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Mass Propagation of Rocky Mountain Juniper From Shoot Tip Cuttings

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Demand has exceeded supply for conservation plantings of Rocky Mountain juniper-Juniperus scopulorum Sarg. Vegetative propagation could provide an alternative source of planting stock. Ortets from 2 to 40 years of age provided cuttings from leaders and first-rank branches. Ramets, 12-cm-long (4.7-in-long) from 2-year-old ortets, rooted at rates of zip to 82%. Treatment of cuttings with 1.6 or 3.0/h indole-3-butyric acid (IBA) accelerated rooting by several months and increased overall rooting success by up to 36%. Stecklings survived at high rates (97%) and developed a normal seedling-like form. Tree Planters' Notes 47(3): 94-99; 1996.

Rocky Mountain juniper (RMJ)— *Juniperus scopulorum* Sarg..— is planted extensively across the Great Plains and Intermountain regions for windbreaks, living snow fences, and wildlife habitat, and to provide wood for fence posts and other specialty uses (Rietveld 1989; Young and Young 1992). Demand for planting stock, however, has exceeded supply recently (Wagner and others 1994), and seedling production is often hampered by erratic, delayed, and low rates of germination (Noble 1990; Rietveld 1989). Wagner and others (1992) discussed potential advantages of shorter production time and opportunity for tree improvement by propagating juniper for conservation plantings from cuttings as an alternative to seedling production.

Junipers are commonly propagated from cuttings, but species that grow upright are considered more difficult to multiply than prostrate forms (Hartmann and others 1990). Dirr and Heuser (1987) described optimal rooting treatments for RMJ cultivars using up to 4.5% indole-3-butyric acid (IBA). Wagner and others (1994) reported less than 10% rooting success of RMJ cuttings from 12-year-old selected ortets ("parent" trees) rooted after dips in liquid Dip'N Grow ®— 0.5% IBA plus 0.25% naphthaleneacetic acid (NAA)-or talc powder with 0.8% IBA.

Greenhouse culture may enhance propagation success. Ramets (vegetatively propagated "daughter" plants) taken from container-grown juniper plants often root at higher rates and develop better root systems than field-grown stock plants (Dirr and Heuser 1987). Although rooting success tends to decline as ortets mature, hedging stock plants may also prolong juvenility and high rooting rates (Hackett 1985).

Few data are available on rooting of container-grown RMJ cuttings from non-selected juvenile ortets. This study examined cutting yield from greenhouse-grown seedlings; effects of cutting size, rooting hormone, and ortet age on adventitious rooting; and growth and form of stecklings (plantable rooted cuttings).

Materials and Methods

Table 1 summarizes observations and rooting experiments conducted with different sources, ages, and containers of ortets used in this study.

Juvenile propagation material. Cuttings were provided by 2-to 5-year-old RMJ seedlings. These ortets were grown at the University of Idaho Forest Research Nursery in Moscow from wild seed (Colorado origin) operationally sown into 66-ml (4-in^3) Ray Leach® pine cells. Seedlings were grown under a regime similar to that for western white pine— *Pinus monticola* Dougl. ex D. Don (Wenny and Dumroese 1987). In both 1992 and 1993, about 200 randomly selected 1-year-old production-run seedlings, with average height of 12 cm (4.7 in) and caliper of 2.2 mm (0.09 in), were transplanted to 4-L pots (400 pots/100 ft^2 of bench area) and were fertilized twice weekly with N/P/K = 20:20:20 at 100 ppm N for 2 growing seasons. The 4-year-old ortets were then transplanted to 8L pots (178 pots/100 ft^2) and fertilized similarly.

Mature propagation material. In October 1993, 480 cuttings were collected from two 40-year-old RMJ trees in Moscow, Idaho, and 1,000 cuttings were harvested in December 1994 from non-selected 12-year-old ortets at the USDA Natural Resources Conservation Service's Plant Materials Center, Aberdeen, Idaho.

Ortet yield. Cuttings were leaders from 2-year-old ortets and first-rank branch tips from older donors. To estimate cutting yield of older ortets, maximum numbers of 12-cm-long (4.7-in-long) branch cuttings were taken from randomly selected 3- and 5-year-old ortets (40/age class). (This paper refers to age classes of ramets that correspond to their ortet age.)

General rooting procedures. For all trials, turgid branch tips were cut to within several millimeters of a pre-determined length at an angle of 45/ to the stem axis. Cuttings were immediately soaked for 30 sec in 1 g/L benomyl and dipped in commercial auxin formulations containing talc with various concentrations of IBA and NAA. Treated cuttings were inserted into 1.5-cm-deep dibble holes in a 3:1:1 (v/v/v) mixture of perlite, peat, and vermiculite. Trays of cuttings were placed on benches shaded to 60% of full sunlight. Minimum relative humidity was 86% and diurnal air temperatures ranged from 15 to 25 /C (59 to 77 /F). The rooting medium was periodically hand-watered to keep it moist, but the cuttings were not fertilized.

Cutting size trial. In mid-November, leaders were cut from 150 dormant 2-year-old RMJ stock plants chosen at random. To assess the effect of length on rooting, cuttings were randomized to alternative lengths, 50 cuttings/length, of 4, 8, and 12 cm (1.6, 3.2, and 4.7 in). All cuttings were dipped in 1.6% IBA. The experiment was repeated in mid-November with ramets from 4-year-old ortets. We recorded percentage rooting, callus formation on unrooted cuttings, basal stem necrosis, average root number, and mean maximum root length after 4 and/or 10 months. Subsequent experiments used 12-cm-long (4.7-in-long) cuttings.

Auxin treatment trials. A series of rooting experiments was conducted with 2-, 3-, 4-, and 5-year-old greenhouse-grown and 12- and 40-year-old field-grown cuttings (table 1). Cuttings were randomly assigned to one of the following treatment groups:

, control (no auxin)
, Hormex®) rooting powders containing talc and either 0.1, 0.3, 0.8, 3.0, or 4.5% IBA

Table 1- *Observations of ortet chid steckling growth and rooting trials conducted with cuttings from juvenile containergrown acrd mature field-grown ortets of Rocky Mountain juniper—* Juniperus scopulorum *Sarg.*

Source material		Observations and rooting trials				
Ortet age (yr)	Container vol.	Ortet yield	Cutting length	Auxin trt.	Leader vs branch	Steckling growth & form
Seedlings						
1	*66 ml					
2	4 L		X	X		
3	4 L	X		X		X
4	8 L		X	X	X	
5	8 L	X		X		
Trees						
12	Aberdeen			X		
40	Moscow			X		X

* Production crop.
trt = treatment

, Rootone® (a powder mixture of 0.2% NAA, 0.1% IBA. and Thiram®)
, Dip'N Grow®, a liquid formulation containing 1.0% IBA and 0.5% NAAdiluted to 0.1% IBA and 0.05% NAA)

Percentage rooting, numbers of roots produced/ steckling, and mortality of unrooted cuttings were recorded every 3 months for a year. In one trial, half of the cuttings (160) were not treated with benomyl.

Leader versus first-rank branch trial. Cuttings of leaders and first-rank branches, 146 cuttings/type, were taken from dormant 4-year-old ortets in winter. We recorded percentage rooting, percentage of stecklings and unrooted cuttings with well-developed callus, number of primary roots per steckling, and incidence of lateral rooting after 6 months.

Steckling growth and form. Stecklings from 3- and 40-year-old ortets were observed for 1 and 2 years, respectively, after rooting. In spring 1995, about 500 newly rooted 12-cm-long (4.7-in-long) stecklings (from 3-year-old ortets) were transplanted into 45/340 copperblocks — 45 cells with 340-ml (20 in^3) capacity, 18 seedlings/ft^2 — containing a 1:1 (v/v) mixture of peat and vermiculite. Stecklings received nutrient applications of N/P/K = 20:7:19 at 192 ppm N once or twice weekly. After 12 months, height and caliper were measured from 40 randomly selected orthotropic (upright) stecklings. Plagiotropism (prostrate form) was assessed in 360 stecklings chosen at random. Stecklings rooted in 1994 from 40-year-old ortets were treated similarly and assessed for plagiotropism after 12 and 24 months.

Data analysis. Uncertainty in means was expressed as standard error (SE). The SAS statistical package (SAS Institute 1989) was used to examine categorical data by maximum likelihood ANOVA with procedure CATMOD. Means were compared by single-degree-of-freedom contrasts. Continuous data were subjected to ANOVA procedure GLM and count data were analvzed by the Kruskal-Wallis test using procedures RANK and GLM with Tukey's studentized test.

Results

Ortet yield. The 3- and 5-year-old ortets produced an average of 14±1 and 34±2 cuttings/ortet, respectively. Stock plants grew vigorously (figure 1) without mortality. Despite dense foliage and close packing, plants remained disease free, but root weevils Otiorhynchus spp.) increasingly infested older ortets.

Cutting size trial. The longest cuttings-12-cm-long (4.7-in-long)-of both 2- and 4- year classes rooted at the highest rate and developed the most callus, the largest number of roots per steckling, and the longest roots

Figure 1—*A hedged seedling ortet of Rocky Mountain juniper—* Juniperus scopulorum *Sarg.—after 5 years of container growth.*

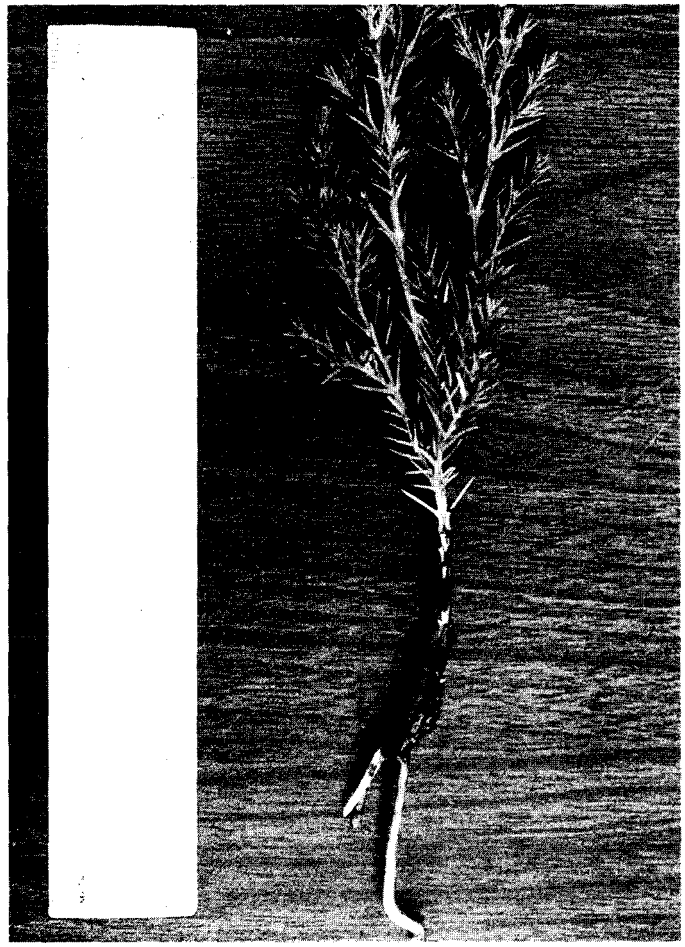

Figure 2—*A branch tip cutting of Rocky Mountain juniper—* Juniperus scopulorum *Sarg.—shortly after root emergence.*

Table 2— *Effect of cutting length on rooting of Rocky Mountain juniper—*Juniperus scopulorum *Sarg.—cuttings, callus formation in unrooted cuttings, stem necrosis, and number and maximum length of roots; data were collected 4 and 10 months after setting cuttings at a rate of 50 cuttings/size/age class*

Ortet age (yr)	Cutting length (cm)	Rooting success (%) (4 mon)	Rooting success (%) (10 mon)	Callused cuttings (%) (4 mon)	Stem necrosis (%) (4 mon)	Ave. no. roots/cutting (10 mon)	Ave. max. root length (cm) (10 mon)
2	4	28 a	52 a	54 a	25 a	1.3 a	12.2 a
2	8	46 b	78 b	82 b	16 ab	2.1 a	14.2 a
2	12	62 c	82 b	90 b	8 b	3.7 b	21.9 b
4	4	0 a	20 a	22 a	18 a		
4	8	4 a	34 b	46 b	20 a		
4	12	18 b	51 c	66 c	4 b		

Percentages and means within columns of each age class with the same letter are similar (α = 0.05).

(table 2). Most unrooted cuttings that developed callus after 4 months subsequently rooted. The 4-year cuttings rooted less frequently than 2-year cuttings. About 5% of unrooted cuttings of each length and age class blackened upward from the base.

Auxin treatment trials. Roots usually emerged from cutting bases and stems within 2 months (figure 2). During the first 6 months after treatment, both 1.6% and 3.0% IBA accelerated rooting of the 2-year cuttings (figure 3). Rooting of controls was initially delayed but

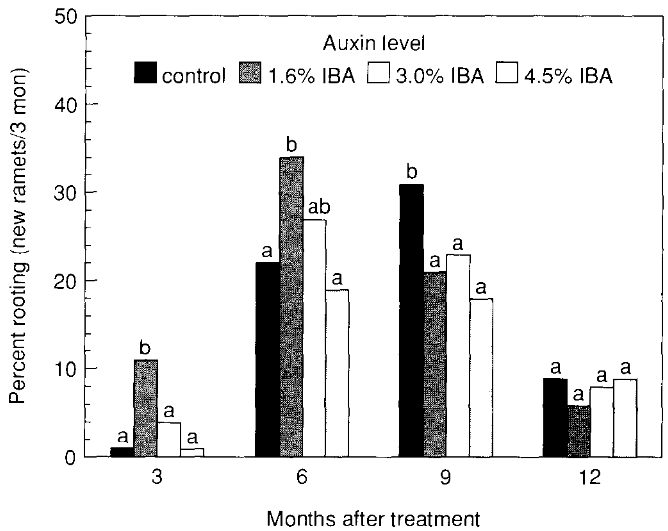

Figure 3—*Rooting of Rocky Mountain juniper*—Juniperus scopulorum *Sarg.—cuttings from 2-year-old ortets versus time.*

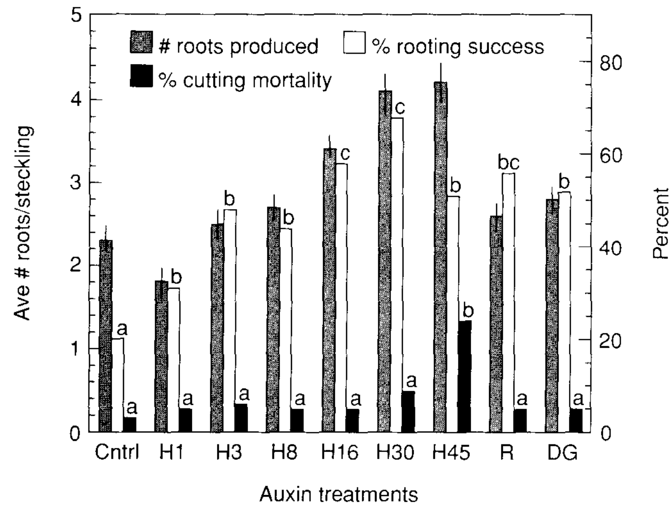

Figure 4— *Root development, rooting success, and mortality of Rocky Mountain juniper*—Juniperus scopulorum *Sarg.—cuttings (3-year-old ortets) 6 months after auxin treatment in October. (H1 to H45 = 0.1, 0.3, 0.8, 1.6, 3.0, & 4.5% IBA; R = Rootone (0.2% NAA + 0.1% IBA); DG = Dip'N Grow (diluted to 0.1% IBA + 0.05% NAA; n=225). Percentages with similar letters within a series are similar (α = 0.05).*

increased sharply between 6 and 9 months, whereas rooting of auxin treated cuttings declined or remained unchanged. Rooting subsequently slowed and ceased by 12 months.

Auxin treatment typically increased overall rooting success in all age classes of cuttings (table 3). After 12 months, highest rooting rates of 2-and 3-year cuttings set in October exceeded 70%, with36% more cuttings in the 3-year class rooted in 3.0% IBA, but only 6% more in the 2-year class. The 12-year cuttings set in January rooted up to 44% less than the 3-year class. Clones of 40-year cuttings rooted at overall respective rates of 4 and 44%.

Within 6 months of treatment in October, cuttings of the 3-year class rooted with 68% success in 3.0% IBA (figure 4). Highest numbers of roots emerged from cuttings in 3.0 and 4.5% IBA, but 4.5% IBA resulted in higher cutting mortality (24%) than other treatments. The powder formulation with 1.6 and 3.0%o IBA resulted in higher rooting success than the liquid formulation with 0.1% IBA and 0.05% NAA but was similar to the result with Rootone. About 23% (37) of the cuttings not soaked in benomyl prior to auxin treatment rotted and died;

Table 3—*Effect of auxin treatment on rooting success 12 months after setting Rocky Mountain juniper*—Juniperus scopulorum *Sarg.—cuttings from 2-, 3-, 12-, and 40-year-old ortets*

	Percent rooting							
	2 yr		3 yr			12 yr	40 yr	
							Oct (n=120)	
Treatment	Mar (n=80)	Oct (n=120)	Jan (n=150)	Jul (n=200)	Oct (n=225)	Jan (n=150)	Clone 1	Clone 2
Control	45	64 ab	22 a	18 a	42 a	6 a	0	1
0.1% IBA						51 a		
0.3% IBA						65 b		
0.8% IBA	59		33 a	42 b	64 b	8 a	8	87
1.6% IBA	65	70 b	51 b	48 b	74 bc	15 a		
3.0% IBA		62 ab	58 b	50 b	78 c	14 a		
4.5% IBA		44 a		43 b	60 b			
Rootone			41 ab		69 b	15 a		
Dip'N Grow	38				68 b			

Percentages within columns with the same letter are similar (α = 0.05); n = number of cuttings per treatment.

7.5% (12) of the cuttings treated with fungicide succumbed.

Leader versus first-rank branch trial. Cuttings from first-rank branches of 4-year-old ortets rooted at slightly higher rates than leaders, but numbers of adventitious roots developed per cutting and maximum root length were similar (table 4). More callusing occurred in both rooted and unrooted cuttings of leaders, whereas twice as many branch cuttings as leaders produced secondary roots. Mortality rates were similar for both types of cutting.

Steckling growth and form. After 1 year of indoor container growth, average height and caliper of stecklings from 3-year-old ortets was 36.1 ± 0.9 cm and 5.4 ± 0.2 mm, respectively. Leaders failed to develop normal form in 12% (43) of the stecklings: 3% (11) were plagiotropic, 2% (7) did not grow after rooting, 6% (22) produced competing leaders, and 1 % (5) died. All bent leaders, however, had begun to develop upright growth.

Two years after rooting, leaders of 92% (81) of the stecklings derived from 40-year-old ortets remained plagiotropic (figure 5). Stecklings continued to produce mature scales versus juvenile needle foliage typical of young ortets.

Figure 5—*Stecklings of Rocky Mountain juniper*—Juniperus scopulorum *Sarg.—after 1 year's container growth.* ***Left:*** *plagiotropic ramet from 40-year-old donor.* ***Right:*** *normal orthotropic ramet from 3-year-old ortet.*

Table 4—*Rooting success, incidence of callus and lateral root formation, and average number of primary roots per steckling from leaders versus first-rank branches of Rocky Mountain juniper*— Juniperus scopulorum *Sarg.—(n = 146 cuttings/type)*

Cutting	Rooting success (%)	Callused stecklings (%)	Primary roots (no.)	Lateral roots (%)	Callused cuttings (%)
Leader	17 a	76 a	2.0 a	20 a	51 a
Branch	24 a	38 b	2.1 a	47 b	36 b

Percentages and means in columns with the same letter are similar (α = 0.05).

Discussion

Ortet yield. Although rootability of RMJ cuttings declines with increased ortet maturity, older ortets can produce more shoots for propagation than younger donors. Results from cutting harvests suggest that Sand 5-year-old ortets could yield from 5,500 to 6,000 cuttings on 100 ft^2 (9.3 m^2) of bench area. Top-pruning to control growth of 2-year-old production seedlings to a final height of 30 to 40 cm and caliper > 5.7 mm (unpublished results) could yield about 2,250 leader cuttings/100 ft^2 from ortets grown in 45/340 copperblocks. Advantages of top-pruning 2-year-old seedlings include high rootability of the juvenile cutting material and possible greater genetic diversity, as well as avoidance of rootability decline, high maintenance costs, and pest buildup in indoor stock plants. Container-grown stock plants, however, can produce multiple crops of cuttings from elite selections at preferred times of year.

Cutting length trial. The longest RMJ cuttings developed more roots than shorter cuttings, similar to increased root counts reported by Henry and others (1992) in 25-cm-long (9.8-in-long) versus 12-cm-long (4.7-in-long) cuttings of eastern redcedar (ERC)— *Juniperus virginiana* L. Higher rooting success in longer RMJ cuttings, however, is different from similar rooting rates for 2 lengths of cuttings observed in the ERC study. Shorter RMJ cuttings may possibly root less frequently because of lower carbohydrate reserves or diminished photosynthetic capacity (Davis 1988).

Auxin treatment trials. Higher IBA levels improved RMJ rooting success, whereas in ERC, 2 and 0.5%o IBA produced similar results (Henry and others 1992). Increased cutting mortality with 4.5% IBA, however, suggests a phytotoxic effect due to high concentration of growth regulator (Hartmann and others 1990). Because cuttings rooted most rapidly after treatment With 1.6 and 3.0% IBA, these concentrations would be optimal for commercial propagation.

Although our experiments did not directly compare rooting success at different times of year, high rooting rates of 2- and 3-year cuttings set in October are consistent with optimal rooting of RMJ and ERC cultivars from October to December (Dirr and Heuser 1987). Low light intensity may have limited rooting of RMJ cuttings set in January because strong light has been found to enhance juniper propagation (Hartmann and others 1990).

Our low success rates of rooting cuttings from non-selected 12-year-old ortets is similar to rooting rates reported by Wagner and others (1994) for selected RMJ ortets of the same age. Large clonal differences in gymnosperm rootability have been reported (Haissig and Riemenschneider 1988), similar to the 86%o range of rooting success between the 2 clones from 40-year-old RMJ ortets.

Leader versus first-rank branch trial. Although differences in rooting success were slight, more RMJ branches than leaders may have rooted due to maturational differences associated with aging (Hackett 1988). Leaders are generally more mature than branches lower on the stem (Geneve 1995), and cuttings taken from lateral shoots of some spruce, pine, and hardwoods consistently root at higher rates than terminal shoots (Hartmann and others 1990).

Steckling growth and form. After 1 year of indoor container growth, RMJ stecklings were similar in size but not as bushy as top-pruned 2-year-old RMJ seedlings. Results suggest that total steckling losses from stunting and mortality after transplanting are small (3%). Because RMJ is not strongly apically dominant and new upright growth developed on previously bent leaders, multiple-stemmed and plagiotropic stecklings derived from juvenile ortets will likely develop normal RMJ habit. The high incidence of plagiotropism and mature foliage developed by stecklings from 40-year-old donors, however, suggest that recovery of upright form may occur slowly if at all. Plagiotropism in stecklings from mature ortets of many conifer species may persist for years (Hackett 1985).

Conclusions

Mass propagation of Rocky Mountain juniper cuttings is feasible with 12-cm-long (4.7-in-long) leaders or terminal branch shoots tips. Treating cuttings from juvenile ortets with 1.6 or 3.0%o IBA can accelerate rooting and increase overall rooting success. Fungicidal dip with 1 g/L benomyl can improve cutting survival. Stecklings survive at high rates and develop a normal seedling-like form.

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