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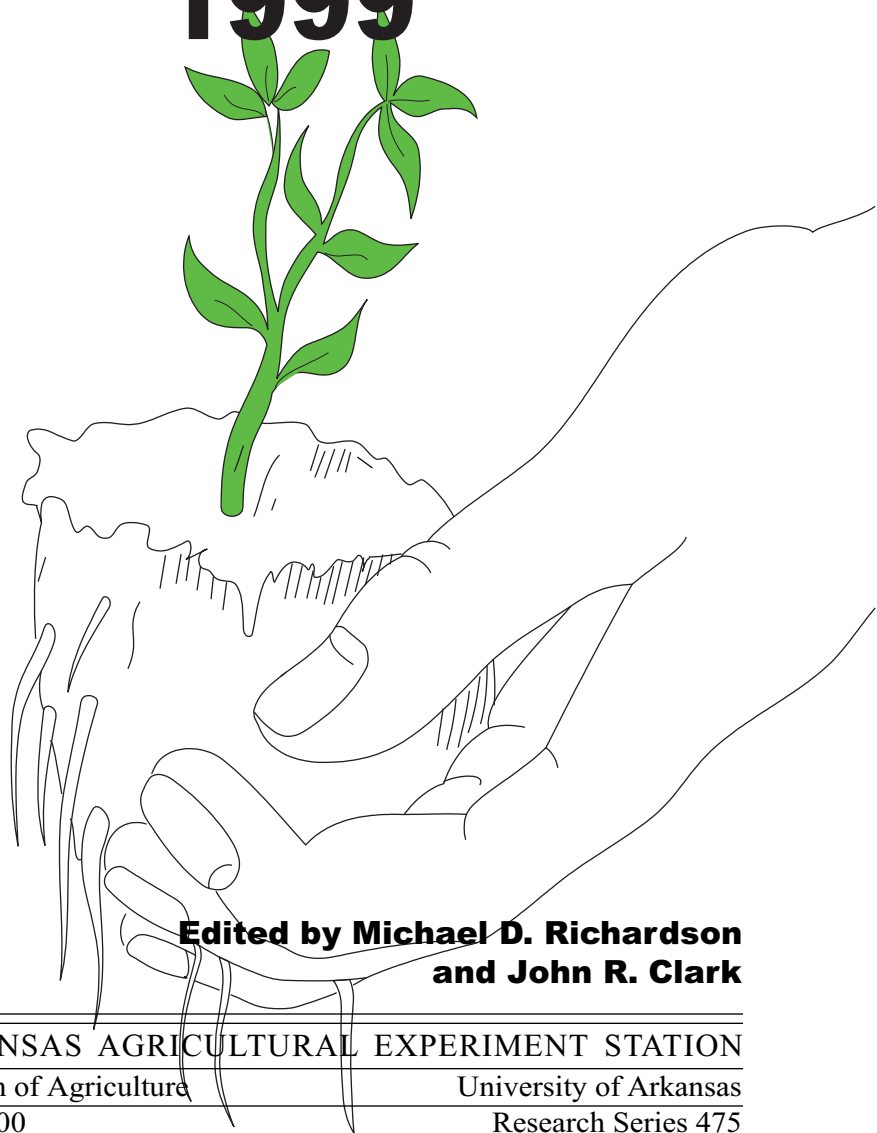
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HORTICULTURAL STUDIES

1999



**Edited by Michael D. Richardson
and John R. Clark**

ARKANSAS AGRICULTURAL EXPERIMENT STATION

Division of Agriculture

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June 2000

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**HORTICULTURAL
STUDIES
1999**

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PREFACE

Horticultural Studies 1999 is the second edition of a Research Series dedicated to horticultural programs in the University of Arkansas Division of Agriculture and the Dale Bumpers College of Agricultural, Food and Life Sciences. This publication summarizes research, extension, and educational activities that serve horticultural industries and interest groups in Arkansas. The goals of this publication are to provide relevant information to the growers and end-users of horticulture crops in Arkansas and to inform the citizens of Arkansas and the surrounding region of activities related to horticulture.

An ongoing mission of the horticulture programs in the University of Arkansas Division of Agriculture is to provide the citizens of our state with a higher quality of life, which includes a safe, affordable food supply, an abundance of natural beauty, and safe, accessible recreation venues. We hope that this publication will be of value to all persons with an interest in Arkansas horticulture. You may find this publication on the Internet at the following address: www.uark.edu/depts/agripub/publications/researchseries/

Michael D. Richardson and John R. Clark, Editors

SPECIAL THANKS

Thanks are expressed to the donors listed below who contributed to horticulture programs in 1999. External support of all programs is critical to the continuing enhancement of horticulture industries in Arkansas.

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1999 HIGHLIGHTS

Every year brings changes to any organization, some fast and furious, others very slow and deliberate. The Department of Horticulture had numerous changes that fit both categories in 1999. The changes that occurred included changes in people, followed by those of programs and other Department components.

PEOPLE

In reviewing 1999, the changes in personnel were substantial in the Department. There were three faculty retirements during the year. Dr. Al Einert (Landscape Horticulture) retired after twenty-nine and one-half years at the U of A, with his entire career spent in our Department. Dr. John King (Turfgrass) also retired. Dr. King was a faculty member for twenty-eight years at the University, the last five in the Department of Horticulture. Finally, Dr. Laurin Wheeler (Forest Ecology) retired after twenty-two years. All of us in the Department wish these three gentlemen the best and say thanks for their many years of service.

Another change that occurred was the departure of Dr. Stephen Myers, Department Head. Dr. Myers left at the end of August to assume duties of department head at the Ohio State University. Thanks to Dr. Myers for his vision and energy contributed to the Department in his three years at the U of A. I was named Interim Head beginning September 1, 1999, by Dean Charles Scifres. Dr. David Hensley begins his appointment as Department Head in August 2000.

New folks joined our Department in 1999 as well. Two new faculty were hired in late 1999, and began their duties in early 2000. Dr. James Cole was hired to conduct research and teach in the area of Landscape Horticulture. He comes from Oklahoma State University, where he completed his Ph.D. in 1999. Dr. Doug Karcher joined the faculty as our second Turfgrass research and teaching faculty member. Dr. Karcher completed his Ph.D at Michigan State University. The Department welcomes these two young scientists and the skills and enthusiasm they bring to our programs. Lastly, the Department will hire a floriculturist in 2000, completing the current planned faculty additions and replacements.

Dr. Christine Beaupre joined the Department in early 1999 to work as a postdoctoral research associate with Dr. Brad Murphy in his molecular biology program. Additionally, support personnel were hired in 1999. Mr. Matthew Pelto joined the Department as a research specialist in woody ornamental tissue culture and molecular biology working with Dr. Jon Lindstrom. Also, Mr. Gene Bordelon joined the turfgrass

research effort as a research specialist working with Dr. Mike Richardson. Finally, Ms. Krista Kugler-Quinn joined the Extension Horticulture staff in Little Rock as an extension associate working in the consumer horticulture and ornamental programs of Ms. Janet Carson and Dr. James Robbins.

Graduate students who joined the Department in 1999 included Brent Burkett (advisor Dr. Lindstrom), Natalie Huber (advisor Dr. Murphy), Erin Thevenot (advisors Drs. Robbins and Gerald Klingaman), Scott Maxwell (advisor Dr. Curt Rom), and Aletta Mazebedi (advisor Dr. Craig Andersen). Graduate students completing their degrees in 1999 included Richelle Sink (advisors Drs. Einert and Klingaman), Matthew Pelto and Eric Stafne (both advised by me), and Mo Brar (advised by Dr. Teddy Morelock). Several of these students have reports on their research in this publication.

Enough on personnel? Well, it is difficult to ever say enough about people—the creative and therefore most important force in any organization. The Department has had and continues to have a creative and enterprising group of minds to lead it and its many activities. The contributions of those who have completed their time are appreciated, and the skills and ambitions of those just coming on board are the bright horizon we see before us.

PROGRAMS—TEACHING

Undergraduate education was one of the brightest areas of Department accomplishment in 1999. The revised curricula were installed fully for all degree programs, and we threw the gates back and welcomed our largest undergraduate enrollment in at least fifteen years (near 100 students representing a 27% increase from 1998). The Turf and Landscape Horticulture major had one of the highest percentage increases in the College of Agricultural, Food and Life Sciences (increased by 132%). The Department envisions a further increase in undergraduate enrollment, including continued growth in concentrations such as turf management, landscape horticulture, and horticultural merchandising, along with increased or sustained enrollment in horticulture production and management and horticultural science. Dr. Rom has an excellent article on the history of undergraduate instruction in this year's *Horticultural Studies*, providing a review of where we have been and where we are headed.

Another area of growth in the teaching program in 1999 was the increased level of scholarship support for Horticulture majors. A total of \$73,965 was provided to forty-one Horticulture undergraduates. Facility development for teaching took a major step forward in 1999, with the continued development of the Horticulture Display Gardens

adjacent to the Plant Science and other agriculture buildings on campus. These gardens are providing a greatly expanded opportunity for instruction in plant materials and landscape installation and maintenance, and of course, in beautifying this area of campus. Further development of the gardens will continue in 2000 and 2001.

PROGRAMS—RESEARCH

Research programs moved ahead in 1999, and many of the achievements are described in the following reports. Research in traditional areas including cultivar improvements and crop management continued, and new and broadening investigations in turfgrass and molecular biology were developed.

The Department also saw advances in research into broader or new areas that need highlighting. A new plant evaluation program undertaken by Drs. Lindstrom, Robbins, and Klingaman at three locations in the state will provide a very broad reflection on adaptation of a range of new ornamental plant species, and the information provided will be directly usable by the landscape and nursery industries to provide an ever-expanding range of plants for selection. Expanded turf research (led by Dr. Richardson and other scientists working in turfgrass) on both warm- and cool-season grasses for a range of uses, including sports turfs and homeowner utilization, is in full swing at multiple sites in the state. Finally, the molecular biology effort in the department led by Dr. Murphy made great strides in 1999 with the attainment of a grant of almost \$1 million to aid in building the research infrastructure at the U of A. The grant will be used to develop a nationally competitive program in plant-based production of recombinant proteins of pharmaceutical interest. This work is in conjunction with the Biological Sciences Department at the U of A and the U of A medical school in Little Rock.

Research in more traditional areas took on some new angles in 1999. Investigations in the area of "nutraceuticals" (compounds such as antioxidants and other health-promoting substances) in several of our leading breeding program crops were greatly expanded. This work, which includes analyses of a range of compounds found in spinach, tomatoes, southernpeas, blueberries, blackberries, table and wine grapes, peaches, and nectarines yielded exciting results, and this area of work is envisioned to expand in 2000 and beyond. Those working in this area include Drs. Morelock and Murphy and me, in addition to Dr. Luke Howard in the Department of Food Science.

A last area of research needing special mention is that of the Extension Specialists who have research appointments (Drs. Craig Andersen, Paul Cooper, Klingaman, Robbins, and Keith Striegler). In

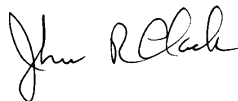
1999, these faculty members significantly expanded research at both on- and off-campus research locations, including some grower production sites. Expansions in vegetable cultivar testing, strawberry plasticulture, ornamental plant evaluation, and ornamental plant cultural investigations occurred. Applied technology for consumer utilization—that is the product of these efforts.

What else is there to say about research in Horticulture at the U of A? More and better! The outlook for 2000 and beyond? More and better still!

PROGRAMS—EXTENSION

Extension programs continue to be the major delivery mechanisms for technology to the public. Extension programs cover the entire range of horticultural needs in the state. In 1999, the Master Gardener program continued to expand under the leadership of Extension Consumer Horticulture Specialist Janet Carson. Currently there are over 1200 active Master Gardeners in Arkansas, with over 450 new Master Gardeners trained in 1999. This program is active in 36 counties in Arkansas, and an estimated 41,000 hours of community service were provided by participants in this program. Expanded programs for fruit growers (directed by Dr. Striegler, Extension Fruit Specialist) were provided in 1999, and these continued into 2000, with experts from within and outside Arkansas offering new and innovative information on strawberry plasticulture and peach and grape production. Farmers' market program development continued in various counties, with promotion of this program by Vegetable Extension Specialist Andersen, along with involvement by Dr. Cooper in Southeast Arkansas. Finally, the ornamental horticulture extension program continues to expand with the Arkansas Select landscape plant promotion program continuing, in addition to an expanded array of commercial ornamental production literature provided by Drs. Robbins and Klingaman. Another significant highlight in the Extension program is "Today's Garden," hosted by Extension Specialist Carson and broadcast statewide on AETN.

I hope these Horticulture Highlights, plus the following research articles, are of value to you, the horticultural clientele we are striving to serve. We at the University of Arkansas are moving ahead—striving to make a difference. Let us hear from you!



John R. Clark
Interim Head and Professor

HORTICULTURAL STUDIES 1999

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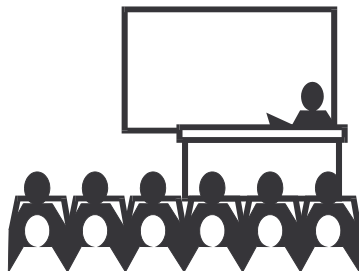
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UNDERGRADUATE PROGRAM DEVELOPMENT IN THE DEPARTMENT OF HORTICULTURE

Curt R. Rom¹

IMPACT STATEMENT

Horticulture undergraduate programs are continually developing to meet the changing needs of the state and the students enrolled in the program. Significant changes in the majors, increased emphasis on undergraduate education and programs, improved advising, and increased recruitment have led to increases in undergraduate enrollments at the end of this century.

BACKGROUND

Horticulture education has been prominent among the agricultural programs of the University of Arkansas since the very inception of the University. The Bachelor of Science in Agriculture (BSA) degree with a major in Horticulture (HORT) was first offered in the 1890s as one of two degrees in agriculture and has been offered continually since then. During that time, especially the last 40 years, there have been significant curriculum changes in the College and Department degree programs. This article highlights the major changes in the Horticulture degree programs, with emphasis on the current programs.

¹ Department of Horticulture, Fayetteville.

FINDINGS

Since the earliest years of horticultural education at the University of Arkansas, courses and degree plans were directed at supporting the horticultural industries of Arkansas and providing science-based, practical education to students so that they could assume management responsibilities in horticultural operations. Originally, the primary educational focus was preparing students to produce horticultural crops, especially fruits and vegetables, as these were important commodities in Arkansas.

Ornamental horticulture and gardening were also important components of early course offerings, with a course called Decorative Gardening being taught as early as 1899. By 1910, the Department of Horticulture had significant course offerings in ornamental horticulture including classes such as Floriculture, Forcing Flowers, Landscape Gardening, and Plant Propagation. In 1930, additional landscape courses such as Landscape Design had been added and were taught consistently until the early 1960s (Table 1). Continuously this century, and especially during the past 30 years, the Department of Horticulture has strengthened educational programs in ornamental and landscape (including turf) horticulture, while traditional fruit and vegetable production courses have declined. These revisions have been necessitated by changes in employment opportunities, needs of the state clientele, and student interests.

Between 1920 and 1960, there were few changes to the horticulture course offerings. Courses consistently offered included Principles of Fruit Production, Orchard Management, Small Fruit Management, Vegetable Gardening, Market Gardening, Systematic Pomology, Evolution of Cultivated Plants and Plant Breeding, Spraying and Spray Materials, and those courses mentioned above.

In 1963, the College introduced five degree plans for the BSA, Plans A - E. Plan A was a General Agriculture degree, and Plan B was a degree in Vocational Agriculture. These two degree plans were cross-disciplinary programs with broad-based agriculture training. Alternatively, students could declare a major from among 14 department majors, such as Horticulture, and pursue three other degree plans. A major consisted of 24 to 30 hours of coursework within the major department or of courses in other departments required by the major department. Within the major, Plan C—Agriculture Production—was a science-based crop production degree plan. Plan D allowed students within a major to declare one of two options (later referred to as minors): Option A—Business or Option B—Agriculture Journalism (later called Communications). Plan E, titled Agriculture Science, was a graduate degree preparatory program emphasizing fundamental science training.

The green-revolution and environmental movements of the early 1970s brought new students into horticulture—especially students interested in ornamental and landscape horticulture. Thus faculty were added in 1971 and 1974 to teach courses in ornamental plants, landscape design, floriculture, plant propagation, nursery management, and home horticulture. Expansion of horticulture undergraduate programs during that time was noted by the emergence of the Horticulture Club, which was first listed as a student organization in the *Catalog of Studies* of the College in 1972. In 1975, the Department of Horticulture added a new major, available in Plan E, Landscape Design and Urban Horticulture (LDUH). At the time of its creation, it was one of only three similar programs in the United States. Enrollment in the department rose from approximately 20 in the 1960s to 150 in 1978.

Act 98 of the Arkansas Legislature of 1989 provided that the Board of Higher Education set a minimum core requirement of courses for all state universities and colleges. In 1993, the University implemented a university core-required curriculum of 35 hours (approximately 8 to 10 courses) in the fundamental sciences, composition, math, history, social sciences, humanities, and the fine arts. This change affected all College degree programs. The five plans that had been used since 1963 were replaced by a College core curriculum of 22 hours (6 hours of composition and speech and 16 hours of core agriculture courses). Additionally, the College required that 18 hours (six courses) be designated as electives to create personalization of a degree program. All departments and majors created minor degree programs of approximately six courses. The Department of Horticulture created minors in Horticulture, and Landscape Design and Urban Horticulture. In 1998, the College reduced its degree requirements for the BSA from 132 to 124 credit hours, a reduction of approximately three courses. The College then dropped its requirements of 16 hours of agriculture core courses and replaced them with a requirement for three “broadening” courses in agriculture of a student’s choice—courses outside of the major department.

In January 1997, the turf research and education program was moved from the Agronomy (now Crop, Soil and Environmental Sciences) Department to Horticulture. With the addition of faculty, new courses and turf emphasis in horticulture were added the following year.

The opportunity created by changes in faculty and College degree requirements allowed the Department of Horticulture to undergo its first significant curriculum revision since 1963. Faculty determined that strengthening undergraduate programs and enrollments were a priority. A review of approximately 15 benchmark Horticulture programs at other Land Grant universities, a review of literature relevant to horticulture degree programs, and surveys of alumni and employers

provided a basis for revising the two degree programs.

The LDUH major was revised to Turf and Landscape Horticulture (TLHT). Within the TLHT major, students were allowed to pursue training in two concentrations: Turf Management or Landscape Horticulture. The HORT major was redesigned to allow students to pursue three concentrations: Horticulture Management and Production, Horticulture Science, or Horticulture Merchandising and Business. The 2-year pre-forestry program (PFOR) was dropped in 1998. Notable changes in the HORT and TLHT curricula included additional courses in communication, interpersonal skills and leadership, business, and earth science. With the electives within the degree programs, students were encouraged to pursue minor degree plans such as agri-business, general business, environmental science, food science, pest management, etc.

Until 1994, undergraduate advising had been distributed among the teaching faculty. However, in 1994, all advising was assigned to two faculty—one for HORT majors and one for LDUH majors. In 1998, this decision was reversed and student advising was again distributed to all undergraduate teaching faculty.

Since its genesis, the Horticulture Club has been important to the Department undergraduate programs. The accomplishments of the Club can be noted in awards. In 1996, it was recognized as an outstanding student organization on the University campus, and again in 1998 it was recognized as the Most Outstanding Special Interest Student Organization by the Registered Student Organizations. In 1999, the Club was recognized as the second-best club in the American Society for Horticultural Science, American Collegiate Branch, Southern Region and was selected as the outstanding small club (35 members or fewer) in the nation by the national American Society for Horticultural Science, American Collegiate Branch. Additionally, during the past 10 years, individual students and student teams have won national competition awards and have been recognized for their scholarship. Club activities that contribute to the undergraduate program are its educational meetings, a large, annual plant sale, community service activities, and the horticulture study tour program (Seattle, 1997; Philadelphia/Washington DC, 1999).

Undergraduate enrollment, according to identified records, was 50 or fewer prior to the early 1970s (Table 2). However, with new course offerings (Table 1) and student interest, enrollments increased to approximately 150 in the late 1970s, after which enrollments declined until the mid-1990s. Again, changes in curricula, addition and modification of courses, and the addition of the turf program to Horticulture in 1997 resulted in increasing enrollments at the end of the 1990s,

with an average relative growth from 1992 through 1999 of 5.4%. A regression analysis of enrollment during the 1990s ($r^2 = .81$; Fig. 1) projects that if enrollment continues at the current rate, the Horticulture program will have 150 students by 2012. It is anticipated that with increased emphasis placed on recruiting and retention, a goal of 150 students may be reached around 2005 to 2007. With the growth in enrollments and changes in academic programs, scholarship support for students has increased from approximately \$18,000 in 1996 to more than \$73,000 in 1999.

Table 1. Course offering changes in the Horticulture Department, University of Arkansas, Fayetteville, 1960-1999.

Year	Change	Course(s)
1960	Existing	Principles of Horticulture, Tree Fruit Crops, Small Fruits, Vegetable Crops, Advanced Vegetable Crops, Horticultural Processing, Landscape Design
1961	Change	Tree Fruits moved from junior to senior level
1962	Drop	Landscape Design
1968	Add	Ornamental Plant Materials; Floriculture
	Move	Principles of Food Technology; Quality Evaluation and Control (to Horticultural Food Science Program)
1972	Change	Ornamental Plant Materials changed to Ornamental Plant Materials and Landscape Design
1973	Add	Plant Propagation
1974	Add	Nursery Management; Landscape Plant Materials
	Change	Ornamental Plant Materials and Landscape Design changed to Woody Plant Materials
1975	Add	Installation and Maintenance of Landscape Plantings; Basic Home Landscape Design
	Change	Landscape Plant Materials to Herbaceous and Indoor Plants
1978	Add	Home Horticulture
1979	Add	Advanced Home Landscape Design; Greenhouse Management
1980	Add	Advanced Woody Plants
1981	Add	Tissue Culture and Biochemical Methods in Plant Breeding
1982	Add	Floral Design
1984	Add	Internship in Landscape Design and Urban Horticulture
	Change	Tissue Culture and Biochemical Methods in Plant Breeding changed from undergraduate to graduate level course
1988	Drop	Advanced Vegetable Crops
1993	Add	Turfgrass and Landscape Management
1995	Add	Special Topics for Horticulture (Freshman Orientation)
1998	Drop	Floral Design
	Add	Tissue Culture; Introduction to Turfgrass; Golf and Sports Turf Management; Commercial and Residential Turfgrass Management; Internship in Turfgrass Management; Internship in Horticulture; Special Topics in Horticulture (Senior Seminar)
	Change	Turfgrass and Landscape Management changed to Landscape Contracting and Maintenance; Installation of Landscape Plantings changed to Landscape Installation and Management
1999	Add	Internship in Horticultural Merchandising
2000	Change	Tree Fruit Science and Small Fruit Production combined into Fruit Production Science and Technology

Table 2. Enrollments (full-time students) in the Horticulture (HORT), Landscape Design and Urban Horticulture (LDUH), Turf and Landscape Horticulture (TLHT), and Pre-forestry (PFOR) majors for selected years, 1969–1999.

Year	HORT	LDUH ^z	TLHT ^y	PFOR ^x	Total	Graduates
1969	20	- ^w	-	na	20	na
1973	50	-	-	na	50	na
1977	107	40	-	na	150	11
1985	42	20	-	na	62	9
1992	36	31	-	2	69	8
1993	33	27	-	6	66	3
1994	31	26	-	6	63	13
1995	41	30	-	4	75	5
1996	52	24	-	2	78	7
1997	47	29	-	1	77	9
1998	52	38	3	-	93	10
1999	40	5	51	-	96	-

^z LDUH major was begun in 1977 and discontinued in 1998; students enrolled in the program were able to elect to stay in the degree plan or move to the TLHT major.

^y TLHT major was implemented in August 1998; the major included students in Landscape Horticulture (previously LDUH) and the new degree concentration, Turf Management.

^x PFOR program was canceled in August 1998.

^w Programs in LDUH began in 1974 and TLHT began in 1998; the PFOR program was terminated in 1998.

na = data not available.

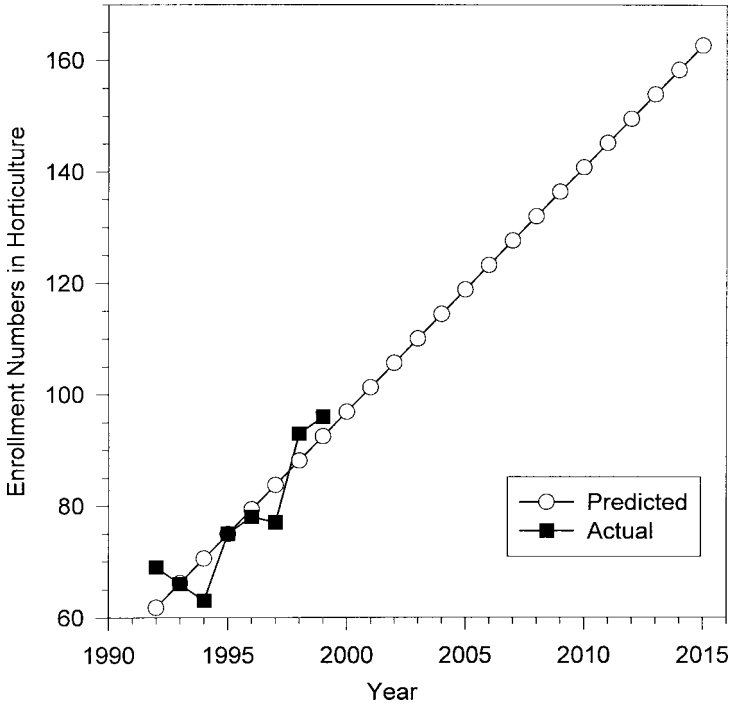


Figure 1. Changes in total undergraduate enrollment (fall semester) 1992-2015. *Actual* figures are total students enrolled in all Horticulture Department majors (full time students) in the fall semester. *Projected* figures are based upon regression estimates (y int. = 53.0, x coef. = 4.39, $r^2 = .81$) of actual enrollments 1992 - 1999.

THRIPS, WEEDS, AND TOMATO SPOTTED WILT VIRUS

*Charles T. Allen¹, Marwan S. Kharboutli¹, Chris D. McAllister²,
Clifford M. Coker, Jr.¹, and Paul E. Cooper¹*

IMPACT STATEMENT

Information in this report suggests that as in other tomato production areas, infected thrips moving into fields (primary infection) are the most significant transmitters of tomato spotted wilt virus (TSWV) to tomatoes in Southeast Arkansas. Also, data reported here and literature from other areas support the conclusion that *Frankliniella occidentalis*, the western flower thrips, is the species most responsible for TSWV transmission to tomatoes in Southeast Arkansas. Preliminary data reported here are providing indications about which weed plants may be the important reservoirs for TSWV in that area.

BACKGROUND

Tomato spotted wilt is a serious disease of homeowner and commercial tomatoes in the South. When infection occurs early in the production season, the disease kills tomato plants before they can set and mature fruit. Later infection slowly kills the plants, but fruit can mature and be harvested for the breaker pick vine-ripe market for which most Southeast Arkansas tomatoes are grown. Unfortunately, when the infected fruit ripens, green spots remain on them, making

¹ Southeast Research and Extension Center, Monticello.

² University of Tennessee, Knoxville.

them unmarketable.

Tomato spotted wilt is caused by the tomato spotted wilt virus. The virus is transmitted to tomato and many other kinds of plants by thrips, tiny sap-sucking insects. Thrips acquire the virus as they feed on tomatoes and other host plants. Thrips can transmit the virus to other plants only if they acquired it as immatures (Ullman et al., 1992). The thrips can then transmit the virus when they become adults.

Studies in other states have indicated that there are two types of TSWV transmission in tomatoes. Primary transmission occurs as thrips acquire the virus from non-cultivated (weed) host plants, become adults, then fly into the tomato fields, where they feed on tomato plants, transmitting the virus. Secondary transmission occurs as immature thrips feed on infected tomato plants in the field, become adults, then move to other non-infected tomato plants, feeding on and infecting them. In Florida, primary transmission of the virus has been shown to be the route responsible for the majority of the infection that occurs there (Puche et al., 1995).

A number of thrips species occur on tomato and non-crop weed hosts in the tomato growing area of southeast Arkansas. However, not all thrips species can transmit TSWV (Ullman et al., 1992).

A thorough understanding of the thrips, the virus, the weed host plants, the tomato plantings and how these interact is necessary if we are to develop cultural management techniques to control TSWV. This study reports some of the first steps in understanding how these organisms interact to affect the commercial tomato industry of Southeast Arkansas.

RESEARCH DESCRIPTION

Thrips were collected from tomato and weed host plants at various times from 1996 through 1999. Many of those collected in 1996 were sent to Dr. Forrest Mitchell's laboratory in Steventville, Tex., for identification and to determine which species were infected with TSWV and the life stages of those species using enzyme-linked immunosorbent assay (ELISA) techniques. Other collections in 1996 through 1999 were made to investigate the thrips species present on weeds, tomatoes, and cotton. Also, flowering weeds around tomato fields were collected in 1998 and 1999 for species determination. Plant material collected was washed to remove the thrips, then it was crushed and tested using ELISA (AG-DIA TOSPO Kit) to determine the presence of the virus. Identification of thrips is continuing at this writing.

FINDINGS

The highest percentage of thrips in the immature stage in tomatoes was never greater than 33% from 1997 to 1999 (Table 1). On average, there were only 8% immatures. In contrast, collections from cotton averaged 61% immatures. On cotton seedlings more than 2 wk old, thrips populations averaged 83% immatures. Apparently, thrips do not reproduce well on tomato plants. The poor reproduction of thrips on tomatoes is evidence that secondary TSWV infection from infected tomato plants in the field probably accounts for only a small part of the disease transmission in the Southeast Arkansas tomato ecosystem. Further, immature thrips mature to adults in about 17 days. Though these data were taken from untreated tomato plants, growers commonly treat tomatoes about once per week with insecticides to control thrips (particularly the immatures). These treatments kill many of the developing immatures, helping to prevent secondary infection. In spite of these treatments, the percentage of plants with symptoms of tomato spotted wilt continues to increase.

Population composition of thrips on tomatoes is very different from populations associated with cotton fields (Table 2). On tomato blooms, 78% of the population was *F. tritici*, 18% was *F. occidentalis*, and 4% was *F. fusca*. This is significant because of the thrips species common in Southeast Arkansas, only *F. occidentalis* and *F. fusca* are capable of transmitting TSWV. Therefore, only about 22% of the total thrips population collected from tomatoes in our study were species capable of transmitting the virus. Apparently, thrips moving into tomatoes from white clover and buttercup do not pose a threat to tomatoes, since the thrips we found on them were 100% *F. tritici*, a species not capable of transmitting the virus. Thrips collections have been made from eight other weed hosts that may harbor the virus, thrips, or both. As of this report, those thrips have not been identified.

Of the thrips collected from tomato and several weed species from the tomato production area, over 17% of the *F. occidentalis* collected were infected with TSWV (Table 3). Although they could not transmit the virus, over 2% of the *F. tritici* collected tested positive for the virus. We believe they had fed on infected plants and were carrying viral particles, but they were unable to transmit them to plants.

Sixteen percent of both Venus' looking glass and buttercup specimens collected in 1999 tested positive for TSWV. Lower percentages of white clover and cutleaf evening primrose were positive, 10% and 6%, respectively (Table 4). Henbit, daisy fleabane and mustard collections had no TSWV-positive plants.

ACKNOWLEDGMENTS

The authors thank Dr. Forrest Mitchell, Texas A & M University, for his collaboration in determination of TSWV-infected thrips, and Drs. Joe Funderburk, University of Florida; Jack Reed, Mississippi State University; and Eugene Burris and Dan Cook, Louisiana State University, for providing us with valuable information and assistance on thrips identification.

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Table 1. Percentage of thrips populations in the immature stage on tomato and cotton on various dates.

Year	Tomato		Cotton	
	Date	% Immatures	Date	% Immatures
1997	7 June	33	6 June	4
			19 June	89
1998	29 May	19	19 May	10
	1 June	12	26 May	71
	5 June	3	3 June	96
1999	17 April	17	27 May	61
	21 April	0	4 June	96
	25 April	6	9 June	67
	28 April	3		
	3 May	0		
	4 May	0		
	12 May	4		
	13 May	3		
	20 May	8		
21 May	8			

Table 2. Percentage of thrips of various species collected from study sites.

Thrips species	Cotton foliage	Cotton traps	Tomato blooms	White clover blooms	Buttercup blooms
<i>Frankliniella fusca</i>	71.6	17.8	4	0	0
<i>F. occidentalis</i>	3.4	11.0	18	0	0
<i>F. tritici</i>	10.8	39.9	78	100	100
<i>Microcephalothrips abdominalis</i>	0.6	3.7	0	0	0
<i>Neohydatothrips variabilis</i>	13.6	27.6	0	0	0

Table 3. Percentages of TSWV-infected thrips¹ of various species collected from tomatoes and weeds in the vicinity of tomato fields.

<i>F. occidentalis</i>	<i>F. tritici</i>	<i>F. fusca</i>	<i>F. minuta</i>	<i>M. abdominalis</i>
17.8	2.12	0	0	0

¹ Collections in July 1996. Five infected thrips were collected from tomato, one from horse nettle and one from morning glory.

Table 4. Percentages of various weeds infected with TSWV.

Venus' looking glass	16	Henbit	0
Buttercup	16	Daisy fleabane	0
White clover	10	Mustard	0
Cutleaf evening primrose	6		



INSECTICIDES FOR CONTROL OF THIRPS IN TOMATOES

Charles T. Allen¹, Marwan S. Kharboutli¹, and Don Wiley²

IMPACT STATEMENT

Thrips are an important pest of tomato production in Southeast Arkansas because they spread the tomato spotted wilt virus (TSWV). Insecticide trials were conducted to determine effective control of thrips in tomato production. The best insecticide treatment provided only 70% control of adult thrips and 86% control of immature thrips in this study. The most consistently effective insecticides for thrips control were Baythroid and Monitor, followed closely by Asana. The spinosins, Tracer and Spintor, provided consistently lower levels of thrips control in these studies.

BACKGROUND

This investigation focused on the use of insecticides to lower thrips populations in Southeast Arkansas to determine the association between thrips and TSWV. Researchers in other states have reported that insecticides do not lower the incidence of tomato spotted wilt, even though thrips are controlled. Still, we wanted to evaluate the per-

¹ Southeast Research and Extension Center, Monticello.

² Drew County Extension Service, Monticello.

formance of available insecticides on thrips populations in tomatoes with the hope of finding products that would reduce TSWV infection.

RESEARCH DESCRIPTION

Insecticide trials were conducted on the Johnny Judkins Farm in Drew County in 1997 and 1998. The tests were small-plot trials (plot size, one row x 20 ft), and each treatment was replicated eight times in 1997 and four times in 1998. Randomized complete block designs were used in each experiment and sprays were applied with a backpack sprayer to both sides of each treated row. Insecticides were applied in 35 gal of solution/acre in 1997 and 20 gal of solution/acre in 1998. Post-treatment counts were made by randomly selecting 15 blooms per plot, collecting the blooms into plastic bags, and transporting samples to the laboratory for processing. Each sample was washed with water and isopropyl alcohol onto a 325 mesh soil screen. The screens were backwashed into Buchner funnels, and the thrips were collected on filter paper. The thrips were then separated into adult and immature cohorts and counted. Representative samples of thrips from these tests were mounted on microscope slides for later species identification. In addition, 25 fruits per plot were examined for worm damage and the presence of tomato fruit worms. The data collected were entered into the Pesticide Research Manager (Gyrlling Data Management), and statistical analyses were run. Analysis of variance ($P \leq .05$) and least significant difference were used to separate the means and determine statistical differences.

RESULTS

Tracer and Spintor are new products from the spinosin class of insecticide chemistry. The two products contain the same active ingredient but are formulated in different concentrations (Tracer, 4 lb/gal; Spintor, 2 lb/gal). None of the insecticides reduced thrips to low levels in these tests (Tables 1 and 2). The average percent control of the best treatment was only 70% for adult thrips (excluding the low infestation data from 19 May 1997) and 86% for immature thrips. Baythroid and Monitor provided the best and most consistent thrips suppression. Asana was almost as effective as Baythroid and Monitor. The spinosin products, Tracer and Spintor, had been reported to provide good thrips control on tomatoes in Florida (J.E. Funderburk, 1997 personal communication). However, they did not perform well against thrips in these studies. Percentages of worm-damaged fruit were statistically similar

among treatments in the 1998 study, but Asana, Monitor, and Baythroid produced numerically better results.

ACKNOWLEDGMENTS

We thank Johnny Judkins for allowing us to do this work on his farm. Also we wish to thank Bayer Chemical Company, Dow AgroSciences, and Dupont for providing us with insecticides and financial support for this work.

Table 1. Insecticides for thrips control, Drew County, 1997.

Insecticide ^z	ai/acre	19 May 1997	26 May 1997	7 June 1997	
		4-DPT ^y adults	3-DPT adults	adults	immature
		-----thrips/15 blooms-----			
Admire 2F	16 oz	1.3 ab ^x	5.6 abc	3.3 ab	0.7 a
Monitor 4	2 pt	0.6 b	2.3 c	3.2 ab	1.2 a
Baythroid 2	2.8 oz	0.3 b	3.5 bc	2.3 b	0.5 a
Tracer 4 SC	2.14 oz	0.5 b	7.6 ab	5.5 ab	3.0 a
Tracer 4 SC	2.85 oz	2.0 a	8.1 a	4.2 ab	2.3 a
Check	—	0.6 b	8.6 a	7.2 a	3.5 a

^z Treatment dates: 15 May 1997, 23 May 1997, and 3 June 1997. Admire was applied as a soil drench on 1 May 1997.

^y DPT = days post-treatment.

^x Means in columns followed by the same letter are not significantly different ($P \leq 0.05$).

Table 2. Insecticides for thrips control, Drew County, 1998.

Insecticide ^z	Rate/ acre	29 May 1998 2-DPT ^y		1 June 1998 5-DPT		5 June 1998 4-DPT		5 June 1998 Worm damage (%)
		adult	immature	adult	immature	adult	immature	
Spintor 2SC	2.9 oz	22.0 ab ^x	7.5 ab	54.3 a	4.5 a	20.3 ab	1.0 a	4.0 a
Spintor 2SC	4.5 oz	13.3 b	11.3 ab	49.3 ab	6.3 a	18.0 ab	2.0 a	3.0 a
Spintor 2SC	5.8 oz	16.5 b	12.8 a	43.5 ab	4.5 a	38.0 a	1.3 a	4.5 a
Check	—	32.0 a	7.5 ab	45.0 ab	6.3 a	26.0 ab	0.8 a	3.0 a
Asana XL	9.7 oz	18.8 b	5.3 ab	33.3 ab	2.5 a	8.3 b	1.3 a	1.5 a
Monitor 4	2 pt	11.5 b	1.5 b	16.0 b	2.8 a	6.8 b	1.3 a	1.5 a
Baythroid 2	2.8 oz	10.0 b	4.3 ab	23.0 ab	1.3 a	6.0 b	0.0 a	1.5 a

^z Treatment dates: 27 May 1998 and 1 June 1998.

^y DPT = days post-treatment.

^x Means in columns followed by the same letter are not significantly different ($P \leq 0.05$).

TOMATO CULTIVAR TRIAL RESULTS, 1999

Paul E. Cooper¹

IMPACT STATEMENT

The evaluation of tomato cultivars and advanced breeding lines continued in 1999. Cultivars differed with respect to yield of various sizes and grades but not to total marketable yield. The breeding line NC 9559 compared very favorably with the industry standards, 'Mountain Spring' and 'Mountain Fresh'.

BACKGROUND

Cultivar selection is very important to the fresh-market tomato industry in Southeast Arkansas. To remain competitive, the industry relies on the use of well-adapted cultivars that produce high yields of superior-quality fruit. In 1992, 'Mountain Spring' was released by Dr. Randy Gardner of North Carolina State University and quickly became the industry standard because of its yields of high-quality fruit (Gardner, 1992). New cultivars are developed and released annually by universities, private seed companies, etc. The purpose of this study was to evaluate new tomato cultivars for their adaptability and potential use in Southeast Arkansas.

¹ Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

This study was conducted on the Roger Pace commercial tomato farm in Drew County. Similar yield trials were conducted at this location from 1995 through 1998. Basic cultural practices used by tomato producers in the area were followed. Cultivars and breeding lines compared in the test were 'Mountain Spring', 'Mountain Fresh', 'Mountain Gold', 'Sunbrite', 'Florida 47', 'Floralina', 'Sanibel', NC 9559, NC 96365, NC 97597, and NC 98274. Seeds were planted on 2 March 1999, plants were transplanted from seedling flats on 22 March, and transplants were set in the field on 16 April.

Black plastic mulch and drip irrigation were used and the beds were fumigated with methyl bromide/chloropicrin (67:33) at the time of laying the plastic. Insects, diseases, and weeds were controlled using recommended practices, and plants were staked, tied, and pruned in a manner consistent with the area. Fruit were harvested from 21 June through 15 July and graded into the following categories: 1) extra large #1 (XL#1), 2) large #1 (L#1), 3) #2, and 4) #3/unclassified. Marketable fruit was composed of the first three grades. The experimental design was a randomized complete block containing four replications and plot size was four tomato plants.

FINDINGS

Yields in 1999 were slightly higher overall than in 1998. Marketable yields ranged from 9.5 to 13.4 lb per plant. There was no significant difference among cultivars as to total marketable yields (Table 1). The cultivars producing the highest yields of XL#1 fruit were 'Mountain Spring', NC 9559, and 'Mountain Fresh' (Table 1). 'Floralina', NC 96365, and 'Mountain Gold' produced the most #2 fruit (data not shown). Average fruit weight was greatest for 'Sunbrite', 'Mountain Spring', and NC 9559 (Table 1).

NC 9559 performed very well in comparison with 'Mountain Spring' and 'Mountain Fresh' for total yield, XL#1 yield, and average fruit weight. These results are similar to data for the 1996-98 trials. NC 9559 is an extended-shelf-life breeding line. 'Floralina' has resistance to Race 3 of *Fusarium* wilt and may be used in place of 'Mountain Spring' and 'Mountain Fresh' where this disease is a problem. 'Sunbrite' produced very well and had the highest average fruit size (Table 1). However, in its first year of these trials, it did not grade as well as 'Mountain Spring' and others.

LITERATURE CITED

Gardner, R.G. 1992. 'Mountain Spring' tomato; NC 8276 and NC 84173 tomato breeding lines. HortScience 27:1233-1234.

Table 1. Yields of tomato cultivars by grade, total marketable yield, and average fruit weight, 1999.

Cultivar	XL #1 (lb/plant)	Total market yield (lb/plant)	Average wt. (oz)
Mountain Spring	8.5 a ^z	13.3	10.7 ab
NC 9559	8.3 a	13.4	10.1 abc
Mountain Fresh	6.8 ab	12.3	8.5 e
Florida 47	4.8 bc	11.6	9.9 bcd
Floralina	4.7 bc	12.9	9.1 cde
Sunbrite	4.4 c	13.2	11.0 a
NC 97597	4.1 cd	11.6	8.3 e
NC 96365	4.0 cde	12.7	8.3 e
Sanibel	3.5 cde	12.3	8.9 e
NC 98274	2.0 de	9.5	8.9 de
Mountain Gold	1.7 e	10.8	9.1 cde
	NS ^y		

^z Means within a column followed by a different letter are significantly different as determined by Duncan's multiple range test ($P \leq 0.05$).

^y NS = not significant.

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Mountain Gold	1.7 e	10.8	9.1 cde
	NS ^y		

^z Means within a column followed by a different letter are significantly different as determined by Duncan's multiple range test ($P \leq 0.05$).

^y NS = not significant.



INSECTICIDAL FOAM: A NOVEL APPROACH TO INSECT CONTROL ON TOMATOES

Marwan S. Kharboutli¹, Charles T. Allen¹ and John Gavin²

IMPACT STATEMENT

Treatment of tomatoes with insecticidal foam compared with a standard insecticide program resulted in similar levels of thrips, tomato spotted wilt virus (TSWV)-infected plants, and fruit damaged by sucking insects. However, tomato plants treated with foam for insect control produced smaller fruit and lower yields per plant than plants treated with conventional insecticides.

BACKGROUND

The concept of using soaps to control insects on plants and animals is not new, with evidence dating back to at least 1787 (Ware, 1994). However, the use of foam for insect control is a new concept. Thrips are important pests of commercial tomato production in Southeast Arkansas because they transmit TSWV. The virus infects tomato plants, killing them before they can set and mature fruit if the infection occurs early in the season. Later infection is often more economically devastating because the tomatoes are picked as breakers (as they begin to turn pink at the blossom end). It is very difficult to determine

¹ Southeast Research and Extension Center, Monticello.

² Bradley County Extension Service, Warren.

whether tomatoes are infected, since tomatoes are often picked, packed, sold, and shipped to a point of sale before they change to their ripened color. When ripe, infected tomatoes have green spots on them that make them unattractive and unsaleable.

Insecticides have provided little help for growers. Research from Florida has indicated that use of insecticides to kill the thrips that carry and transmit the disease not only does not work, but sometimes increases the incidence of the disease (J. E. Funderburk, 1997 personal communication). This is believed to be the result of irritation by the insecticide that causes the thrips to feed briefly on a plant, then move to another plant, and repeat this process again and again before the thrip dies, thus effectively spreading the virus.

If an insecticidal foam could be used to control thrips in tomato fields, the increased TSWV transmission from the insecticide irritation might be avoided. Also, if the foam could provide good suppression of all the insect pests in tomato fields, growers and the general public might benefit by having insecticide-free tomatoes.

RESEARCH DESCRIPTION

This study was conducted on the Clanton Farms (Sweeny Place) in Bradley County. Plots were 9 rows by 100 ft long. A randomized complete-block design was used to assign treatments to plots. The treatments were either the standard use of commercial insecticides or insecticidal foam applications at regular intervals (Table 1). Thrips were counted at regular intervals (25 blooms collected per plot); plants with TSWV infection were counted (examination of 100 plants per plot); and fruit weight and insect damage were assessed (harvest, counts, and weights, and examination of all fruit on four plants per plot).

'Mountain Spring' was the cultivar used. Plants were transplanted on 3 April 1999. The transplants were set 20 in. apart with 66 in. between rows. The field was set up in nine-row blocks with 10-ft unplanted borders between blocks. First bloom was seen on 9 April 1999. Standard production practices were used, with only the insecticide practices altered on the foam plots. All plots were sprayed with fungicides (10 April: Benlate 16 oz/acre + ManKocide 5 lb/acre; 20 April: Quadris 6.2 oz/acre; 30 April: ManKocide 5 lb/acre; 8 May: ManKocide 5 lb/acre, 14 May: Quadris 6.2 oz/acre; 24 May: ManKocide 5 lb/acre; and 5 June: Bravo 3 pt/acre).

Data were entered into Agriculture Research Manager (ARM) software and processed using ARM and Costat Statistical Software.

FINDINGS

No significant differences in season-long thrips populations were seen between plots treated with conventional insecticides and those treated with foam applications (Table 2). There was also no significant difference between conventionally treated plots and foamed plots with respect to TSWV infection levels. Sucking-insect damage (probably mostly *Lygus* sp.) was not significantly higher in foamed plots than in conventionally treated plots, but a trend toward numerically higher damage levels in the foam-treated plots was seen. Worm-damaged fruit were counted, but damage was extremely low in both foamed and conventionally treated plots, primarily because of low fruitworm pressure (data not shown).

Numbers of fruit produced per plant were not different between the conventional insect control and the foam-treated plots (Table 3). However, the weight of fruit per plant (25 May data) and the average weight of individual fruit (5 June data) were lower in the foamed than in the conventionally treated plots. Percentages of cracked fruit were not different between foamed and conventionally treated plots.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Andrew Templeton and Mr. Bo Templeton of Safe Harvest Corp. for allowing us to test their insecticidal foam technology in this study. Also, we wish to thank Mr. Randy Clanton and Clanton Farms for allowing us to do this work on their farm.

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Table 1. Summary of insecticide/foam treatments of study plots, Hermitage, Ark., 1999.

Foam		Conventional	
Date	Treatment	Date	Treatment
10 April	foamed	10 April	Asana XL, 4.6 oz
11 April	foamed	20 April	Baythroid 2, 2.8 oz
15 April	foamed	24 April	Baythroid 2, 2.8 oz
19 April	foamed	30 April	Asana XL, 4.6 oz
20 April	foamed	8 May	Asana XL, 4.6 oz
24 April	foamed	14 May	Baythroid 2, 2.8 oz
27 April	foamed	24 May	Baythroid 2, 2.8 oz
30 April	foamed	4 June	Asana XL, 4.6 oz
3 May	foamed		
8 May	foamed		
11 May	foamed		
16 May	foamed		
23 May	foamed		
26 May	foamed		
31 May	foamed		
4 June	foamed		
7 June	foamed		

Table 2. Effects of treatments^z on thrips, sucking-insect damage, and percentage of TSWV-infected plants. Hermitage, Ark., 1999.

Treatment	Thrips ^y			TSWV infection ^x (%)	Sucking-insect damage ^w (%)
	Adults	Immatures	All		
Conventional	39.7 a	4.2 a	43.9 a	5.3 a	23.7 a
Foam	43.5 a	3.8 a	47.2 a	4.8 a	33.5 a

^z Means in columns followed by the same letter are not significantly different ($P \leq 0.05$).

^y Summary of season-long thrips counts.

^x Summary of three TSWV counts (5 May, 13 May, and 20 May).

^w Sucking-insect damage (primarily *Lygus* damage) on 5 June sample.

Table 3. Effects of treatment on fruit size and production,^z Hermitage, Ark.,1999.

Treatment	25 May			5 June			Cracked fruit (%)
	Fruit/ plant	Yield wt. (kg/plant)	Fruit wt. (g)	Fruit/ plant	Fruit wt. (kg/plant)	Fruit wt. (g)	
Conventional	34.5 a	2.5 a	73.0 a	39.3 a	5.4 a	137.7 a	24.0 a
Foam	31.3 a	1.9 b	58.5 a	35.5 a	4.3 a	119.7 b	21.3 a

^z Means in columns followed by the same letter are not significantly different ($P \leq 0.05$).



VEGETABLE BREEDING IN ARKANSAS: A HISTORICAL PERSPECTIVE

Teddy E. Morelock¹

IMPACT STATEMENT

After a producer decides what crop to produce, the next most important decision is what cultivar will be grown. Arkansas has a long and diverse history of vegetable production. Because of the unique climate requirements, it has been necessary that cultivars be developed to meet industry needs. The vegetable breeding program at the University of Arkansas has produced 39 cultivars: 2 cucumber, 1 mustard, 3 okra, 12 southernpea, 6 spinach, 10 tomato, 3 turnip, and 2 watermelon. These cultivars have been the backbone of this industry, sometimes comprising over 90% of the acreage of that particular vegetable and providing millions of dollars of benefit to the state of Arkansas and its citizens.

BACKGROUND

The vegetable breeding program at the University of Arkansas was started in the late 1940s by Dr. V.M. Watts. His work included watermelon, southernpeas, and tomatoes. As the departmental faculty grew, the southernpea breeding program was taken over by Dr. John L. Bowers

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and the tomato breeding program by Dr. Joe McFerran. The programs were further expanded over the years.

FINDINGS

WATERMELON BREEDING

Dr. Watts emphasized fruit quality and resistance to *Fusarium* wilt in watermelon breeding. The bulk of this breeding program was carried out at the Southwest Research and Extension Center at Hope. The program released two cultivars: 'Hope Diamond', which is a Black diamond-type melon resistant to *Fusarium* wilt, and 'White Hope', which is a long, gray melon with good fruit quality and excellent resistance to *Fusarium* wilt. Unfortunately, it was released after 'Charleston Gray' was released by Dr. Fred Andrus of the USDA-ARS Vegetable Breeding laboratory, Charleston, S.C., and these two cultivars were very similar. 'Charleston Gray' went on to become the dominate watermelon cultivar in the United States.

The watermelon breeding program that was started by Dr. Watts was not continued after he retired in 1968. The most lasting effect of this program was the discovery of a glabrous seedling in a population of irradiated watermelons. This seedling was also male sterile. These genetics were investigated by several watermelon breeders in other states as a potential tool to produce hybrid watermelon, but the male sterile trait was never commercially utilized because of associated problems with fruit quality.

TOMATO BREEDING

At the time Dr. Watts started the tomato breeding program in the 1940s, there were approximately 40,000 to 50,000 acres of tomatoes in Northwest Arkansas that were grown primarily for the processing industry. The program developed the cultivar Indark which was very popular with the processing industry in Indiana. A fresh-market tomato breeding effort was started in the early 1950s to service the staked pink tomato industry in Southeast Arkansas. The aim of the program was to develop a high-quality pink tomato that was resistant to *Fusarium* wilt. The first product of this program was 'Bradley', which Dr. Joe McFerran released in 1961. 'Bradley' was a very successful cultivar and benefitted the industry greatly, but fruit cracking was a serious deficiency of this cultivar. The breeding program began to breed for crack resistance and was later aided by the fruit-cracking screening method of vacuum immersion. This allowed tomato fruits to be screened for crack resistance in the laboratory, which is more accurate than

depending on natural screening in the field. This technique led to the release of 'Traveler' in 1970, which dominated the industry in Southeast Arkansas for several years. The next release was 'Traveler 76', released in 1976. It had better fruit size and a higher level of crack resistance than 'Traveler'. The next release was 'VF Pink', which was the first Arkansas cultivar to have resistance to both *Fusarium* wilt and *Verticillium* wilt, and it was released in 1981. This resistance was important, as *Verticillium* wilt was becoming established in some production fields in Southeast Arkansas. 'Ozark Pink' was the last pink-fruited, staked tomato developed by the program, and it was released in 1985. The value of this program to the state is difficult to judge, but developed cultivars at the University of Arkansas dominated the tomato industry for about 25 years, comprising 70-90% of the total acreage. With annual sales of \$5-10 million, it is conservative to say that the Arkansas breeding program put tens of millions of dollars in the pockets of Arkansas producers.

Processing tomatoes were also a part of the breeding program, and a good-quality, high-yielding line, designated 7985, was released in 1981. Also, a limited amount of breeding was done with small-fruited pickling types. 'Pope' was released in 1966 to fill this need, and a jointless version, 'J. Pope', was released in 1977.

OKRA BREEDING

The okra breeding program was initiated by Dr. McFerran in the late 1950s with the goal of developing superior processing cultivars for the freezing industry in Arkansas and adjacent states. The objectives were to develop high-yielding, spineless cultivars that had dark-green pods with better pod-wall thickness and seed retention in the cut pods than 'Clemson Spineless' (the industry standard) and that were produced on moderate-sized, non-suckering plants. The cultivars developed by the program were 'Lee', released in 1978, 'Jefferson', released in 1981, and 'Jade', released in 1988. It is difficult to put a value on the industry since all the okra that presently supplies area processors is imported from Mexico. This program was terminated several years ago, but a few advanced lines still exist and they will be evaluated for potential release.

SOUTHERNPEA BREEDING

Southernpea (cowpea) is an important processing crop in Arkansas and the southeastern United States. It is widely grown as a fresh-market vegetable and is highly prized by home gardeners. It is high in

protein, dietary fiber, and folic acid.

The breeding program at the University of Arkansas was started by Dr. Watts but was turned over to Dr. Bowers in the early 1950s. By nature, the plant is viney and sets pods over a long period of time. As the breeding program progressed, the habit was changed to a bush plant-type with no basal runners and concentrated pod set with the pods set above the foliar canopy. Since southernpea has always been an important processing crop for the region, quality of the processed crop has always been an integral part of the breeding program. All of the cultivars released in the past 25 years have had good processing characteristics, such as freedom from splits and color stability of the eyes.

'Monarch Blackeye' was the first cultivar from the program, released in 1957. 'Crimson' (Arkansas 83) was the first highly successful cultivar released by the program. It was a browneye-type released in 1965 that had reduced vining, high yield, and excellent processing characteristics. 'Mekan', a pinkeye released in 1967, was the first truly bush-type cultivar developed by the program, but it never became popular. 'Bush Purple Hull', released in 1973, had better yield potential than 'Mekan' but never caught on with the industry primarily because it was very susceptible to bacterial blight. 'Elite', released in 1978, was an excellent-quality cream that was well-accepted by the processing industry to fill the needs for a cream pea. 'Erectset', released in 1981, was the first truly erect-pod type developed by the University of Arkansas. It was grown on a moderate scale by the industry because of the limited demand for a cream crowder. 'Epoch', a pinkeye released in 1984, has an excellent bush plant and good processing characteristics but was never overly successful because it was not a heavy yielder under some circumstances.

In 1985 Dr. Bowers retired, and southernpea breeding was placed under Dr. Morelock's direction. 'Encore', released in 1986, is a purple-hull browneye that processed well and produced high yields but was not popular with processors because of its browneye. However, it was popular with home gardeners and market gardeners because of its high shell-out percentage. 'Early Acre', released in 1990, is a small-seeded cream that matures 7-10 days earlier than the industry standard, 'White Acre'. 'Early Acre' has a small bush plant, which is superior to the viney-plant type of 'White Acre', and 'Early Acre' has excellent processing and culinary characteristics.

In 1995 three cultivars were released by the breeding program. 'Excel' is a bush, pinkeye purple-hull type. It processes well, has good yield potential, and has met moderate success in the industry. 'Arkansas Blackeye #1' is a high-yielding, bush-type blackeye with excellent processing characteristics that fills the need for a blackeye adapted to

Arkansas and the mid-South. 'Early Scarlet' is a high-yielding, red-podded pinkeye. It produces a large bush-type plant free of basal runners and has concentrated pod set that matures in 65 days under Arkansas conditions. It has been well-received by the processing industry, and one local processor has shifted a significant portion of acreage to this cultivar.

The southernpea breeding program will continue to emphasize high yield, good processing characteristics, and superior plant characteristics in the various maturity groups of all the important horticultural types. The program plans to release four new cultivars in 2000. These are a high-yielding, late-maturity pinkeye; an early, pinkeye purple-hull that is tolerant to soils with a high pH; an early, small-seeded cream with superior bush plant-type; and a brown crowder with a bush plant-type that is superior to the viney brown crowder presently the industry standard.

SPINACH BREEDING

Spinach has long been an important processing crop in Arkansas. The Arkansas Agricultural Experiment Station cooperated with the US Department of Agriculture spinach breeding program for several years and, in doing so, participated in joint releases of Hybrid 612 in 1962 and 'Bounty' in 1970. In the early 1970s, when the USDA ended its spinach breeding program, the University of Arkansas started a program to fill the void. The Arkansas program was founded with Dr. Bowers and Dr. Jack Goode of the Department of Plant Pathology as co-leaders. The major emphasis was white-rust resistance. A disease screening nursery was established at the Vegetable Substation in Van Buren, but when it was moved to the Kibler site in 1974, it was necessary to establish a new nursery site, one that still exists today. This nursery provides an excellent site to screen for white rust, *Fusarium*, as well as other diseases and is a valuable component of the program. In 1980 two white-rust-resistant cultivars, 'Ozarka' and 'Greenvalley', were released. Both cultivars had good white-rust resistance and were grown by the industry, but they needed higher levels of disease resistance and a faster growth rate.

On Dr. Bowers' retirement in 1985, the program leadership was assumed by Dr. Morelock. In 1987 'Fallgreen' was released. It had a higher level of white-rust resistance than 'Ozarka' or 'Greenvalley' and was well-received by the industry. 'Fallgreen' was also popular as a fresh-market cultivar in the wintergarden area of southern Texas, where at one time it comprised 95% of the acreage. The processing industry's demand for a faster growing, flat-leaf spinach with strong white-rust

resistance led to the development of F88-380, which has filled this niche in Arkansas, Oklahoma, and Texas.

The Arkansas spinach breeding program will continue to meet industry needs and will continue to emphasize multiple disease resistance and local adaptation. Current plans include the release of a new fresh-market, semi-savoy cultivar within the next year, and the beginning of advanced testing of a new flat-leaf breeding line that has a more upright plant habit, excellent color, and good white-rust resistance.

The breeding program has also started to explore improving the nutritional value of spinach. Breeding lines and cultivars were analyzed for lutein content, and lutein was found to vary greatly among genotypes. Therefore, it should be possible to breed for further increases in lutein content. Lutein is a carotenoid with no vitamin activity, but it is a strong antioxidant and has been shown to be beneficial in preventing macular degeneration. Plans are also being made to analyze folic acid content and examine differences in flavor.

CUCUMBER BREEDING

The cucumber breeding program was started in the early 1950s by Dr. Bowers to address the needs of the pickling industry in Arkansas. The major emphases were disease resistance and pickling quality. The cultivar 'Southern Pickler' was released by the program and met with moderate success. In the late 1950s, Dr. Goode was hired in the Department of Plant Pathology, and eventually, his cucumber disease-resistance work and the cultivar development work in the Department of Horticulture merged to form a much stronger overall breeding program. The program evolved to emphasize both pickling quality and quantitative disease resistance to anthracnose and other diseases.

In the mid 1970s, a spontaneous mutation found in the breeding nursery at Hope drastically changed the overall focus of the breeding program. This mutant had a smaller plant with reduced leaf and stem size as well as a highly branched plant habit that dramatically changed the yield potential. This trait was called "little leaf," and it caused great excitement in the pickling cucumber business. The greatest limitation of this mutant was the fact that it had rather poor fruit quality and was late maturing. It was out-crossed to types with high fruit quality and reselected for little-leaf plant type, disease resistance, and fruit quality, which resulted in several high-quality breeding lines. Dr. Bowers retired in 1985, leaving Dr. Goode to finish the work on this project. The project was in the midst of release and the filing of an application for plant variety protection when Dr. Goode passed away in 1988. The result of this work, 'Arkansas Little Leaf' (H-19), was released in 1989.

This development caused a tremendous amount of interest in the industry, but field production management—together with the fact that 'Arkansas Little Leaf' was about 7-10 days later maturing than commonly grown cultivars—resulted in limited success. Even today the little-leaf material has more of the characteristics of the ideal pickling cucumber cultivar for machine harvest than any other cucumber. The bank of breeding material is maintained today by the Department of Horticulture, and it has been recently used in disease studies. However, very little breeding is being done because of the lack of cucumber production in Arkansas.

GREENS BREEDING

Greens for processing have been an important part of Arkansas horticulture for many years. In the late 1950s the need for a turnip green with better processed color prompted Dr. McFerran to start a breeding effort to address this need. Resulting releases were 'Crawford' in 1965 and 'Improved Crawford' in 1974. Both of these cultivars were well-accepted by the industry and replaced the industry standard, 'Shogoin'. In the mid-1980s it became apparent that 'Improved Crawford' had not been maintained by the seed industry and that there was a need for it to be reselected, but no usable seed of the original release existed. The result of the new turnip breeding effort by the Department is 'Fortress', which has excellent color, an upright plant habit, and tolerance to the disease white spot, which has limited the production in our area.

The greens breeding program is still being conducted in the department by Dr. Morelock. There are plans to release a collard cultivar in the near future when adequate seed can be produced. Additional work with mustard and turnip greens are also planned.



SPINACH BREEDING PROGRAM YIELDS LINES CONTAINING HIGH LEVELS OF CAROTENOID ANTIOXIDANTS

J. Brad Murphy and Teddy E. Morelock¹

IMPACT STATEMENT

A comparison of commercial spinach cultivars and University of Arkansas breeding lines revealed that several lines exhibit higher than average contents of both lutein and β -carotene, two important dietary antioxidants implicated in the health benefits of fresh fruits and vegetables. These findings suggest that carotenoid antioxidant levels in spinach could be further enhanced by a directed breeding program.

BACKGROUND

Dietary carotenoid antioxidants from fresh fruits and vegetables have long been known to play an important role in human health. Their importance is receiving increased attention, and they have now been implicated in contributing to the prevention of cancer (Khachik et al., 1995; Cowley, 1998). Dark-green leafy vegetables, such as spinach and kale, are relatively high in carotenoids, especially lutein (Mangels et al., 1993; Khachik et al., 1995). Lutein is of particular

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interest because it has a high antioxidant activity and has been directly implicated in cancer prevention (Khachik et al., 1995) and in reduction of macular degeneration (Sommerburg et al., 1998). To determine the feasibility of increasing overall carotenoid antioxidants and lutein content in spinach, an analysis of carotenoid content and composition was undertaken to determine variation within and between lines. A total of 18 spinach lines, including commercial cultivars and University of Arkansas breeding lines, were evaluated.

RESEARCH DESCRIPTION

Mature (fully expanded) leaves were collected on 15 December 1997, at the University of Arkansas Vegetable Substation, Kibler, from a fall-planted breeding nursery. Single leaves from five plants from each line were harvested, placed in plastic bags in an ice chest, and transported to Fayetteville, where they were stored frozen at -4°F until extracted for carotenoid analysis.

Leaf discs of approximately 100 mg (1.3 cm in diameter) were punched from the frozen leaves, weighed, and extracted in 2.5 mL of acetone-ethyl acetate (3:2 v/v). Water (2 mL) was added, the mixture centrifuged, and the ethyl acetate phase recovered. The volume was brought to 2 mL with ethyl acetate, then a 1-mL aliquot was filtered through a 0.2 mm: Polypure filter. A 10- μL sample was separated on a Spherisorb ODS1 column using a 30-min gradient of ethyl acetate (0 to 67%) in acetonitrile-water-triethylamine (9:1:0.01 v/v) at a flow rate of 1 mL per minute (Norris et al., 1995). Carotenoids were monitored at 440 nm and identified and quantified by comparison to standards.

FINDINGS

Our study found that two spinach lines from the University of Arkansas breeding program, 'Fall Green' and F380, contained higher than average levels of both lutein and β -carotene. This was particularly true for lutein, for which their contents ranked highest of all lines studied and were roughly 53% higher than the average (Fig. 1). Their β -carotene content was only about 8% above average, and they ranked near the middle of all lines studied (data not shown). This is reflected in the low correlation coefficient ($r^2 = 0.39$) between lutein and β -carotene content. A preliminary study of only seven lines had suggested that lutein and β -carotene levels were highly correlated ($r^2 = 0.95$; Murphy and Morelock, 1999); however, this relationship did not hold up when the additional lines were included. There was a much stronger correlation ($r^2 = 0.88$) between lutein and chlorophyll-a content, indicative of

the important role of lutein in protecting against photo-oxidative damage (Pallett and Young, 1993). The low correlation between lutein and β -carotene indicates that a breeding program should be able to further enhance their contents independently of each other. This agrees with the known differences in their biosynthetic pathways, in which different sets of enzymes are involved in the synthesis of lutein and β -carotene from their common precursor, lycopene (Pogson et al., 1996).

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ACKNOWLEDGMENTS

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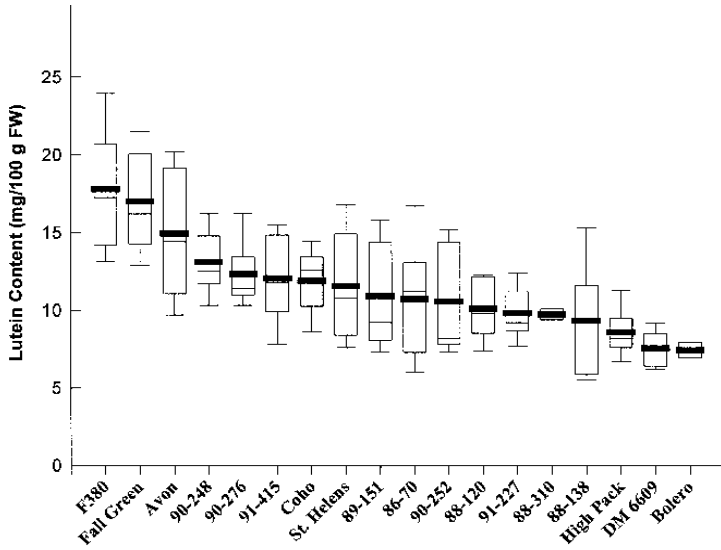


Figure 1. Lutein content of 18 lines of spinach as determined by high performance liquid chromatography analysis.



COMPARISON OF FERTIGATION VS. SURFACE-APPLIED NITROGEN APPLICATIONS AND RATES FOR HIGHBUSH BLUEBERRY: 1999 RESULTS

Ray A. Allen and John R. Clark¹

IMPACT STATEMENT

In recent years, the application of fertilizers through the drip or trickle irrigation system, i.e., fertigation, has received much interest. A trial investigating the fertigation of the highbush blueberry cultivar 'Bluecrop' compared with a surface-applied fertilizer application showed no major effects or advantages of one method over the other. Overall, foliar nitrogen (N) levels increased with increasing N rates independent of application method, while most other foliar elements were affected only slightly by N rate. Yield and berry weight were not consistently affected by either method of delivery or N rate. Based on the findings of this study, either method of application was acceptable. Also, the common N rate of 120 lb/acre for mulched highbush blueberries was found to be adequate, while higher rates were not found to be beneficial.

BACKGROUND

Investigations have previously been done on the effective N source and rate for highbush blueberry in Arkansas (Clark, et al, 1991). Recommended N rates range from 60-120 lb/acre. Higher rates have been

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suggested, but their value has not been tested or confirmed in Arkansas. A foliar N level of 1.65% has been established as the minimum for optimum performance (Eck, 1977). Nitrogen is normally applied to blueberries in three equal applications of a surface-applied dry fertilizer at 6-wk intervals, beginning at budbreak. This often places the last application in the dry summer period, when it is not adequately made available to the plant by rain. Fertigation can theoretically remedy this by immediately making fertilizer available to the root zone for uptake by the plant. However, blueberry plant response to fertigation has not been studied under Arkansas conditions. This study was conducted to investigate the effects of N delivery method (fertigation vs. surface application) at various rates of N.

RESEARCH DESCRIPTION

In March 1994, a planting of 'Bluecrop' highbush blueberry was established at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, on a Captina silt loam soil. A 6-in. layer of sawdust mulch was applied to the planting and maintained for the duration of the study. Fertilizer treatments consisted of 0, 60, 120, 180, and 240 lb/acre of actual N applied by broadcasting on the mulched surface or injecting through the irrigation lines. Treatments were initiated the first year and maintained through 1999, and ammonium sulfate was the N source. The dry surface applications (broadcast) were begun at budbreak and were made again 6 and 12 wk later. Fertigation was begun at the time of the first dry application, and the total N was applied in 12 applications at intervals of approximately 7-10 days, with the application period extending into late July. Six replications of two-plant plots were assigned to each treatment in a complete randomized block design. Berries of each bush were harvested and weighed at weekly intervals beginning in early June, and a 50-berry sample of each plant was taken to determine average berry weight. Foliar and soil samples were taken in early to mid-August and analyzed for mineral nutrient content. Data were analyzed by SAS and means separated by least significant difference (LSD).

FINDINGS

The fertilizer application method affected foliar levels of potassium, calcium, sulfur, manganese and soil pH, nitrate, and phosphorus (Tables 1, 2, and 3). The rate of N influenced foliar N, sulfur, and manganese and soil pH. There was a significant interaction of method and N rate for levels of foliar potassium and soil nitrate.

Surface broadcasting increased foliar levels of potassium, sulfur, and manganese, increased soil nitrates and phosphorus, and decreased soil pH and calcium (Tables 1, 2 and 3). Fertigation increased foliar

calcium and manganese and soil nitrates; it decreased foliar potassium, soil pH and calcium, and soil phosphorus at the two lower N rates (Tables 1, 2 and 3). The differences among most variables were small, and foliar values for the 120 lb/acre or higher N rate were within acceptable limits (Eck, 1988), except for foliar manganese. The two higher rates of N by fertigation and all except the lowest rate of surface-applied N raised foliar manganese levels above acceptable levels (Eck, 1988).

Soil pH decreased and foliar levels of N, sulfur, and manganese increased in a linear fashion as N rate increased (Tables 1, 2 and 3). Soil pH and foliar sulfur remained within acceptable limits at all rates, and foliar N was at desired levels for all N rates except the 60 lb/acre fertigation method (Tables 1 and 3). A N rate of 120 lb/acre was adequate to raise foliar N levels to the minimum of 1.6% recommended for highbush blueberry. As previously stated, foliar manganese was at undesirably high levels at most rates (Table 2).

While all fertilization treatments resulted in numerically higher yields, neither the rate of N nor the application method consistently affected yield per plant (Table 2). Likewise, the effects of application method and rate of N on berry weight were rather small and were not statistically different among the means (Table 2).

Results from 1999 showed little practical effect or advantage to either method of application on any of the variables measured. Greater effect was attributed to rates of N application on many of the variables, in particular foliar levels of N, sulfur and manganese. Since N application rate of 120 lb/acre resulted in adequate levels of foliar N and since higher rates resulted in excessive levels of foliar manganese without consistently increasing yields, there is currently no basis to recommend higher levels of N fertilization than those presently used.

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Table 1. Foliar macroelement content for method of application and nitrogen rate treatments to highbush blueberries: sixth-year results (1999).

Application method	N rate ^z	% dry wt.					
		N	P	K	Ca	Mn*	S
Control	0	1.41 ^c	0.06	0.50	0.69	0.16	0.09 e
Surface	60	1.62 bc		0.44	0.71	0.15	0.11 cde
Surface	120	1.61 bc	0.06	0.45	0.76	0.15	0.11 cd
Surface	180	1.97 a	0.06	0.72	0.64	0.14	0.14 ab
Surface	240	1.93 a	0.07	0.55	0.70	0.16	0.16 a
Fertigation	60	1.42 c	0.07	0.46	0.75	0.16	0.10 de
Fertigation	120	1.62 bc	0.06	0.39	0.78	0.16	0.11 cde
Fertigation	180	1.81 ab	0.06	0.41	0.89	0.16	0.12 bc
Fertigation	240	1.90 a	0.06	0.38	0.78	0.17	0.12 bc

^z Rate in total N in lb/acre, based on 1089 plants/acre.

^y Mean separation when *F*-test for rate was significant by least significant difference ($P = 0.05$).

Table 2. Yield, berry weight, and foliar microelement content for method of application and N rate treatments to highbush blueberries: sixth-year results (1999).

Application method	N rate ^z (g/plant)	Yield (g)	Berry wt.	ppm dry wt.			
				Fe	Mn	Zn	Cu
Control	0	105	1.3	63	186 d ^y	9.0	5.1
Surface	60	765	1.5	75	378 cd	9.5	4.9
Surface	120	903	1.6	59	554 a-c	8.19	4.5
Surface	180	193	1.5	82	620 ab	9.3	4.1
Surface	240	696	1.6	76	721 a	9.1	5.1
Fertigation	60	351	1.4	111	267 d	13.2	5.4
Fertigation	120	854	1.8	78	395 b-d	9.5	5.5
Fertigation	180	818	1.3	78	475 bc	10.6	5.4
Fertigation	240	1144	1.6	65	584 a-c	8.8	4.7

^z Rate of actual N in lb/acre, based on 1089 plants/acre.

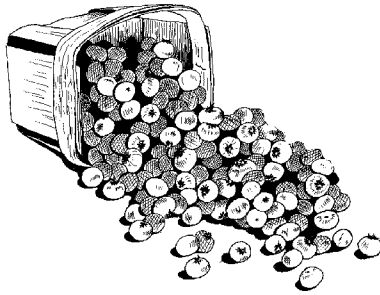
^y Mean separation when *F*-test for rate was significant by least significant difference ($P = 0.05$).

Table 3. Soil analysis values from summer samples for pH, electrical conductivity (EC), nitrate (NO₃), P, K, and Ca for method of application and nitrogen rate treatments to highbush blueberries: sixth-year results (1999).

Application method	N rate ^z	pH	EC	lb/acre dry wt.			
				NO ₃	P	K	Ca
Control	0	6.7 a ^y	124	8.1	51.0	200.1	3297
Surface	60	5.6 bc	107	7.2	57.2	156.8	1997
Surface	120	5.2 c	122	17.0	57.4	145.2	1547
Surface	180	5.4 bc	122	14.1	72.5	149.0	1825
Surface	240	5.1 c	132	20.8	64.5	159.1	1880
Fertigation	60	6.5 a	117	9.5	47.8	190.3	3018
Fertigation	120	6.0 ab	107	7.3	46.0	154.0	2266
Fertigation	180	6.1 ab	121	10.3	53.7	175.2	2412
Fertigation	240	5.4 bc	114	7.7	57.5	141.2	1682

^z Rate of actual N in lb/acre, based on 1089 plants/acre.

^y Mean separation where *F*-test for rate was significant by least significant difference (*P* = 0.05).



NITROGEN RATE RESPONSE IN 'CAPE FEAR' SOUTHERN Highbush BLUEBERRY

Manjula Carter,¹ John R. Clark,² and J. Mike Phillips¹

IMPACT STATEMENT

Blueberry production since the 1980s in central and southern Arkansas has relied on rabbiteye (*Vaccinium ashei*) cultivars. However, southern-adapted rabbiteyes are susceptible to frost damage during early bloom and ripen later than highbush. In recent years, the southern highbush blueberry, a hybrid of the northern highbush (*V. corymbosum*) and one or more southern *Vaccinium* species, has been developed as an alternative to the traditional rabbiteye in southern Arkansas. Previous research on southern highbush blueberries in Arkansas has focused on cultivar development and testing, with only limited research on the cultural aspects of production. Our study focused on the response of 'Cape Fear' southern highbush to a range of fertilizer nitrogen (N) rates. The results of our study indicated that 'Cape Fear' responded similarly to N rate and had foliar N levels comparable to northern highbush cultivars, and that the recommended rate of 60 to 120 lb/acre of actual N on mulched highbush is also acceptable for southern highbush.

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BACKGROUND

The response of southern highbush blueberry to varying levels of fertilizer N has not been evaluated in Arkansas. Application rates for highbush blueberries in the United States usually range from 60 to 120 lb of N/acre, and foliar N content of 1.6% is considered the minimum for optimal plant performance. Higher N rates are often required when organic mulches such as pine straw or sawdust are applied to the plants. Clark et al. (1994) reported that, when fertilized at similar N rates, highbush and southern highbush blueberries were similar in foliar elemental content, while the rabbiteye blueberry differed in foliar levels of many elements. The objective of this study was to determine the optimal fertilizer N rate for the southern highbush blueberry.

RESEARCH DESCRIPTION

A planting of pine-straw-mulched 'Cape Fear' southern highbush blueberry was established in late winter of 1994 at the Southwest Research and Extension Center, Hope. The soil type was a Bowie fine sandy loam. The plants were fertilized uniformly with ammonium sulfate for the first 3 years (1994-1996). In 1994, 60 lb/acre of actual N was applied to all plants, while in 1995 and 1996, 90 lb/acre of actual N was applied. Nitrogen rate treatments (0, 60, 120, 180 and 240 lb N/acre) were begun in 1997 and continued in 1998 and 1999. Urea was chosen as a less acidifying N source, since the average pH of the planting was < 5.3 for all 3 years of treatments. Urea was surface-applied on the mulched area under the plants, with the first application at budbreak followed by two more applications at 6-wk intervals. One-third of the total annual N was applied at each date. In 1998 and 1999, soil samples were taken in the spring prior to fertilization to determine whether N applied the previous year influenced current soil analysis values. Fruit yields and berry weights were measured twice weekly over the entire fruiting season, and foliar samples were collected at the end of the season (late July/early August). The experimental design was a randomized complete block with five replications. Data were collected from only one plant in the two-plant plots and data were analyzed by SAS.

FINDINGS

In 1999, soil pH, calcium, and magnesium levels were not significantly affected by N rate (Table 1), whereas in 1998, these levels were decreased significantly as N rate increased (1998 data not shown). Nevertheless, in 1999, the same trend toward reduced values for these

variables was seen. Soil electrical conductivity was unaffected by N rate (Table 1), although a trend for increased electrical conductivity with the higher N rates was evident. No consistent relationship was evident between N application rate and soil nitrate (Table 1). In 1998, soil nitrate was positively correlated with N application rates, with the 240 lb of N/acre rate having the highest nitrate values. As in previous years, soil levels of sodium, iron, manganese, copper, and zinc were unaffected by N rate (data not shown). These data indicate that the carryover effect of N applications from 1998 was minimal. However, annual soil analysis is recommended to monitor possible changes in soil pH, electrical conductivity, calcium, and magnesium with the higher N rates to ensure that these variables stay within acceptable levels.

Yield was not significantly influenced by N rate (Table 2), although the lowest mean yield was found with the highest N rate (240 lb of N/acre). This supports previous data that showed no consistent relationship between yield and N rate for 'Cape Fear' southern highbush blueberry. Berry weight was also similar for all treatments in 1999 as in 1997 and 1998 (Table 2).

Foliar N was significantly higher than the control for N rates of 180 and 240 lb/acre and was greatest (2.58%) with the 240 lb N/acre rate (Table 2). However, as in previous years, foliar N was statistically similar among the 60, 120 and 180 lb N/acre treatments, and was greater than the critical value of 1.6% for all N rates and the control. Although consistent foliar N responses were not observed in this study, no data support using the 180 and 240 lb/acre rates on southern highbush blueberries. It appears that the common N rates of 60 to 120 lb/acre are also adequate for southern highbush.

In 1999, as in 1997 and 1998, foliar phosphorus, calcium, magnesium, and sulfur were not affected by N rate (Table 2). Foliar potassium was also unaffected by N rate in 1999, whereas in 1998, foliar potassium increased with N rate. Microelemental levels (iron, manganese, zinc, and copper) did not respond to N rate (data not shown).

LITERATURE CITED

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Table 1. Soil analysis values from February 1999 for a planting of 6-year-old 'CapeFear' southern highbush blueberry as affected by 1998 urea-N fertilization level at the Southwest Research and Extension Center, Hope, 1999.

N (lb/acre)	pH	EC ^z (Micromhos/ cm)	Nitrate	P	K	Ca	Mg	S
lb/acre								
Control	5.4 a ^y	50 a	10 b	60 a	99 a	1172 a	95 a	19 a
60	5.7 a	43 a	9 b	44 a	108 a	1278 a	79 a	16 a
120	5.0 a	62 a	16 a	68 a	103 a	967 a	84 a	27 a
180	4.3 a	72 a	19 a	88 a	94 a	577 a	61 a	27 a
240	4.8 a	47 a	10 b	82 a	96 a	673 a	69 a	26 a

^z Electrical conductivity.

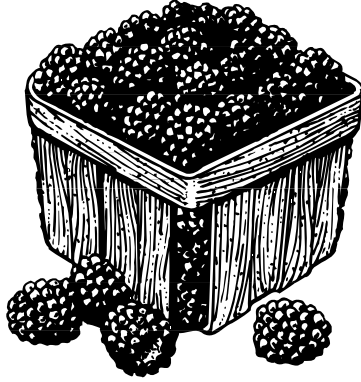
^y Within a column, numbers followed by the same letter are not significantly different as determined by least significant difference ($P = 0.05$).

Table 2. Yield, berry weight, and foliar macroelemental analysis of 6-year-old 'Cape Fear' southern highbush blueberry as affected by urea-N fertilization level at the Southwest Research and Extension Center, Hope 1999.

N (lb/acre)	Yield ^z (g)	Berry wt.	N	P	K	Ca	Mg	S
% dry wt.								
Control	6115 a ^y	0.67 a	1.74 c	0.09 a	0.56 a	0.64 a	0.26 a	0.16 a
60	5201 a	0.65 a	1.97 bc	0.10 a	0.67 a	0.63 a	0.23 a	0.15 a
120	5329 a	0.63 a	2.00 bc	0.10 a	0.69 a	0.59 a	0.21 a	0.15 a
180	5689 a	0.57 a	2.09 b	0.10 a	0.74 a	0.67 a	0.22 a	0.15 a
240	2231 a	0.51 a	2.58 a	0.11 a	0.82 a	0.64 a	0.21 a	0.17 a

^z Yield in lb/acre based on plant density of 1089 plants/acre.

^y Within a column, numbers followed by the same letter are not significantly different as determined by least significant difference ($P = 0.05$).



'APACHE' THORNLESS BLACKBERRY PRODUCES LARGER FRUIT AND HIGHER YIELDS THAN PREVIOUS THORNLESS, ERECT CULTIVARS

John R. Clark and James N. Moore¹

IMPACT STATEMENT

Blackberry production is a very viable option for small-fruit growers in Arkansas because of both the natural adaptation of blackberry and the fruit's high value. Public blackberry breeding has been conducted in the United States since the early 1900s, but in the last 40 years major cultivar improvements have been made. For most of this period, the University of Arkansas has been a leader in blackberry cultivar improvement. 'Apache' is the ninth release in a series of erect-growing, high-quality, productive blackberry cultivars developed by the University of Arkansas, and it is the third thornless, erect cultivar released. 'Apache' produces larger fruit and higher yields than previously released Arkansas thornless, erect cultivars. Thus 'Apache' adds an improved option for blackberry producers in their cultivar selection.

BACKGROUND

The blackberry breeding program at the University of Arkansas was begun in 1964 by Dr. James N. Moore with a number of breeding

¹ Both authors are associated with the Department of Horticulture, Fayetteville.

objectives, including upright or erect-caned plant stature; improved fruit size; high productivity; and high quality including improved flavor, excellent plant adaptation, and thornlessness. The first cultivars released from the program in 1974 were the thorny 'Comanche' and 'Cherokee', and the first thornless, 'Navaho', was released in 1989. The unique characteristics of 'Navaho', and the later-released thornless 'Arapaho', were upright canes on a thornless plant. 'Apache' offers this same type of plant architecture with improved fruit size and productivity.

RESEARCH DESCRIPTION

'Apache' was selected in 1991 from a seedling field at the University of Arkansas Fruit Substation, Clarksville. Testing of 'Apache' has been done primarily at Clarksville, with additional testing at Hope (Southwest Research and Extension Center) and Fayetteville (University of Arkansas Agricultural Research and Extension Center). In all plantings, standard cultural practices for erect blackberry production were used, including annual preemergence and postemergence herbicide applications, annual spring nitrogen fertilization using ammonium nitrate, summer tipping of primocanes at approximately 42 in., and dormant pruning. All plantings received a single application of liquid lime sulfur at budbreak for control of anthracnose.

DESCRIPTION AND PERFORMANCE

'Apache' usually produced higher yields than 'Arapaho' and 'Navaho' in all years of comparative yield trials at Clarksville, Hope, and Fayetteville (Table 1). 'Apache' appears to be equally productive in all areas evaluated in Arkansas.

Fruit weight of 'Apache' is a noteworthy attribute, in that it is larger than either 'Arapaho' or 'Navaho', usually twice as large as 'Navaho' and 80% larger than 'Arapaho' (Table 2). 'Apache' also maintains very good fruit weight over its harvest season. In 1997, when the average fruit weight for the season at Clarksville was 9.5 g, the lowest average fruit weight recorded was 7.1 g at the last harvest date. In 1998, with an average of 10.0 g, the lowest fruit weight recorded during the harvest season was 8.5 g. Additionally, uneven drupelet set has often been observed in 'Navaho' and has been attributed to some degree of sterility. 'Apache' has excellent fruit fertility and full drupelet set.

'Apache' blooms 2-3 days later than 'Arapaho' and 2-3 days before 'Navaho' (Table 3). First harvest date for 'Apache' averages 15 days

later than 'Arapaho' and 5 days later than 'Navaho' (Table 3). Peak harvest date of 'Apache' is 7 days earlier than 'Navaho', and last harvest date is 6 days earlier. On average, the fruiting period for 'Apache' is 10 days shorter than 'Navaho'.

Fruit of 'Apache' are blocky and conical and very attractive, with a glossy, black finish. Fruit firmness was rated lower for 'Apache' than for 'Navaho' but comparable to 'Arapaho' (Table 3). Soluble solids concentration of 'Apache' averaged 10.7% over 5 years, compared with 11.4% for 'Navaho' and 9.6% for 'Arapaho'. Flavor of 'Apache' was rated very good (8.8), which is between 'Arapaho' (8.3) and 'Navaho' (9.2) (Table 3). Postharvest evaluations of 'Apache' indicated that it did not store as well as 'Navaho' but did perform better than 'Shawnee' in storage trials (postharvest information provided by Dr. Penny Perkins-Veazie, USDA-ARS, Lane, Okla.). Seeds of 'Apache' are significantly heavier than either 'Arapaho' or 'Navaho' (Table 3).

Canes of 'Apache' are thornless, and 'Apache' is more erect than either of the comparative thornless erect cultivars (Table 3). 'Apache' can be grown in a hedgerow without trellis support when primocanes are tipped at 42" to control primocane length and encourage lateral branching. Vigor and health ratings of 'Apache' were higher than those for either 'Arapaho' or 'Navaho' (Table 3). Ratings for winter injury for 'Apache' have been comparable to 'Arapaho' or 'Navaho'. Minimum low temperatures during the years of evaluation at Clarksville were: 1992-93, 22 °F; 1993-94, 9 °F; 1994-95, 13 °F; 1995-96, 1 °F; 1996-97, 10 °F; and 1997-98, 20 °F. Additionally, in 1996 a spring freeze (10 °F) occurred on 10 March, near budbreak, and probably further damaged the cultivars after the winter minimum of 1 °F. Only in 1996 was a winter injury rating of less than 10 recorded for 'Apache'. Sprouting of root cuttings of 'Apache' was higher than the previously released thornless cultivars (data not shown), and it quickly establishes a well-filled hedgerow. The chilling or rest-period requirement has not been measured but appears to be similar to that of 'Navaho', which has a higher chill requirement than other Arkansas cultivars. Chilling requirement should not be a limiting factor in Arkansas but should be considered in low-chill areas of the southern United States or in other low-chill regions of the world.

'Apache' is moderately resistant to anthracnose, and no disease problems have occurred in evaluations where a single lime sulfur application was used. No orange rust has been observed on 'Apache' in any plantings. Reaction of 'Apache' to rosette/double blossom has not been determined.

'Apache' should be popular as a commercial cultivar, as well as an option for home gardens. 'Apache' is expected to perform well in

areas where 'Arapaho' or 'Navaho' are adapted. An application for a plant patent has been filed for 'Apache', and propagation is restricted to licensed nurseries.

ACKNOWLEDGMENTS

We thank Kenda Woodburn, Jack Young, Andy Allen, Effie Gilmore, David Gilmore, Paula Watson, Gina Fernandez, Kelly Irvin, Manjula Carter and Maurus Brown for assistance in data collection during the evaluation of 'Apache'. Additionally, appreciation is expressed to P. Perkins-Veazie and J. Collins (USDA-ARS) for postharvest evaluation of 'Apache'.

Table 1. Yield (lb/acre) of three thornless blackberry cultivars at three locations in Arkansas from plantings established in 1996.

Cultivar	1997	1998
<i>Clarksville</i>		
Apache	9,019 a ^z	6,861 a
Arapaho	4,411 b	4,441 b
Navaho	13,453 a	4,254 b
<i>Hope</i>		
Apache	4,029 a	12,977 a
Arapaho	3,246 a	8,664 b
Navaho	2,700 a	9,925 ab
<i>Fayetteville</i>		
Apache	6,680 a	7,455 a
Arapaho	1,828 b	4,461 b
Navaho	2,420 b	4,273 b

^z Mean separation within location and year by *t*-test ($P \leq 0.05$).

Table 2. Fruit weight (g/fruit) of three thornless blackberry cultivars at three locations in Arkansas from plantings established in 1996.

Cultivar	1997	1998
<i>Clarksville</i>		
Apache	10.0 a ^z	9.5 a
Arapaho	5.4 b	5.2 b
Navaho	5.1 b	4.6 b
<i>Hope</i>		
Apache	6.6 a	8.4 a
Arapaho	4.7 b	5.0 b
Navaho	3.9 c	4.9 b
<i>Fayetteville</i>		
Apache	8.9 a	7.4 a
Arapaho	4.7 b	3.5 b
Navaho	3.2 b	3.1 b

^z Mean separation within location and year by *t*-test ($P \leq 0.05$).

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

Characteristic	Apache	Arapaho	Navaho
Date^z			
10% bloom	30 Apr.	27 Apr.	2 May
50% bloom	6 May	4 May	8 May
Harvest			
First	20 June	5 June	15 June
Peak	30 June	12 June	7 July
Last	27 July	14 July	2 Aug.
Fruit			
Firmness ^x	8.2	8.3	8.7
Flavor ^y	8.8	8.3	9.2
Seed fresh weight (mg/seed)	12.6 a ^w	8.7 c	10.6 b
Seed dry weight (mg/seed)	4.8 a ^w	3.3 c	4.2 b
SSC (%) ^u	10.7	9.6	11.4
Plant^w			
Vigor	9.5	7.2	7.3
Health	9.7	8.3	8.8
Erectness	9.0	8.5	8.0
Winter injury	9.5	9.3	9.5

^z Means of 2 years, 1997 and 1998.

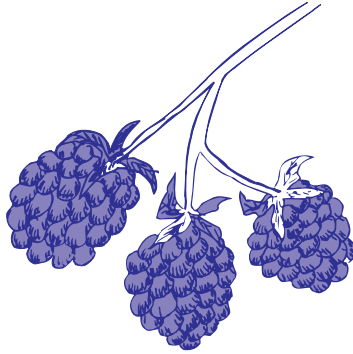
^y Means of 6 years, 1993 through 1998.

^x Rating scale of 1 to 10 where 10 = best.

^w Data from 1998; means within each row separated by *t*-test ($P \leq 0.05$).

^v Means of 5 years, 1993, 1994, 1995, 1997, 1998.

^u SSC = soluble solids concentration.



‘CHICKASAW’ BLACKBERRY: IMPROVED POSTHARVEST HANDLING CHARACTERISTICS, LARGER FRUIT, AND HIGH YIELDS

John R. Clark and James N. Moore¹

IMPACT STATEMENT

Blackberry production is a very good option for small-fruit growers in Arkansas because of the natural adaptation of blackberry and the fruit’s high value. Public blackberry breeding has been conducted in the United States since the early 1900s, but in the last 40 years, major cultivar improvements have been made. For most of this period, the University of Arkansas has been a leader in blackberry cultivar improvement. ‘Chickasaw’ is the 10th release in a series of erect-growing, high-quality, productive blackberry cultivars developed by the University of Arkansas. ‘Chickasaw’ produces larger fruit, has comparable-to-higher yields, and has improved postharvest handling characteristics compared with ‘Shawnee’, the current thorny, erect cultivar with a similar season of ripening.

BACKGROUND

The blackberry breeding program at the University of Arkansas was begun in 1964 by Dr. James N. Moore with a number of breeding

¹ Both authors are associated with the Department of Horticulture, Fayetteville.

objectives, including upright or erect-caned plant stature, improved fruit size, high productivity, high quality including improved flavor, excellent plant adaptation, and thornlessness. The first cultivars released from the program in 1974 were the thorny 'Comanche' and 'Cherokee', followed by 'Shawnee' in 1983. 'Shawnee' has been the most widely planted erect blackberry in recent years, and 'Chickasaw' was released to provide an improved cultivar with a ripening season similar to 'Shawnee'.

RESEARCH DESCRIPTION

'Chickasaw' was selected in 1988 from a seedling field at the University of Arkansas Fruit Substation, Clarksville. 'Chickasaw' has been evaluated most thoroughly at this location, and at research stations at Hope (Southwest Research and Extension Center) and Fayetteville (University of Arkansas Agricultural Research and Extension Center). In all plantings, standard cultural practices for erect blackberry production were used, including annual preemergence and postemergence herbicide applications, annual spring nitrogen fertilization using ammonium nitrate, summer tipping of primocanes at 42 in., and dormant pruning. All plantings received a single application of liquid lime sulfur at budbreak for control of anthracnose.

DESCRIPTION AND PERFORMANCE

'Chickasaw' produced the highest numerical yields in all comparisons at all three locations where yields were recorded, although yields were statistically similar to 'Shawnee' in most comparisons, and with 'Kiowa' in two of four comparisons (Table 1). 'Chickasaw' appears to be equally productive in all areas evaluated in Arkansas.

Fruit weight of 'Chickasaw' was greater than that of 'Choctaw' and 'Shawnee' in all but one comparison, and similar to that of 'Kiowa' at Fayetteville (Table 2). 'Chickasaw' maintains very good fruit weight over its harvest season. In 1997, when the average fruit weight of 'Chickasaw' for the season at Clarksville was 11.0 g, the lowest average fruit weight recorded was 8.0 g at the last harvest date. In 1998, with an average of 10.5 g, the lowest fruit weight recorded during the harvest season was 9.3 g. 'Chickasaw' has excellent flower and fruit fertility and full drupelet set.

'Chickasaw' blooms an average 1 to 3 days later than 'Choctaw', 4 days before 'Shawnee', and 3 days before 'Kiowa' (Table 3). First harvest date for 'Chickasaw' averaged 10 days later than 'Choctaw' and 3 days later than 'Shawnee' and 'Kiowa'. Peak harvest date of 'Chickasaw'

was 1 day later than 'Shawnee' at Clarksville and 7 days later than 'Shawnee' and 'Kiowa' at Hope (Table 3). Average length of fruiting period for 'Chickasaw' was 40 days, compared with 32 days for 'Choctaw', 43 days for 'Kiowa', and 38 days for 'Shawnee'.

Fruit of 'Chickasaw' are long, cylindrical, and slightly flattened and very attractive, with a glossy, black finish. Average fruit weight of primary fruit in 1998 was 11.4 g, secondary 11.0 g, and tertiary, 10.7 g, reflecting a consistently large fruit size among these locations on the inflorescence. Fruits per cluster averaged 6, with a range of 4 to 19 per inflorescence. Fruit firmness was higher for 'Chickasaw' than 'Shawnee' or 'Choctaw' but comparable to 'Kiowa' (Table 4). Soluble solids concentration of 'Chickasaw' averaged 9.6% over 8 years. Flavor of 'Chickasaw' was rated higher than that of 'Kiowa' and 'Shawnee' but lower than the flavor of 'Choctaw' (Table 4). Postharvest evaluations of 'Chickasaw' indicated that overall it was superior in storage to 'Shawnee', specifically performing better than 'Shawnee' in percentage of leaky fruits and soft berries. 'Chickasaw' had more drupelet reddening than 'Shawnee' during fruit storage (postharvest storage information provided by Dr. Penny Perkins-Veazie, USDA-ARS, Lane, Okla.). Seeds of 'Chickasaw' were similar in weight to 'Shawnee' but heavier than 'Choctaw' seeds (Table 4).

Canes of 'Chickasaw' are thorny, with a thorn density similar to 'Shawnee' but less than that of 'Kiowa'. 'Chickasaw' was rated similar to 'Choctaw' in cane erectness, more erect than 'Kiowa', and slightly less erect than 'Shawnee' (Table 4). 'Chickasaw' can be grown in a hedgerow without trellis support, with primocanes tipped at approx. 42 in. to control primocane length and encourage lateral branching. Vigor and health of 'Chickasaw' were rated high, similar to 'Shawnee' and higher than 'Choctaw' and 'Kiowa' (Table 4). Ratings for winter injury for 'Chickasaw' have been comparable to 'Shawnee' and 'Kiowa' and slightly higher than 'Choctaw' (Table 4). Minimum low temperatures during the winter of years of evaluation at Clarksville were as follows: 1989-90, -9 °F; 1990-91, 7 °F; 1991-92, 10 °F; 1992-93, 22 °F; 1993-94, 9 °F; 1994-95, 13 °F; 1995-96, 1 °F; 1996-97, 10 °F; 1997-98, 20 °F. Additionally, in 1996 a spring freeze (10 °F) occurred on 10 Mar., near budbreak, and probably further damaged the cultivars after the winter minimum of -1 °F. Sprouting of root cuttings of 'Chickasaw' has been good, as evidenced by good stand establishment from root cuttings in the replicated trials (data not shown).

'Chickasaw' is moderately resistant to anthracnose, and the only fruit anthracnose we observed was in 1997 on early-ripening berries. No orange rust has been observed on 'Chickasaw' in any plantings. Reaction of 'Chickasaw' to rosette/double blossom has not been deter-

mined. Slight evidence of infections of powdery mildew (some leaf curling) were observed in 1993 and 1997, but no damage to the plants (e.g., defoliation, loss of leaf health) was noted.

'Chickasaw' should be popular as a commercial cultivar, as well as an option for home gardens. It is expected to perform well in areas where 'Shawnee', 'Choctaw', or 'Kiowa' are adapted. An application for a U.S. plant patent has been filed for 'Chickasaw', and propagation of this cultivar is restricted to licensed nurseries.

ACKNOWLEDGMENTS

We thank Kenda Woodburn, Jack Young, Andy Allen, Effie Gilmore, David Gilmore, Paula Watson, Gina Fernandez, Kelly Irvin, Manjula Carter, and Maurus Brown for assistance in data collection during the evaluation of 'Chickasaw'. Additionally, appreciation is expressed to P. Perkins-Veazie and J. Collins (USDA-ARS) for postharvest evaluation of 'Chickasaw'.

Table 1. Yield (lb/acre) of blackberry cultivars at three locations in Arkansas from plantings established in 1996.

Cultivar	1997	1998
<i>Clarksville</i>		
Chickasaw	11,003 a ^z	9,899 a
Choctaw	6,671 a	7,119 a
Shawnee	7,958 a	7,516 a
<i>Hope</i>		
Chickasaw	7,027 a	15,318 a
Choctaw	3,833 b	9,064 b
Kiowa	886 c	9,947 b
Shawnee	3,771 b	15,261 a
<i>Fayetteville</i>		
Chickasaw	10,261 a	10,036 a
Choctaw	3,581 b	5,978 b
Kiowa	8,780 a	8,944 ab
Shawnee	7,256 ab	7,893 ab

^z Mean separation within location and year by *t*-test ($P \leq 0.05$).

Table 2. Fruit weight (g/fruit) of blackberry cultivars at three locations in Arkansas from plantings established in 1996.

Cultivar	1997	1998
<i>Clarksville</i>		
Chickasaw	11.0 a ^z	10.5 a
Choctaw	6.1 c	5.4 c
Shawnee	8.4 b	7.4 b
<i>Hope</i>		
Chickasaw	8.8 a	8.5 a
Choctaw	5.3 c	4.3 c
Kiowa	7.3 b	7.8 b
Shawnee	7.3 b	6.3 b
<i>Fayetteville</i>		
Chickasaw	10.2 a	8.3 a
Choctaw	5.3 b	3.3 c
Kiowa	10.0 a	8.1 ab
Shawnee	7.9 ab	5.4 b

^z Mean separation within location and year by *t*-test ($P \leq 0.05$).

Table 3. Bloom and fruit maturity dates of blackberry cultivars at two locations in Arkansas from plantings established in 1996.

Characteristic	Chickasaw	Choctaw	Kiowa	Shawnee
<i>Clarksville</i>				
Date ^z				
10% bloom	25 Apr.	23 Apr.	-	29 Apr.
50% bloom	29 Apr.	30 Apr.	-	6 May
Harvest				
First	10 June	30 May	-	7 June
Peak	21 June	7 June	-	20 June
Last	20 July	1 July	-	17 July
<i>Hope</i>				
Date ^y				
10% bloom	14 Apr.	13 Apr.	16 Apr.	15 Apr.
50% bloom	18 Apr.	15 Apr.	21 Apr.	21 Apr.
Harvest				
First	29 May	20 May	26 May	26 May
Peak	22 June	1 June	15 June	15 June
Last	6 July	22 June	8 July	29 June

^z Average of two years, 1997 and 1998.

^y Data from one year, 1998.

Table 4. Fruit and plant characteristics of blackberry cultivars at the University of Arkansas Fruit Substation, Clarksville.

Characteristics	Chickasaw	Choctaw	Kiowa	Shawnee
Fruit				
Firmness ^{zy}	7.9	7.1	7.8	7.1
Flavor ^{zy}	8.1	8.6	7.6	7.4
Seed fresh wt. (mg/seed)	9.1 a ^x	6.5 b	-	8.8 a
Seed dry wt. (mg/seed)	4.1 a ^x	2.2 b	-	3.7 a
SSC (%) ^w	9.6	8.7	9.7	9.3
Plant				
Vigor ^{zy}	8.9	8.0	8.1	9.0
Health ^{zy}	8.7	8.1	8.3	8.4
Erectness ^{zy}	8.6	8.6	7.0	9.3
Winter injury ^{zy}	8.8	7.9	8.5	8.6

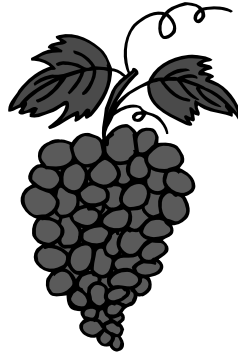
^z Rating scale of 1 to 10 where 10 = best.

^y Means of 9 years, 1990 through 1998.

^x Data from 1998; means within rows separated by *t*-test ($P \leq 0.05$).

^w Means of 8 years, 1990 through 1995, 1997, 1998.

^v Means of 8 years, 1990, 1991, 1993 through 1998.



‘JUPITER’ SEEDLESS TABLE GRAPE—ANOTHER OPTION FOR ARKANSAS GROWERS

John R. Clark and James N. Moore¹

IMPACT STATEMENT

Table grape production is a viable, high-value option for grape and small-fruit producers in Arkansas. Arkansas has a long tradition of juice and wine grape production, but table grape production was begun only in the late 1970s and early 1980s, based on the introduction of ‘Venus’ by the University of Arkansas. Subsequent cultivars released by the program have helped develop this industry, but growers continue to need improved cultivars. ‘Jupiter’ is the fifth cultivar in a series of seedless table grapes released from the University of Arkansas. The release of this new cultivar will expand the options for eastern table grape growers, specifically providing a muscat-flavored seedless table grape.

BACKGROUND

The University of Arkansas table grape breeding program was begun by Dr. James N. Moore in 1964 and has provided several cultivar options for Arkansas growers, including the above-mentioned ‘Venus’ as well as ‘Reliance’, ‘Mars’, and ‘Saturn’. Growers continue to

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need new cultivars with a variety of plant and fruit characteristics, including high yields, resistance to fruit cracking, more complete seedlessness, and non-slip-skin fruit texture. 'Jupiter' exhibits a number of improvements and provides a new option for growers of eastern-U.S. table grapes.

RESEARCH DESCRIPTION

'Jupiter' was selected in 1984 in a seedling vineyard at the University of Arkansas Fruit Substation, Clarksville. The source of the muscat flavor of 'Jupiter' was the *Vitis vinifera* cultivar, 'Gold', and the source of seedlessness was 'Glenora'.

Kniffin and bilateral cordon training systems were used in the testing of 'Jupiter' at Clarksville (Fruit Substation) and Fayetteville (University of Arkansas Agricultural Research and Extension Center). Vines were trickle irrigated, had fungicide and insecticides applied according to a commercial pest control program, received annual preemergence and postemergence herbicide applications, and were fertilized annually with nitrogen. Also, 'Jupiter' was evaluated at West Lafayette, Ind., by Dr. Bruce Bordelon, Purdue University.

DESCRIPTION AND PERFORMANCE

Fruit of 'Jupiter' is reddish-blue at early maturity and becomes completely blue when fully mature. Berry shape is oval to slightly oblong. Berry weight of 'Jupiter' averaged 5.5 g over 12 years of evaluation, larger than that of the comparison cultivars 'Venus', 'Reliance', and 'Mars' (Table 1). Evaluations of gibberellic acid and girdling effects on berry weight of 'Jupiter' have not been conducted. 'Jupiter' berries are non-slip-skin and semi-crisp. Small, soft seed traces have occasionally been observed in some berries of 'Jupiter' but were usually considered negligible because of the size, softness, and non-slip-skin texture of the berries. Skin cracking has not been observed on 'Jupiter' in any of the evaluations, although severe fruit cracking was seen on 'Reliance' and other crack-susceptible genotypes. Skin of 'Jupiter' is of medium thickness and is edible. Flavor of 'Jupiter' is a mild muscat and has been consistently rated high, exceeded only by 'Reliance' among the comparison cultivars (Table 1). Soluble solids concentration of 'Jupiter' averaged 19.8% over 12 years, higher than that of 'Venus' and 'Mars' but not as high as 'Reliance' (Table 1). Postharvest and processing evaluations have not been conducted on 'Jupiter'.

Clusters of 'Jupiter' are conical and occasionally have a shoulder. Cluster weight averaged 257.1 g over the 12-year study period, which

is similar to 'Venus' but smaller than 'Reliance' (Table 1). Cluster fill ratings averaged 8.5 for 'Jupiter' indicating well-filled clusters. However, the clusters are not too tight to hinder handling or packaging. Shatter of berries from the clusters at maturity has not been observed, and the clusters hang well on the vines after achieving full maturity. Some berry shatter in postharvest handling was observed in 1999, which suggests that growers consider using bags or clamshell marketing containers, rather than bulk fruit containers.

Yields of 'Jupiter' were equal to or exceeded those of 'Venus' and 'Mars' in the replicated trials (Table 2). Crop ratings, taken over 12 years, were higher for 'Jupiter' than for 'Venus', 'Reliance', and 'Mars', indicating consistent cropping during the evaluation period (Table 1). In only one of the 12 years of evaluation was a crop rating of less than 7 (on a 10-point scale with 10 being a full crop) recorded for 'Jupiter'. This occurred in 1996, when emerging buds were damaged by a spring freeze. 'Jupiter' vines have not been evaluated for the effects of flower cluster thinning, but excessive cropping has not been observed on 'Jupiter' in Arkansas. However in Indiana, 'Jupiter' was noted to have a tendency to overcrop if the flower clusters were not thinned.

The average maturity date of 'Jupiter' was 24 July at Clarksville, and is considered an early, mid-season-maturity cultivar (Table 1). It ripened 5 days later than 'Venus' and 5 and 12 days earlier than 'Reliance' and 'Mars', respectively. Budbreak of 'Jupiter' is similar to 'Venus' and 4 days earlier than budbreak of 'Mars' (Table 1).

Vines of 'Jupiter' have medium vigor, similar to 'Venus' in pruning weight and 'Reliance' in vigor rating, but less vigorous than 'Mars' (Table 1). Growth habit is mostly procumbent, although not as procumbent as 'Mars'. Shoot positioning is more easily done on 'Jupiter' than 'Mars' because of it has lower vigor and less tendril interference than 'Mars'. 'Jupiter' shoots mature early, with wood maturity extending to the shoot tips in the fall. Minimum winter temperature at Clarksville from 1987 through 1998 was -8°F in December 1989, although the lowest temperature for most winters was from 1 to 9°F . Winter injury was not observed during this period. 'Jupiter' fruited consistently during all years of evaluation and had a crop rating of 10 (indicating a full crop) for the 1990 season following exposure to -8°F . Observations of 'Jupiter' in West Lafayette, Ind., indicated that it was moderately hardy, similar in hardiness to 'Suffolk Red', hardier than 'Einset Seedless', 'Canadice', 'Himrod', 'Marquis', 'Remaily Seedless', 'Saturn', 'Vanessa Seedless' and 'Venus', and less hardy than 'Mars' and 'Reliance'. Some vine death occurred after exposure to -26°F in the West Lafayette planting. A spring freeze near budbreak (10°F in March) reduced the crop of 'Jupiter' in Clarksville in 1996, but freeze damage ratings to breaking buds were similar to those of 'Mars', and less damage was

noted than that associated with 'Venus'.

'Jupiter' has shown moderate resistance to black rot, powdery mildew, and anthracnose (in tests using a commercial fungicide program). Slight infections of powdery mildew were observed in 2 of the 12 years of evaluation. Neither black rot nor anthracnose was observed with the commercial fungicide program used in the test vineyard. No powdery mildew, black rot, or phomopsis cane and leaf spot was observed in Indiana evaluations. Downy mildew has been observed on 'Jupiter', and susceptibility to downy mildew is similar to that of 'Venus'. However, downy mildew has not been a concern when a commercial fungicide program is used. Overall, plant health ratings for 'Jupiter' were high during the 12 years of evaluation, exceeding that of 'Venus' and near that of 'Mars' and 'Reliance' (Table 1). 'Jupiter' is moderately sensitive to phenoxy-herbicides but not as sensitive as 'Mars', 'Sunbelt', or 'Remaily Seedless' (determined in Indiana testing). Green June beetles have fed on ripening fruit of 'Jupiter' in some years, and it is suspected that the aromatic fruit coupled with early ripening contributes to this insect activity. Additionally, feeding by some mammals has been noted in Arkansas and Indiana.

'Jupiter' is recommended for trial where other eastern U.S. table grape cultivars are adapted. An application for a U.S. plant patent has been filed, and propagation is allowed only by nurseries licensed to propagate this new cultivar.

ACKNOWLEDGMENTS

We thank Kenda Woodburn, Andy Allen, Effie Gilmore, David Gilmore, Paula Watson, Gina Fernandez, Kelly Irvin and Maurus Brown for their assistance in data collection during the evaluation of 'Jupiter'. Additionally, appreciation is expressed to Dr. Bruce Bordelon at Purdue University, West Lafayette, Ind., for testing of 'Jupiter'.

Table 1. Plant and fruit characteristics of four table grape cultivars grown at the University of Arkansas Fruit Substation, Clarksville.

Characteristic	Jupiter	Mars	Reliance	Venus
Date				
Budbreak ^z	25 Mar.	29 Mar.	-	25 Mar.
Harvest ^y	24 July	05 Aug.	29 July	19 July
Berry				
Weight (g) ^x	5.5	2.6	2.1	3.0
Flavor ^{yw}	9.2	8.3	9.6	8.0
SSC (%) ^{yv}	19.8	17.6	22.1	17.3
Cluster				
Weight (g) ^u	257.1	214.2	311.4	266.6
Fill ^t	8.5	6.7	7.6	7.8
Plant				
Crop ^{yw}	8.1	7.3	7.9	6.5
Health ^{yw}	8.7	9.3	9.1	7.8
Vigor ^{yw}	8.3	9.3	8.4	7.8
Pruning weight/vine (lb) ^{zs}	1.5	4.1	-	1.5

^z Means of 2 years, 1997 and 1998, recorded on 12 vines planted in 1995 and trained to a bilateral cordon system.

^y Means of 12 years, 1987-1988; data collected on three vine plots, trained to a four-arm Kniffin system.

^x Berry weight each year was an average of 25 berries per three-vine plot.

^w Rating scale of 1 to 10 where 10 = best.

^v SSC = Soluble solids concentration.

^u Cluster weight each year was an average of five clusters per three-vine plot.

^t Cluster fill rating of 1 to 10 where 10 = very tight cluster.

^s Vines were balanced pruned to a 30 + 10 formula, with 30 buds left on the vine for the first pound of pruning wood and 10 buds for each subsequent pound.

Table 2. Yield, berry, and cluster weights, and soluble solids of three table grape cultivars grown at two locations in Arkansas.^z

Cultivar	1997				1998			
	Yield (ton/acre)	Cluster wt. g	Berry wt. g	Soluble solids (%)	Yield (ton/acre)	Cluster wt. g	Berry wt. g	Soluble solids (%)
<i>Clarksville</i>								
Jupiter	7.5 a ^y	154.0 a	4.3 a	21.2 a	13.2 a	194.7 a	4.5 a	20.6 a
Mars	4.4 b	77.0 b	3.9 ab	18.7 b	12.0 a	144.9 b	3.5 b	19.2 b
Venus	8.3 a	185.6 a	3.4 b	16.6 c	11.6 a	163.0 b	3.3 b	18.0 c
<i>Fayetteville^x</i>								
Jupiter	-	221.0 a	4.0 a	18.1 a	-	-	3.9 a	16.5 a
Mars	-	199.1 a	3.5 a	15.6 b	-	-	3.5 a	14.2 b
Venus	-	248.6 a	3.6 a	16.1 b	-	-	3.6 a	14.0 b

^z Data were collected from four three-vine plots planted in 1995 and trained to a bilateral cordon system. Yields are based on 544 vines/acre.

^y Mean separation within location by *t*-test ($P \leq 0.05$).

^x Yield data from Fayetteville not presented in 1997 because of crop reduction from frost after budbreak; 1998 yield and cluster weight data not presented because of crop reduction from green June beetle infestation.



‘NEPTUNE’ SEEDLESS TABLE GRAPE PROVIDES NEW WHITE GRAPE OPTION

John R. Clark and James N. Moore¹

IMPACT STATEMENT

Table grape production is a viable, high-value option for grape and small-fruit producers in Arkansas. Arkansas has a long tradition of juice and wine grape production, but table grape production was only begun in the late 1970s and early 1980s, based on the introduction of ‘Venus’ by the University of Arkansas. Subsequent cultivars released by the program have helped in the development of this industry, but growers continue to need new cultivar improvements. ‘Neptune’ is the sixth in a series of seedless table grapes released from the University of Arkansas. The release of this new cultivar is intended to expand the options for Arkansas and eastern-U.S. table grape growers, specifically providing a new white seedless option.

BACKGROUND

The University of Arkansas table grape breeding program was begun by Dr. James N. Moore in 1964 and has provided several cultivar options for Arkansas growers, including the above-mentioned ‘Venus’ and also ‘Reliance’, ‘Mars’, and ‘Saturn’. Growers continue to need

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new cultivars with a variety of plant and fruit characteristics, including high yields, resistance to fruit cracking, more complete seedlessness, white skin, and non-slip-skin fruit texture. 'Neptune' exhibits a number of improvements and provides a new white-fruited option for growers of eastern-U.S. table grapes.

RESEARCH DESCRIPTION

'Neptune' was selected in a seedling vineyard at the University of Arkansas Fruit Substation, Clarksville, in 1988 and has been tested there and at Fayetteville (Arkansas Agricultural Research and Extension Center). Kniffin and bilateral cordon training systems were used in the testing of 'Neptune'. Vines were trickle irrigated, had fungicide and insecticides applied according to a commercial pest control program, received annual preemergence and postemergence herbicide applications, and were fertilized annually with nitrogen.

DESCRIPTION AND PERFORMANCE

Berries of 'Neptune' are elliptic to slightly ovate and averaged 2.5 g over 8 years, larger than 'Reliance' but smaller than 'Venus' (Table 1). Berry size exceeded 4 g in some years. Berries of 'Neptune' are non-slip-skin and seedless, although small, soft seed traces can be occasionally observed. Flavor is fruity and pleasant but not the foxy flavor characteristic of *Vitis labrusca* cultivars. Skin thickness is moderate, similar to that of 'Venus'. Fruit cracking has never been observed with 'Neptune', even in years when severe cracking was seen on 'Reliance' and other crack-susceptible genotypes. Soluble solids of 'Neptune' averaged 19.7% over the 8-y study period, higher than that of 'Venus' and 'Mars', but lower than 'Reliance' (Table 1).

Clusters of 'Neptune' are conical and often have a small shoulder, and are very attractive. Cluster weight averaged 345.2 g over 7 years (Table 1). Cluster weight of 'Neptune' in replicated trials ranged from 200 to 610 g, larger than 'Venus' or 'Mars' in all comparisons (Table 2). Cluster fill ratings averaged 9.3 for 'Neptune', higher than the ratings of other cultivars (Table 1). Shatter of berries from the clusters at maturity has not been observed. In addition, clusters have hung well on the vines after achieving full maturity and have shown little shatter in handling after harvest.

Yields of 'Neptune' were usually lower than those for 'Venus' and 'Mars' at Clarksville but similar or higher than those cultivars at Fayetteville in 1997 and 1998 (Table 2). In 1999, yield at Fayetteville was comparable to that of 'Venus' and exceeded that of 'Mars' (data not

shown). A closer vine spacing (8 ft) within the row might be considered as a method to increase per acre yields for this cultivar, since it does not exhibit high vigor. Crop ratings, taken over 8 years, were generally similar for 'Neptune' compared with the other cultivars under evaluation, indicating consistent cropping during the evaluation period (Table 1). In only 2 of the 8 years of crop evaluation was a crop rating (at the time of fruit maturity) of less than 7 (on a 10-point scale with 10 being a full crop) recorded for 'Neptune'. A rating of 5 was given in 1992 following a mid-winter low of 10 °F and a late-spring freeze of 22 °F near bud break, and a rating of 2 was given in 1996 following a mid-winter low of 1 °F and a late-spring freeze of 10 °F, again near bud break. 'Neptune' vines have not been evaluated for the effects of flower cluster thinning. However, this practice is currently not encouraged due to natural cluster fill of 'Neptune', and flower cluster thinning could lead to excessive berry tightness of the clusters.

The average maturity or harvest date of 'Neptune' was 4 August at Clarksville, and it is considered a mid-season maturity cultivar (Table 1). 'Neptune' ripened 17 days later than 'Venus', 7 days later than 'Reliance', and 3 days earlier than 'Mars'. Budbreak of 'Neptune' is similar to 'Venus' and 4 days earlier than 'Mars' (Table 1).

Vines of 'Neptune' have medium vigor, and average vigor rating was 7.1 compared to the more vigorous cultivars 'Reliance' (8.1) and 'Mars' (9.0) (Table 1). Pruning weight for 'Neptune' was less than for 'Venus' or 'Mars'. Growth habit of 'Neptune' is semi-upright, and not as procumbent as most of the other Arkansas-developed cultivars. 'Neptune' shoots mature similar to 'Venus' but not as early as 'Mars'. Overall, hardiness of 'Neptune' appears similar to that of 'Venus' but not as hardy as 'Mars' or 'Reliance'. However, testing in other locations have not been conducted. 'Neptune' had a full crop in 1997 following a mid-winter low of 1 °F, so hardiness appears to be good.

'Neptune' has shown moderate resistance to the diseases black rot and anthracnose in field conditions and these diseases have not been observed on this cultivar under the commercial fungicide program utilized during evaluation. Slight to moderate infections of powdery mildew on leaves were observed in 2 of 8 years of evaluation, but no berry cracking resulted from powdery mildew. Downy mildew was observed on 'Neptune' in 2 of 8 y, and susceptibility to downy mildew appears similar to that of 'Venus'. However, downy mildew has not been a concern with the utilization of proper fungicides.

'Neptune' is recommended for trial where other eastern U.S. table grape cultivars are adapted. An application for a plant patent has been filed for 'Neptune' and propagation is restricted to nurseries licensed to propagate this new cultivar.

ACKNOWLEDGMENTS

We thank Kenda Woodburn, Andy Allen, Effie Gilmore, David Gilmore, Paula Watson, Gina Fernandez, Kelly Irvin and Maurus Brown for assistance in data collection during the evaluation of 'Neptune'.

Table 1. Plant and fruit characteristics of four table grape cultivars grown at the University of Arkansas Fruit Substation, Clarksville.

Characteristic	Neptune	Mars	Reliance	Venus
Date				
Budbreak ^z	25 Mar.	29 Mar.	-	25 Mar.
Harvest ^y	04 Aug.	07 Aug.	28 July	18 July
Berry				
Weight (g) ^{xw}	2.5	2.8	2.3	2.9
Flavor ^{vv}	8.0	8.2	9.4	7.9
SSC (%) ^{wu}	19.7	17.8	22.3	17.5
Cluster				
Weight (g) ^{ls}	345.2	220.6	294.5	193.1
Fill ^r	9.3	7.7	8.3	7.4
Plant				
Crop ^{wv}	7.3	7.5	8.0	6.8
Health ^{wv}	7.6	8.9	8.9	7.1
Vigor ^{wv}	7.1	9.0	8.1	7.1
Pruning wt./vine (lb) ^{2q}	1.1	4.1	-	1.5

^z Means of two years, 1997 and 1998, recorded on 12 vines planted in 1995 and trained to a bilateral cordon system.

^y Means of 9 years, 1990-1998; data collected on three-vine plots, trained to a four-arm Kniffin system.

^x Berry weight each year was an average of 25 berries per three-vine plot.

^w Means of 8 years, 1991-98; data collected on three-vine plots, trained to a four-arm Kniffin system.

^v Rating scale of 1 to 10 where 10 = best.

^u SSC = soluble solids concentration.

^t Means of 7 years, 1991-95 and 1997-98; data collected on three-vine plots, trained to a four-arm Kniffin system.

^s Cluster weight each year was an average of five clusters per three-vine plot.

^r Cluster fill rating of 1 to 10 where 10 = very tight cluster.

^q Vines were balanced pruned to a 30 + 10 formula, with 30 buds left on the vine for the first pound of pruning wood and 10 buds for each subsequent pound.

Table 2. Yield, berry and cluster weights and soluble solids of three table grape cultivars grown at two locations in Arkansas.^z

Cultivar	1997				1998			
	Yield (ton/acre)	Cluster wt. g	Berry wt. g	Soluble solids (%)	Yield (ton/acre)	Cluster wt. g	Berry wt. g	Soluble solids (%)
<i>Clarksville</i>								
Neptune	4.9 b ^y	241.0 a	3.3 a	22.3 a	5.8 b	200.0 a	2.9 b	22.6 a
Mars	4.4 b	77.0 c	3.9 a	18.7 b	11.9 a	144.9 b	3.5 a	19.2 b
Venus	8.3 a	185.6 b	3.4 b	16.6 c	11.6 a	163.0 b	3.3 a	18.0 c
<i>Fayetteville^x</i>								
Neptune	3.3 a	610.0 a	4.3 a	19.8 a	4.5 a	336.7 a	3.9 a	15.7 a
Mars	1.6 a	199.1 b	3.5 a	15.6 b	2.7 b	163.3 b	3.5 a	14.2 bc
Venus	1.5 a	248.6 b	3.6 a	16.1 b	1.5 b	167.5 b	3.6 a	14.0 c

^z Data were collected from four, three-vine plots planted in 1995 and trained to a bilateral cordon system. Yield is based on 544 vines/acre.

^y Mean separation within location by *t*-test ($P \leq 0.05$).

^x Yield was reduced due to frost damage to buds and emerging shoots in Fayetteville in 1997; 1998 yield on 'Venus' reduced approximately 22% from green June beetle feeding damage.

EFFECTS OF PLANT GROWTH REGULATORS ON TISSUE CULTURE OF 'NAVAHO' AND PRIMOCANE-FRUITING BLACKBERRY SELECTIONS

Matthew C. Pelto and John R. Clark¹

IMPACT STATEMENT

Tissue culture is a common method of propagating blackberries. However, various cultivars or genotypes often have different tissue culture media requirements for maximum success. This study evaluated five concentrations of BA [*N*-(phenylmethyl)1*H*-purine-6-amined], with and without IBA (1*H*-indole-3-butyric acid) and GA₃ (gibberellic acid), to determine which concentration and combination of these plant growth regulators (PGRs) enhanced microshoot proliferation for 'Navaho' and five Arkansas primocane-fruited (APF) selections. The best microshoot proliferation across genotypes was observed at 4.0 mg/L of BA without IBA and GA₃. It was also found that microshoots rooted directly into a mixture of vermiculite, peat, and perlite when treated with a common rooting compound. This information enhances the ability of research and nursery industry facilities to rapidly produce large numbers of 'Navaho' and primocane-fruited blackberries.

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BACKGROUND

In vitro, single-node tissue culture has been used to successfully propagate the erect thornless blackberry 'Navaho', but only three to five new microshoots were produced from an original single node (Fernandez and Clark, 1991). Higher levels of shoot proliferation are typically achieved for other plant species and other blackberry genotypes using shoot tips as the culture tissue; therefore, the use of this tissue plant should produce higher proliferation levels in 'Navaho' as well. Our goal was to maximize microshoot proliferation from blackberry shoot tips by using various PGR concentrations and combinations.

RESEARCH DESCRIPTION

In January 1998, actively growing shoot tips from 'Navaho' and five APF selections (APF-4, APF-8, APF-12, APF-13, and APF-14) were collected from source plants. During disinfestation, the shoot tips were trimmed to 1 to 2 cm (0.39 to 0.78 in.) and dipped in a solution of 70% ethanol and five drops of Tween-20 for 1 minute. The shoots were then immersed for 5 minutes in 100 mL of 0.1 % w/v benomyl 50WP (0.05 % methyl-1-[butylamino]carbonyl]-*H*-benzimidazol-2 -carbamate) and agitated for 15 minutes in 100 mL of a solution consisting of 15% v/v chlorine bleach (0.79% w/v sodium hypochlorite) and five drops of Tween-20.

After disinfestation, the shoot tips were transferred to a laminar vertical flow cabinet, where they were rinsed three times in autoclaved, deionized water, trimmed to remove damaged tissue, and aseptically transferred to 20 x 150 mm Bellco culture tubes (one shoot tip per culture tube) containing 10 mL of a PGR-free liquid medium. This initiation medium consisted of half-strength Murashige and Skoog (1962) basal salts with the minimal organic supplements described by Linsmaier and Skoog (1965) and 30 g/L sucrose. The pH of the medium was adjusted to 5.8 with 1.0 M sodium hydroxide prior to autoclaving (Broome and Zimmerman, 1978). The medium served to decrease or prevent phenolic blackening and to detect cultures contaminated with fungi or bacteria. Shoot-tip cultures were maintained for 4 days in the liquid initiation medium under bright white fluorescent lights for a 16-hour day at 24 °C (75.2 °F) while being gently agitated on a rotary shaker.

For all treatments, PGRs were filter-sterilized and added to the medium after it was autoclaved at 121 °C (250 °F) at 15 psi for 15 minutes. All media treatments contained full-strength Murashige and Skoog (1962) basal salts, the Linsmaier and Skoog (1965) organics (100 mg/L *myo*-inositol and 0.4 mg/L thiamine HCL), 80 mg/L adenine

hemisulfate, 170 mg/L sodium phosphate monobasic, 30 g/L sucrose, and 7 g/L agar (Anderson, 1980). The medium was dispensed in 20-mL aliquots into 125-mL glass jars, and these culture vessels were capped with Magenta-B lids. Cultures were maintained at 22 °C (71.6 °F) under fluorescent lights ($53 \mu\text{mol m}^{-2} \text{s}^{-1}$) for a 16-hour photoperiod. After the cultures were transferred to the proliferation medium, the Magenta-B cover and the vessel were placed between a single layer of Parafilm to reduce moisture loss during the subculture period.

The experiment was a 5×2 factorial, testing five BA levels and two IBA and GA_3 levels in which all treatments were arranged in a completely randomized design with six replications (one replication consisted of one shoot tip per culture vessel) per treatment. Experimental BA concentrations were 0.0, 1.0, 2.0, 4.0, and 10.0 mg/L, and IBA concentrations were 0.0 and 0.1 mg/L. GA_3 was added at a concentration of 0.1 mg/L to all treatments that included IBA. After one 35-day subculture period, the microshoot clumps were separated, and usable microshoots (0.2 in. in length) were counted under aseptic conditions.

The experiment was repeated once, and shoots produced by a given treatment were used as replicates for that same treatment in the next subculture. Microshoot number data were analyzed by SAS with mean separation by least significant difference.

After data collection at the end of the second 35-day subculture period, microshoots were dipped in Rootone F (0.067% naphthylacetamide, 0.033% 2-methy-1-naphthylacetic acid, 0.057% 1*H*-indole-3-butyric acid, and 4.000% tetramethylthiuramdisulfide) and planted directly in covered containers filled with a 4:2:1 mixture of vermiculite, peat, and perlite.

FINDINGS

The highest level of shoot proliferation for 'Navaho' and the APF selections was attained with 4.0 mg/L of BA without the addition of IBA and GA_3 (Fig. 1). When cultured with 2.0 mg/L of BA, 0.1 mg/L of IBA, and 0.1 mg/L of GA_3 , shoot proliferation for all genotypes fell within the range of three to five microshoots per original explant, similar to the finding of Fernandez and Clark (1991). At the 2.0-mg/L BA concentration without IBA and GA_3 , the average shoot proliferation was higher than reported by Fernandez and Clark (1991) (Fig. 1). Similarly, the average microshoot proliferation at 4.0 mg/L of BA with IBA and GA_3 ranged from three to five shoots per initial culture, but the average shoot proliferation at the same concentration without IBA and GA_3 greatly exceeded the range observed by Fernandez and Clark (1991).

IBA and GA₃ significantly reduced shoot proliferation at the best BA concentration (4.0 mg/L).

When total shoots were averaged across all PGR concentrations, APF-8 exhibited the highest level of proliferation. APF-12, APF-13, APF-14, and 'Navaho' were not significantly different from one another, and APF-4 had a significantly lower average shoot yield than APF-8, APF-12, and APF-14 but was not significantly different from APF-13 and 'Navaho' (data not shown).

'Navaho' microshoots rooted in 2 wk on an in vitro medium that included 0.1 mg/L of IBA and 0.1 mg/L of GA₃ but lacked the BA and activated charcoal reported earlier (Fernandez and Clark, 1991). This is an interesting result, since the medium also included adenine hemisulfate, which has been reported to inhibit rooting (Anderson, 1980). Further, it was found that in vitro rooting was unnecessary, since the 'Navaho' and APF selection microshoots could be efficiently and rapidly induced to root by dipping them in Rootone F and planting them directly in the 4:2:1 mixture of vermiculite, peat, and perlite within a plastic-wrapped container. 'Navaho' microshoots started rooting after 4 days, and the APF selections usually required 7 days to begin rooting. The time involved in rooting with Rootone F was less than the 2 wk required for rooting on either in vitro rooting medium.

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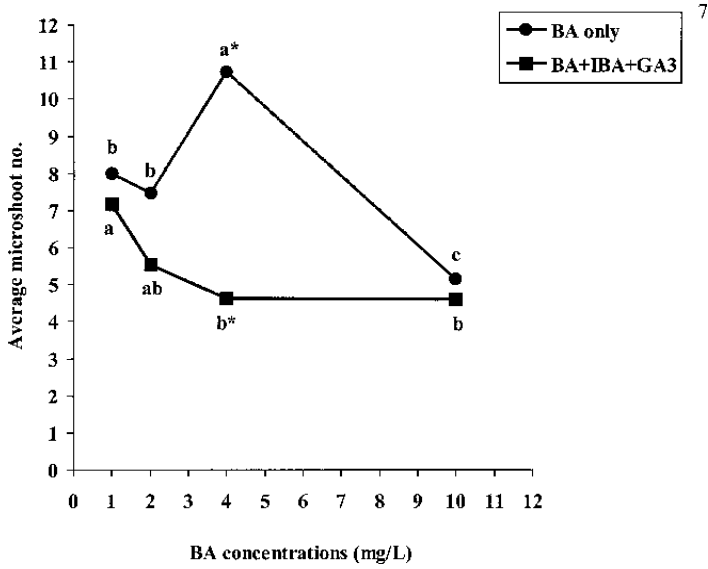
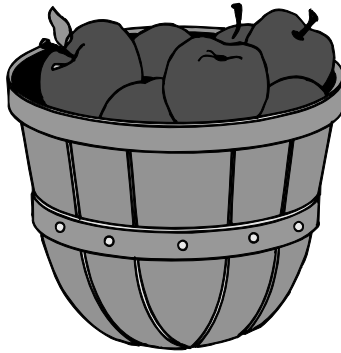


Figure 1. Effect of PGR treatments on microshoot proliferation of the APF selections and 'Navaho'. Data points on the same line with the same letter are not significantly different as determined by LSD ($P \leq 0.05$). The asterisks (*) indicate the only BA concentration in which the treatment without 0.1 mg L^{-1} IBA and 0.1 mg L^{-1} GA₃ is significantly different from the treatment containing the two other PGRs as determined by LSD ($P \leq 0.05$).



EFFECT OF CULTIVAR, PREPLANT TREATMENT, AND FERTILIZER APPLICATION METHOD ON GROWTH AND PERFORMANCE OF APPLE: EIGHTH-YEAR RESULTS

Curt R. Rom¹

IMPACT STATEMENT

Preplant treatments of methyl bromide fumigation or winter solarization have improved tree survivability, growth, and yield. Method of fertilizer application also has significant growth and yield implications. A study was conducted to evaluate the effects of preplant and fertilizer treatments on high-density apple orchards in Arkansas. Immediately replanting an apple on an existing orchard site without applying preplant treatments to reduce the incidence of apple replant disorder, or not fertilizing a tree during its establishment year, resulted in significantly reduced tree survival and yield, even in the eighth production season, 1999. These results have implications for the establishment of new high-density orchards in Arkansas.

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BACKGROUND

High-density apple orchards are planted on the basis of the potential for significantly higher earlier yields compared with traditional orchards. Two important aspects of maximizing the potential of high-density orchards are how the soil is treated prior to planting and the method of fertilizer application during the establishment years. This study evaluated these orchard management factors.

Apple trees planted in soils that previously grew apples often display apple replant disorder (ARD). ARD is a complex of biotic, abiotic, and edaphic factors that lead to reduced tree growth, lower yields, and premature tree death. It has been suggested that ARD can be reduced by preplant soil fumigation, especially with methyl bromide. However, because of the imminent elimination of this fumigant, alternative soil treatments are being sought. One possible solution is to use passive soil solarization by covering soils with polyethylene films and allowing solar heat to pasteurize the soil.

High-density orchard fertilization is not well understood, neither the amount nor the method of fertilization to optimize tree growth and fruiting. Fertiligation has been suggested as an efficient method for the delivery of nutrients to the plant rhizosphere. Recently, reports have indicated that fall application of nitrogen fertilizers may improve fruit set and early fruit growth while limiting excessive vegetative growth.

RESEARCH DESCRIPTION

A study was conducted to evaluate the influences of preplant soil treatments and fertilizer delivery on the growth and productivity of two apple cultivars, 'Jonee' and 'Smoothie Golden Delicious'. Immediately after harvest, the existing apple orchard was removed on 15 September 1990, and efforts were made to remove all roots. The soil was then chisel-ripped to a depth of 19.7 in. in four directions (longitudinally, latitudinally, and diagonally). Agricultural lime (12.3 lb/ha) was incorporated through discing to raise the soil pH to approximately 6.2. On 7 November 1990, beds 3.9 ft wide, 401.5 ft long, and 7.8 in. high were built. A study was established as a split-split plot with whole plots being cultivar, the split plot as preplant treatments, and the split-split plot as fertilizer treatments. The field had six replicated main plots running north and south. The soil replant treatments were randomly assigned within each cultivar plot. Fertilizer treatments were randomly assigned as single-tree experimental units within each of the 36 soil preplant treatment plots. A total of 216 trees were planted comprising six replications of each factorial combination. Data of tree growth, yield, foliar nutrient content, and soil nutrient status were

collected annually and analyzed using SAS. The least-squares mean with the PDiff option of a *t*-test comparison of variables among all treatments was utilized.

The three preplant treatments established were an untreated control (C), a winter solarization treatment (WS), and a fumigated treatment (F). For the WS and F treatments, row beds were covered with 1.5 mil black polyethylene film. In the F treatments, two 1.5-lb canisters of methyl bromide (Bromo-Gas with 2% chloropicrin) were dispensed under the film in November. The WS and F plots were left covered from November 1990 until tree planting the following spring.

Six fertilizer treatments were begun after tree planting in April 1991: (a) untreated control, (b) spring topdress, (c) fall topdress, (d) split (spring/fall) topdress, (e) spring fertigation, and (f) fall fertigation. An equal amount of nitrogen, phosphorus, potassium, and calcium was added for each fertilizer treatment. Fertilizer rates were increased annually with increasing tree age. Topdressings were made using a dry fertilizer formulation and scattered uniformly under the drip line of the tree. Fertigation treatments were applied with a soluble fertilizer formulation injected through a drip-emitter irrigation line with a single 15.1 l/h emitter per tree. In 1999, spring fertilizer consisted of 7.7 oz of N/tree supplied as calcium nitrate. Spring fertigation was applied in 10 equal treatments from 14 May until 12 July. Topdress applications were made 18 May. No fall fertilizer was applied in 1999, as the study was completed and terminated, but fall topdress and fertilizer treatments were applied in fall 1998: fertigation was applied in eight equal applications beginning 24 September (after harvest) until 5 November; topdress applications were made 5 November 1998.

FINDINGS

The data reported here are the main effects of the treatments for the terminal year of the study, 1999, when the trees were in their ninth growing season and had their eighth harvest (Table 1). Although statistical analysis indicated some interaction of treatments for a few variables, generally the greatest source of variation was the main plots, with the greatest percentage of variation due to cultivar, then fertilizer treatment, followed by preplant treatment (analysis not shown).

The cultivar 'Smoothie Golden Delicious' produced larger trees in tree height, spread, and trunk cross-sectional area (TCSA) than 'Jonee'. There was essentially no increase in tree height or spread for the two cultivars in 1999 compared with 1998 (data not presented), but the relative growth rate of TCSA increased 22% for 'Smoothie Golden Delicious' compared with 13% for Jonee. This was due to a relatively severe infection of fireblight, *Erwinia amylovora*, in 'Jonee' in 1999,

limiting growth. Average fruit size and total yield per tree were greater for 'Smoothee Golden Delicious' than 'Jonee'. However, there was no significant difference in yield efficiency, expressed as yield per cm² TCSA.

Trees in all preplant treatments had similar height and TCSA, but trees grown on plots fumigated in November 1990 were significantly wider than untreated controls. Average fruit size was heavier in F plots than in C, but there were no significant yield differences. It is interesting to note that F yields were significantly higher in previous years (data not reported), and in 1999 yields were 21% greater than controls.

Fertilizer treatment had no significant effect on tree height in 1999, but trees that had received spring fertigation were significantly narrower and had smaller TCSA than trees in other treatments. This was due to severe manganese toxicity, indicated by foliar analysis and apple measles symptomatology observed in years 3 and 4 due to significantly reduced soil pH in spring-fertigated plots. The low soil pH was attributed to use of ammonium nitrate as the nitrogen fertilizer source (1991-1993). After 1993, calcium nitrate fertilizers were used, and soil pH depression in spring-fertigated plots was not as precipitous. However, spring-fertigated trees annually had very high foliar levels, approaching toxicity, of manganese (data not presented). Similarly, fruit yield of spring-fertigated trees was less than other treatments, except fall-fertigation, which was intermediate, although fertilizer treatment had no effect on fruit size and yield efficiency.

Yields in 1999 were similar to 1998 but less than 1997 (data not presented) and were equivalent to approximately 400 bushels/acre. The lower yields than expected for this trial are explained by the treatment differences that reduced yields, especially the unfertilized or spring-fertigated and the control preplant treatments, and the behavior of the tree in response to the environment. The 1997 yields were large, approximately 630 bushels/acre (2.2 lb/tree), which were appropriate for the age of the tree. However, biennial bearing, a problem for both cultivars, reduced yields in 1998. Further, because of record hot temperatures during the 1998 growing season, return bloom in this trial and others was not at the trees' potential. Observation and rating of bloom density (data not reported) for 1997-1999, support this conclusion.

ACKNOWLEDGMENT

The contributions of Mr. R. Andy Allen, Research Specialist, to this project are acknowledged. Mr. Allen maintained plots and assembled data.

Table 1. Effect of cultivar, preplant treatment (1990), and annual fertilizer treatment on growth and yield of apples, 1999, Fayetteville.

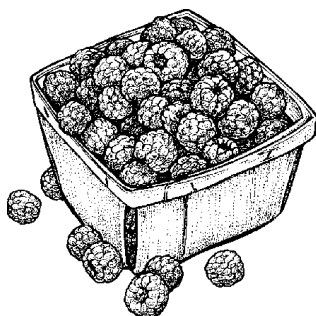
Treatment	Tree height (m) ^z	Tree width (m) ^y	TCSA ^x (cm ²)	Increase in TCSA (cm ²)	Average fruit wt. (g)	Total yield (kg)	Yield efficiency (kg/cm ²)
<i>Cultivar</i>							
Jonee	2.69 b	2.36 b	41.3 b	4.59 b	134.7 b	10.9 b	0.283 a
Smoothie	3.32 a	2.74 a	72.3 a	13.4 a	172.4 a	17.8 a	0.273 a
<i>Preplant treatment</i>							
Control	3.02 a	2.47 b	52.1 b	8.4 a	147.5 b	12.9 a	0.253 a
Solarization	2.95 a	2.54 ab	54.2 b	9.4 a	155.0 ab	13.8 a	0.305 a
Fumigation	3.04 a	2.64 a	64.1 a	9.1 a	158.1 a	16.3 a	0.277 a
<i>Fertilization treatment^w</i>							
Control	3.03 a	2.56 ab	61.9 a	8.9 abc	149.6 a	14.7 a	0.234 a
Spring Top	3.07 a	2.62 ab	59.8 ab	9.4 ab	156.9 a	16.0 a	0.286 a
Fall Top	3.07 a	2.66 a	63.2 a	10.1 a	154.0 a	16.3 a	0.288 a
Split Top	3.02 a	2.63 a	58.7 ab	9.6 ab	151.2 a	15.0 a	0.296 a
Spring Fert	2.84 b	2.33 c	42.3 c	7.4 c	157.7 a	10.8 b	0.283 a
Fall Fert	3.00 a	2.50 b	54.9 b	8.3 bc	151.8 a	13.2 ab	0.282 a

^z Mean separation within treatments and columns with a *t*-test by least squares means comparison among treatments, using the PDIFF option; means followed by different lowercase letters are significantly different from each other.

^y Tree width is the average of within-row and across-row widths at the widest point in each tree.

^x TCSA = trunk cross-sectional area at 9.8 in. above graft union.

^w Fertilizer treatments applied annually; top = topdress with dry formulated fertilizer, Fert = fertigation of soluble fertilizer through drip irrigation system.



LEAF GAS EXCHANGE CHARACTERISTICS OF RED RASPBERRY GERMPLASM IN A HIGH-TEMPERATURE ENVIRONMENT

Eric T. Stafne, John R. Clark, and Curt R. Rom¹

IMPACT STATEMENT

A limiting factor in plant adaptation can be the ability of a species to maintain photosynthesis (uptake of carbon dioxide, or CO₂) in high heat, as is common in the summer months in Arkansas and other southern states. The lack of adaptation of red raspberry cultivars developed in non-southern areas of the United States is likely due to this and other factors. This study was conducted to determine the effects of high heat (95 °F) on net CO₂ uptake, evapotranspiration, and stomatal conductance (g_s) for a number of raspberry genotypes. Carbon dioxide uptake ranged from 2.08 to 6.84 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and varied greatly among genotypes, indicating that diverse CO₂ uptake levels exist at high temperatures in raspberry germplasm. NC 296, a selection of *Rubus coreanus* from China, and 'Dormanred', a southern-adapted raspberry cultivar with *R. parvifolius* as a parent, had the highest CO₂ uptake. Evapotranspiration and g_s did not differ among genotypes. Our findings, coupled with plant performance in high heat conditions, can be used to identify potential raspberry germplasm for breeding southern-adapted red raspberry cultivars.

¹ All the authors are associated with the Department of Horticulture, Fayetteville.

BACKGROUND

Interest in the red raspberry (*R. idaeus*) in the southern states has increased recently (Clark and Rom, 1997), but the region suffers from a lack of southern-adapted cultivars with commercial quality (Moore, 1997). Currently available cultivars developed outside of the South are not well-adapted for several reasons, including lack of adaptation to high light intensities and hot summer temperatures (Moore, 1997). Traditionally, Southern Asia has been the source of *Rubus* plant material with tolerance to heat and drought. Unfortunately, commitment to the development of heat-tolerant, commercial-quality cultivars in North America has not been sustained. In addition, no efficient procedure exists to identify selections that are heat tolerant or to determine which species have the most to offer a breeding program. Gas exchange characteristics of *Rubus* germplasm may indicate adaptation to high heat conditions and may be useful for selecting breeding material.

The objectives of this study were to examine gas exchange characteristics among a broad range of genotypes that had not been studied previously and to determine whether gas exchange characteristics contribute to heat tolerance.

RESEARCH DESCRIPTION

Fourteen diverse genotypes from varying origins were used in an observational study (Table 1), and 18 genotypes were used in a replicated study (Table 2). Many of these genotypes are native to regions where summer conditions are hot and humid. Plants were potted in 1-gal pots in a commercial potting medium containing a controlled-release fertilizer and grown in the greenhouse for several months until the experiment was initiated. Plants were placed in three growth chambers on 22 May 1998 for the replicated study and 3 July 1998 for the observational study. Growth chamber temperatures were 95 °F (35 °C) during the daytime (16-h photoperiod) and 77 °F (25 °C) at night to approximate summer conditions in the southern United States.

Gas exchange measurements were taken 2 and 4 wk after the pots were placed in the growth chamber with a CIRAS-1 portable infrared gas analyzer (IRGA) and Parkinson leaf cuvette (2.5 cm²) on two leaves per primocane. Leaves were at 75-85% of full expansion at the time of measurement. Plants were watered as needed, and no water stress occurred prior to or during enclosure in the growth chamber. Measurements were taken on the same day of the week between 8 a.m. and 12 noon. Data for the replicated study was analyzed by SAS.

FINDINGS

For the observational study, the Oregon-USDA (ORUS) selections generally scored low for all dependent variables, indicating a lack of adaptation to high heat. The Louisiana genotypes were among the highest performers for all dependent variables, indicating better adaptation to the temperatures in our study. *R. innominatus* exhibited surprisingly high evapotranspiration and g_s rates (data not shown) in relation to its low CO_2 exchange rate.

'Dormanred' did not show as high a CO_2 exchange rate in the observational study as in the replicated study (Tables 1 and 2). This may be due to the later measurement dates or variation among plants used. Melcher 92-3-34 and 96-2-41, both having high CO_2 exchange rates in our study, are offspring from crosses that include at least one red raspberry parent with heat tolerance. Gas exchange measurements for these genotypes may reflect inherited heat tolerance properties from the parental material. Melcher 93-5-41 is a cross between OR 1030, an Oregon-developed red raspberry selection, and *R. occidentalis*, the North American black raspberry. It displayed lower rates for all variables compared with the other Melcher genotypes. This result is consistent with results seen among the ORUS selections in both studies.

Evapotranspiration and g_s did not differ among genotypes in the replicated study (data not shown). Average stomatal conductance declined from 234 to 157 $\text{mmol m}^{-2} \text{s}^{-1}$ from the second to the fourth week. Assimilation varied from a high of 6.84 for NC 296 to a low of 2.08 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for ORUS 1728-1 (Table 2). NC 296, 'Dormanred', 'Mandarin', and 'Jingu Jeugal' (S. Korean breeding program) displayed the highest CO_2 exchange rates. The ORUS series, all siblings, differed both within and among selections in which CO_2 exchange varied from 2.08 (ORUS 1728-1) to 4.59 $\mu\text{mol m}^{-2} \text{s}^{-1}$ (ORUS 1728-5). Even though all of the ORUS series were selected in Oregon and subjected to identical experimental conditions in this study, the variation expressed was significant.

Several genotypes in the replicated study were hybrids of *R. parvifolius*, but not the same clones. *R. parvifolius* is reported to be adaptable to high temperature (Moore, 1997). 'Dormanred', a *R. parvifolius* derivative, is adapted to the southern United States, and in this study exhibited a high CO_2 exchange rate, especially in comparison with ORUS 1728-1. This high CO_2 exchange rate may contribute to the adaptation of 'Dormanred' to high temperature. The wide range in CO_2 exchange among the 10 *R. parvifolius*-derived genotypes in our study may reflect variation in adaptation of *R. parvifolius* genotypes to high temperature or in their specific combining abilities in hybridizations with other non-*R. parvifolius* genotypes. It could also reflect the

fact that the parents of the ORUS series were selected under Pacific Northwest rather than Southern conditions. Variation in CO₂ exchange among offspring from the cross *R. parvifolius* x 'Tulameen' (ORUS 1728-1, 1728-4, and 1728-5) is noteworthy. Also, NC 296, ORUS 1725-1, and ORUS 1725-2, all of which had *R. coreanus* collected from the same Chinese location as a parent, differed considerably. NC 296 was selected in North Carolina, whereas ORUS 1725-1 and 1725-2 were selected in Oregon. This difference in environment of selection could have contributed to the difference in CO₂ exchange.

Although measurement of a larger range of genotypes would be needed to more precisely quantify the variation in CO₂ exchange in red raspberry germplasm, our data show that variability in CO₂ exchange exists among the genotypes tested. Also, CO₂ exchange is inhibited by nonstomatal factors at high temperatures, implying that photosynthetic activity is being controlled by physiological processes unrelated to stomatal function. Future studies should test the responses of the genotypes at high field temperatures to determine how they compare with those in a controlled environment.

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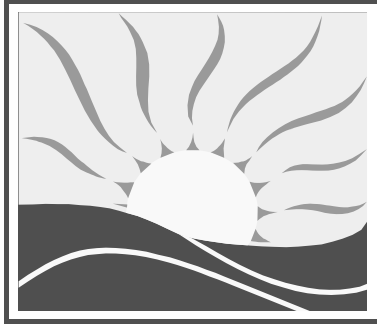
Table 1. Genotype, parentage, location where genotype was selected, and CO₂ exchange rates of raspberry germplasm at 35 °C for the observational study.

Parentage	Location	Genotype	CO ₂ exchange rates ($\mu\text{mol m}^{-2} \text{s}^{-1}$)
Bababerry x Dormanred	Louisiana	Melcher 92-3-34	5.73
Mandarin x Melcher 94-3-206	Louisiana	Melcher 96-2-41	4.60
Dorsett x <i>R. parvifolius</i>	Mississippi	Dormanred	3.64
OR 1030 x <i>R. occidentalis</i>	Louisiana	Melcher 93-5-41	3.10
<i>R. parvifolius</i> 1658-2236 x Tulameen	Oregon	ORUS 1730-4	2.65
(<i>R. innominatus</i> O.P.) x O.P.	N. Carolina	NC 405	2.25
	Jiangxi, Japan	<i>R. innominatus</i> (NC 1768)	1.83
<i>R. parvifolius</i> 1658-2236 x Tulameen	Oregon	ORUS 1730-6	1.73
[NC 86-14-1(<i>R. trivialis</i>) x Glen Prosen]	N. Carolina	NC 354	1.58
	Japan	<i>R. phoenicolasius</i>	1.58
<i>R. parvifolius</i> 1659-2239 x Tulameen	Oregon	ORUS 1728-2	1.45
<i>R. parvifolius</i> 1659-2239 x Tulameen	Oregon	ORUS 1728-3	1.30
<i>R. coreanus</i> 1634-1923 x Meeker	Oregon	ORUS 1725-3	0.55
<i>R. coreanus</i> 1634-1923 x Meeker	Oregon	ORUS 1725-6	0.50

Table 2. Genotype, parentage, location where genotype was selected, and CO₂ exchange rate of raspberry germplasm at 35 °C for the replicated study.

Parentage	Location	Genotype	CO ₂ exchange rates (μmol m ⁻² s ⁻¹)
<i>R. coreanus</i> (RUB 1635 O.P.)	SW China	NC 296	6.84 a ^z
Dorsett x <i>R. parvifolius</i>	Mississippi	Dormanred	6.42 ab
(<i>R. parvifolius</i> x Taylor) x Newburgh	N. Carolina	Mandarin	5.69 abc
<i>R. crataegifolius</i>	S. Korea	Jingu Jeugal	5.04 bcd
NC 177 (<i>R. innominatus</i> O.P.) x Comox	N. Carolina	NC 365	4.68 cde
<i>R. parvifolius</i> 1659-2239 x Tulameen	Oregon	ORUS 1728-5	4.59 cde
	Jiangxi, China	<i>R. innominatus</i>	4.47 cdef
<i>R. parvifolius</i> 1658-2236 x Tulameen	Oregon	ORUS 1730-5	3.98 cdefg
	Honshu, Japan	<i>R. parvifolius</i>	3.73 defg
<i>R. parvifolius</i> 1659-2239 x Tulameen	Oregon	ORUS 1728-4	3.39 defg
<i>R. parvifolius</i> 1658-2236 x Tulameen	Oregon	ORUS 1730-2	3.35 defg
<i>R. parvifolius</i> 1658-2236 x Tulameen	Oregon	ORUS 1730-3	3.32 efg
	Honshu, Japan	<i>R. illecebrosus</i>	3.28 efg
<i>R. coreanus</i> 1634-1923 x Meeker	Oregon	ORUS 1725-1	3.15 efg
<i>R. parvifolius</i> 1658-2236 x Tulameen	Oregon	ORUS 1730-1	2.71 fg
Sunrise x Taylor	Maryland	Sentry	2.60 fg
<i>R. coreanus</i> 1634-1923 x Meeker	Oregon	ORUS 1725-2	2.58 fg
<i>R. parvifolius</i> 1659-2239 x Tulameen	Oregon	ORUS 1728-1	2.08 g

^z Mean separation by *t*-test, $P \leq 0.05$. n = two to three replicate plants/genotype; two sample leaves/replication.



BERMUDAGRASS CONTROL WITH ARSENAL

John Boyd¹ and Brian N. Rodgers²

IMPACT STATEMENT

Experiments were conducted during 1998-1999 to evaluate the herbicide Arsenal (imazapyr) for bermudagrass control. In the 1998 study, Arsenal controlled bermudagrass ($\geq 93\%$) at either 1.0 or 2.0 qt/acre, with the 2.0 qt/acre rate providing slightly more consistent control. Three applications of Roundup Pro at 2.0 qt/acre were needed to provide equivalent control. Results from the 1999 study were very consistent with the 1998 results. In each experiment, 0.5 qt/acre of Arsenal was insufficient for bermudagrass control. During each year, tank-mixing 2.0 qt/acre Roundup Pro with Arsenal at 0.5, 1.0 and 2.0 qt/acre did not improve control over Arsenal alone, and mixing Finale at 4.0 qt/acre with 1.0 qt/acre Arsenal reduced control by 70% compared with Arsenal alone.

BACKGROUND

Bermudagrass is the most important weed in Arkansas sod production. Eradication of bermudagrass is also a major obstacle at other turfgrass sites in the South that are being converted to another species or a different bermudagrass variety. Previous research with

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Roundup Pro (Johnson, 1988) showed that three applications of Roundup were required over a single growing season to give complete bermudagrass control. Increasing the rate of Roundup did not reduce the number of applications required for complete control (Johnson, 1988). Earlier research with Arsenal (Boyd, 1991) showed that 1.5, 2.0 and 3.0 qt/acre of Arsenal, applied in September, provided 85%, 89%, and 97% control, respectively, of common bermudagrass 1 year after treatment. Research conducted on a sod farm in Alabama (Griffin, 1994) reported that 1.5 qt/acre of Arsenal gave $\geq 90\%$ control and 2 qt/acre of Arsenal gave 100% control of common bermudagrass. One objective of the current study was to determine whether 'Tifway' bermudagrass could be controlled with a single herbicide application. Because Arsenal has extended residual activity, the other goal was to determine whether the rate of Arsenal required for complete bermudagrass control could be reduced by tank-mixing with other herbicides.

RESEARCH DESCRIPTION

The research sites were on an established 'Tifway' hybrid bermudagrass sod field at Winrock Grass Farm in central Arkansas. Initial herbicide applications were made during late May of 1998 and 1999. The carrier volume was 20 gal/acre, and a nonionic surfactant at 0.5% v/v was added to all treatments. Both studies were arranged in a randomized block design with four replications and a plot size of 6 by 10 ft. The soil texture was a silt loam with 43% sand, 39% silt, and 18% clay, a pH of 4.7, and a cation exchange capacity (CEC) of 6. The site was not irrigated; herbicide applications were timed to coincide with active growth of the bermudagrass. Visual ratings were conducted approximately every 30 days during the growing season. Total rainfall was 42 in. during the 1998-1999 trial and 14 in. during the 5-month evaluation period for the trial initiated in 1999.

FINDINGS

Our results with Arsenal (Table 1) were consistent with those reported earlier (Boyd, 1991, Griffin, et. al., 1994). The 2.0 qt/acre rate of Arsenal was needed to give complete bermudagrass control, but the level of control with 1.0 qt/acre was not statistically different. Adding Roundup (2 qt/acre) to Arsenal did not improve control over Arsenal alone, and tank-mixing 4.0 qt/acre of Finale with Arsenal reduced control severely. Overall control was generally better in this study than our earlier Arsenal work (Boyd, 1987). Possible reasons for this variation are the difference in application timing (spring vs. fall), mowing

height differences between pasture and sod farms, application volume (10 vs. 20 gal/acre), or the relative Arsenal tolerance of common bermudagrass compared with 'Tifway'.

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ACKNOWLEDGEMENTS

Thanks to Winrock Grass Farm, Frank Whitbeck, Arnie Jester, and Calvin Taber for their support.

Table 1. 'Tifway' hybrid bermudagrass control with Arsenal 1998-1999.

Herbicide	Product rate/acre	Applications	1998-1999 ^y	1999 ^x
			336 DAIT ^w	152 DAIT
			————-% Control ^z ————	
Arsenal	2 qt	1	100 a ^v	100 a
Arsenal + Roundup Pro	2 qt + 2 qt	1	98 a	98 a
Roundup Pro	2 qt	3	96 a	100 a
Arsenal + Roundup Pro	1 qt + 2 qt	1	95 a	92 a
Arsenal	1 qt	1	93 a	91 a
Arsenal + Roundup Pro	1 pt + 2 qt	1	68 b	63 b
Arsenal + Finale	1 qt + 4 qt	1	33 c	33 c

^z Based on a 0 to 100 scale where 0 = no control and 100 = complete control.

^y Application Dates: 29 May 1998, 13 July 1998, and 2 October 1998.

^x Application Dates: and 21 May 1999, 13 July 1999, and 14 September 1999.

^w Days after initial treatment.

^v Means within each column followed by the same letter are not significantly different according to the Duncan's multiple range test ($P \leq 0.05$).



TURFGRASS SEED GERMINATION AS INFLUENCED BY TEMPERATURE AND PLANT GROWTH REGULATORS

D.E. Longer, D.M. Oosterhuis, and R. Nanayakara¹

IMPACT STATEMENT

Research was conducted to determine the effects of temperature and the plant growth regulator PGR IV on germination and seedling growth of six turfgrass species. Seeds of each species were placed in paper germination pouches and germinated in an incubator at 10, 15, 20, 25, or 30 °C for a period of 21 days. Duplicate samples were treated with PGR IV, a commercially available plant growth regulator consisting of a proprietary blend of indole butyric acid and gibberellic acid and a fermentation broth. PGR IV had no influence on the percentage of germination of any species but did increase root and shoot dry weight in tall fescue and perennial ryegrass.

BACKGROUND

Seed germination is influenced by oxygen availability, water, and proper temperature. For optimal germination, most grass species also require exposure to light. Both cool- and warm-season grass species have cardinal germination temperatures. These values are determined for each species by conducting germination tests over a range of tem-

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peratures, spaced at small temperature intervals. Although numerous commercial products have claimed to enhance germination for a wide variety of plant species, very few have proven effective. Several new categories of germination-enhancing plant growth regulators have proven effective in field crops but have not been tested on turfgrass species. A study was conducted to determine the influence of a plant growth regulator on the germination temperature requirements of six turfgrass species.

RESEARCH DESCRIPTION

The grasses studied were common bermudagrass, Kentucky bluegrass, tall fescue, perennial ryegrass, creeping bentgrass, and centipede grass. Each species was tested at six different temperatures, 5, 10, 15, 20, 25 and 30 °C. Within each temperature treatment, seeds were either treated with PGR IV or untreated. There were three replications per treatment.

Specially prepared germination packets were used to germinate the seeds in a controlled climate chamber. The plant growth regulator (PGR IV, Microflow Corp, Lakeland, Fla.) solution was prepared by using 6.2 µL in 2 L of distilled water. Twenty milliliters of PGR IV solution was added to the germination paper and allowed to air dry. Each packet contained 50 seeds and was considered an experimental unit. Germination packets were set in plastic trays, water was added to the plastic trays, and the trays were placed in a temperature-controlled climate chamber. On day 14, the percentage of germination was determined, and on day 21, the seedlings were harvested for root and shoot dry weight.

FINDINGS

Application of PGR IV did not influence germination percentages for any grass species at any temperature (data not shown). The warm-season species, common bermudagrass and centipedegrass, had poor germination at temperatures below 25 °C. Even at 30 °C, germination values were still considerably lower in warm-season than cool-season species.

Creeping bentgrass and Kentucky bluegrass demonstrated a rapid increase in germination as temperatures increased from 10 to 15 °C, but as in the other species, no interaction with the growth regulator was detected.

A significant ($\alpha = 0.05$) species x temperature x growth regulator interaction was detected for shoot and root dry weights. Germination and growth of common bermudagrass, creeping bentgrass, and

centipedegrass were not affected by PGR IV.

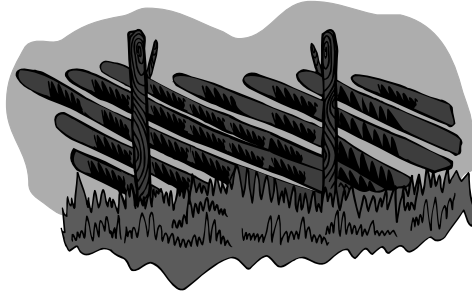
Significant PGR IV treatment effects were found in tall fescue and perennial ryegrass (Table 1). Root and shoot dry weight was greater for PGR IV-treated tall fescue than for the untreated control at 15 °C, and treated tall fescue seeds produced more dry weight than the control at every temperature (Table 1). Similar increases due to PGR IV were found in perennial ryegrass except at 25 °C.

PGR IV positively influenced the root and shoot dry weight accumulation patterns of two cool-season turfgrass species; tall fescue and perennial ryegrass. The data also indicate that more growth occurs at cooler temperatures in treated seedlings than in the controls. From a practical standpoint, PGR IV would be valuable when applied to tall fescue and/or perennial ryegrass seed that is typically sown in the cool seasons of spring and fall.

Table 1. Root and shoot dry weight of six turfgrass species at five temperatures with and without PGR IV.

Species	PGR IV	Germination temperatures				
		10 °C	15 °C	20 °C	25 °C	30 °C
		(mg)				
Common bermuda	+	0	0	0	0	0
	-	0	0	0	0	0
Kentucky bluegrass	+	0	0	1.79	-	-
	-	0	0	0.97	-	-
Tall fescue	+	1.21 ^z	1.69	2.28	3.23	2.44
	-	0.28	0.40	1.85	2.22	2.10
Perennial ryegrass	+	1.39	1.54	2.00	2.47	2.49
	-	1.15	1.31	1.91	2.51	1.93
Creeping bentgrass	+	0	0	0	0	0
	-	0	0	0	0	0
Centipedegrass	+	0	0	0	0	0
	-	0	0	0	0	0

^z Significant differences ($P < 0.05$) existed in tall fescue and perennial ryegrass between treated and untreated plots over the entire temperature range.



COLD TOLERANCE OF ‘TIFTON 419’ BERMUDAGRASS AS AFFECTED BY LATE-SEASON NITROGEN APPLICATIONS AND TRINEXAPAC-ETHYL (Primo)

Michael D. Richardson and John R. Bailey III¹

IMPACT STATEMENT

Hybrid bermudagrasses occasionally suffer significant damage when below-normal winter conditions occur. In an attempt to enhance cold tolerance of these grasses, a study was undertaken to assess the effects of late-season nitrogen (N) fertilization and applications of the growth regulator trinexapac-ethyl (Primo) on morphology and cold tolerance of ‘Tifton 419’ hybrid bermudagrass. Nitrogen applications after 15 August significantly enhanced the number of total rhizomes, the primary winter-survival organ in bermudagrass. Primo had no effect on the morphology of the grass but did enhance the freeze-tolerance of the rhizomes that were present. These studies suggest that applications of late-season N and Primo may impact winter-survival of hybrid bermudagrass in areas where winterkill is a problem.

BACKGROUND

The transition zone presents golf and sports turf managers with an array of problems relative to stress tolerance and survival. Although

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creeping bentgrass (*Agrostis stolonifera*) continues to be the grass of choice for putting greens in the region, warm-season grasses such as bermudagrass (*Cynodon* spp.) and zoysiagrass (*Zoysia* spp.) predominate on other intensively managed turf areas such as fairways, tees, and athletic fields. Zoysiagrass is generally more cold-tolerant than bermudagrass and is found more frequently in the northern extremes of the transition zone. The most extensively used bermudagrass cultivars are hybrids between *Cynodon dactylon* and *C. tranvaalensis*. These hybrids lack the cold tolerance of zoysiagrass, and severe loss of stand due to winter kill is routinely reported in the upper regions of the transition zone about 1 out of every 5 years (John King, University of Arkansas, personal communication). This winter injury is especially prevalent in intensively managed areas such as golf course fairways and tees, where high levels of fertilizer, low mowing heights, and intensive traffic predispose the grass to cold-induced injury.

Management of bermudagrass to enhance cold tolerance has often focused on avoiding late-season N applications and increasing potassium fertilization (Reeves, et al., 1970). Late-season applications of N are believed to promote excessive shoot growth, which prevents or reduces the accumulation of storage carbohydrates and other protective osmolytes. However, recent studies by Goatley et al. (1998) suggest that N fertilization may play less of a role in winter injury than previously believed.

Plant growth regulators are playing an ever-increasing role in turf management programs. These materials were originally used to reduce mowing and suppress seed-head development, but they have also been shown to affect turfgrass population dynamics and to precondition grasses to stress. Recent studies have shown that Primo can be effectively used to precondition both warm-season and cool-season grasses to various types of turfgrass stress. Some of the beneficial effects of Primo include increased root growth, reduced water use, and enhanced shade tolerance. Recent studies of shade tolerance by Qian and Engelke (1999) demonstrated that applications of Primo to 'Diamond' Zoysiagrass enhanced photosynthesis and increased carbohydrate levels relative to controls. These results suggest that reduced consumption of fixed carbohydrates (i.e., reduced leaf growth) allows photosynthate to be stored for later use.

The enhanced soluble carbohydrate levels observed in grasses treated with Primo suggest that plants treated with this material could better survive forms of desiccation stress, including drought, salinity, and freezing. To test this hypothesis, an experiment was conducted to assess the effects of Primo on morphology and cold tolerance of an established hybrid bermudagrass turf. The effects of late-season N applications on morphology and cold tolerance were also studied.

RESEARCH DESCRIPTION

A study was conducted at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, on an established area of 'Tifton 419' bermudagrass. This area had not been used previously for experimental purposes but had been managed under moderate intensity with respect to fertilization, mowing, and weed control. Preemergent herbicide (Ronstar G) was applied on 6 March and 15 Sept. 1998 to control grassy weeds, and the fertilization program included monthly applications of agriculture-grade fertilizers at a rate equivalent to 1 lb of N/1000 ft². Irrigation was used as necessary to prevent drought, and plots were maintained at 0.75 in. mowing height prior to and throughout the experiment.

Experimental treatments were combined in a factorial arrangement and applied in a split-plot design, with N fertilization treatments as the whole plots and growth regulator (Primo) as the split-plot. Plots were arranged in a randomized complete block design with four replications. The three N treatments were: (1) no N fertilizer after 1 Aug., (2) 1 lb N/1000 ft² on 15 Aug., and (3) 1 lb N/1000 ft² on 15 Aug. and 15 Sept. Growth regulator splits were: (1) Primo at 0.38 oz/1000 ft² on 15 Aug., (2) Primo at 0.38 oz/1000 ft² on 15 Aug. and 15 Sept., and (3) no Primo. Fertilizer was applied in the form of urea, and Primo was applied with a carbon dioxide sprayer in the equivalent of 1.25 gal of water/1000 ft².

Plots were routinely rated for turf color and quality until turf was completely dormant. On 5 Jan. 1999, plots were sampled with a core sampler (7.4 x 6.4 cm) and morphological measurements were made for rhizome mass and number, shoot mass, root mass, crown and stolon density, and rhizome and stolon internode length. Additional plugs were taken on 10 Jan., and rhizomes were separated and either analyzed for total nonstructural carbohydrates (Smith, 1981) or assessed for freezing tolerance. Each experimental unit in the freeze test consisted of four to five rhizomes with a total of approximately 20 nodes. Each experimental unit was grouped, wrapped in moist cheesecloth, and maintained at 4 °C for 24 h prior to moving into the controlled freeze chamber (Tenney Jr., New Brunswick, N.J.). Samples were placed in the freeze chamber at 0 °C, and the temperature was decreased from 0 to -2 °C over a 2-h period. Samples were held at -2 °C for 2 h, at which time samples were removed and reacclimated in a refrigerator at 4 °C for 24 h. The remaining tissues were subjected to -4, -6, and -8 °C in 2-h increments, and samples were removed at each temperature and moved to the refrigerator. After the reacclimation period, rhizomes were potted in a commercial greenhouse mix and maintained under greenhouse conditions until regrowth occurred. Percent rhizome

survival and recovery was assessed by counting the number of nodes that regrew from each treatment. Data were analyzed by general analysis of variance procedures using the split-plot model.

FINDINGS

Both N fertility and Primo had a significant effect on turf color, while turf quality was primarily affected by Primo applications (Table 1). In agreement with Goatley et al. (1998), late-season applications of N improved the quality and color of the turf in the fall period and prolonged the green period later into the fall. Two applications of Primo produced better color and higher quality than a single application at most observation dates. The overall effects of late-season applications of Primo were an improvement in turf color and a delay in dormancy as measured by turf color (Table 1). This is significant in that aesthetic properties of bermudagrass can be maintained longer into the winter. There was no significant interaction between N fertilization and Primo application in regard to turf aesthetic properties.

Primo did not affect the morphological characteristics of the bermudagrass turf (Table 2). It is noteworthy that Northwest Arkansas experienced a very mild fall in 1998 and the bermudagrass stayed green until early December. Assuming the grass was still metabolically active well into November, the growth-regulator effects may have subsided when dormancy was complete. Although it was expected that Primo would either increase crown, stolon, or rhizome density or shorten internode length, these results were not observed.

Late-season N fertilization affected both rhizome and crown density and stolon internode length of hybrid bermudagrass (Table 2). There were no interactions between N and Primo for any parameter.

Freeze tolerance data (Table 3) indicated that rhizomes had suffered some damage due to an early winter cold period, as noted by the >30% drop in survival of all rhizomes, even at -2°C . Late-season N fertilization had no effect on the survival of bermudagrass rhizomes at any freezing temperature (Table 3). This contradicts the general belief that late-season N should be avoided to prevent winter damage. However, these results need to be repeated before general statements regarding N fertilization and cold tolerance can be assessed.

Primo applications had a significant effect on the freeze tolerance of bermudagrass rhizomes, and this effect was observed on rhizomes exposed to both -2 and -4°C (Table 3). This is a significant finding in that a number of turf managers are using Primo to prepare bermudagrass turf for winter overseeding. Although the effects of Primo on freeze tolerance of rhizomes at -6 and -8°C were not statistically

significant, more rhizomes survived with both single and dual applications of Primo compared with the control. Dual applications of Primo were slightly better than a single application, but the effect on rhizome survival was significant only at -2°C .

Although Primo enhanced freeze tolerance of bermudagrass rhizomes in this test, this finding could not be attributed to carbohydrate accumulation, as there was no significant difference in percent carbohydrates between treated and untreated rhizomes (Table 3). Nitrogen fertilization also had no effect on carbohydrate accumulation in bermudagrass rhizomes, suggesting that other mechanisms of freezing tolerance are active in Primo-treated plots; this needs further investigation.

In summary, late-season applications of N and Primo enhanced overall quality of bermudagrass turf compared with untreated plots. In addition, dormancy was delayed in the treated plots, which would extend the overall performance of the turf. Applications of Primo also had a significant effect on freeze tolerance of bermudagrass rhizomes, especially at modest freezing temperatures (-2 and -4°C). Future investigations will evaluate repeated applications beginning earlier in the season and continuing later in the year.

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ACKNOWLEDGMENTS

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Table 1. Turf quality and turf color of 'Tifton 419' bermudagrass, as affected by late-season application of nitrogen and Primo.

	Turf quality ^z				Turf color ^z				
	Aug.	Sep.	Oct.	Avg.	Aug.	Sep.	Oct.	Nov.	Avg.
<i>Nitrogen fertilization</i>									
None after 1 Aug.	7.2	6.7	6.3	6.7	6.5	6.2	5.8	4.5	5.8
1 lb N (15 Aug.)	6.9	6.7	6.1	6.6	6.9	6.4	6.1	4.9	6.1
1 lb (15 Aug.) + 1 lb (15 Sep.)	7.0	6.8	6.2	6.7	6.9	6.8	6.3	6.1	6.5
LSD (0.05) ^y	ns	ns	ns	ns	ns	0.5	0.4	0.6	0.5
<i>Primo (0.38 oz/1000)</i>									
Control	7.1	6.2	5.0	6.1	6.3	5.4	4.5	4.5	5.2
15 Aug.	7.1	7.0	6.3	6.8	7.2	6.9	6.2	5.3	6.4
15 Aug. and 15 Sep.	7.0	7.1	7.3	7.1	6.9	7.0	7.6	5.7	6.8
LSD (0.05)	ns	0.4	0.6	0.2	0.6	0.5	0.6	0.6	0.3

^z Turf quality and color are rated on a scale of 1 to 9, with 9 being highest quality or best color.

^y LSD = least significant difference; ns = nonsignificant difference among the means.

Table 2. Morphological characteristics of 'Tifton 419' bermudagrass as affected by late-season application of N and Primo.^z

	Rhizome wt./ plug (g)	Root wt./ plug (g)	Shoot	Root: shoot	Rhizome density/ rhizomes/ 10 cm ³ soil	Stolon density/ stolons/ 10 cm ²	Crown density/ crowns/ 10 cm ²	Internode rhizome length stolon mm
<i>Nitrogen Fertilization</i>								
None after 1 Aug.	2.63	0.43	1.81	0.27	3.1	157.1	22.5	15.9 5.8
1 lb N (15 Aug.)	3.46	0.50	1.55	0.34	4.1	171.8	32.5	16.1 6.8
1 lb (15 Aug.) + 1 lb (15 Sep.)	3.31	0.47	1.70	0.31	4.3	167.1	36.3	14.9 7.3
LSD (0.05) ^y	ns	ns	ns	ns	0.8	ns	10.6	ns 1.2
<i>Primo (0.38 oz/1000)</i>								
Control	3.29	0.48	1.55	0.35	3.9	166.1	28.3	15.5 6.8
15 Aug.	3.29	0.50	1.62	0.32	4.2	176.4	33.5	15.5 6.8
15 Aug. and 15 Sep.	2.82	0.43	1.88	0.25	3.4	153.5	29.6	15.8 6.4
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns ns

^z All data were collected from replicated plugs 5 cm in diameter and 7.6 cm deep. Plugs were sampled on 5 Jan. 1999.

^y LSD = least significant difference; ns = nonsignificant difference among the means.

Table 3. Total non-structural carbohydrate and percent freeze survival of 'Tifton 419' bermudagrass rhizomes as affected by late-season application of nitrogen and Primo.^z

	Total non-structural carbohydrate (g kg ⁻¹)	% rhizome survival			
		-2 °C	-4 °C	-6 °C	-8 °C
<i>Nitrogen Fertilization</i>					
None after 1 Aug.	63.1	53.6	49.7	42.2	0.0
1 lb N (15 Aug.)	73.6	60.0	49.3	33.5	7.8
1 lb (15 Aug.) + 1 lb (15 Sep.)	70.8	53.4	44.4	38.5	0.0
LSD (0.05) ^y	ns	ns	ns	ns	ns
<i>Primo (0.38 oz/1000)</i>					
Control	67.7	46.0	36.6	32.4	0.0
15 Aug.	70.1	54.9	50.5	38.0	1.9
15 Aug. and 15 Sep.	69.7	68.4	57.6	43.7	6.0
LSD (0.05) ^y	ns	9.8	10.0	ns	ns

^z Plugs were sampled on 5 Jan.

^y LSD = least significant difference; ns = nonsignificant difference among the means.

METHODS OF PROPAGATING ZOYSIAGRASS FROM SPRIGS

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and Brian N. Rodgers²*

IMPACT STATEMENT

Establishment of zoysiagrass (*Zoysia japonica*) from sprigs is often impractical for golf courses and sports fields because of the slow growth rate of the species and subsequent long establishment period. A study was conducted at Fayetteville and Little Rock to evaluate three methods of propagating zoysiagrass from vegetative cuttings and to assess the effects of postplant nitrogen (N) fertilization on establishment. A new method of establishment, named Z-NET, proved to be better than traditional sprigging at the Fayetteville site, but not at Little Rock. Topdressing the sprigs with 0.5 in. of native soil also significantly improved establishment compared with traditional sprigging. Applications of N during establishment had little or no overall effect on grow-in.

BACKGROUND

Zoysiagrasses (*Zoysia* spp.) continue to expand in popularity on golf courses, commercial sites, and home lawns throughout the tran-

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sition zone because of their excellent wear tolerance, winter hardiness, playability, and overall turf quality. The major zoysiagrass cultivar, 'Meyer', is a vegetatively propagated, spreading grass that once established, produces a dense, thick turf that competes well with weedy plants. However, 'Meyer' has a very slow overall growth rate relative to other warm-season grasses, and is difficult to establish in most situations. Because of this slow growth, most sites that choose zoysiagrass establish the site from sod. Sod farmers also face the same problem with establishment of the species, and the long grow-in period adds substantial production costs.

The primary means of establishing 'Meyer' zoysiagrass is to broadcast vegetative sprigs at a rate of approximately 800 bushels/acre. This method is effective, but most growers anticipate a 12- to 18-mo period from planting to establishment of a harvestable zoysiagrass sod. In recent years, a new technique of planting zoysiagrass, called Z-NET, was introduced from Japan (Miyachi et al., 1993). This method consists of a biodegradable netting with zoysiagrass sprigs intertwined within the netting. This net/sprig combination is then rolled onto a site in a similar fashion to sod, topdressed with 6 to 12 mm of soil, and watered according to need. The original manuscript citing this technology (Miyachi et al., 1993) found that the Z-NET planting method could produce a complete zoysiagrass cover in 85 to 110 days from planting. However, their study was flawed in that there was no comparison to traditional sprigging techniques to demonstrate whether the method was superior to existing methods.

Postsprigging fertilization of zoysiagrass is also poorly understood. The few studies that have addressed this issue have produced inconsistent results from using N fertilizers during establishment (Carroll et al., 1996; Fry and Dernoedon, 1987). However, most sod growers in the region continue to fertilize zoysiagrass heavily during establishment in an attempt to enhance grow-in.

The U.S. marketing rights to Z-NET technology were licensed by Winrock Grass Farms in 1998. In an attempt to evaluate this technology further, a study was designed to test it against traditional sprigging methods for 'Meyer' zoysiagrass. The effects of postplanting N rates on establishment of turf cover were also tested.

RESEARCH DESCRIPTION

Propagation studies were conducted at two sites in the state. The first site was at Winrock Grass Farms near Little Rock (loam soil, pH 6.7), and the second was at the University of Arkansas Agricultural Research and Extension Center, Fayetteville (silt loam soil, pH 6.2).

Each site was fertilized with 20 lb of 0-20-20/1000 ft² and prepared to seedbed quality prior to planting. Because of different climatic conditions, the Little Rock site was planted on 13 May 1999 and the Fayetteville site planted on 8 June 1999. The planting design and method were identical for each site.

The experimental design of the study was a split-plot design, with propagation method as the main plot and postplanting fertilization rate as the subplot. Main plots were 8 x 40 ft and treatments were as follows: (1) Z-NET planting with 200 bushels of sprigs/acre and topdressed with 0.5 in. of native soil, (2) traditional sprigging at 800 bushels/acre, and (3) traditional sprigging at 800 bushels/acre and topdressed with 0.5 in. native soil. The subplots were 8 x 8 ft, and treatments consisted of 0, 0.25, 0.5, 0.75, and 1.0 lb of N/1000 ft²/mo. All fertilizer was applied as agricultural-grade urea (46-0-0).

To assure uniform planting densities in the traditional sprigged plots, the main plots were planted in 8 x 8-ft increments using a volume of sprigs obtained from shredding 1.17 yd² of 'Meyer' sod. This sprigging rate (800 bushels/acre) is based on the definition that 1 bushel of sprigs equals the sprigs obtained from 1 yd² of sod (McCarty et. al, 1999). Sprigs were uniformly broadcast over the entire plot, pressed lightly into the soil using a disk, and rolled with a water-filled roller to smooth the site. The soil used for topdressing the plots was screened through a soil sifter prior to application to a 0.5-in. depth with a track-mounted topdresser. Oxadiazon (Ronstar) was applied to all plots at 3 lb a.i./acre immediately after planting to suppress weeds, and water was applied as needed during the test to provide optimal growing conditions.

Plots were rated monthly for percentage of cover using a grid that separated each plot into four 4 x 4-ft quadrants. Each quadrant was visually rated from 0 to 100% cover, and the four subsamples were averaged for a final cover value. Data from each measurement date were analyzed by analysis of variance procedures using the split-plot model.

FINDINGS

A uniform, weed-free stand was established at both sites with all propagation methods. Analysis of the data across sites indicated a significant location effect (analysis not shown); therefore, all subsequent data are presented by location. Propagation method had a significant effect on turf cover at all evaluation dates and at both locations (Fig. 1). Nitrogen also had a significant influence on percentage of cover at the Fayetteville location, but less of an effect at Little Rock (Fig. 2). There

were no significant interactions between planting method and N fertilization for any evaluation period.

There were significant differences between the two sites relative to propagation method (Fig. 1). An interesting aspect of the location effect is that all plots at the Little Rock site lagged behind the Fayetteville site relative to percentage of cover at 60 and 90 days after planting (DAP), even though the site was planted 4 wk earlier. A possible explanation for this is a difference in soil temperatures between sites: soil temperature at the time of planting in Little Rock was 75 °F, while in Fayetteville it was 88 °F. This would suggest that early planting of zoysiagrass sprigs may not be advantageous and, in fact, may suppress the sprigs that are planted. Although there are no data in the literature to support this, it would appear that an 80 to 85 °F soil temperature should be attained before planting zoysiagrass sprigs.

At the Fayetteville site, the Z-NET method outperformed traditional sprigging at 60, 90, and 120 DAP, with the Z-NET method producing 10 to 15% faster cover rates (Fig. 1). However, at the Little Rock site, Z-NET produced similar cover rates relative to traditional sprigging and even lagged behind traditional sprigging at 120 DAP. It should be noted that the Z-NET technology uses only 200 bushels of sprigs/acre compared with 800 bushels/acre for traditional sprigging, so this technology did produce similar or better results with far less planting material. At both locations, the best propagation method proved to be the traditionally sprigged plots topdressed with 0.5 in. of native soil. This is an interesting finding and suggests that covering the sprigs with either soil or some other form of mulch may be more important than the method in which the sprigs are placed on the ground.

Nitrogen had a very small, but significant effect on rate of cover of zoysiagrass sprigs at the Fayetteville site, with 0.75 and 1.0 lb of N/1000 ft²/mo outperforming the lower rates at 60 and 90 DAP. However, it should be noted that even though the increase was statistically significant, the actual increase due to fertilization was generally only 5 to 10%. There were no N fertilization effects at 60 and 90 DAP in Little Rock, and a slight decrease in rate of cover at 120 DAP was noted with the highest rates of N. Collectively, these data suggest that N fertilization has a minimal effect on growth of zoysiagrass sprigs, a finding supports previous work (Carroll et al., 1996). The minor increase in growth may not justify the cost of fertilizer.

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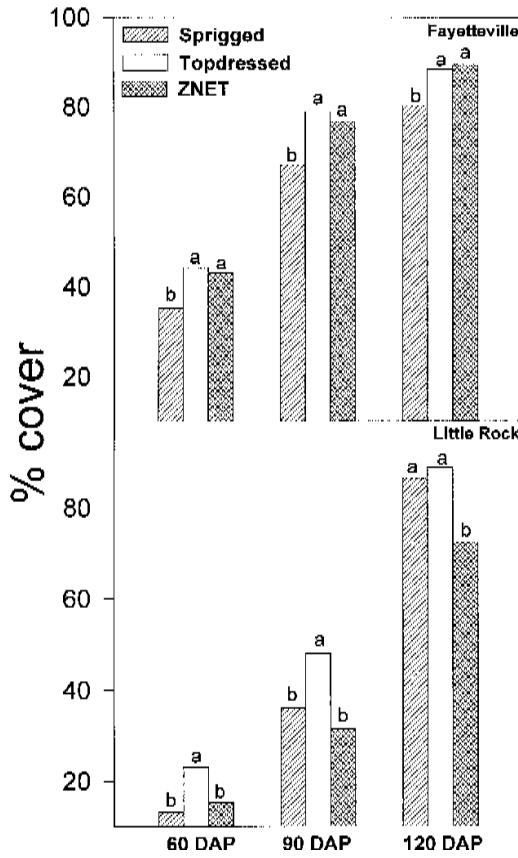


Figure 1. The effect of propagation method on establishment of 'Meyer' zoysiagrass at various days after planting (DAP) at two locations in Arkansas. Different letters within a location and evaluation date indicate a statistical difference between means at the 0.05 level of probability, as determined by least significant difference.

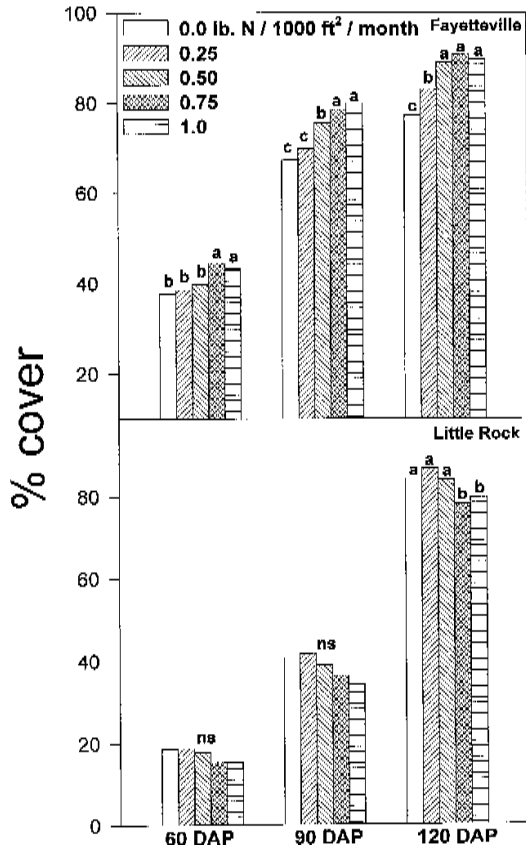


Figure 2. The effect of nitrogen fertilization rates on establishment of 'Meyer' zoysiagrass at various days after planting (DAP) at two locations in Arkansas. Different letters within a location and evaluation date indicate a statistical difference between means at the 0.05 level of probability, as determined by least significant difference. ns = nonsignificant.



TOP-DRESSING A HIGH-SAND CONTENT PUTTING GREEN WITH INORGANIC SOIL AMENDMENTS

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IMPACT STATEMENT

A field study was designed to study several inorganic soil amendments as a substitute for sand in the top-dressing of an aerified, sand-based putting green. Several forms of natural zeolites, calcined clays, and diatomaceous earth were blended with sand and used to backfill aerification holes on a sand-based putting green. Several of these amendments enhanced turfgrass recovery and quality in this study, but many failed to perform as well as sand. The major chemical property of these amendments that was unique from sand was a high cation exchange capacity (CEC), which should facilitate nutrient retention. However, most of the products failed to meet the proper particle size distribution for inclusion in a U.S. Golf Association (USGA) green. Further study is needed to clarify the role of inorganic amendments in sand-based putting greens.

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BACKGROUND

Since the early 1960s, one of the major advances in the field of golf and sports turf management has been the development of growing media with high sand content for putting greens and athletic fields. The USGA has been the leading proponent and developer of this technology, and the USGA green is the most widely accepted form of green construction being used in the industry today (Anonymous, USGA, 1993). The primary advantages of sand technology are that the growing media remains well-drained under a range of conditions and that it resists foot and equipment compaction. However, a sand medium has poor nutrient-holding characteristics and is subject to leaching of nutrients and agricultural pesticides.

In recent years, there has been an active interest in substituting other inorganic materials for sand in USGA-type green construction. The materials that have received the most attention include various forms of zeolites, calcined clays, and diatomaceous earth. These products have similar physical characteristics to sand (i.e., porous and compaction-resistant) but provide the added benefit of enhancing nutrient-holding capacity through inherent CEC. Several studies have indicated that zeolites, calcined clays, and diatomaceous earth can significantly enhance nutrient retention in a sand matrix (Bigelow et al., 1997; Kithome et al., 1998) and improve the performance of the grass growing in that medium (Ervin et al., 1999; Huang and Petrovic, 1996). The inorganic amendments can also be preloaded with cations such as NH_4^+ to further enhance their performance (Andrews et al., 1999).

Although the construction of new putting greens using inorganic sand substitutes is getting most of the current research effort, many existing sand-based greens may also benefit from this technology. A common management program on greens is to core-aerify the green one to two times per year and backfill the aerification holes with pure sand. This program enhances or maintains the long-term physical structure of the green. Because aerification holes are routinely back-filled with pure sand, there is an opportunity to replace the sand with other amendments, including the inorganic amendments listed above. This report describes one part of a long-term study to modify the sand matrix of a USGA putting green with inorganic amendments; this segment of the study examined the recovery from aerification of a USGA green amended with 14 inorganic amendments. The report also describes the chemical and physical properties of those materials.

RESEARCH DESCRIPTION

This study was conducted on a USGA-type putting green at Pinnacle Country Club in Rogers, Ark. The green was planted with 'Penn Links' creeping bentgrass and maintained according to procedures consistent with the remainder of the golf course. On 19 Oct. 1999, the green was aerified in one direction using a hollow-tine aerifier with 0.5 x 3.0-in. tines with 2 x 2-in. spacing. Cores were removed from the green prior to establishment of the plots. The plot layout was a randomized complete block design with three replications. Individual treatment plots were 4 x 4 ft. A total of 13 soil amendment treatments were blended with pure sand at a 20% (v/v) rate. Sand alone was used as the control. A 1-ft³ volume of blended material was spread evenly across each plot and hand-brushed into the aerification holes. This amount of material was calculated as the approximate amount needed to both fill the aerification holes and topdress the plot with 0.125 in. of mix.

Regrowth of the aerification holes was estimated beginning on day 7 after application of treatments, and continued regularly for approximately 1 month. Regrowth ratings were visually assessed on a scale of 0 to 9, with 0 representing no regrowth and 9 representing complete recovery. The 0 to 9 scale was converted to percent recovery by multiplying by 11.1.

Samples from each amendment were submitted to the University of Arkansas Agricultural Services Laboratory for analysis of nutrient content, pH, electrical conductivity, and CEC (by ammonia acetate substitution). A particle-size analysis was conducted for all the materials, with the primary focus on sand-size separates. A 40-g sample of each amendment was passed through a series of sieves with a minimum hole size of 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.1 mm, and 0.05 mm. The amount of material collected on each sieve was weighed and the percentage of total sample was calculated for each fraction.

Data for each rating day were analyzed by analysis of variance procedures using SAS. Mean separation was conducted by least significant difference (LSD) with a probability level of 0.05. Chemical and physical data for each material was determined on a single sample, so statistical analysis was not possible on that data. Regression analysis was used to assess the relationship between nitrogen (N) content and CEC of the amendment to regrowth of the aerification holes.

FINDINGS

Chemical and physical analysis of the materials indicated that the inorganic amendments have distinct properties relative to sand

(Tables 1 and 2). Most of these amendments have a high CEC relative to sand (Table 1), and several of the products contain a significant amount of total N, which is preloaded by the submitting companies. The N content of the materials ranged from 133 mg/kg for sand to 13,090 mg/g for ZeoSand 25DR. As a group, the zeolites had a much higher CEC, followed by diatomaceous earth and calcined clays. The high CEC relative to sand would likely affect the long-term ability of the root-zone to retain nutrients. Many of the products also have chemical properties that would be considered undesirable over an extended period. Clinolite and Ecosand have a very high pH (8.9 and 8.6, respectively) which would affect nutrient availability over time. In addition, several of the zeolite materials contained 40 to 70 times more sodium than sand, a property that could affect total salinity in the system.

In order for these inorganic amendments to be used in a USGA green, the physical properties of the material must meet size characteristics that will prevent changes in porosity or hydraulic conductivity of the root zone (Anonymous, USGA, 1993). Of the 14 inorganic amendments tested in this study, only five products met the requirements set forth by the USGA with respect to particle size distribution (Table 2): sand, Zeoponix A, ZeoSand N, Red Plus, and Profile. All the other products contained too many particles in the 1-2 mm range, which according to USGA specifications can only make up 10% of the total size class.

Performance of these materials as topdressing amendments was assessed by evaluating the recovery of aerification holes after amendments were added (Table 3). Analysis of variance indicated a significant treatment effect on all rating days. Over the course of the study, a few general trends were noted. The amendments Red Plus 25DR, Zeoponix B, and Ecosand 25DR enhanced regrowth of aerification holes at all rating dates compared with Ecosand, Clinolite, Red Plus, and PSA. The other products were intermediate at all rating dates and were not statistically different from each other or from the high and low performers. A significant aspect of these results was that none of the products produced a significantly better regrowth than sand, and several actually failed to perform at a level equivalent to sand.

It was predicted that the nutrient-holding capacity (i.e., CEC) or N content of these materials was a likely explanation for the variable regrowth patterns observed in the test. Regression analysis of CEC or total N against regrowth at 29 days after treatment indicated no correlation with either of these parameters (data not shown). Similar results were obtained when N and CEC were regressed against regrowth at other evaluation periods. The explanation for this lack of response

may reside in the fact that the N release characteristics of these materials is dependent on pH, temperature, and amount of N loaded relative to CEC (Kithome et al., 1998). Therefore, some of the total N that was reported in the analysis (Table 1) may have not been available for plant growth or was released at a rate that was not sufficient for optimal growth.

In summary, several inorganic soil amendments proved to be as good or better than sand for topdressing and filling aerification holes. Several of these products had high CEC values and matched the appropriate textural class for a USGA green. Ongoing research will include further amending of the same plots with the inorganic materials and analysis of the long-term effects of those amendments on turf performance and soil physical and chemical properties.

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Table 1. Electrical conductivity (EC), pH, cation exchange capacity (CEC), and mineral content of inorganic soil amendments, as determined by the Agricultural Services Laboratory,^z Fayetteville.

Amendment	Material	pH	EC ($\mu\text{mhos cm}^{-1}$)	CEC (cmol kg^{-1})	N	P	K	Ca	Mg	Na	S	Fe
Clinolite	zeolite	8.9	46	49.4	207	3	804	2108	250	219	20	15
Ecosand	zeolite	8.6	475	112.4	298	4	4220	6157	172	4019	70	20
Profile	calcined clay	7.0	684	23.9	161	21	987	2732	258	94	349	179
PSA	diatomaceous earth	6.3	203	47.3	426	17	917	2218	384	988	86	78
Red Plus	calcined clay	5.9	203	7.3	245	47	609	606	185	49	264	142
Red Plus 25 DR	calcined clay	6.8	7780	27.7	5528	441	6157	4714	1236	2526	2118	230
Sand	sand	8.6	123	0.7	133	7	37	119	23	21	7	19
ZeoSand T	zeolite	7.4	6270	109.0	434	4	4405	7295	678	4672	8558	12340
ZeoSand N	zeolite	6.5	10040	144.8	3557	6	6237	5031	317	14790	2504	1610
Zeoponix A	zeolite	7.6	350	133.9	3089	485	6406	5464	300	1576	129	31
Zeoponix B	zeolite	7.6	1230	94.1	4839	522	1699	3722	226	692	662	20
ZeoPro	zeolite	7.7	1051	86.0	2831	411	2521	4839	277	695	933	19
ZeoSand 25DR	zeolite	7.3	5420	104.1	13090	504	6641	6549	724	4608	1363	120
ZeoSand 10DR	zeolite	7.5	2730	108.2	3974	286	5388	6425	488	4285	812	79

^z Procedures: pH and EC by electrode, Mehlich III extraction, ICP; CEC by exchange with 1M ammonium acetate (pH = 7.0).

Table 2. Particle size analysis (sand separates only) of inorganic soil amendments used in topdressing study. USGA specifications for particle size analysis are given for comparison.

Amendment	>2 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	<0.1 mm
	% of total					
Clinolite	0.1	34.7	46.6	13.9	3.7	1.0
Ecosand	0.1	38.1	52.8	8.7	0.1	0.2
Profile	0.0	0.0	66.8	32.5	0.5	0.1
PSA	0.2	56.4	38.0	4.0	1.1	0.4
Red Plus 25DR	0.0	13.1	68.4	17.7	0.7	0.1
Red Plus	0.1	0.3	77.2	21.0	1.1	0.3
Sand	0.0	0.3	5.5	71.8	22.5	0.1
Zeoponix A	0.4	7.8	55.8	27.0	6.0	3.1
Zeoponix B	0.1	18.2	54.2	25.1	1.9	0.5
Zeopro	0.0	21.0	53.9	21.9	2.8	0.4
Zeosand 25DR	0.3	49.3	45.3	5.0	0.1	0.1
Zeosand T	0.8	30.8	56.3	11.7	0.4	0.0
Zeosand N	0.4	1.6	66.2	17.1	7.1	7.6
Zeosand 10DR	0.2	41.1	50.1	8.1	0.3	0.2
USGA specs ^z	————— < 10% ^y —————		————— > 60% ^y —————		<25%	<10%

^z USGA specifications for constructing a putting green (<http://www.usga.org/green/>).

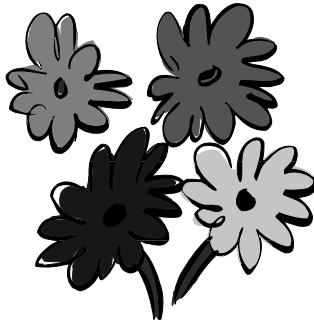
^y The two size classes above the dashed line are combined for comparison to the specifications.

Table 3. Recovery of creeping bentgrass (cv. Penn Links) following core-aerification, as affected by several inorganic soil amendments.^z

Amendment	Days after aerification						
	7	14	17	20	23	26	29
% recovery of aerification holes							
Red Plus 25DR	44.4	70.3	81.4	85.1	85.1	85.1	96.2
ZeoponixB	48.1	62.9	74.0	75.9	85.1	85.1	92.5
ZeoSand 25DR	40.7	55.5	72.8	74.0	74.0	77.7	85.1
Sand	37.0	62.9	69.1	70.3	70.3	70.3	81.4
ZeoPro	40.7	59.2	60.0	61.0	74.0	74.0	81.4
Profile	44.4	74.0	74.0	77.7	77.7	77.7	81.4
ZeoponixA	37.0	48.1	71.6	72.1	74.0	74.0	81.4
ZeoSand N	40.7	55.5	65.4	66.6	70.3	74.0	77.7
ZeoSand T	40.7	48.1	60.0	59.2	74.0	74.0	74.0
ZeoSand 10DR	33.3	51.8	64.1	64.8	66.6	66.6	74.0
Red Plus	37.0	55.5	61.7	62.9	66.6	66.6	70.3
PSA	29.6	44.4	50.6	55.5	55.5	59.2	66.6
Clinolite	29.6	48.1	50.6	50.0	55.5	55.5	59.2
Ecosand	25.9	40.7	43.2	44.4	44.4	44.4	55.5
LSD (0.05) ^y	11.9	15.8	15.4	15.5	14.5	14.9	16.5

^z Amendments were mixed at 20% (v/v) with sand and topdressed to fill aerification holes and cover plot surface to a depth of 3 mm.

^y LSD = Mean separation for treatments within a column at the 0.05 level of probability.



EFFECT OF COMPOST AND FERTILIZER ON ESTABLISHMENT OF ANNUAL COLOR BEDS

James Robbins and Janet Carson¹

IMPACT STATEMENT

Research was conducted to evaluate the effects of bed preparation, compost, and fertilizer on the establishment of annual color beds. The use of fertilizer and compost had a significant effect on the establishment of annual bedding plants. Initial growth of annuals was greatly enhanced by soluble or slow-release fertilizer. Compost may be beneficial in the early stages of bedding-plant establishment. Rototilling prior to planting increased the growth of annuals during the early stages of establishment, but the benefit may not be long-term.

BACKGROUND

Recent legislation has made it difficult to dispose of organic waste materials (Saarela, 1998). As a result, a number of companies have been established to process organic waste products into compost. While research has been conducted on the use of composted organic products for container media (McConnell and Shlaralipour, 1991; Purman and Gouin, 1992), very little has been done on the establishment of annual color beds.

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RESEARCH DESCRIPTION

A study was conducted to evaluate the effect of bed preparation, compost, and fertilizer on the establishment of annual color beds. Treatments were applied to a previously undisturbed site in Little Rock. The soil is classified as Carnasaw-Mountainburg Association with a pH of 6.2. All plots except the control were cultivated with a rototiller to a depth of 6 in. For treatments including a composted product, the tilled plot received a 2-in. layer of compost that was tilled in lightly. Three compost products were evaluated in the trial: Back to Earth Resources (BER), Inc., Slaton, Tex.; American Composting (AC), Little Rock; and Earth Care Technologies (ECT) Inc., Lincoln. Fertilizer treatments included a soluble fertilizer (13-13-13) applied at the rate of 1.8 lb of nitrogen (N)/1000 ft² at planting on 16 April 1999 and reapplied on 16 July. The second fertilizer treatment included a single application of slow-release fertilizer (Scotts Osmocote 7 14-14-14) applied at a rate of 3.6 lb of N/1000 ft² at planting. Fertilizers were applied as a topdress after planting the annuals but before the plots were mulched with a 2-in. layer of pine bark. Plots were treated with Pendulum 2G (pendimethalin) at 200 lb/acre to control weeds. Treatment plots were 3 x 3 ft and were replicated three times in a block design. Annuals used in this study were 'Wave' petunias and 'Showstar' *Melampodium*. Data collected included number of flowers, a growth volume index ($\pi r^2 h$), and shoot fresh weight. One-third of the 'Wave' petunias were harvested on 18 June to obtain a shoot fresh weight, and remaining petunias were harvested on 19 August. Data were analyzed using the spatial model of PROC MIXED with variances modeled as varying anisotropically with distance.

FINDINGS

Fertilizer. Significant treatment effects were observed by the fourth week with the petunia plots (Table 2). While both soluble and slow-release fertilizers increased growth of petunias, soluble fertilizers were the more effective. Petunia plants treated with soluble fertilizer were three times larger than non-fertilized plants by the fourth week. For *Melampodium* (Table 3), both soluble and slow-release fertilizers were more effective in the establishment period compared with the no-fertilizer treatment. The difference likely reflects a high fertilizer requirement during the establishment period. Although petunia appears to require higher amounts of nutrients during the establishment period, there was no difference between fertilized and non-fertilized plots by the end of the study (Tables 2 and 3).

Bed preparation/compost. The use of BER compost delayed the growth of petunia during the first 3 wk of establishment (Table 4). The mean growth index for the BER plants was almost 70% less than the rototilled, no-compost treatment. The dramatic reduction in growth may be a result of the high salt content or high potassium (Table 1) of the BER compost. Growth of petunia plants in the tilled treatments without compost and the ECT and AC compost treatments was not significantly different from the no-till plots during the first 3 wk of establishment.

After 9 wk the effects of bed preparation and compost on petunia growth were different from early data (Table 4). While the benefit of tilling plots was still the same as using a compost product, the benefit of tilling was decreased from the third to ninth week. Petunia plants grown in the BER-treated plots recovered well from their initial slow start. By the ninth week, petunia plants in the no-till plots were significantly smaller than other bed preparation treatments. No-till plants were half the size of plants grown in plots using yard waste-based compost products (ECT and AC). The best treatments continued to be the yard waste-based compost products ECT and AC. By the end of the experiment, the no-till treatments were statistically smaller than plots amended with ECT compost (Table 4).

Initial growth results for *Melampodium* were similar to petunia, although the BER caused a significant delay in the establishment of this annual (Table 5). This effect was totally reversed by the end of the experiment. Rototilling planting beds with no added compost resulted in the poorest growth at the end of the experiment.

Overall, these results suggest that fertilizer and compost can have a significant effect on the establishment of annual bedding plants. The dramatic differences in growth at the fourth week means that a homeowner or landscaper would observe a noticeable impact with these planting practices.

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ACKNOWLEDGEMENTS

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Table 1. Chemical properties of compost products.

Compost	pH	EC (mmho/cm)	P ————— K ————— Ca ————— Mg ————— Na				
			P	K	Ca	Mg	Na
BER	8.4	5.6	850	23225	4650	1850	525
AC	7.7	0.8	325	4375	6500	1100	350
ECT	4.9	1.7	475	550	4050	325	200

Table 2. Effect of fertilizer on the growth of 'Wave' petunia.

Fertilizer	Growth index (cm ³)		Shoot fresh wt. (g)			
	3.5 wk		9 wk	18 wk		
None	1044	c ^z	282	b	805	a
Soluble	3416	a	498	a	1104	a
Slow-release	2252	b	396	ab	1042	a

^z Mean separation within columns by Tukey's Least Significant Difference ($P = 0.05$).

Table 3. Effect of fertilizer on the growth of 'Showstar' *Melampodium*.

Fertilizer	Growth index (cm ³)	Shoot fresh wt. (g)
	3.5 wk	18 wk
None	296 b ^z	598 a
Soluble	640 a	691 a
Slow-release	806 a	737 a

^z Mean separation within columns by Tukey's Least Significant Difference ($P = 0.05$).

Table 4. Effect of bed preparation/compost type on the growth of 'Wave' petunia.^z

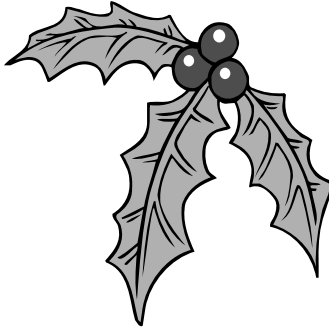
Bed preparation/ compost	Growth index	Mean shoot fresh wt.	
	(cm ³)	(g)	
	3.5 wk	9 wk	18 wk
Rototilled	2856 a ^z	331 ab	832 bc
BER	892 b	388 ab	1211 ab
AC	2417 a	511 a	954 abc
ECT	3128 a	488 ab	1345 a
No till	1894 b	240 b	604 c

^z Mean separation within columns by Tukey's Least Significant Difference ($P = 0.05$).

Table 5. Effect of bed preparation/compost type on the growth of 'Showstar' *Melampodium*.

Bed preparation/ compost	Growth index (cm ³)	Shoot fresh wt. (g)
	3.5 wk	18 wk
Rototilled	716 a ^z	465 c
BER	280 b	872 a
AC	484 ab	796 ab
ECT	815 a	676 abc
No till	610 ab	545 bc

^z Mean separation within columns by Tukey's Least Significant Difference ($P = 0.05$).



ARKANSAS PLANT EVALUATION PROGRAM

*Jim A. Robbins,¹ Jon T. Lindstrom,² Gerald Klingaman,²
Scott Starr,² and Janet B. Carson¹*

IMPACT STATEMENT

The Arkansas Plant Evaluation Program is designed to evaluate woody and herbaceous plant material in a scientific manner at three hardiness zones across Arkansas. Each year a new group of herbaceous and woody plants will be planted and evaluated for a period of time. Trees and shrubs will be monitored for 5 years and herbaceous plants for 3 years. The program is designed to introduce “new” ornamental plant material to the state and increase ornamental production in the state.

BACKGROUND

The Arkansas Plant Evaluation program is being modeled after successful programs in other states. The unique aspects of the Arkansas program are that replicate plants are used and that plants are evaluated at multiple sites within a single state. Information on plant adaptation of various ornamental species is needed to increase precision for landscape plant selection.

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RESEARCH DESCRIPTION

The three test sites are Southwest Research and Extension Center, Hope (hardiness zone 8a), Little Rock/Cammack property (zone 7a), and the University of Arkansas Agricultural Research and Extension Center, Fayetteville (zone 6b). As much as possible, the three test sites were prepared in a similar manner. Plants needing full sun were grown in row-type beds 3 ft wide with a 7-ft grass alley. Plant groups are planted together (e.g., trees were planted together). Trees were spaced 10 ft apart, shrubs 6 ft apart, and herbaceous perennials 4 ft apart. For shade-requiring plants, separate evaluation sites were established under natural shade at all three test sites. The Little Rock site was planted on 10 March; Fayetteville was planted on 11 March; and Hope was planted on 13 April, all in 1999. At Hope and Fayetteville, plants were irrigated by a drip system and at Little Rock by hand watering. Plants were fertilized and mulched after planting and post-emergent herbicides were used at all three test sites. No disease or insect control was implemented in 1999. The oak and *Styrax* were pruned following final growth measurements to establish a tree-like habit. Pruning consisted of removing the bottom third of limbs. Final growth measurements were taken 28 October at Little Rock, 25 October at Fayetteville, and 19 October at Hope.

FINDINGS

In general, the best growth for the 15 shrubs and two trees was observed at the Little Rock site (Table 1 and 2), where plants received a few hours of shade during the morning hours. Fayetteville and Hope are very exposed, full-sun sites, and the Fayetteville site is also characterized by consistent winds. All three sites had above-normal temperatures and below-normal rainfall in 1999.

***Rhododendron* 'Autumn Amethyst' (Encore, Azalea Series).** Performance of this species was excellent at all three sites. Rebloom was noted in late July and continued into fall. The plant appears to be slightly wider (2.6 ft) than tall (2 ft). This is the largest of the three azaleas under evaluation. Best growth was in Little Rock, with Fayetteville a close second (Table 1). Plants at both sites grew almost 10 in. in volume during 1999.

***Rhododendron* 'Autumn Coral' (Encore, Azalea Series).** Performance was excellent at all three sites. Rebloom was most significant and consistent on this cultivar. Rebloom was noted in mid-July and continued through the fall. Plant shape appears to be wider (1.9 ft) than tall (1.1 ft). The Little Rock site was clearly the best location for this cultivar. Growth in Little Rock was nearly double that of the

other two locations (Table 1).

***Rhododendron* 'Autumn Embers' (Encore; Azalea Series)**. Performance was excellent at all three sites. Like the other Encore series plants, winter hardiness is a critical factor to be monitored in the future. Rebloom was the least on this cultivar, although some rebloom was noted in the fall. Overall shape is similar to 'Autumn Coral'. The Little Rock site was again noted for the greatest increase in growth (Table 1).

***Camellia sasanqua* 'Hot Flash'**. Performance was good at all three sites. Flowering commenced in mid November at the Fayetteville site. Plant shape is almost as wide (1.9 ft) as it is tall (1.6 ft). Growth rates at Fayetteville and Hope were nearly equal (Table 1). Performance at Little Rock was probably limited by a lack of irrigation during the extended hot and dry periods of the summer.

***Ilex* x 'Little Red'**. Performance was good at all three test sites. The best growth rates were observed in Little Rock, where the plants increased in growth an average of 1.3 yd³. On average, the plant is slightly taller (3.4 ft) than it is wide (3 ft).

***Ilex* x Oakleaf**. Performance was good at all three test sites. The plant is clearly taller (4 ft) than it is wide (1.7 ft). A strong pyramidal shape is developing without shearing.

***Ilex* x 'Dixie Dream'**. Performance was good at all three test sites. Plants are mostly an upright pyramidal shape (2.8 ft tall by 1.9 ft wide).

***Abelia* x *grandiflora* 'Sunrise'**. Performance was fair at all three sites. *Abelia* clearly struggled at Hope and Fayetteville. Spider mites were noted on the plants at Fayetteville. Growth rate at Little Rock was the best, and that rate was nearly double that of Hope and seven times that of Fayetteville (Table 1). The plant offers a unique change in foliage variegation during the season that will likely be a plus in the consumer market. Average plant width (2.2 ft) is twice the height (1.1 ft).

***Ligustrum* 'Green Meatball'**. Performance was good at all three sites (Table 1). Based on growth during the 1999 season, a serious question arises as to the shape of this plant. While the cultivar name suggests a rounded plant, the plant developed an extremely open, wispy habit at all three sites. Vigorous new growth developed in all directions on this plant.

***Itea virginica* 'Henry's Garnet'**. Performance was good at all three sites (Table 1). Plants were observed to be suckering at all three sites by the end of the season. Typically maroon fall color was observed by late October at Fayetteville and Little Rock. Flowers appeared for a brief period in early to late May.

***Rhaphiolepis* 'Bay Breeze'**. Performance was good at all three sites (Table 1). A slightly showy flower display was noted in spring and

then again in mid-summer. Plant habit is clearly spreading (1.5 ft) rather than tall (9 in). Foliar leaf spot was noted on the plants.

***Loropetalum* ‘Plum Delight’.** Performance was mixed (Table 1). Plants grew at an aggressive rate in Little Rock but struggled at Fayetteville and Hope. Plant color was a deep, rich maroon in Fayetteville but was a more washed-out brown-purple at the other two sites. Plants flowered in November in both the Fayetteville and Little Rock locations.

***Lagerstroemia* x ‘Pocomoke’.** Considering the size of the initial liners, this plant had remarkable growth and performance for small plants in field conditions (Table 1). Flowering began in mid-July but peaked toward the end of August. Of the two dwarfs being tested, this appears to be the best. Average shape is 11.8 in. wide by 7.8 in. tall.

***Lagerstroemia* x ‘Chickasaw’.** Like ‘Pocomoke’, considering the size of the initial liners, the extent of growth is amazing (Table 1). ‘Chickasaw’ was unusual in flowering. Beautiful, glossy, red ceramic flower buds appeared in July but were slow to open until late August or into early September. Buds almost appeared “blind,” as the petals barely emerged from the calyx. The overall impact of the flower display was not as good as that seen with ‘Pocomoke’.

***Lagerstroemia indica* ‘Velma’s Royal Delight’.** Growth was statistically similar for this entry among sites (Table 1). Peak flowering for this clear purple selection was noted in late July.

***Styrax japonicus*.** Growth was good at all three test sites. Peak flowering was in mid- to late May. New growth on plants in Little Rock were covered by aphids early in the season, but this did not last or affect the overall plant growth. Growth increases were very similar at all three test sites (Table 2).

Oak hybrid. A preliminary assessment is that this plant is *Quercus* x *comptoniae*. Growth was good at all three sites and fairly consistent across sites (Table 2).

ACKNOWLEDGMENTS

The ornamentals team thanks the following sources for their donations: Arkansas Nurseryman’s Association, Morningside Nursery, Pittman Nursery, Flowerwood Nursery, Hines Nurseries, and Greenleaf Nursery.

Table 1. Mean change in growth index (yd³) for shrubs.^z

Location	Azalea			Camellia Hot Flash	Holly		
	Autumn Amethyst	Autumn Coral	Autumn Embers		Little Red	Oakleaf	Dixie Dream
Fayetteville	0.150 b	0.061 b	0.048 a	0.055 ab	0.162 b	0.110 a	0.083 a
Little Rock	0.256 a	0.103 a	0.098 a	0.005 b	1.26 a	0.277 a	0.231 a
Hope	0.236 ab	0.053 b	0.025 a	0.065 a	0.422 b	0.169 a	0.185 a

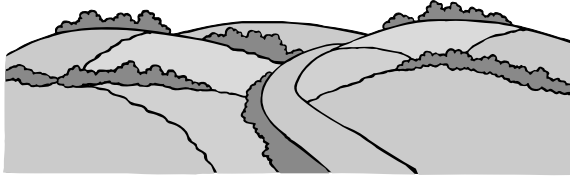
Location	Raphiolepis Bay Breeze	Loropetalum Plum Delight	Lagerstroemia		Velma's Royal Delight
			Pocomoke	Chickasaw	
Fayetteville	0.016 b	0.162 ab	0.010 a	0.004 a	0.019 a
Little Rock	0.045 a	1.178 a	0.036 a	0.013 a	0.036 a
Hope	0.012 b	0.040 b	0.022 a	0.006 a	0.042 a

^z Mean separation within columns by Tukey's Least Significant Difference ($P = 0.05$).

Table 2. Mean year-end growth measurements for trees.^z

	Styrax		Oak	
	Height (cm)	Trunk diameter (cm)	Height (cm)	Trunk diameter (cm)
Fayetteville	258 a	3.4 a	181 b	2.0 b
Little Rock	263 a	3.3 a	228 a	2.0 b
Hope	246 a	3.2 a	214 ab	3.1 a

^z Mean separation within columns by Tukey's Least Significant Difference ($P = 0.05$).



ROLE OF TREHALOSE IN DESICCATION TOLERANCE OF ENDOPHYTE-INFECTED TALL FESCUE

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Melody L. Marlatt,² and J. Brad Murphy¹*

IMPACT STATEMENT

A fungal endophyte (*Neotyphodium coenophialum*) that naturally infects tall fescue (*Festuca arundinacea*) enhances host survival under heat and drought conditions compared with non-infected plants. However, the mechanism for this enhanced drought tolerance is unclear. Trehalose, a disaccharide, is known to accumulate in desiccation-tolerant plants, fungi, and invertebrates, where it protects these organisms under severe stress conditions. To assess the role of trehalose in desiccation protection of endophyte-infected tall fescue, carbohydrate analysis of endophyte cultures and endophyte-infected tall fescue plants was conducted. Endophyte cultures that were subjected to water deficit stress exhibited changes in growth and carbohydrate profiles. Field studies comparing well-watered and water-stressed plants demonstrated similar changes in carbohydrate profiles.

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BACKGROUND

Endophytes are symbiotic fungi found in many cool-season grasses and have been shown to increase drought tolerance, insect and disease resistance, and general host vigor, especially under stress conditions. In tall fescue infected with *N. coenophialum*, enhanced drought tolerance is well documented. However, the basic physiological mechanisms are unclear.

Osmotic adjustment, or osmoregulation, is the accumulation of compatible, soluble solutes in response to long-term water deficit. Osmotically active compounds include non-structural, soluble carbohydrates, ions such as potassium, calcium, and sodium, and proteins and amino acids such as glycine-betain and proline. The major soluble carbohydrates in tall fescue are polymeric fructans, the disaccharide sucrose, and the monosaccharides fructose and glucose. In the early 1990s, Richardson and Bacon (1994) identified sugar alcohols associated with the endophytic fungus infecting tall fescue. These sugar alcohols or polyols—mannitol and arabitol—are common osmolytes in fungi.

Another carbohydrate commonly found in fungi and a broad range of desiccation-tolerant organisms is trehalose, a disaccharide (consisting of two glucose molecules). Trehalose is found in fungi such as dry active baker's yeast *Saccharomyces cerevisiae*, slime mold macrocysts *Dictyostelium*, and certain fungal spores. Several plant species known as resurrection plants (*Sporobolus stapfianus*, *Selaginella lepidophylla*, and *Myrothamnus flabellifolius*) contain high levels of trehalose and can survive extended periods of desiccation. On the basis of the widespread occurrence of trehalose in fungal systems and the documented effects of fungal endophytes on water deficit stress in tall fescue, studies were conducted to determine whether trehalose is present in endophyte-infected tall fescue and in endophytes grown in vitro.

RESEARCH DESCRIPTION

Carbohydrate analysis. Carbohydrates were analyzed following the protocol of Chapman and Horvat (1989). After samples were freeze-dried and ground to a powder, soluble carbohydrates were extracted with 75% ethanol. Soluble carbohydrates were converted to their volatile, oxime-trimethylsilyl (TMS) derivatives and separated on a gas chromatograph. Elution peaks were identified by comparison to known standards and were compared with a synthetic sugar standard, phenyl β -D-glucoside, for quantification.

Field study. To investigate the presence of trehalose in endophyte-

infected tall fescue, a rainout shelter at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, was utilized to induce a uniform drought event. Populations from the cultivar 'HiMag' were used in this trial. One population was an endophyte-free control (HM-), and three populations (HM4, HM8, and HM9) were inoculated with unique endophyte (*N. coenophialum*) strains isolated from drought-resistant hosts. The statistical design was a split-plot design with two irrigation regimes, well-watered and drought, and six replications of the four 'HiMag' populations in each water regime. The dry-down period was initiated on 3 June 1999. Fifty-eight days later, when drought plots showed severe signs of water stress, leaf pseudostems were harvested 1 cm above the meristem and immediately frozen in liquid nitrogen for subsequent carbohydrate analysis. At the time of harvest, average water potential of the drought-stressed plots was -4.6 MPa and turgor potential was 0.4 Mpa, while well-watered plots had a water potential of -0.5 MPa and turgor potential of 1.4 MPa. Differences in carbohydrate levels were analyzed with use of analysis of variance procedures.

Endophyte culture. To determine whether trehalose is a component of endophyte (*N. coenophialum*) metabolism, one of the endophyte strains inoculated into the 'HiMag' population was cultured on osmotically adjusted potato dextrose agar (PDA). The endophyte inoculated into HM8, designated E8, was re-isolated from its host and maintained on PDA at 21°C in darkness. When cultures reached a diameter of 1.5 to 2 cm, discs were cut from the endophyte culture and homogenized in sterile water. An aliquot (1.75 mL) of the homogenized mycelium was used to inoculate the water-stress medium, which consisted of PDA amended with glycerol to simulate water potentials of 0 , -0.3 , -0.7 , and -1.3 Mpa. Prior to inoculation, a sterile cellophane membrane was laid over the solidified medium. After 34 days, cultures were harvested from the cellophane membrane and analyzed for soluble carbohydrate content. Changes in carbohydrate content were statistically analyzed using the SAS GLM procedure.

FINDINGS

When grown on osmotically adjusted PDA, endophyte E8 produced consistent levels of trehalose, but levels were low compared with arabitol and mannitol (Fig. 1). At moderate water stress, -0.7 MPa, mannitol and arabitol were at significantly higher levels than trehalose and may be acting as osmoregulators. Richardson et al. (1992) also reported the presence of arabitol and mannitol in endophyte cultures but did not report trehalose in those studies. Although the amount

produced is low, this is the first report of the presence of trehalose in the endophyte of tall fescue. In general, this endophyte had poor growth on all the media, but growth of the endophyte was significantly greater on the -0.3, -0.7, and -1.3 MPa media than on the 0 MPa medium, with -1.3 MPa medium having the greatest dry weight increase (data not shown). This indicates that optimal growth occurs not in water-saturated conditions but under slight-to-moderate water tension.

In the field studies, there were significant differences in plant carbohydrates between well-watered and drought-stressed plots (Table 1). However, there were no significant endophyte effects on any plant-derived carbohydrates. Sucrose increased in all drought-stressed plots, which would support its role as an osmoregulant in many higher plants.

There were no significant differences between fungal carbohydrates in well-watered versus drought-stressed plots. Interestingly, arabinol was not present in any of the endophyte-infected 'HiMag' populations (Table 1), although it was present in the endophyte strain E8 tested in vitro on PDA (Figure 1). In addition, arabinol was previously reported by Richardson et al. (1992) in an endophyte-infected tall fescue ('Kentucky 31') plant. Mannitol, a fungal-produced carbohydrate, was present in endophyte-infected plants and not in endophyte-free plants. Similarly, trehalose was present only in endophyte-infected, drought-stressed plants. Under well-watered conditions, some HM- plots also had trehalose present. Although this requires further investigation, the presence of trehalose on endophyte-free plots may be explained by fungal contamination from *Rhizotonia solani*, which was prevalent on all of the well-watered plots but not on the drought-stressed plots.

It has been predicted that the total biomass of the endophyte is less than 1% of the total plant biomass, which would explain why the fungal carbohydrate pool is much lower than the plant carbohydrate pool (Table 1). This dilution effect would suggest that the fungal contribution to the total osmotic pool has a lesser role. Concentrations of trehalose in endophyte-infected plants appear to be too low to act as an osmoregulator. However, trehalose also has a non-osmotic role in stressed organisms, where it effectively stabilizes dry membranes, phospholipid bilayers, and proteins (Crowe et al., 1987; Crowe et al., 1993). Bilayer membranes are composed of fatty acid derivatives with long hydrophobic tails and hydrophilic head groups, which helps them to form sheet-like structures surrounding cells and organelles. In a normal aqueous environment, the hydrophobic tails on the bilayer interior are in a semi-fluid state. When membranes are desiccated or frozen, the tails become rigid and break when rehydrated or thawed. Trehalose binds to the hydrophilic head groups on the exterior of the membrane and stabilizes the semi-fluid state of the membrane during

desiccation. Crowe et al. (1987) found that proteins and membranes that were dehydrated in the presence of trehalose were fully functional when rehydrated.

In conclusion, trehalose was identified in both endophyte-infected tall fescue plants and cultures of *Neotyphodium* endophytes. Although the quantities present in these studies suggest an insignificant effect on osmotic potential, trehalose may serve to protect membranes under severe desiccation.

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Table 1. Gas chromatography results of soluble carbohydrates in endophyte-infected tall fescue pseudostems harvested 31 July 1999 from the rainout shelter at the University of Arkansas Agricultural Research and Extension Center, Fayetteville.

Endophyte	Plant carbohydrates			Fungal carbohydrates		
	Sucrose	Glucose	Fructose	Arabitol	Mannitol	Trehalose
	mg/g dry weight					
	Drought-stressed					
HM-	142.9	28.9	19.9	0	0	0
HM4	173.4	28.9	19.0	0	0.6	1.4
HM8	179.9	27.0	15.3	0	0.1	0.7
HM9	166.7	27.8	16.8	0	0.1	0.4
	Well-watered					
HM-	44.2	32.3	26.3	0	0	0.8
HM4	48.5	30.0	23.5	0	1.2	0.6
HM8	47.0	33.0	25.6	0	0.3	0.2
HM9	48.8	35.4	27.6	0	0.1	0.2
Water regime ^z	**	NS	NS	***	**	***
Endophyte	**	***	NS	NS	NS	NS
Endo x Water	**	NS	NS	NS	NS	NS

^z NS, not significant at $P = 0.05$; ** $P > 0.01$; *** $P > 0.001$.

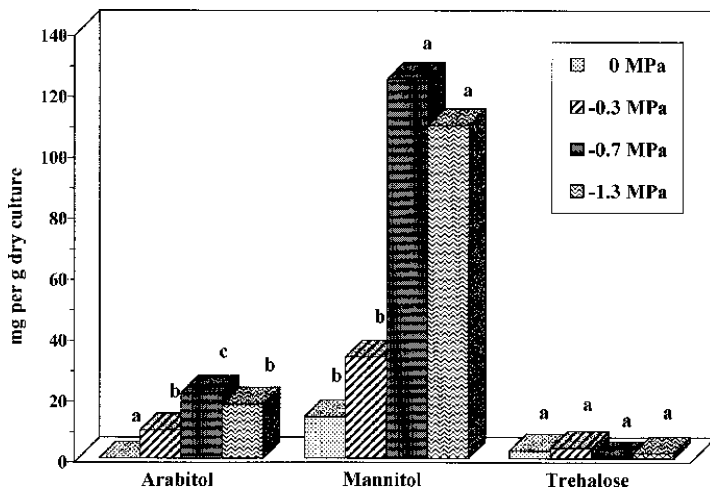
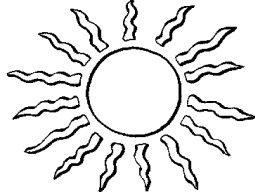


Fig. 1. Soluble carbohydrates extracted from endophyte 8 grown on osmotically adjusted potato dextrose agar.



ESTABLISHMENT AND GROWTH OF GROUNDCOVER SPECIES UNDER SUN AND SHADE CONDITIONS

Richelle A. Sink,¹ Alfred E. Einert,¹ Gerald L. Klingaman,¹ and Ronald W. McNew²

IMPACT STATEMENT

Hedera helix (English ivy), *Euonymus fortunei* 'Coloratus' (purpleleaf wintercreeper euonymus), and *Liriope spicata* (creeping lily-turf) were grown outdoors and evaluated for 1 year in a full-sun and 60% shade environment. Calculations were made to compare the cost of planting and maintaining *E. fortunei* 'Coloratus' to known values for fescue sod, a common turf option for shaded areas. Major influences on the rate of groundcover establishment were light condition and species. Establishment and survivability of *Hedera* in full sun was influenced mainly by lack of acclimation from shade to sun. There was no significant difference in establishment rates between *Liriope* and *Euonymus*. *Hedera* was established in one season under 60% shade and can be considered competitive with turf under the same conditions. Estimated costs for establishing and maintaining *Euonymus* were found to be less than 50% of the cost for establishing and maintaining fescue sod.

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BACKGROUND

Use of groundcovers in the landscape is often limited because of their slow establishment rate compared with turf. While popular recommendations exist for general groundcover maintenance procedures, no economic data are available to provide relative costs on groundcover establishment. This study was initiated to determine a successful program for the establishment of three commonly used groundcover species planted in full sun and 60% shade and to calculate costs of planting and maintenance during the first year of growth.

RESEARCH DESCRIPTION

This study was conducted at the University of Arkansas Agricultural Research and Extension Center, Fayetteville. On 3 June 1998, 96 plots (32 plots per species) were each planted with 16 plants, spaced on 12-in. centers. A total of 512 plants of each species were planted in beds prepared with 2 in. of mushroom compost. The beds were mulched with 2 in. of ground hardwood mulch and irrigated with a manual sprinkler irrigation system as needed from June until September. A shade structure covered with black shade cloth provided 60% light penetration. Two randomized complete block designs were used, one for four beds under shade and one for four beds under sun conditions. Data collected included percentage of canopy cover and costs for plot establishment and maintenance.

FINDINGS

Establishment (June-November). Growth (percent canopy cover) for all three groundcover species under both light conditions was greatest in the months from August to November (Figs. 1 and 2), except for *H. helix* growing under full-sun conditions (Fig. 5): After 1 wk in the ground, leaves of *H. helix* began showing signs of chlorosis and necrosis in full sun. Nearly 50% of this species died within 3 months in the full-sun treatment, even though *Hedera* has been noted as adaptable to full sun or shade. While *Hedera* is adapted to shade, these results suggest this species is poorly adapted to full sun in Northwest Arkansas. Although references and popular literature report that *Hedera* is adapted to full sun, little research exists on sun adaptation, and cases may be very site- and cultivar-specific.

Under the shade, *H. helix* grew vigorously from planting and throughout the summer and had the fastest canopy coverage of all species in both light treatments, achieving the highest canopy cover

(71%) after only 5 months (Fig. 2).

E. fortunei 'Coloratus' performed well under both the 60% shade and full-sun conditions. Most plots under both light conditions had near 50% coverage by November (Figs. 1 and 2).

By November, there were no significant difference in *Liriope* establishment due to light condition, and it achieved a mean percentage canopy cover of 47% after 5 months from planting. In full sun the species suffered some blade loss, presumably as it acclimated to the higher light environment. This loss is reflected as a slight drop in percent canopy cover from July through August (Fig. 2).

After one season, *L. spicata* and *E. fortunei* 'Coloratus' achieved 50% cover or greater when the soil was amended with organic matter prior to planting, and plants were irrigated as needed. Results also indicate that a groundcover planting of *Hedera*, under 60% shade with irrigation and soil preparations, can have establishment levels as high as 95% in one season of growth.

Post Establishment. By late March 1999, *Euonymus* had produced substantial new growth on all plants, as evidenced by canopy cover percentages from March through May 1999 (Figs. 1 and 2). New growth produced on this species nearly tripled the previous growth percentages because of the unique architecture of second-year growth. Whereas first-year growth produced only opposite leaves from each node along the stem, second-year growth produced lateral stems and additional leaves from these existing nodes.

By May, the highest canopy coverage was found in *Euonymus* plots both in 60% shade and sun. The mean of the light treatments, 77 and 74%, respectively, were not significantly different (Figs. 1 and 2). In the sun, all three species were significantly different from one another. The lowest coverage was found for *Hedera* in the sun, where very few plants had survived, resulting in a mean canopy coverage of 0.03% (Fig. 2).

Maintenance for all three species was minimal. There were significant differences between light treatment and weeding times in that the sun plots took more than twice as long to weed as the shade plots (data not shown). There were no significant differences for weeding times among species.

Comparisons between the estimated cost for groundcover and turf establishment (planting and maintenance) for 1 year were made using information obtained locally for turf and the costs recorded from this study for *E. fortunei* 'Coloratus'. These cost estimates included planting, labor, and maintenance for fescue sod and the *Euonymus*, and costs for mulching the *Euonymus*. Maintenance of fescue sod included fertilizer and herbicide applications as well as mowing. Groundcover

maintenance included hand-weeding. Calculations were based on a per square yard area. Soil preparation costs and water were not included, but were expected to be nearly the same for both fescue and *Euonymus*.

Estimated costs for establishing *Euonymus* were \$6.39/yd² and for sodded fescue were \$10.69/yd². After establishment, annual maintenance costs for a sodded fescue turf would be 5.6 times higher than for a *Euonymus* groundcover planting per year. This estimate was calculated using values based upon local lawn maintenance fees for these services over a 1-year period.

Although these percentages for canopy cover may be lower than the establishment of seeded or sodded turf in one growing season, minimal water applications, little if any herbicide or insecticide applications (no pesticides and only one herbicide application was applied in this study after planting), minor maintenance, and ornamental qualities of these three species make them ideal alternatives to low-traffic areas of the landscape in this area of the United States.

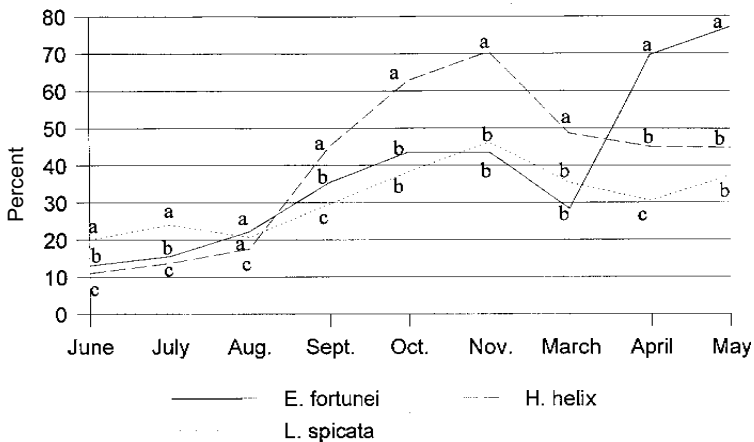


Figure 1. Percentage of canopy cover for *Euonymus fortunei* 'Coloratus', *Liriope spicata*, and *Hedera helix* under 60% shade from June 1998 through May 1999. Means within each month from June through May with the same letter are not significantly different as determined by *t*-test ($P \leq 0.05$).

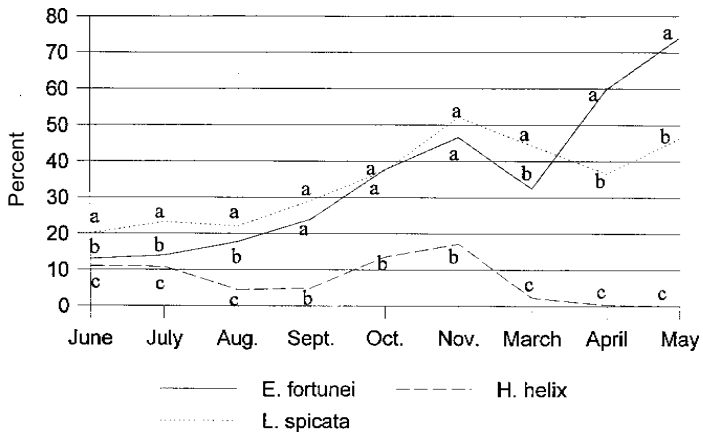
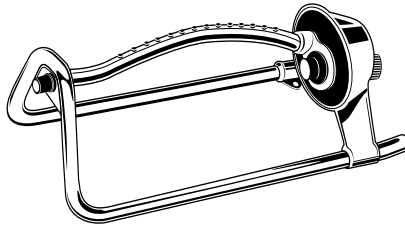


Figure 2. Percentage of canopy cover for *Euonymus fortunei* 'Coloratus', *Liriope spicata*, and *Hedera helix* under full sun from June 1998 through May 1999. Means within a month (July through May) with the same letter are not significantly different as determined by *t*-test ($P \leq 0.05$).



PRECIPITATION EVALUATION OF ROUND- AND SQUARE-PATTERNED IMPACT SPRINKLERS

Scott Starr and Gerald Klingaman¹

IMPACT STATEMENT

In the fall of 1999, two types of impact sprinklers were evaluated to determine the distribution of precipitation under normal operating conditions. The sprinkler types included a traditional round-patterned design (Rain Bird Maxi-Bird) and a recently developed sprinkler delivering water in a square pattern, called Square Shooter. The square-patterned sprinkler was more precise in delivering a uniform distribution of water. It accomplished this uniformity using half as many sprinklers as those with the round-patterned design.

BACKGROUND

Water conservation is a critical issue in many parts of the United States and the world. As demand for water increases, more stringent regulations governing water use are becoming evident in states and communities across the country. There is increasing pressure to require responsible use of water for irrigation of ornamental plantings in urban landscapes.

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The ultimate goal in irrigation is to deliver water as precisely as possible over a specific area. As a result, considerable engineering technologies have been used to create various high-quality irrigation products. While many excellent landscape irrigation products exist, improved efficiency is still important as increases in population and seasonal water shortages place strains on current resources.

RESEARCH DESCRIPTION

Four plots, each measuring 20 x 40 ft, were established at the University of Arkansas Agricultural Research and Extension Center, Fayetteville. The plots were adjacent to each other, and sprinklers were plumbed into perimeter positions using the manufacturers' specifications for spacing and adjustments. Two replicate plots were established for each of the sprinkler designs. Both sprinkler types used in the study are housed in a plastic case, installed flush with the ground, and pop up during operation to 7 cm above grade. In this study, normal irrigation placement practices were used except that all the equipment was placed on the ground surface rather than being buried in trenches. All sprinklers were set at 28 cm above the ground.

A pressure regulator and flow meter were installed on each plot. Flow rates were recorded for each run, and the operating pressure was 50 psi. Each run time was 20 min. and was executed when wind conditions were still. Precipitation for each run was collected in test tubes calibrated to measure in millimeters. The tubes were arranged in the plots on either 2-ft or 1-m spacings. Sprinkler placement varied for each sprinkler type and experiment and is detailed in Figures 1 and 2.

FINDINGS

The Square Shooter sprinkler produced a more uniform distribution of water than the round-patterned Rain Bird sprinkler (Table 1 and Figs. 1, 2, and 3). The average flow meter and precipitation volume of the Square Shooter plots were approximately half those of the Rain Bird plots, since sprinkling with Square Shooter requires half the number of sprinklers. In many situations this could be desirable, since applying water to the same area in twice the time would probably result in better soil penetration and less run off.

An arrangement of Square Shooter sprinklers, with all three sprinklers spaced on one side of the existing plots, was evaluated in two experiments. Because of high winds, data from these experiments were not as reliable as those obtained with the other two sprinkler

designs (data not shown). However, these preliminary numbers suggest that not only half the sprinklers but also half the pipe and trenching can result in an acceptable distribution of water. Since this would only be possible with a square-patterned sprinkler, this could prove to be another desirable feature of this new sprinkler design.

Table 1. Round- and square-patterned sprinkler performance.

Precipitation data				
Sprinkler	Plot average (mm)	Standard error of average	Standard deviation	Coefficient of variation
2-ft spacing ^z				
Rain Bird	15.29	0.07	4.61	0.30
Square Shooter	7.38	0.03	1.86	0.25
1-m spacing ^{z,y}				
Rain Bird	15.89	0.22	3.41	0.21
Square Shooter	8.94	0.12	1.11	0.12
1-m spacing ^x				
Square Shooter	8.16	0.11	2.61	0.32

^z Distance between collection points in a square grid layout.

^y See also Figures 1,2, and 3.

^x 1-m between collection points and all three sprinklers aligned on one edge.

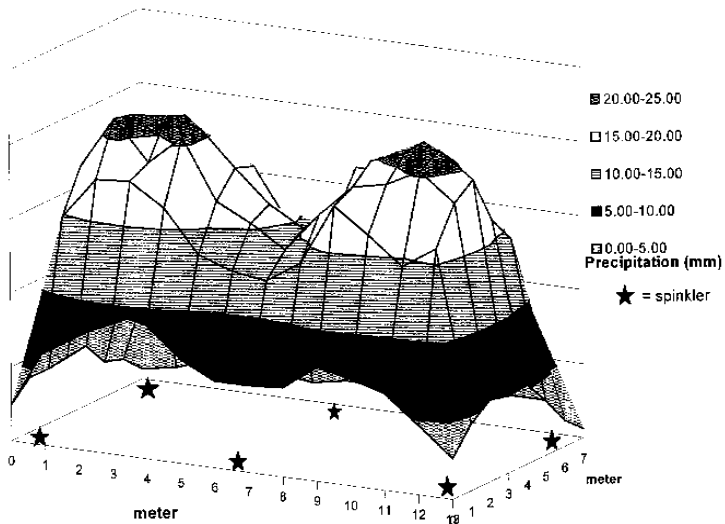


Figure 1. Average precipitation for Rain Bird Maxi-Bird impact sprinkler over three 20-min runs on two 20 x 40-ft plots with collection points at 1-m increments in a square grid including one set of points 0.5 m outside the target area.

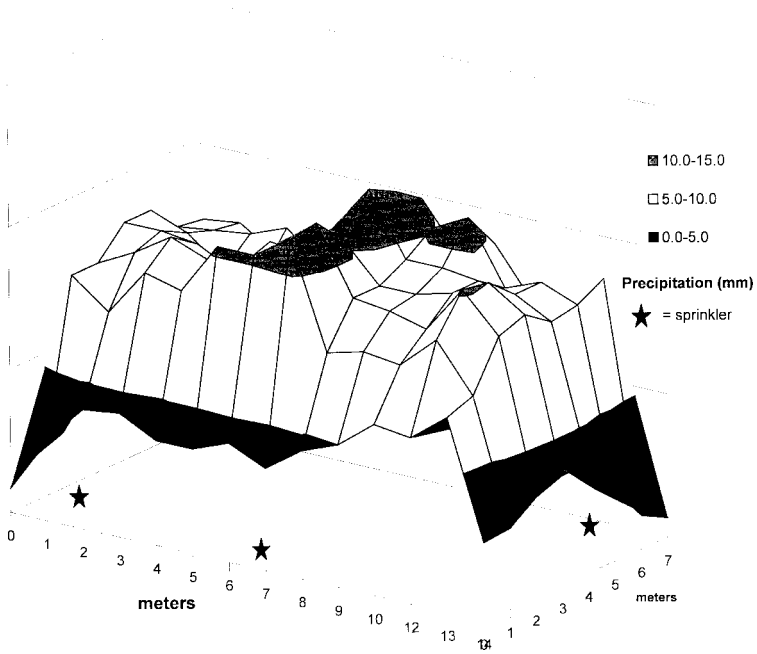


Figure 2. Average precipitation for Square Shooter impact sprinkler over three 20-min runs on two 20 x 40-ft plots with collection points at 1-m increments in a square grid pattern including one set of point 0.5 m outside the target area.

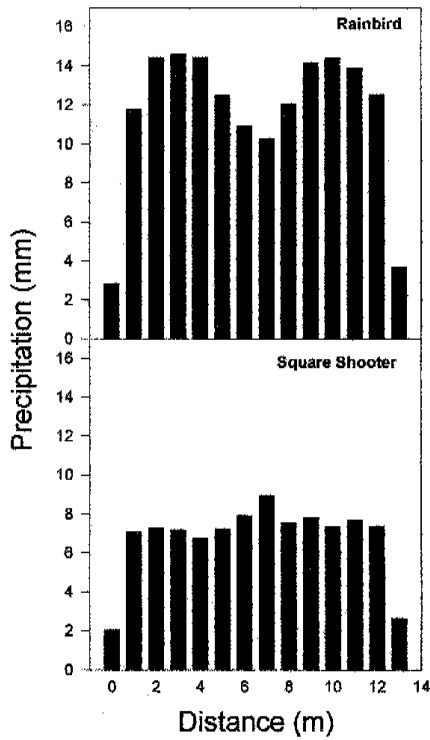


Figure 3. Precipitation averaged across the width of the 20 x 40-ft plots for the Rain Bird and Square Shooter impact sprinklers for three runs with collection points at 1-m increments in a square grid including one set of points 0.5 m outside the target area.

Conversion Table

U.S. to Metric			Metric to U.S.		
to convert from	to	multiply U.S. unit by	to convert from	to	multiply metric unit by
length			length		
miles	kilometers	1.61	kilometers	miles	.62
yards	meters	.91	meters	yards	1.09
feet	meters	.31	meters	feet	3.28
inches	centimeters	2.54	centimeters	inches	.39
area and volume			area and volume		
sq yards	sq meters	.84	sq meters	sq yards	1.20
sq feet	sq meters	.09	sq meters	sq feet	10.76
sq inches	sq centimeters	6.45	sq centimeters	sq inches	.16
cu inches	cu centimeters	16.39	cu centimeters	cu inches	.06
acres	hectares	.41	hectares	acres	2.47
liquid measure			liquid measure		
cu inches	liters	.02	liters	cu inches	61.02
cu feet	liters	28.34	liters	cu feet	.04
gallons	liters	3.79	liters	gallons	.26
quarts	liters	.95	liters	quarts	1.06
fluid ounces	milliliters	29.57	milliliters	fluid ounces	.03
weight and mass			weight and mass		
pounds	kilograms	.45	kilograms	pounds	2.21
ounces	grams	28.35	grams	ounces	.04
temperature			temperature		
F	C	$5/9(F-32)$	C	F	$9/5(C+32)$