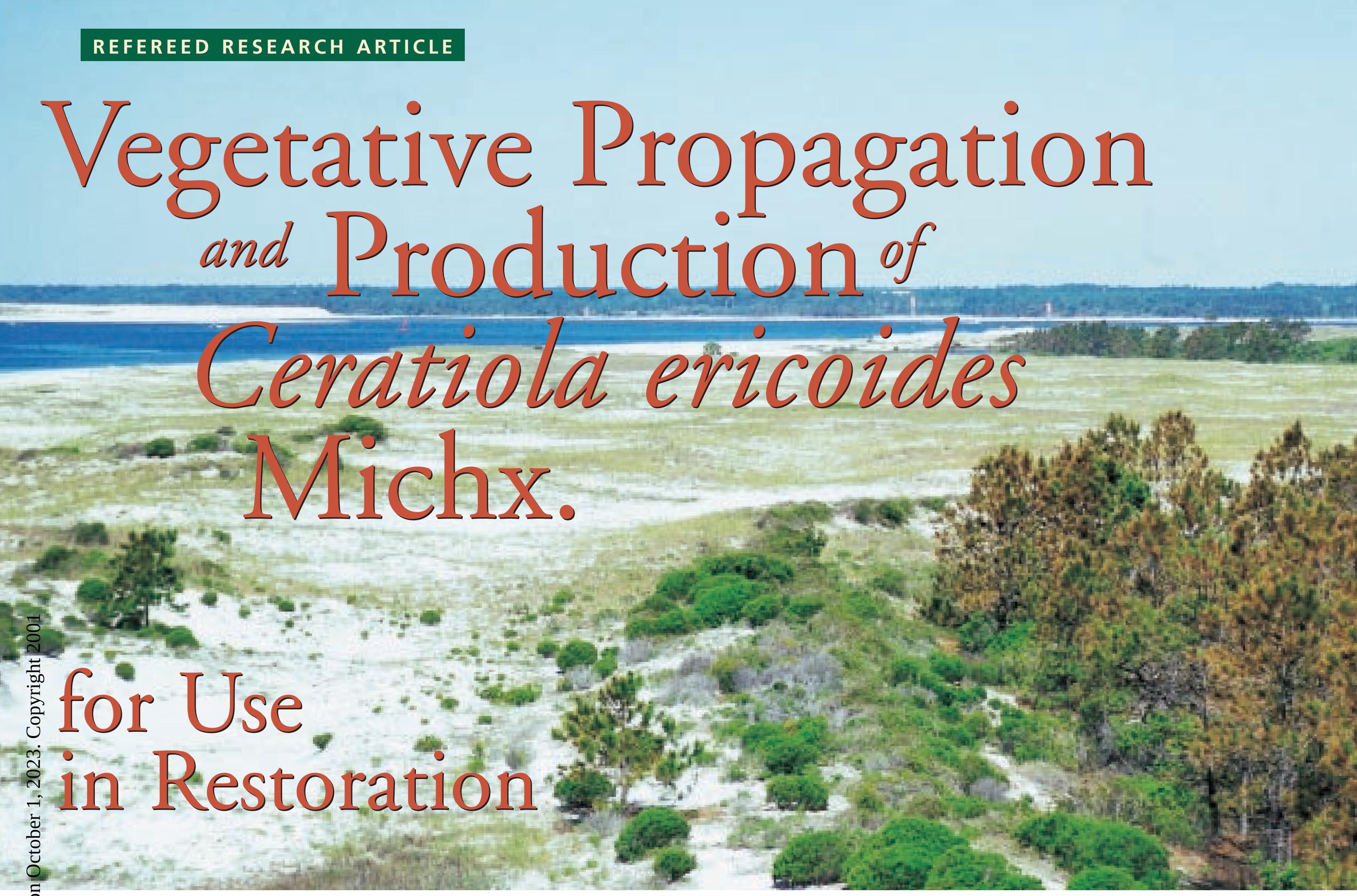
REFEREED RESEARCH ARTICLE

Vegetative Propagation *and* Production *of* *Ceratiola ericoides* Michx. for Use in Restoration



An extant population of Ceratiola ericoides *on a dune ridge at Fort Pickens, Santa Rose Island, Florida. Photo by Mark Thetford.*

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ABSTRACT

Successful propagation of *Ceratiola ericoides* was achieved using field collected softwood stem cuttings. Our results, using cuttings collected 2 different years, 2 rooting substrates, and 10 levels of auxin treatment, indicate successful rooting (82% to 100%) occurred both with and without auxin treatment. The most consistent rooting of *C. ericoides* was achieved using a perlite:vermiculite rooting substrate with little or no difference among rooting percentages, root number, root length, or estimated total root length for cuttings of both male and female plants. An improvement of root quality (increased root number and root length) occurred with the application of a synthetic auxin (α-naphthaleneacetic acid and indole-3-butyric acid) but we recommend concentrations below 5000 ppm. Using standard nursery methods, 73% of the rooted cuttings produced acceptable plants.

KEY WORDS: rooting, auxin, α-naphthaleneacetic acid, NAA, indole-3-butyric acid, IBA, Florida rosemary, Florida scrub

NOMENCLATURE: (plants) Godfrey (1988); (animals) ITIS (2001)

Florida rosemary (*Ceratiola ericoides* Michx. [Empetraceae]) is a woody, evergreen, dioecious shrub endemic to coastal and xeric areas of Florida, Georgia, and South Carolina (Godfrey 1988). *Ceratiola ericoides* is an important species of the globally imperiled Florida scrub community and a dominant dune binding species of the intermediate and backdunes of barrier islands of Florida (FNAI 1990). The juicy, yellow fruit of *C. ericoides* contains 2 seeds and is eaten by harvester ants (*Pogonomyrmex badius* Latreille [Formicidae]), mice (principally *Peromyscus polionotus* Wagner [Muridae]) and birds, especially the resident Eastern Towhee (*Pipilo erythropthalamus* L. [Fringillidae]) and a species federally listed as threatened, the Florida Scrub Jay (*Aphelocoma coerulescens coerulescens* Bosc [Corvidae])(Johnson 1982). Also, *C. ericoides* supports 2 host-specific herbivorous arthropods (Myers 1992).

Because *C. ericoides* is an obligate seeder requiring a relatively long period of development before reaching reproductive age, recolonization by this species is slow and frequent overwash or fire can eliminate *C. ericoides* (Menges 1998). Based on observations made on the Shell-Crooked Island barrier complex, *C. ericoides* is thought to dominate only portions of the system stable for at least 50 y (Johnson 1997). Florida populations generally have a male to female sex ratio of 1:1 and the mean age of reproductive individuals is 13 to 16 y for coastal populations (Gibson and Menges 1994). In inland scrub areas where *C. ericoides* is affected by fire, it recolonizes solely from a seedbank in the second season after a fire and becomes reproductive in about 10 y (Johnson 1982).

Florida scrub occurs only on the Florida central ridge, coastal peninsula, and coastal panhandle (Myers 1992). Coastal peninsula and panhandle scrub is restricted to narrow strips along the coast and on barrier islands. This community type is dominated by *C. ericoides* with or without evergreen or nearly evergreen oaks (*Quercus* L. [Fagaceae]) occasionally with a pine (*Pinus* L. [Pinaceae]) overstory. In all 3 locations, scrub communities have diminished as a result of urban development and citrus production. About 85% of the original scrub in the Lake Wales Ridge has been lost to citrus cultivation and residential development in the past 50 y (Christman and Judd 1990). Even less scrub remains in coastal areas. The few hundred, extant scrub patches that remain are small, isolated, and unprotected, particularly in coastal areas (Menges 1998).

Photo by Mack Thetford

Figure 1 • Collecting C. ericoides *cuttings on Santa Rosa Island following over wash by hurricanes Erin and Opal.*

TABLE 1

Auxin treatments

Auxin treatment	Active ingredient (ppm)	
	Indole-3-butyric acid	Naphthaleneacetic acid
None (control)	0	0
Hormodin 1 [a]	3000	0
Hormodin 3	8000	0
IBA 1000 [b]	1000	0
IBA 5000	5000	0
NAA1000 [b]	0	1000
NAA 5000	0	5000
Dip'N Grow (1:20) [c]	476	238
Dip'N Grow (1:10)	909	455
Dip'N Grow (1:5)	1667	833

[a] Commercially available talc formulation.

[b] Liquid formulations prepared by dissolving the respective acids in 500 ml isopropyl alcohol to create a 10,000 ppm stock solution and further diluting with distilled water.

[c] Commercially available liquid formulation, diluted with distilled water.

Increased hurricane and tropical storm activity over the last 3 decades along the panhandle of Florida has impacted barrier island scrub communities (Johnson and Barbour 1992; FNAI 1997). In October 1995, Hurricane Opal's 3.6 to 4.5 m (12 to15 ft) storm surge leveled extensive sections of sand dunes, partially denuded remaining fragments, damaged barrier island scrub communities, and destroyed seed banks. Therefore, plant recolonization may be slow (Cousens 1988; Gibson and Looney 1992; Morton and others 1994).

Reestablishment of reproductive *C. ericoides* to inland scrub and intermediate and backdune areas after initial foredune reestablishment or to denuded fragments will increase diversity and provide cover and a source of food for wildlife. Also, because of the initial rarity and substantial loss of the scrub community, conservation efforts that include restoration of abandoned pastures and citrus groves require the availability of this key plant species. However, *C. ericoides* is not commercially available, and evaluation of this species for inland scrub and dune restoration will first require development of propagation and production protocols. The uniform, globose canopy and dark, evergreen foliage of *C. ericoides* also make it extremely desirable as a home landscape plant in the developed portions of the barrier island communities. These ornamental characteristics may allow for a broader commercial demand of *Ceratiola* which makes production by commercial nurseries more practical. *Ceratiola ericoides* production has been impossible on a commercial scale because seed germination is difficult and vegetative propagation techniques are lacking (Johnson 1986).

Selection of an appropriate propagation substrate depends on the species, cutting type, season, and propagation system (Hartman and others 1997). Various materials and mixtures of materials are used for rooting cuttings but there is no single ideal propagation mix. Water management within the propagation system is a critical factor in the selection of a propagation substrate; delivery of sufficient water to maintain cutting turgor while essential, may over-saturate the propagation substrate, thereby preventing adequate aeration. Rarely can a root initiation response be attributed to differences in aeration due to the physical properties of the various media (Tilt and Bilderback 1987). Most aerobic requirements for root initiation (Loach 1985) are supplied by diffusion of oxygen through the aerial portion of the cutting to its base. However, water films both within and around the base of the cutting can obstruct the free passage of oxygen to developing root initials. Hence the water holding capacity of a given substrate, while having no influence on root initiation, may influence the success of subsequent root development for a given species.

Our study objectives were to: 1) evaluate the effectiveness of common auxin sources on rooting of *C. ericoides*; 2) evaluate the influence of 2 substrates on the rooting response of *C. ericoides*; 3) determine if sex influences *C. ericoides* rooting response; and 4) determine if pine bark-based substrates are suitable for production of *C. ericoides*.

MATERIALS AND METHODS

Ceratiola ericoides Propagation

We collected softwood cuttings of *C. ericoides* from the eastern end of Santa Rosa Island, a coastal barrier island (Lat 30° 18'N, Long 87° 16'W) between 09:00 and 10:00 on 23 July 1996 (Figure 1). Cuttings were segregated by sex, placed in plastic bags, and stored in a cooler for transport. Prior to treatment that same day, cuttings were recut to a length of 9 cm (3.6 in) and the foliage removed from the basal 4 cm (1.6 in) of each cutting. We used 10 auxin treatments (Table 1). NAA (α-naphthaleneacetic acid) and IBA (indole-3-butyric acid) were each dissolved in isopropyl alcohol to prepare 10,000 ppm stock solutions for further dilution with distilled water. Dilution ratios of Dip'N Grow were based on label recommendations. The basal 1 cm (0.4 in) of each cutting was treated with an auxin solution for 1 s followed by 15 min of air drying prior to insertion to a 2 cm (0.8 in) depth in a 10 cm (4 in) deep nursery

TABLE 2

Physical properties of propagation substrates and components utilized for propagation of Ceratiola ericoides

Substrates	Total porosity	Container capacity [a]	Air space [a]	Bulk density (g/cc)
	% volume			
Pine bark:sand (6:1; v:v)	79	59	20	0.54
Perlite:vermiculite (1:1; v:v)	90	66	24	0.16
Components				
Aged pine bark (< 1.3 cm [0.5 in])	82	62	20	0.36
Course builders sand	45	37	8	1.55
Perlite	84	39	45	0.16
Vermiculite (Hort Grade, #2 US)	89	74	15	0.29

[a] Container capacity and air space are not fixed values and are valid for a 2-in-tall (50 ml) container only.

flat containing 72 cell inserts filled with a substrate of 1:1 (v:v) perlite:vermiculite or 6:1 (v:v) pine bark:sand. Intermittent mist operated 6 to 8 s every 10 min from 07:00 to 20:00 daily, and cuttings were maintained under natural photoperiod. Cuttings were sprayed every 2 wk with Daconil (chlorothalonil) at a rate of 1.2 ml/l (1 tsp/gal) to control fungal diseases. Our experimental design was a split-split plot arranged in a randomized complete block with main plots consisting of propagation substrates, sub-plots consisting of cutting sex and sub-sub-plots representing the 10 auxin treatments (a total of 40 treatments). Each replication of a substrates sex, auxin treatment combination consisted of 6 cuttings for an experiment total of 2400 cuttings. The experiment was terminated after 12 wk.

A second propagation experiment was initiated in 1997 to confirm our 1996 results because donor plants from which cuttings for the 1996 experiment were collected had very little time to recover from the effects of hurricanes Erin and Opal. The 1997 experiment utilized the same treatment structure as the 1996 experiment with the following modifications. Cuttings were collected on 16 July 1997, stored overnight in a cooler at 4.4 °C (40 °F), and treated with the appropriate auxin prior to sticking. The experimental design was a

TABLE 3

Influence of year, substrate, and cuttings sex on the rooting of Ceratiola ericoides

Propagation substrate	Cutting sex	Year 1996	Year 1997	*P* value 1996 versus 1997
		Rooting (%)		
Pine bark:sand (6:1)		79 b [a]	94 b	0.0001
Perlite:vermiculite (1:1)		97 a	95 a	0.4
		Root number		
Pine bark:sand (6:1)	Female	6.5 c	7.2 b	0.16
	Male	6.6 c	9.2 a	0.0001
Perlite:vermiculite (1:1)	Female	12.1 b	9.3 a	0.0001
	Male	13.9 a	8.9 a	0.0001
		Root length (cm [b])		
Pine bark:sand (6:1)	Female	2.4a	4.2b	0.0001
	Male	2.2a	4.8a	0.0001
Perlite:vermiculite (1:1)	Female	1.9b	4.7a	0.0001
	Male	2.7a	4.3b	0.0001
		Estimated total root length (cm)		
Pine bark:sand (6:1)	Female	22 c	35 b	0.0001
	Male	23 bc	48 a	0.0001
Perlite:vermiculite (1:1)	Female	27 b	49 a	0.0001
	Male	42 a	44 a	0.4

[a] In each column, means followed by different letters are significantly different ($\alpha = 0.05$).

[b] 1 cm = 0.4 in

TABLE 4

Influence of year and auxin treatment on the percent rooting and root number of Ceratiola ericoides

Auxin treatment	Rooting (%)			Root number		
	1996	1997	*P* value	1996	1997	*P* value
None (control)	82 c[a]	96 a	0.001	8.4 c[a]	9.8 a	0.07
Hormodin 1	90 b	100 a	0.01	9.4 bc	9.8 a	0.6
Hormodin 3	89 b	100 a	0.006	10.6 ab	9.3 a	0.08
IBA 1000	84 c	100 a	0.0002	8.3 c	9.3 a	0.15
IBA 5000	86 bc	94 a	0.08	7.4 c	6.5 b	0.2
NAA 1000	99 a	94 a	0.2	11.0 a	9.1 a	0.009
NAA 5000	92 b	73 b	0.0001	11.1 a	5.0 b	0.0001
Dip'N Grow 1:20	83 c	98 a	0.0005	9.8 b	9.3 a	0.5
Dip'N Grow 1:10	86 bc	96 a	0.02	10.4 ab	9.8 a	0.4
Dip'N Grow 1:5	88 bc	96 a	0.045	11.4 a	8.6 a	0.0003

[a] In each column, means followed by different letters are significantly different ($\alpha = 0.05$)

split-split plot arranged in a randomized complete block with 3 cuttings per auxin treatment (a total of 40 treatments) and 4 replications. The experiment was terminated after 13 wk.

For both experiments, percent rooting, root number, and length of the 5 longest primary roots >1 mm (0.01 in) were recorded. An additional estimate of root system quality is the estimated total root length per cutting. Estimated total root length is defined as the product of the mean primary root length per cutting and the root number per cutting. While it is expected that this equation will overestimate the total root length per cutting, it nevertheless provides a valid demonstration of the combined effects of changes in root number and the mean length per root. Significance of main effects of year, rooting substrate, cutting sex, and auxin treatment and interactions were determined using the general liner models and lsmeans procedures of SAS (SAS Institute Inc 1989).

Physical Properties of Substrates

Total porosity, container capacity (water-holding capacity), and air space for each propagation substrate and individual components were determined using a volume displacement procedure. Six individual cells from 72 cell flat inserts were filled with substrate samples from the 1997 propagation experiment and distilled water was added to the top of the substrate and allowed to equilibrate for 15 min. Water was allowed to drain into a graduated cylinder for 60 min. After drainage, wet weights were recorded. Samples were placed in a forced air drying oven at 110 °C (230 °F)for 24 h and dry weight recorded. Container capacity, air space, and total porosity were determined with the following calculations:

$$\textit{Container capacity (CC)} = \frac{\textit{(Wet weight-dry weight)}}{\textit{Volume of sample}}$$

$$\textit{Air space (AS)} = \frac{\textit{Volume of water drained from sample}}{\textit{Volume of sample}}$$

$$\textit{Total porosity} = CC + AS$$

Ceratiola ericoides Production

Liners (rooted cuttings) from experiment 1 were immediately returned to the 72 cell flats after evaluation, moved to a 70% shade structure for 6 wk, and placed in a full sun production area with overhead irrigation where they overwintered prior to potting into 1.5-l (1-qt) containers on 25–26 March 1997. We used 2 substrates composed of 6:1 (v:v) pine bark:sand or 6:1:1 (v:v:v) pine bark:sphagnum peat:sand amended with 3.0 kg (5 lb) dolomitic limestone, 0.9 kg (1.5 lb) Micromax (The Scotts Company, Marysville, Ohio) and 3.0 kg Osmocote (18N: $6P_2O_5$:$12K_2O$; 8 to 9 mo formulation at 21 °C [70 °F], The Scotts Company, Marysville, Ohio) per m^3 (5 lb/yd^3). Liners were categorized on the basis of cutting sex and rooting substrate resulting in 4 distinct groups: female or male cuttings rooted in perlite:vermiculite and female or male cuttings rooted in pine bark:sand. Plants received no pesticide applications and were irrigated as needed. Plants were evaluated 29 October 1997 (22 wk after potting) for survival, shoot height, shoot number, and shoot number increase (secondary branching from the base).

RESULTS AND DISCUSSION

Substrate Physical Properties

Physical properties of the propagation substrates differed from the individual substrate components (Table 2.) Incorporating sand with pine bark reduced total porosity and air space compared to pine bark alone while incorporating perlite with vermiculite increased total porosity. Both water holding capacity and air space of perlite:vermiculite were greater than pine bark:sand. An effect of adding sand to a pine bark substrate is that the infiltration rate (movement downward) of water is slowed and better lateral wetting occurs (Bilderback and others 1994). Because much of the air space in the pot is replaced by sand particles, some plants may not grow as rapidly if water is never limited (Bilderback and others 1994). Previous research describing physical properties of substrates has shown that while total porosity is a property of the substrate alone and is independent of container size, container capacity and air space are influenced by substrate and container size (Fonteno and Bilderback

1993). For the low profile, small volume cells of the propagation flat, the container depth ultimately increases water holding capacity at the expense of air space because a perched or saturated water table is created by the bottom of the container (Bilderback 1999). The reduced air space of the pine bark:sand substrate, a consistently moist rooting bench and a perched water table may have created a rooting environment where air space was reduced, resulting in frequent waterlogging and anoxia of roots.

Ceratiola ericoides Propagation

Percent Rooting

Percent rooting was high for both years, ranging from 73% to 100%, regardless of substrate or auxin treatment (Tables 3 and 4). Significantly higher rooting percentages occurred in perlite:vermiculite compared to pine bark:sand. However, while rooting percentages for perlite:vermiculite were consistent between years, rooting percentages for pine bark:sand improved in 1997 resulting in a significant interaction between propagation substrate and year.

Auxin treatment influenced the percentage of cuttings that rooted but rooting percentages differed by year (Table 4). Rooting percentages increased for all treatments from 1996 to 1997 with the exception of NAA at 5000 ppm which decreased from 92% to 73%. In 1996, NAA and talc formulations of IBA resulted in rooting percentages greater than the nontreated control. However, in 1997 none of the auxin treatments resulted in rooting percentages greater than that of nontreated cuttings. Rooting percentages for all auxin treatments except NAA at 5000 ppm were similar to the nontreated cuttings with a range of 95% to 100%. Similar rooting percentages among treatments suggests auxin application was unnecessary to achieve rooting of *C. ericoides* cuttings collected in 1997. Interactions between the main effects of rooting substrate, cutting sex, and auxin treatment were absent.

Root Number

While main effects of substrate and auxin treatment were significant, significant three-way (year, sex, substrate) and two-way (year, auxin) interactions were present. In 1996, greater root numbers developed on cuttings rooted in perlite:vermiculite than in pine bark:sand while fewer roots were produced on cuttings from female plants than cuttings from male plants when rooted in perlite:vermiculite (Table 3). Yet, in 1997 root numbers were similar among cuttings rooted in perlite:vermiculite and cuttings from male plants rooted in pine bark:sand. In both years, the cuttings of

TABLE 5

Influence of year, substrate and auxin treatment on the mean root length (cm[a]) of Ceratiola ericoides

Auxin treatment	Pine bark:sand		*P* value	Perlite:vermiculite		*P* value		
	1996	1997	1996 versus 1997	1996	1997	1996 versus 1997	Pine bark versus perlite–1996	Pine bark versus perlite–1997
None (control)	2.1cd [b]	5.0 ab	0.0001	1.7 c	5.3 ab	0.0001	0.3	0.5
Hormodin 1	3.2 a	5.2 ab	0.0001	1.9 bc	5.0 bc	0.0001	0.0001	0.7
Hormodin 3	2.8 ab	5.4 a	0.0001	1.9 bc	6.0 a	0.0001	0.003	0.2
IBA 1000	2.2 cd	5.0 ab	0.0001	1.6 c	4.9 bc	0.0001	0.07	0.7
IBA 5000	2.5 b	2.7 c	0.6	1.6 c	3.1 d	0.0001	0.002	0.3
NAA 1000	2.3 bcd	4.8 ab	0.0001	2.6 a	4.4 c	0.0001	0.4	0.3
NAA 5000	1.9 cd	2.3 c	0.3	2.8 a	1.9 e	0.02	0.004	0.4
Dip'N Grow 1:20	2.0 cd	4.8 ab	0.0001	2.5 ab	5.2 ab	0.0001	0.16	0.3
Dip'N Grow 1:10	2.4 bc	4.5 b	0.0001	2.9 a	4.2 c	0.0001	0.14	0.5
Dip'N Grow 1:5	1.8 d	5.1 ab	0.0001	3.4 a	4.6 bc	0.0001	0.0001	0.3

[a] 1 cm = 0.4 in
[b] In each column, means followed by different letters are significantly different ($\alpha = 0.05$).

female plants rooted in pine bark:sand produced the least number of roots. On average, cuttings rooted in perlite:vermiculite produced 11 roots per cutting, while cuttings rooted in pine bark:sand produced 7 roots per cutting. In 1996, Hormodin 3, NAA, and Dip'N Grow increased root number compared to nontreated cuttings (Table 4). However, in 1997, no auxin treatment increased root number compared to nontreated cuttings while IBA at 1000 ppm and NAA at 5000 ppm decreased root number.

Root Length

On average, cuttings produced longer roots in 1997 (4.5 cm [1.8 in]) than in 1996 (2.3 cm [0.9 in]; $P = 0.0004$; Table 3). Because root length for cuttings of male and female plants differed between 1996 and 1997 for cuttings rooted in both pine bark:sand and perlite:vermiculite, a significant three-way interaction occurred (year, sex, substrate). However, on average, differences between the substrate:sex combinations were less than 1 cm (0.4 in) within each year and may not represent a biologically significant difference. The main effect of auxin treatment ($P = 0.0001$) was also significant but a three-way interaction (year, substrate, auxin; $P = 0.018$) was also present (Table 5). With the exception of IBA at 5000 ppm and NAA at 5000 ppm the mean root length increased within each substrate treatment between the 1996 and 1997 experiments ($P = 0.02$ to 0.0001).

The effects of auxin treatment on root length differed within each year of the experiment. In 1996, mean root length for cuttings treated with Hormodin 1, Hormodin 3, and IBA at 5000 ppm was greater when rooted in pine bark:sand while mean root length for cuttings treated with NAA at 5000 ppm and Dip'N Grow (1:5) were greater when rooted in perlite:vermiculite. In contrast, mean root length for each auxin treatment was not influenced by propagation substrate in 1997.

Estimated Total Root Length

The main effects of year ($P = 0.006$), cutting sex ($P = 0.03$), and substrate ($P = 0.0001$) were all significant and a year by cutting sex by substrate interaction ($P = 0.0002$) was present (Table 3). On average, estimated total root length of cuttings rooted in 1997 (44 cm [17.3 in]) exceeded that of cuttings rooted in 1996 (29 cm [11.4 in]) while estimated total root length of cuttings rooted in perlite:vermiculite (40 cm [15.7 in]) was greater than cuttings rooted in pine bark:sand (32 cm [12.6 in]). In both years, the smallest root systems were produced by female cuttings rooted in pine bark:sand. The effects of auxin treatment on estimated total root length differ within each year of the experiment (Table 6). In 1996, estimated total root length for cuttings treated with Hormodin 1 and Hormodin 3 was greater when rooted in pine bark:sand while estimated total root length for cuttings treated with NAA at 1000 or 5000 ppm and Dip'N Grow (all rates) were greater when rooted in perlite:vermiculite. In contrast, no auxin resulted in an increase of the estimate total root length in 1997. In 1997, estimated total root length was suppressed for cuttings treated with IBA at 5000 ppm or NAA at 5000 ppm, regardless of the propagation substrate used. However, although root length for cuttings treated with 5000 ppm NAA was suppressed compared to other treatments, the authors considered the NAA-treated cuttings to be of acceptable quality for subsequent liner production (Figure 2).


Photo by Mack Thetford

Figure 2 • Ceratiola ericoides *growing in 1050 cm³ (4 in) pots in July 1998. Cuttings were rooted during summer 1997 and potted in spring 1998.*

Overall, cuttings collected in 1997 rooted at higher percentages, produced more roots per cutting, and exhibited greater root length and estimated total root length than cuttings collected in 1996. This difference in rooting response may be related in part to the condition of the stock plants from which the cuttings were taken (Moe and Andersen 1988; Veierskov 1988). In 1996, cuttings were collected less than 12 mo after stock plants were impacted by 2 hurricanes, while in 1997 stock plants had nearly 2 y to recover from hurricane effects. Stock plant condition also appears to interact with the effects of the propagation substrate on measures of root quality. Only in 1996, when cuttings were collected from recently stressed stock plants, did rooting percentages, on average, fall below 95%. The influence of stock plant condition on measures of root quality are also evident in the reduction in root numbers for female cuttings rooted in pine bark:sand substrate in 1996. Female cuttings flowered and produced fruit while rooting thereby creating an additional sink for carbohydrates other than the developing roots. In 1997, when cuttings were taken from nonstressed stock plants, the occurrence of flowering and fruit production concurrent with root initiation and development did not appear to reduce measures of root quality. With an easily rooted species it makes little difference if flowering or nonflowering shoots are used for propagation, but with difficult to root species this can be an important

TABLE 6

Influence of year, substrate and auxin treatment on the estimated total root length (cm[a]) of Ceratiola ericoides

Auxin treatment	Pine bark:sand		P value	Perlite:vermiculite		P value		
	1996	1997	1996 versus 1997	1996	1997	1996 versus 1997	Pine bark versus perlite–1996	Pine bark versus perlite–1997
None (control)	19 b [b]	48 a	0.0001	21 cd	59 ab	0.0001	0.6	0.09
Hormodin 1	31 a	50 a	0.001	24 cd	51 abc	0.0001	0.1	0.8
Hormodin 3	30 a	46 a	0.005	28 c	63 a	0.0001	0.6	0.01
IBA 1000	19 b	44 a	0.0001	21 cd	54 abc	0.0001	0.7	0.1
IBA 5000	20 b	21 b	0.8	19 d	26 d	0.2	0.8	0.4
NAA 1000	20 b	48 a	0.0001	40 b	46 c	0.3	0.0001	0.7
NAA 5000	18 b	20 b	0.8	47 b	16 d	0.0001	0.0001	0.5
Dip'N Grow 1:20	22 ab	48 a	0.0001	39 b	51 abc	0.04	0.0003	0.6
Dip'N Grow 1:10	26 ab	48 a	0.0001	47 b	48 bc	0.8	0.0001	0.9
Dip'N Grow 1:5	22 ab	42 a	0.0006	58 a	48 bc	0.1	0.0001	0.3

[a] 1 cm = 0.4 in
[b] In each column, means followed by different letters are significantly different ($\alpha = 0.05$).

factor (Hartmann and others 1997). This has been demonstrated previously with blueberry (*Vaccinium atrococcum* Gray (Heller) [Ericaceae]) where shoots containing flower buds rooted poorer than cuttings with only vegetative buds (O'Rourke 1940), and with olive (*Olea europaea* L. [Oleaceae]) where rooting of cuttings with reproductive organs attached was prevented by fruit growth or fruit ripening, as carbohydrates were diverted towards the reproductive organs rather than to the IBA-treated bases of the cuttings (del Rio and others 1991). The differences in cutting response to auxin treatments in 1996 and 1997 may also be attributed in part to the condition of the stock plants. When cuttings were taken from non-hurricane-stressed stock plants (1997), both nontreated and auxin-treated cuttings rooted at percentages greater than 90%, hence, no significant improvement could be demonstrated with the application of an auxin. When cuttings were taken from the hurricane-stressed stock plants (1996), nontreated cuttings rooted at 82% and several auxin treatments resulted in improved measures of root quality. Overall, the results of these experiments suggest no external auxin application is necessary for the successful rooting of softwood cuttings of *C. ericoides* and that either pine bark:sand or perlite:vermiculite are suitable propagation substrates when cuttings are collected from nonstressed stock plants. In addition, rooting percentages and measures of root quality of cuttings collected from hurricane-stressed stock plants may be improved with the application of an auxin and use of a perlite:vermiculite substrate.

Ceratiola ericoides Production

Ceratiola ericoides survival was unaffected by production substrate or cutting sex. Regardless of substrate or cutting sex, *C. ericoides* survival (73%) shoot number (12) and shoot number increase (6) were similar, and although plants produced in pine bark:sand were significantly shorter than plants grown in pine bark:peat:sand (41 versus 43 cm [16.1 versus 16.9 in], respectively), this difference is probably not commercially important. Additional factors such as the chemical and physical structure of the production substrate should be investigated to determine the optimal production substrate for this species.

CONCLUSIONS

Our results demonstrate that both male and female *C. ericoides* can be successfully rooted from softwood cuttings using a perlite:vermiculite substrate with cuttings yielding similar rooting percentages, root number, root length, and estimated total root length. In addition, nursery professionals may achieve an improvement of root quality by increasing root number and root length with the application of a synthetic auxin containing IBA or NAA. Care should be taken to avoid liquid formulations of auxins at concentrations above 5000 ppm, because those concentrations suppressed root number and root length of *C. ericoides* in our rooting environment. Using pine bark:sand as a propagation substrate for *C. ericoides*, while also successful, may result in an unfavorable environment for root growth as a result of low air space and potential waterlogging of the rooting environment.

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