Table 2. Linear regression analysis from the comparison of root-medium pH, electrical conductivity (EC), and NO_3-N and K concentrations measured in solutions obtained with the rhizon soil solution sampler (RSSS) and saturated-media extract (SME) methods measured in ten species grown with three fertilizer concentrations methods from Expt. 3. Data are presented in Fig. 3.

Parameter	Slope	Intercept	CV	Units
pH	0.9	0.2	7.7	pH
EC	1.1	0.2	38.5	$dS \cdot m^{-1}$
NO_3-N	1.1	8	52.0	$mg \cdot L^{-1}$
K	1.0	16	39.7	$mg \cdot L^{-1}$

RSSS compared to that measured with the SME method, but the differences tended to be small (0.1 $dS \cdot m^{-1}$ difference per 1 $dS \cdot m^{-1}$ increase in EC, 10 $mg \cdot L^{-1}$ difference per 100 $mg \cdot L^{-1}$ increase in NO_3-N).

Conclusion

The RSSS was found to be an acceptable method of nutrient extraction from soilless container root media and the pH, EC, and NO_3-N and K concentrations measured with the RSSS were similar to those measured by the standard SME method. The RSSS also is fast, nondestructive, and economical ($6 to $7 per RSSS tube). A protocol could be used with the RSSS that would significantly reduce sampling variability by leaving the probe in the same pots over the duration of a crop or by inserting the probe into the same location in different pots.

There were some limitations to using the RSSS. The RSSS can be damaged by scraping against the side of hole made in the pot for insertion into root medium, bent by use of excessive force or rapid insertion into the medium or damaged by being left in the sun for long periods of time. With the RSSS, the medium must have a high moisture content (such as just after an irrigation) before a sample can be extracted, which limits when the sample can be taken. The pot-to-pot variability was consistent with what we have observed with SME and 1:2 testing methods, where medium is removed from a pot. Therefore, under commercial conditions, we suggest using a composite sample from five to ten pots, as is recommended with other sampling methods currently used, to measure the nutrition levels in container media (Biernbaum et al., 1993).

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Factors Affecting Propagation of *Clematis* by Stem Cuttings

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Additional index words. media, node position, root emergence

Summary. Effect of media type, cultivar, and indole-3 butyric acid (IBA) application on *Clematis* spp. stem cutting rooting was studied. Cutting survival across all treatments was highest on 'Comtesse de Bouchard' and 'Gypsy Queen' cuttings and lowest on 'Jackmani' cuttings. Cutting survival was greatest in perlite and lowest in peat–perlite–vermiculite. IBA application increased 'Jackmani' cutting survival only. Time of root emergence was longest on 'Jackmani' and least on 'Gypsy Queen' cuttings across treatments. Root emergence occurred first in sand and perlite and last in peat–perlite across treatments. Root dry mass on cuttings from 'Jackmani' and *Clematis viticella* purpurea plena elegens plants were unaffected by medium type. In contrast, root dry mass on 'Comtesse de Bouchard' cuttings was highest in perlite and root dry mass on 'Gypsy Queen' cuttings was highest in sand, perlite, and peat–perlite–vermiculite. The best media for propagating clematis were sand and perlite. Benefits to rooting cuttings in sand or perlite were similar, except rooting cuttings in perlite resulted in higher cutting root dry mass.

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There are >200 species of perennial herbs or woody climbing vines that constitute the group of plants we refer to as clematis (*Clematis* L. or T. Moore) (Evison, 1977; Liberty Hyde Bailey Hortorium, 1976; Lloyd, 1989). Clematis propagation techniques have changed over time. Many clematis were originally propagated commercially by grafting scions onto *C. vitalba* or *C. viticella* rootstock (Evison, 1977, 1991; Lloyd, 1989). Clematis are now commercially propagated from seed or by rooting single-node cuttings (Evison, 1977; Lloyd, 1989). Species are often propagated by seed (Evison, 1977). Most clematis cultivars are propagated vegetatively because cultivars can revert and exhibit original species traits when seed propagated (Evison, 1977). Current commercial clematis propagation is based on cutting propagation since most clematis sold are cultivars.

Growers often have difficulty rooting clematis cuttings. About 10% to 80% of clematis cuttings fail to root, depending on species, media, cultivar, and time of year (T. Donahue, personal communication; Auld and Carrall, 1985; Hatch, 1980). The objectives of this study were to determine the impact of rooting media, cultivar, and indole-3 butyric acid (IBA) application on clematis stem cutting rooting.

Materials and methods

Seven-node stock plants of *Clematis* x *jackmanii* T. Moore (*C. lanuginosa* x *C. viticella*) 'Jackmani', 'Comtesse de Bouchard', 'Gypsy Queen' and *Clematis viticella* purpurea plena elegans L. were obtained on 25 Apr. 1991 from Donahue's Greenhouses (Fairbault, Minnesota). Plants were transported to St. Paul, Minn., and were placed in a glasshouse (20 ± 2 °C air temperature) under natural photoperiodic conditions.

Single-node cuttings (1000) were harvested from plants on 3 May 1991. Cuttings included 1 to 3 cm of stem section with the node located on the upper one-third of the cutting. Five cuttings were harvested from each plant. Cuttings were treated with or without 0.1% IBA (Hormex 1, Brooker Chem. Co., North Hollywood, Calif.) and placed in a humidity chamber (2 mil clear polyethylene) in a glasshouse for rooting (24 ± 3 °C air temperature under natural photoperiod). Humidity averaged 86% in the chamber. Cuttings were placed in one of five different media for rooting: 1) washed brown river sand (sand), 2) 1 washed sand : 1 sphagnum peat (v/v) (sand–peat), 3) 1 sphagnum peat : 1 perlite (v/v) (peat–perlite), 4) perlite, or 5) 2 sphagnum peat : 1 perlite : 1 vermiculite (v/v) (peat–perlite–vermiculite).

Data were collected on percent rooting, time to root emergence, and root dry mass. Time of root emergence was defined as that time when primary roots were 3 mm long. Determining time of root emergence required media removal and replacement. Percent survival and root dry mass data were collected 56 d after treatment initiation. The experiment was organized as a completely randomized design in a 4 × 5 × 2 factorial arrangement with cultivar, medium, and IBA application as main effects (40 treatment combinations, 25 replicates/treatment). Analysis of variance (ANOVA) and post hoc tests (Fischer's LSD) were conducted. Arcsine transformation was conducted on all percentage data before analysis. ANOVA identified that no third-order interactions were significant.

Table 1. Interaction between rooting media and cultivar on *Clematis* spp. percent cutting survival, time to root emergence (d), and root dry mass after 56 d. Letters not in parenthesis indicate comparisons between media types. Letters in parenthesis indicate comparisons between cultivars.

	Medium type[z]					
Cultivar[z]	Sand	Sand–Peat	Peat–Perlite	Perlite	Peat–Perlite–Vermiculite	Mean[y]
			Percent cutting survival			
Jackmani	66 b (ab)	38 ab (a)	38 ab (a)	44 ab (a)	34 a (a)	44 (a)
Comtesse	55 ab (a)	50 a (ab)	60 ab (b)	86 b (b)	74 ab (b)	65 (b)
purpurea	70 ab (ab)	66 ab (ab)	32 a (ab)	80 b (b)	48 ab (ab)	59 (ab)
Gypsy	90 b (b)	70 ab (b)	74 ab (b)	84 b (b)	52 a (ab)	74 (b)
Mean[x]	70 ab	56 ab	51 ab	74 b	52 a	
			Time to root emergence			
Jackmani	43 a (b)	54 b (b)	50 ab (b)	43 a (a)	46 ab (a)	46 (c)
Comtesse	34 a (a)	46 bc (b)	48 c (b)	33 a (bc)	40 ab (a)	39 (b)
purpurea	35 a (a)	37 a (a)	41 a (ab)	38 a (ac)	38 a (a)	38 (ab)
Gypsy	33 a (a)	39 b (ab)	41 b (ab)	34 a (a)	36 ab (a)	36 (a)
Mean	36 a	43 bc	45 c	36 a	39 b	
			Root dry mass (µg × 1000)			
Jackmani	43 a (a)	10 a (a)	9 a (a)	67 a (ab)	34 a (a)	34 (a)
Comtesse	77 b (ab)	23 ab (a)	19 a (a)	178 c (c)	70 b (ab)	87 (b)
purpurea	62 a (ab)	31 a (a)	9 a (a)	48 a (a)	45 a (a)	42 (ab)
Gypsy	103 b (b)	36 a (a)	27 a (a)	111 b (b)	92 b (b)	75 (b)
Mean[x]	73 b	27 a	18 a	109 c	69 b	

[z]Five media were evaluated: 1) 100% washed sand (sand), 2) 50% washed sand and 50% sphagnum peat (sand–peat), 3) 50% sphagnum peat and 50% perlite (peat–perlite), 4) 100% perlite, and 5) 50% sphagnum peat, 25% perlite and 25% vermiculite (peat–perlite–vermiculite). Four clematis were evaluated: 1) 'Jackmani', 2) 'Comtesse de Bouchard' (Comtesse), 3) *Clematis viticella* purpurea plena elegans' (purpurea), and 4) 'Gypsy' Queen (Gypsy).
[y]Numerals represent the mean percent survival of cuttings across media types.
[x]Numerals represent the mean percent survival of cuttings across cultivars.

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Results

Cutting survival. The impact of medium on cutting survival varied with cultivar. Cutting survival of 'Jackmani' cuttings was highest in sand (Table 1). Cutting survival of 'Comtesse de Bouchard' and *Clematis viticella* purpurea plena elegans cuttings was highest in perlite. Cutting survival of 'Gypsy Queen' cuttings was highest in sand and perlite. Cutting survival across all treatments was highest on 'Comtesse de Bouchard' and 'Gypsy Queen' cuttings and lowest on 'Jackmani' cuttings. Cutting survival was greatest in perlite and lowest in peat–perlite–vermiculite (Table 1). IBA application increased 'Jackmani' cutting survival only (Table 2).

Time to root emergence. Cultivar and medium interacted to affect time of root emergence. Time of root emergence was longest on 'Jackmani' and shortest on 'Gypsy Queen' cuttings across treatments. Time of root emergence on cuttings of 'Jackmani', 'Comtesse de Bouchard', and 'Gypsy Queen' was shortest in sand and perlite (Table 1). In contrast, *Clematis viticella* purpurea plena elegens time of root emergence was unaffected by medium. Root emergence occurred first in sand and perlite and last in peat–perlite across treatments.

Root dry mass. Medium and cultivar interacted to affect cutting root dry mass. Root dry mass on cuttings from 'Jackmani' and *Clematis viticella* purpurea plena elegens plants were unaffected by medium type (Table 1). In contrast, root dry mass on 'Comtesse de Bouchard' cuttings was highest in perlite and root dry mass on 'Gypsy Queen' cuttings was higher in sand, perlite, and peat–perlite–vermiculite. Root dry mass was least in sand–peat and sand and greatest in perlite across treatments (Table 1). Root dry mass varied among cultivars and was least on 'Jackmani' cuttings and greatest on 'Comtesse de Bouchard' and 'Gypsy Queen' cuttings (Table 1).

Discussion

The best media for propagation of clematis were sand and perlite. Benefits to rooting cuttings in sand or perlite were similar except rooting cuttings in perlite resulted in higher cutting root dry mass (Table 1). Differences in cutting rooting in various media were most obvious with easily rooted cultivars such as 'Comtesse de Bouchard' and 'Gypsy Queen' and least in the difficult-to-root plants 'Jackmani' and *Clematis viticella* purpurea plena elegens.

Previous reports recommended other media than those suggested here for clematis propagation (Auld and Carrall, 1983; Evison, 1977; Lloyd, 1989). The Jon Innes mix (1 sterilized loam : 2 peat : 3 sand) is recommended by Lloyd (1989). Evison (1977) recommended a medium composed of 1 loam : 1 peat : 2 grit : and 2 screening sand for rooting clematis. Auld and Carrall (1983) recommended a medium composed of 2 German peat : 3 coarse washed sand. Peat-based media in this study resulted in inferior rooting (Table 1). Sand is the primary medium used in the United States for commercial clematis propagation (D. Donahue, personal communication). Our data confirm the basis for this decision but suggest that perlite may be an alternative medium with equal or better potential rooting.

Data presented here suggest that IBA application may be useful on difficult-to-root cultivars or species only (Table 2). IBA application to the base of the cutting is recommended to enhance rooting of clematis (Auld and Carrall, 1985; Evison, 1977; Hatch, 1980; Lloyd, 1989) but has not been documented through research. Since only one IBA concentration was evaluated, additional treatments would be necessary for a definitive conclusion regarding the effectiveness of IBA in clematis propagation.

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Table 2. Effect of cultivar and IBA treatment on the percent of *Clematis* cuttings that rooted 56 d after emergence of treatments. Letters indicate comparisons between cultivars.

IBA treatment	Cultivar[z] Jackmani	Comtesse	purpurea	Gypsy	Mean
	Percent survival				
No IBA	23 a[y]	79 a	61 a	68 a	58 a
IBA application (0.1%)	65 b	51 b	58 a	80 a	63 a

[z]Four clematis were evaluated: 1) 'Jackmani', 2) 'Comtesse de Bouchard' (Comtesse), 3) *Clematis viticella* purpurea plena elegans (purpurea), and 4) 'Gypsy Queen' (Gypsy).
[y]Numerals represent means.

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