2003 growing season. Data will continue to be collected on these cultivars throughout the 2005 growing season and will be published by NTEP.

Table 1. Spring green-up, turf quality, leaf color, leaf texture, and seedhead presence ratings for the commercially available cultivars from the 2003 growing season of the 2002 NTEP Bermudagrass Trial.

	Spring green-up[z]	Turf Quality[y]							Turf Color[x]	Leaf Texture[w]	Seedhead Presence[v]
									Evaluation date		
Cultivar	4/13	5/20	6/25	7/28	8/21	9/16	10/04	Avg.	6/25	7/28	
	rating value										
Arizona Common	1.0	4.0	4.7	6.0	5.7	5.0	6.0	5.2	4.5	5.3	5.0
Ashmore	2.0	6.7	6.9	6.0	5.0	3.3	5.7	5.6	4.3	9.0	1.0
Aussie Green	3.0	7.7	8.0	8.7	9.0	8.3	6.3	8.0	8.3	8.0	1.0
Celebration	1.0	7.3	7.0	8.3	8.3	8.0	7.0	7.7	8.7	6.7	1.7
GN-1	1.0	6.7	7.7	8.3	8.0	7.0	6.3	7.3	9.0	7.7	2.3
MS-Choice	2.0	5.7	7.0	7.7	7.0	5.7	6.3	6.6	8.0	6.7	2.3
Midlawn	2.3	7.3	7.3	7.7	8.0	7.7	6.3	7.4	8.0	7.7	1.3
Mohawk	1.0	4.3	4.7	6.0	5.7	4.7	5.3	5.1	4.7	5.3	4.0
NuMex Sahara	1.0	3.7	4.3	6.0	6.0	5.3	5.3	5.1	6.0	5.3	4.7
Panama	1.0	4.7	3.8	6.7	6.0	5.0	6.0	5.4	5.7	5.3	2.3
Patriot	2.3	7.7	8.7	9.0	8.7	8.3	5.3	7.9	8.7	7.3	1.0
Princess 77	1.0	6.7	6.3	7.0	7.0	6.3	6.0	6.6	6.7	7.3	2.3
Riviera	2.7	6.7	7.0	7.7	7.3	6.7	5.7	6.8	7.3	7.0	2.7
SR 9554	2.0	5.3	5.2	7.0	6.0	4.3	6.0	5.6	5.0	5.7	3.0
Southern Star	1.7	5.0	5.7	5.7	5.0	4.0	5.7	5.2	6.0	5.3	3.7
Sundevil	2.3	5.0	6.0	5.3	5.3	4.7	5.0	5.2	6.0	5.7	3.7
Sunstar	1.0	4.3	5.3	6.0	5.7	4.7	5.7	5.3	5.0	5.3	4.0
Tifsport	1.7	7.7	7.3	8.3	8.7	8.7	7.0	7.9	8.0	7.7	1.3
Tifway	2.7	6.7	7.0	7.7	7.7	7.0	6.7	7.1	7.3	8.3	1.7
Transcontinental	2.3	5.3	5.3	5.3	5.0	4.0	5.3	5.1	6.0	6.0	4.3
Yukon	2.7	7.0	7.7	7.3	7.7	7.0	5.7	7.1	8.0	6.7	1.7
$LSD_{0.05}$[u]	0.86	1.30	2.30	3.30	4.30	5.30	6.30	0.69	1.01	0.82	1.17
Significance[t]	***	***	***	***	***	***	***	***	***	***	***

[z] Spring green-up rated on a scale of 1 to 9 (9 = complete green turf, 1 = complete dormant turf).

[y] Quality rated on a scale of 1 to 9 (9 = ideal dark green, uniform, dense, fine-textured turf, 1 = dead turf).

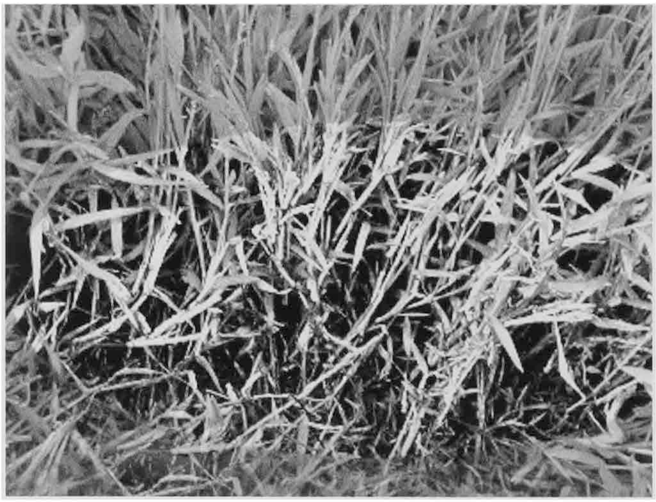
[x] Color rated on a scale of 1 to 9 (9 = ideal dark green turf, 1 = brown/tan turf).

[w] Texture rated on a scale of 1 to 9 (9 = very fine texture, 1= very coarse texture).

[v] Seedhead presence rated on a scale of 1 to 9 (9 = complete seedhead coverage, 1 = no seedheads).

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

[t] ***, ** significant at the 0.001 and 0.01 probability level, respectively.



Effects of Several Pre-plant Nutrient Programs on the Establishment and Nutrient Content of Creeping Bentgrass

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Additional Index Words. seaplant, amendment, putting green, golf

Summary. Establishment of creeping bentgrass (*Agrostis stolonifera* L.) is often a slow process in sand-based putting greens due to the poor nutrient- and water-holding characteristics of the medium. A study was designed to test the effects of several pre-plant, organic soil amendments on establishment of creeping bentgrass in a sand-based putting green in Johnson, Ark. The treatments included a standard pre-plant treatment (Milorganite at 146 kg N ha^{-1} (3.0 lb N / 1000 ft^{-2}) + methylene urea at 146 kg N ha^{-1} (3.0 lb N / 1000 ft^{-2}) and three treatments containing a new, proprietary material called Architect's Blend, which is designed to provide all of the nutrients necessary to establish bentgrass in sand with a single application. Architect's Blend was applied at either 7320 kg ha^{-1} (150 lb 1000 ft^{-2}) or 3660 kg ha^{-1} (75 lb 1000 ft^{-2}). A final treatment included Architect's Blend at 3660 kg ha^{-1} (75 lb 1000 ft^{-2}) + methylene urea at 146 kg N ha^{-1} (3.0 lb N / 1000 ft^{-2}). Data on establishment rates were collected weekly. Root and shoot growth and shoot tissue nutrient analysis were determined at 6 and 8 weeks after planting. The high rate of Architect's Blend (Arch. 150) produced faster grow-in than any of the other treatments, resulting in a 2-week increase in complete coverage. Treatments had minimal effects on shoot or root growth or tissue nutrient levels.

Rapid establishment of creeping bentgrass greens is desirable to hasten the opening of new golf courses and renovation projects. A number of products, generally classified as soil additives or bio-stimulants, are currently being used to speed-up this process. New formulations are being developed that allow a manager to incorporate all of the necessary nutrients into a single composite product for ease of application. The following study was designed to compare a new pre-plant amendment called Architect's Blend to traditional pre-plant amendments such as Milorganite (Milorganite, Inc., Milwaukee, WI).

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Materials and methods

A sand-based putting green was constructed at Clear Creek Golf Club in Johnson, Ark.,during the summer of 2003. The green was comprised of a 12-inch deep, 85% sand and 15% Dakota Peat mix rootzone over 4 inches of crushed limestone aggregate. All materials were tested for physical properties and selected based on USGA recommendations (Anonymous, 1993).

Just prior to seeding the green, four amendment treatments were incorporated into the sand rootzone. The treatments were as follows: 1) Architect's Blend at 7320 kg ha^{-1} (150 lb 1000 ft^{-2}), 2) Architect's Blend at 3660 kg ha^{-1} (75 lb 1000 ft^{-2}), 3) Architect's Blend at 3660 kg ha^{-1} (75 lb 1000 ft^{-2}) + methylene urea (MU, 40-0-0) at 146 kg N ha^{-1} (3.0 lb N / 1000 ft^{-2}) and 4) greens-grade Milorganite (6-2-0) at 146 kg N ha^{-1} (3.0 lb N / 1000 ft^{-2}) + MU at 146 kg N ha^{-1} (3.0 lb N / 1000 ft^{-2}). Treatments 1, 3 and 4 provided a total N level of 292 kg N ha^{-1} (6.0 lb N 1000 ft^{-2}), while treatment 2 provided a total N level of 146 kg N ha^{-1} (3.0 lb N 1000 ft^{-2}). The materials were incorporated into the top 5.0 cm of the existing soil mix. Plot size for the individual treatments was 1.82 x 9.14 m (6 x 30 ft) and the experimental design was a randomized complete block design with 4 replications..The entire green was seeded on 15 Sep. 2003 with a blend of 'A4' / 'G6' creeping bentgrass at a rate of 61 kg pure-live-seed (PLS) ha^{-1} (1.25 lb PLS 1000 ft^{-2}).

Mowing was commenced at 4 weeks after seeding and was initially set to a height of 0.64 cm (0.25 inch). Fertilization of the entire green also started on this date and consisted of bi-weekly application of a foliar fertilization program (Emerald Isle, True Foliar, Ann Arbor, MI) that delivered a complete fertilizer at the rate of 4.44 kg N ha^{-1} (0.091 lb N / 1000 ft^{-2}), 1.56 kg P ha^{-1} (0.032 lb P 1000ft^{-2}), and 3.46 kg K ha^{-1} (0.071 lb K 1000ft^{-2}) every 2 weeks.

Turfgrass establishment rates were monitored weekly during the grow-in using digital image analysis (Richardson et al., 2001). At 6 and 8 weeks after planting (WAP), two soil cores (2.54 x 30 cm) were removed from each plot and the sand was washed from the roots for a determination of maximum root length and root weight. Also at 6 and 8 WAP, a single pass was made through each plot with a mower to determine shoot growth. A sub-sample was taken from the clipping harvest, dried in a forced air oven at 60°C for 48 h and ground to pass a 1-mm screen. Leaf tissues were analyzed using inductively coupled plasma (ICP) emission spectroscopy (Donahue and Aho, 1992) for all nutrients except N, which was analyzed by combustion analysis (Campbell, 1992).

Results and discussion

A uniform stand of creeping bentgrass was attained across the entire experimental area. Turfgrass cover ratings were similar for the four treatments through the first 4 weeks of the trial (Figure 1), but began to separate at the 36 and 48 days after planting treatments. On those dates, the Arch.-150 treatment resulted in more turfgrass cover than any of the other treatments. There were statistical differences in turfgrass cover among all treatments, with ranking being Arch.-150 > Milorganite + MU > Arch. 75 + MU > Arch. 75 (Figure 1). The differences between the top three treatments and the Arch. 75 are not surprising, as they have twice as much available N as the Arch. 75. However, the differences between the top three treatments indicate that actual fertility may not be as important as the form of fertility. A Milorganite pre-plant application, such as the one tested in this trial, has been commonly used in this type of seeding for many years (McCarty, 2001). However, the Arch.-150 treatment out-performed this treatment, even with the same amount of actual nutrients. Milorganite is an activated sewage sludge product that is pelletized for application, while the Architect's blend is a proprietary formulation of bio-stimulants and plant and seaplant meals.

One of the most important aspects of turfgrass establishment is the number of days required to reach full coverage. For each treatment, the number of days required to reach both 80% and 100% coverage was calculated. The Arch-150 treatment required significantly fewer days than any other treatment to reach both 80% and 100% coverage (Table 1). The Arch.-150 treatment reached 100% coverage approximately 2 weeks prior to any other treatment. This would be a significant advantage for golf course superintendents during construction or renovation, as this time saved in establishment would allow the course to open sooner.

Data on root and shoot growth was inconclusive, as the differences between treatments were small and variable (Table 2). At 8 WAP, there was a slight reduction in root wt. in the Arch.-75 + MU treatment compared to other treatments. Also, there was a significant reduction in shoot wt. of the Arch.-75 treatment at 8 WAP (Table 2). There were no significant differences observed for other treatments and variables.

There were significant treatment effects on nutrient content at both the 6 and 8 WAP sampling dates (Table 3). At 6 WAP, N, P, K, Ca, Mg, and S were all affected by pre-plant treatments, with the major difference being observed between the Arch.-75 treatment and all other treatments. This is not surprising, as this treatment received half the amount of total fertility as the other treatments. The differences between other treatments was small and not significant for most parameters tested. At 8 WAP, the differences due to treatment were even less pronounced and there was no treatment effect on N or K (Table 3).

Conclusions

The results of this study demonstrate that pre-plant organic matter treatments can have a significant impact on bentgrass establishment in high sand content putting greens. The proprietary product, Architect's Blend, produced the most favorable results when used at the high rates. Assuming it is cost-competitive, this product should benefit golf course superintendents, as excellent grow-in results can be attained using a single, composite material.

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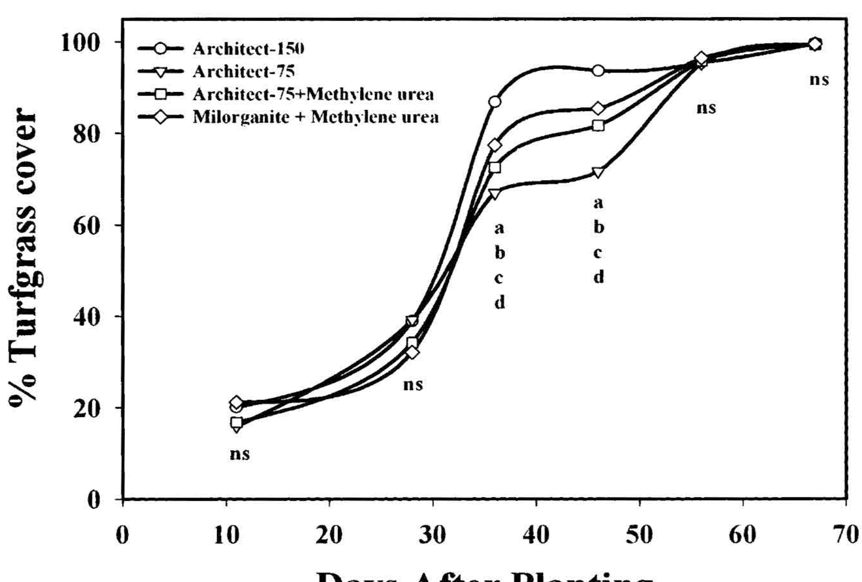

Fig. 1. Establishment of creeping bentgrass, as affected by four pre-plant soil amendments. Letters indicate a significant difference (P=0.05) between treatments at each evaluation date. ns - no significant difference between treatments at that date.

Table 1. Days for creeping bentgrass to reach either 80% or 100% coverage, as affected by various pre-plant fertilizer treatments.

Treatment	80% Cover	100% Cover
	------------------- days to reach	---------------------
Arch.150	34 d†	40 b
Arch.75	50 a	56 a
Arch. 75 + methylene urea	43 b	56 a
Milorganite + methylene urea	37 c	55 a

† - different letters indicate a significant difference (P=0.05) between treatments for that level of turfgrass coverage.

Table 2. Effects of various pre-plant fertilizer treatments on shoot and root characteristics of creeping bentgrass.

Treatment	Root length (cm)		Root Wt. (g)		Shoot Wt. (g m^{-2})	
	6 WAP†	8 WAP	6 WAP	8 WAP	6 WAP	8 WAP
Arch.150	18.60	19.00	4.60	4.60	1.30	2.00
Arch.75	17.90	19.50	4.80	4.20	1.28	1.26
Arch.75 + methylene urea	19.20	16.60	3.60	3.60	1.14	2.32
Milorganite + methylene urea	19.90	18.00	4.00	4.60	1.20	1.94
LSD (0.05)	NS‡	NS	NS	0.30	NS	0.58

† - WAP - weeks after planting

‡ - NS - not significantly different at the P = 0.05 level of probability

Table 3. Tissue analysis of creeping bentgrass, as affected by various pre-plant fertilizer treatments. Samples were collected at 6 and 8 weeks after planting.

Treatment	N	P	K	Ca	Mg	S
	------------------------			% dry wt.		------------------------
			6 weeks after planting			
Arch.150	2.9	0.36	1.17	0.43	0.20	0.36
Arch.75	1.5	0.19	0.75	0.22	0.13	0.23
Arch. 75 + methylene urea	2.2	0.26	1.05	0.32	0.18	0.31
Milorganite + methylene urea	2.3	0.28	0.97	0.27	0.19	0.27
LSD (P=0.05)	0.6	0.07	0.23	0.09	0.04	0.08
			8 weeks after planting			
Arch.150	4.7	0.62	2.47	0.36	0.25	0.44
Arch.75	4.1	0.54	2.19	0.29	0.23	0.37
Arch. 75 + methylene urea	4.6	0.52	2.24	0.29	0.23	0.38
Milorganite + methylene urea	4.8	0.61	2.44	0.33	0.27	0.39
LSD (P=0.05)	NS†	0.05	NS	0.04	0.02	0.03

† NS - not significant at the P = 0.05 level of probability

Further Evaluations of Postemergence Herbicides on Seedling Bermudagrass

M.D. Richardson[1], J.W. Boyd[2], J.H. McCalla[1], D.E. Karcher[1], and J.W. Landreth[1]

Additional Index Words. Sencor, MSMA, Confront, Trimec, Monument, flazosufuron, Revolver, Drive, Lontrol, *Cynodon*

Summary. Bermudagrass (*Cynodon dactylon* [L.] Pers.) is the major turfgrass used for golf course fairways, tees, sports fields, and home lawns in the transition zone and farther south. In recent years, efforts to develop seed-propagated cultivars have been successful. Seeded cultivars have not been used to any great extent in the turfgrass industry and data on establishment and management are lacking. The objective of this study was to determine the tolerance of seedling bermudagrass to several commonly used postemergence herbicide combinations. 'Riviera' bermudagrass was seeded on 15 June 2003. Twelve different herbicide combinations were applied to the seedling turf at 2 weeks after emergence. Bermudagrass seedlings showed good tolerance to most of the herbicides, including popular herbicide combinations such as Trimec Classic + MSMA and Manor + MSMA. The only herbicides that caused significant levels of damage were a combination of Sencor and MSMA. These data demonstrate that the tolerance of seedling bermudagrass to postemergence herbicides is good and that a range of postemergence herbicides can be used during establishment.

Bermudagrass (*Cynodon* spp.) continues to be the predominant turfgrass used for golf course fairways, tees, and roughs throughout the South and into the transition zone. The popularity of this species is based on the performance of improved cultivars at low mowing heights, the recuperative potential of the turf, and the tolerance of the grass to a wide range of turfgrass pests.

In the past two decades, major efforts by both academic and industry breeders have been underway to select improved *C. dactylon* clones and make crosses to produce fertile, seed-propagated cultivars of bermudagrass that can be used in high-maintenance turfgrass situations. As a testament to those efforts, the seed-propagated cultivars in the 2002 National Turfgrass Evaluation Program bermudagrass trial outnumber the vegetative hybrids by two to one (Rogers 2003). It is almost certain that these breeding efforts will continue to yield significant changes in seed-propagated bermudagrasses and these cultivars will soon be a major force in the turfgrass industry.

Although the quality of seeded bermudagrass cultivars has undoubtedly not reached its peak, several cultivars have been released from breeding programs, some of which have rated very well in cultivar trials around the U.S.. The cultivars, 'Riviera', 'Princess', and 'Yukon' have received the most attention by the turfgrass industry due to the vast improvement in turfgrass quality noted with these cultivars, as well as improvements in stress-related issues such as cold tolerance. Other cultivars such as 'Mirage', 'Southern Star', 'Blackjack', and 'Transcontinental' have also been released in recent years and these cultivars also show improvement over earlier seeded bermudagrass types (Morris, 2003).

With the rapid release of seeded bermudagrass cultivars, there is a great need to understand factors that influence the establishment and maintenance of these grasses. Some of the issues that need to be addressed include weed control strategies, methods to use these grasses in turf renovation, and the testing of these grasses in fringe environments. Research on seeded bermudagrass establishment and management has been conducted and is ongoing at numerous universities throughout the transition zone, including Oklahoma State Univ., Kansas State Univ., Univ. of Kentucky, Purdue Univ., and Mississippi State Univ.. At the Univ. of Arkansas, we have focused on two major factors of seeded bermudagrass use and management. These include the tolerance of seedling bermudagrass to common postemergence herbicides and the effect of establishment procedures on first-year winter survival.

Several trials investigating the tolerance of seedling bermudagrass to common postemergence herbicides have already been conducted at our location (McCalla and Richardson, 2002). The intent of these trials has been to determine how early after seedling emergence herbicides can be safely applied and to determine which specific herbicides are safe to use during this early stage of growth.

In a previous trial (McCalla and Richardson, 2002), individual herbicides that are routinely used to control grassy and broadleaf weeds were applied at labeled rates to bermudagrass seedlings at one, two, and four weeks after emergence (WAE). The chemicals tested included 2,4-D, dicamba, clopyralid, quinclorac, metsulfuron, diclofop and MSMA. Herbicide injury was monitored frequently after application of the herbicides and turfgrass cover was documented at 30 and 60 days after treatment (DAT).

The overall results of this trial indicated a good tolerance of seedling bermudagrass to all of the postemergence herbicides tested (McCalla and Richardson, 2002). Diclofop applications to seedling bermudagrass resulted in significant injury in the first seven days after application, but this injury subsided quickly and there was no difference in turfgrass cover between any of the herbicide treatments and the control at 30 DAT. Other herbicides that caused injury included metsulfuron and dicamba, but the bermudagrass quickly recovered from the initial injury caused by these herbicides.

Although the results of these trials indicated a good tolerance of seedling bermudagrass to postemergence herbicides, this was certainly

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not an exhaustive list of herbicides and the turfgrass industry generally applies combinations of materials to enhance the effectiveness of the control. As such, the objective of this trial was to investigate the tolerance of seedling bermudagrass to combination herbicides rather than individual compounds, as the use of tank mixes or combination products to control weeds is a much more common practice than the use of single herbicide compounds.

Materials and methods

In this trial, a single herbicide application date (2 weeks after emergence) was tested. Plots were established at the University of Arkansas Research and Extension Center in Fayetteville, Ark. The area was fumigated with methyl bromide prior to establishing 'Riviera' seeded bermudagrass at 48.8 kg pure live seed (PLS) ha^{-1} (1.0 lb. PLS / 1000 ft^2) on 15 June 2003. The herbicides and rates tested in this trial are listed in Table 1. Data collected included a visual rating of herbicide injury (0-9, with 0 = no injury and 9 = completely dead) periodically after herbicide application and turfgrass establishment rates were determined using digital image analysis (Richardson et al., 2001) at 7, 14, and 21 days after treatment (DAT).

Results and discussion

Significant herbicide injury was observed with several of the herbicide combinations at 3 DAT (Table 2), with the most severe injury observed on turf treated with Sencor + MSMA. The injury caused by Sencor + MSMA plots was very severe at all of the early rating dates and was still present at 21 DAT. This herbicide was also tested at 4 WAE (data not shown) and the injury was not as severe as the applications made at 2 WAE, indicating that this treatment might be used after mowing has commenced. The effects of MSMA + Sencor was also observed in the turfgrass cover data, as those plots had only 24% cover at 7 DAT, while the control plots had over 95% cover (Table 3). A significant reduction in turfgrass cover was still observed in Sencor + MSMA plots at 14 and 21 DAT.

MSMA when combined with either Trimec Classic or Confront also caused significant injury to the seedling turf (Table 2). Although these treatments caused a significant decrease in turfgrass cover at 7 DAT (Table 3), these plots had recovered significantly by 21 DAT and turfgrass cover was near the control plots. Other treatments tested in this trial caused little or no injury to the bermudagrass seedlings.

Conclusions

Weed control during the establishment phase will be critical to successfully establish bermudagrass turf from seed. The results from this trial will provide golf course superintendents and other turfgrass managers a wide array of herbicides that can be used during seeded bermudagrass establishment. Greenhouse studies conducted at our location have also shown that herbicide tolerance levels are similar for a range of seeded bermudagrass cultivars (data not shown).

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Table 1. Herbicide treatments applied to seeded bermudagrass at 2 weeks after emergence.

Sencor + MSMA	0.38 + 2.0 lb. ai / acre	0.42 + 2.24 kg ai / ha
Trimec Classic + MSMA	3.5 pints / acre + 2.0 lb. ai / acre	3.5 pints / acre + 2.24 kg ai / ha
Confront + MSMA	1.0 pt / acre + 2.0 lb. ai / acre	1.2 l / ha + 2.24 kg ai / ha
Monument + MSMA	0.56 oz / acre + 2.0 lb. ai / acre	0.039 kg / ha + 2.24 kg ai / ha e
Flazosulfuron + MSMA	3.0 oz / acre + 2.0 lb. ai / acre	0.21 kg / ha + 2.24 kg ai / ha
Revolver + MSMA	17.4 oz / acre + 2.0 lb. ai / acre	1.21 kg / ha + 2.24 kg ai / ha
Drive + MSMA	0.75 + 2.0 lb. ai / acre	0.84 + 2.24 kg ai / ha
Manor + MSMA	0.5 oz / acre + 2.0 lb. ai / acre	0.035 kg / ha + 2.24 kg ai / ha
Drive	0.75 lb. ai / acre	0.84 kg ai / ha
Drive fb Drive	0.5 fb 0.5 lb. ai / acre	0.56 fb 0.56 kg ai / ha
Lontrol + MSMA	0.38 + 2.0 lb. ai / acre	0.42 + 2.24 kg ai / ha
Untreated Control		

Table 2. Tolerance of 'Riviera' seedling bermudagrass to postemergence herbicides applied at 2 weeks after emergence.

Herbicide	3DAT†	5DAT	7DAT	10DAT	14DAT	21DAT	28DAT	Avg.
		-----------------------------		Herbicide Injury ‡	-----------------------------			
Sencor + MSMA	8.0	7.8	7.5	6.5	4.3	2.0	0.0	5.1
Trimec Classic + MSMA	2.3	3.0	3.3	2.5	1.8	0.0	0.0	1.8
Confront + MSMA	1.5	3.0	2.3	1.5	0.8	0.0	0.0	1.3
Monument + MSMA	3.3	2.8	1.3	0.8	0.8	0.3	0.0	1.3
Flazosulfuron + MSMA	2.3	2.3	1.8	1.5	0.8	0.0	0.0	1.2
Revolver + MSMA	2.8	2.3	1.0	1.3	0.8	0.3	0.0	1.2
Drive + MSMA	1.5	2.8	1.8	1.3	0.3	0.0	0.0	1.1
Manor + MSMA	2.0	1.8	1.3	0.8	0.3	0.0	0.0	0.9
Drive	0.5	1.3	1.5	1.3	0.8	0.5	0.0	0.8
Drive fb Drive	0.5	1.0	1.3	0.8	0.8	1.3	0.0	0.8
Lontrol + MSMA	2.0	1.8	0.3	0.5	0.5	0.0	0.0	0.7
Untreated Control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.8	1.3	1.3	1.2	0.7	0.4	0.0	0.6

†- DAT – days after treatment

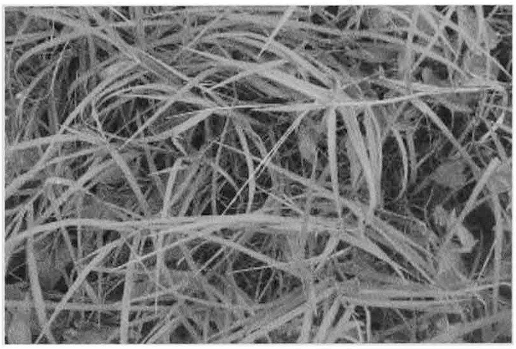
‡- herbicide injury was rated on a scale of 0-9, with 0=no injury and 9=dead turf.

Table 3. Establishment rates of 'Riviera' seedling bermudagrass after applying postemergence herbicides at 2 weeks after emergence.

Herbicide	7 DAT†	14 DAT	21 DAT
	----------------------	Turfgrass Cover ‡ (%)	-------------------
Sencor + MSMA	24.2	75.1	89.0
Trimec Classic + MSMA	64.6	94.0	97.3
Confront + MSMA	79.2	95.7	97.3
Monument + MSMA	94.0	99.0	98.7
Flazosulfuron + MSMA	88.4	97.5	97.4
Revolver + MSMA	92.0	98.4	98.5
Drive + MSMA	97.2	99.5	98.7
Manor + MSMA	87.9	97.7	98.5
Drive	96.6	99.7	99.3
Drive fb Drive	97.4	99.5	99.3
Lontrol + MSMA	98.2	99.3	99.5
Untreated Control	95.1	99.2	99.4
	13.8	4.0	1.6

†- DAT — days after treatment

‡- turfgrass cover was measured using digital image analysis.



Sod Production Using Seeded Bermudagrass

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Summary. The development of improved seeded bermudagrass cultivars has led to an increased interest in these grasses for numerous areas of turfgrass use. One area that has yet to be investigated is the potential to produce sod using a seed-propagated bermudagrass, rather than the standard practice of vegetative propagation, which is currently used. To this end, a series of studies are underway to investigate the effects of various production techniques on seeded bermudagrass sod production. A study was established during the 2003 growing season at a sod farm in Little Rock, Ark. An area was seeded with 'Riviera' bermudagrass at a seeding rate of 56 kg pure-live-seed (PLS) ha^{-1} (50 lb PLS A^{-1}). Plots were split into treatments that received either netting (Conwed fibers) or no netting immediately after planting. In addition, plots were treated with either 1.16 or 0.58 l ha^{-1} (16 or 8 oz. A^{-1}) of trinexapac-ethyl (TE; trade name 'Primo'). At 10, 12, and 14 weeks after planting (WAP), strips of sod were harvested form each plot and the amount of harvested crop was determined from each treatment. In addition, harvested sod was tested for sod strength. The results of these studies indicated that netting was the critical component for producing sod with seeded bermudagrass. The netted plots had greater than 90% harvest at all harvest dates, while the non-netted plots had less than 20% harvest at any of the harvest dates. The TE had no effect on sod harvested or sod strength. These studies demonstrate that sod can be produced using seeded bermudagrass, but netting will decrease the time required to produce a marketable crop and reduce the amount of waste.

Across the southern United States and throughout the transition zone, bermudagrasses (*Cynodon* spp.) continue to be the major turfgrass species for golf courses, sports fields, lawns, and utility turf areas. Although hybrid (*C. dactylon* x *C. transvaalensis*) bermudagrass cultivars such as 'Tifway', 'Tifgreen', and 'Midlawn' have been the most widely utilized for high-maintenance turf sites, these grasses carry the sterile characteristics of the *C. transvaalensis* parent and subsequently have to be vegetatively propagated. These grasses have been the backbone of the southern U.S. sod industry.

In the past decade, a number of new seeded bermudagrass cultivars began to appear on the market as several commercial and academic breeding programs continued to search for new germ plasm and make new crosses. Although some of the earlier cultivars such as 'Guymon', 'Sonesta', and 'NuMex Sahara' suggested promise, most failed to produce a turf quality that was better than 'Arizona Common' and certainly not within the quality range of the established hybrids. However, in the 1997 National Turfgrass Evaluation Program bermudagrass trial, new seeded cultivars such as 'Princess' and 'Riviera' ranked at the top of this trial for both seeded and vegetative types of bermudagrass (Morris, 2000). These grasses have the potential to revolutionize the sod industry by offering a seeded option for sod growers which may considerably increase the production volume of warm-season sod farms.

The University of Arkansas has done a considerable body of research on the improved, seeded bermudagrasses, investigating the effects of planting date, planting rates, and weed control strategies to successfully establish this crop. We have observed that a full stand of bermudagrass can be established in as little as 4 weeks (J.H. McCalla, unpublished). However, it is uncertain whether this young stand has the tensile strength to be harvested as sod, as there have been no studies using seeded bermudagrass for sod production. In addition, techniques such as netting, which are commonly used on cool-season sod crops (Beard et al., 1980), may also be applied to seeded bermudagrasses, further reducing the production period and increasing the strength of the bermudagrass sod.

Studies on cool-season grasses have shown that netted grasses can be lifted and transplanted in as little as 12 weeks (Beard et al., 1980) and a local sod producer has indicated that netted sod has been effectively harvested as early as 8 weeks (Roger Gravis, Quail Valley Grasses, personal communication). The cost to net sod is approximately $.05 / yard, so this technique does not add considerably to the price of production. In addition, netting has been shown to reduce the amount of waste product during harvest of sod, as the tensile strength of the net will hold marginal sod together. Bermudagrass typically has weak sod quality, especially in late summer (Anonymous, 1995) and the addition of net to the production process should improve the overall quality and quantity of harvested sod.

Another technique that has been used to enhance sod strength in seeded grasses is the application of plant growth regulators to enhance lateral development and increase tensile strength. Work on Kentucky bluegrass has indicated that sod strength can be enhanced using trinexapac-ethyl (TE) (Henderson et al., 1999) and this compound can be safely used on bermudagrass (Richardson, 2002).

The overall goal of this project is to determine a set of best management practices for using improved seeded bermudagrasses for sod production. Under that goal, several objectives will be addressed. The

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first objective is to determine the minimum time from planting to harvest of the seeded bermudagrass cultivar Riviera. The second objective is to investigate the effects of net-planting and TE on seeded bermudagrass production. The last objective is to determine the effects of re-seeding on the recovery of harvested bermudagrass and the production of a second crop. This report describes the first year of research dealing with the first two objectives.

Materials and methods

A 0.40 ha (1.0 acre) area was seeded with 'Riviera' bermudagrass at Quail Valley Farms in Little Rock, Ark. The area had been fallow for a full season and cleaned of weeds with 3 successive applications of glyphosate. The seeding rate was 56 kg PLS ha^{-1} (50 lbs PLS A^{-1}). The plot area was laid out in a strip-split-plot design, with netting being the first main effect and trinexapac-ethyl (TE) at either 1.16 or 0.58 l ha^{-1} (16 or 8 oz. A^{-1}) being the second split. The entire area was seeded with a mechanical seeder and the netting, which was 4.6 m (15 ft) wide, was laid immediately after seeding.

The plot area was maintained to promote germination and rapid establishment. The plot area was mowed twice weekly at 2.54 cm (1.0 in) and fertilized bi-weekly with 56 kg N ha^{-1} (50 lb N A^{-1}) as urea. The plot area had excellent germination and establishment and had formed a complete turfgrass cover at approximately 6 weeks after planting. Due to weather constraints, the first harvest was not attempted until 10 weeks after planting (WAP), but successive harvests were made at 12 and 14 WAP.

During the harvest, two passes were made down the length of the netted or control plots with a Brower sod harvester, cutting sod into pads that were approximately 45 cm (18 in) wide x 76 cm (30 in.) long. Sod within the three TE treatments was handled separately. Two parameters were measured within each net x TE plot: 1) Percentage of pads that were able to be handled without damage and 2) sod strength of the harvested pads.

Results and discussion

The analysis of variance indicated a significant effect of netting at all harvest dates, while TE was not significant at any harvest date, nor was there a significant netting x TE interaction (data not shown). The overall results of this trial were very interesting in that the seeded bermudagrass plots that had been netted could be harvested completely at 10 weeks after planting with less than 10% waste, while the control (non-netted) plots had very poor sod quality and <20% could be harvested even at the last harvest date (Table 1). For the netted plots, sod quality remained very high, with almost 100% harvest from the netted plots at the 12 and 14 weeks after planting harvests.

Sod strength was measured at each harvest using a sod harvester designed originally at Michigan State University (Sorochan et al., 2001) and modified slightly for these purposes. The machine operates by initiating a lateral pull on an immobile pad of sod and recording the maximum shear force required to break an individual piece of sod. Within each net x TE plot, eight pads were collected (if available) and analyzed with the sod stretcher. The sod stretch data did not yield any significant findings during this trial, in that the netted plots had similar sod strength across growth regulator treatments, while the non-netted sod had very poor sod strength regardless of growth regulator (data not shown).

Conclusions

From this study, it was obvious that netting will be a major factor for producing bermudagrass sod from seed, but these plots will be monitored through next season to determine at what point non-netted turf produces a sod crop. With netting, sod can be harvested as soon as 10 weeks after planting under good growing conditions. TE had no effect on sod strength in this study, which is different from trials conducted on cool-season grasses.

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Table 1. Percent harvested bermudagrass sod, as affected by netting treatment. Sod was harvested at 10, 12 and 14 weeks after planting (WAP).

	10 WAP	12 WAP	14 WAP
	------------------------- % harvested sod	--------------------------	
Netted	96.0	98.8	100
Control	19.0	2.0	10.9
LSD (0.05)	17.1	3.7	10.9

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