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Cutting Type and Time-of-Year Affect Rooting Ability of Hardy Minnesota *Prunus* Species

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Chemical abbreviations: EtOH, ethanol; IBA, indole-3-butyric acid; K-IBA, indole-3-butyric acid potassium salt

Abstract

Many species within the genus *Prunus* are difficult to root, and most cultivated accessions are grafted for propagule production. The University of Minnesota *Prunus* germplasm and cultivar releases include a variety of ornamental and edible fruit types that have received little research focus. Many accessions have never been evaluated for the ability to root, even though at least one sour cherry, *P. cerasus* 'Northstar', is sold on its own root system. Two experiments were conducted to evaluate if cutting position, time of year, or auxin treatment are important for terminal and basal softwood-semi-hardwood rooting success of: I) *P. ×cistena* (control); *P. armeniaca* 'Westcot', and 'Hardygold'; *P. cerasus* 'Northstar', and 'Meteor'; *P. domestica* 'Superior', and *P. spp*. 'Alderman' treated with 0.0041 M (1000 ppm) or 0.017 M (4000 ppm) indole-3-butryric acid-potassium salt (K-IBA) and II) *P. ×cistena* (control) and *P. spp*. 'Alderman' treated with 0.00033 M (80 ppm) of K-IBA and 80 ppm Indole-3-caprioc acid (ICapA). Cuttings were taken biweekly (5 June-11 Sept.. 2012) and then monthly until 4 Dec. 2012. After six weeks in the mist, cuttings were scored for callus formation, root development, and bud break (leaves, flowering). The highest frequency of rooting occurred in June and again in Oct.-Dec. for *P. ×cistena* and July, Sept.-Oct. for *P. armeniaca* 'Westcot'. All other cultivars had very low or no rooting. On average, regardless of genotypic variability, all *Prunus* analyzed had ≤60% rooting, which is less than commercially acceptable. The highest mean percent rooting ranged from 1.1% (*P. spp*. 'Alderman') to 24.1% (*P. armeniaca* 'Westcot') and 40.2% (*P. ×cistena*), although many had 100% rooting in specific cutting harvest weeks. Unexpected leaf and/or flowering of cuttings occurred as early as early June for 'Westcot', 'Superior', 'Alderman', and *P. ×cistena* (Growing Degree Days (GDD) = 837) or late June for 'Hardygold', 'Meteor', and 'North Star' (GDD =1070) was unprecedented. The reasons for such a quick release from dormancy, often without the accumulation of chilling units, are unknown.

The large and economically important genus *Prunus* includes many species that serve a variety of commercial functions throughout the world including fruit crops (apricots, peaches, plums, and sweet and tart cherries, ornamental and landscape uses as well as medicinal plants (*P. africana* Kalkman*)* (Potter, 2012*)*. However, in USDA Zones 3 and 4, low temperatures, lack of winter hardiness, and spring frosts limit the *Prunus* species that can be successfully cultivated (Andersen and Weir, 1967). Even if winter hardy, the majority of cultivars in this genus were often reported to be short lived (20-25 years; Taylor, 1965).

Since many *Prunus* cuttings do not reliably root, the majority of genotypes used for fruit production are propagated via grafting onto a rootstock (Hartmann et al. 1997), but some may benefit from planting on their own root system (Tworkoski and Takeda, 2007). Propagation via rooted cuttings is inexpensive in comparison to other vegetative means, and many rootstocks and ornamental plants are propagated using this method (Hartmann et al. 1997; Tworkoski and Takeda, 2007). However, little is known about the capability of *Prunus* cultivars hardy to northern latitudes to form adventitious roots and produce rooted cuttings reliably (Reigard et al., 1990).

There are many factors that impact the rooting of cuttings including genotype, auxin

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type and concentration, juvenility, time of cutting collection, level of hardening of cutting, as well as physiological and environmental conditions (Hartmann et al., 1997; Pijut and Espinosa, 2004; Strauch et al., 1985; Tworkoski and Takeda, 2007). Previous studies have demonstrated that the time of year in the growing season impacts rooting success in some *Prunus* species. For example, *P. serotina* Ehrhart (black cherry) achieved the highest rooting success in March, prior to flowering (Dehgan and Sheehan, 1990). In contrast, when peach (*P. persica* Batsch.) cuttings were collected in both Aug. and Oct., only the Aug. cuttings rooted (Tworkoski and Takeda, 2007), indicating that different physiological stages can be important for rooting success of different species or genotypes.

For many species, softwood cuttings have greater rooting success than hardwood cuttings (Couvillon, 1988; Hartmann et al., 1997). Easy and fast rooting make softwood cuttings an attractive method of propagation in species that do not generally root easily, although hardwood cuttings do not desiccate as easily, are easier to transplant, and less expensive than softwood cuttings (Hartmann et al., 1997). The rooting potential of interspecific cherry hybrids was often determined with the use of softwood cuttings (Wagner et al., 1985; Strauch et al., 1985).

The addition of auxin often aids in increasing the percentage of rooting in species that are difficult to root (Hartmann et al., 1997). The effect of IBA concentration is species- and genotype-specific. Indole-3-butyric acid (IBA) has been shown to be effective in peach and sweat cherry cultivars (Coulvillon, 1985; Strauch et al., 1985). However, the concentration of auxin and type of cutting affects rooting success (Tworkoski and Takeda, 2007). Reighard et al. (1990) utilized 0.0099 M (2000 ppm) IBA when testing the rooting of 400 genotypes of different *Prunus* species, whereas de Oliveira et al. (2003) showed that for some peach cultivars 0.0062 M (1500 ppm) IBA was effective. Strauch et al. (1985) concluded 0.0041 M IBA was effective for the *Prunus* species and cultivars tested. Adventitious rooting with IBA application on cuttings placed in heated soil under intermittent misting has occurred in cultivars of sweet and sour cherry (Larsen, 1982; Schimmelpfeng, 1965; Schönberg, 1963) and ornamental cherry species (Lamb and Nutty, 1971; Monin and Trefois, 1967; Rowe-Dutton, 1959). Rooting of some rootstocks via softwood cuttings was productive for "vigorously growing species", e.g. *P. cerasifera* Ehrh. 'Myrobalan', a common plum rootstock (Jeremin et al., 2002). In other cases, hardwood cuttings rooted better for *Prunus* rootstocks 'Ishtara', 'St. Julien', and 'Mahaleb' (Christov and Koleva, 1995; Szecsko et al., 2002).

Although, 'North Star' and some of the ornamental cultivars are not grafted, very little is known about the rooting of cuttings from winter-hardy genotypes. The objectives of this study were to determine whether cutting (node) position, time of year during growing season (softwood vs. hardwood cuttings), and concentration or type of auxin alters rooting success of seven winter-hardy *Prunus* genotypes.

Materials and Methods

Experiment 1: Genotypes. Cuttings of seven *Prunus* cultivars were taken every two weeks (n=10 cuttings/genotype/week) beginning 5 June 2012 (week 23) at the University of Minnesota's research center in Excelsior, MN (44°52'06.5"N lat., 93°38'03.9"W long.; Table 1). The frequency was reduced to once per mo. beginning with the collection in week 37, with the final collection in week 49. Week number is defined as the number of weeks from 1 Jan. (week 1). All cuttings from a genotype were collected from one or two trees at the research center. Trees from which the cuttings were harvested were managed for fruit not cutting production.

Rooting Treatments. The cuttings were wrapped in damp towels, placed in plastic bags, and stored at 4°C for 2 to 4 h before processing. Approximately 0.5 cm of both

Table 1: Species, fruit type (apricot, tart cherry, plum, sand cherry), and genotypes of *Prunus* germplasm used in Experiments I and II. Collection location of trees used for cuttings in these experiments was the Horticultural Research Center, University of Minnesota, Excelsior, MN.

Species	Fruit type	Genotypes	Experiment
P. armeniaca	Apricot	'Hardygold'	I
		'Westcot'	I
P. cerasus	Tart Cherry	'Meteor'	I
		'Northstar'	I
Prunus spp.	Plum	'Alderman'	I & II
		'Superior'	I
P. ×cistena	Purpleleaf Sand Cherry	*P. ×cistena*	I & II

the distal and proximal ends of each cutting was removed. Each cutting was then cut in half (length-wise), yielding distal and proximal sections from which the leaves were removed from each proximal end (to 5-6 cm from the base of each cutting). This created n=10 distal and n=10 proximal cuttings per genotype per week. Each of these was then scored twice vertically with a blade for 2.5 cm on the proximal end of each cutting for increased surface area for auxin uptake. Two auxin concentrations of Indole-3-butyric acid-potassium salt (K-IBA) were used in this experiment: 0.0041 M and 0.017 M (1000 and 4000 ppm, respectively). The control treatment was 0.0041 M (1000 ppm) K-IBA instead of 0 M K-IBA, since previous studies showed rooting of all cuttings at 0.0041 M K-IBA to the same as 0.0 M K-IBA (Nečas and Krška, 2013). The scored ends were then submerged in 3 cm K-IBA solution for 10 s, yielding four treatment groups: basal and distal cuttings with 0.0041 M and 0.017 M K-IBA. Following treatment, the proximal end of each cutting was inserted to a depth of approximately 3 cm into washed, pasteurized river sand in 10 cm deep web flats (20 cm x 20 cm). The flats were then placed under an intermittent mist system in a greenhouse (Saint Paul, MN; 44°59'17.8" N lat., -93°10'51.6"W long.) for six weeks of rooting (21$\pm$0.8 / 21$\pm$0.7°C, day / night, 16 h, 0600–2200 HR) high intensity discharge lighting at a minimum set point of 150 µmol m^{-2} s^{-1}, a mist frequency of 10 minute intervals (mist nozzles, reverse osmosis water) during 0600-2200 HR with a 7 s duration. Cuttings were randomized, blocking by week number they were taken and auxin treatment (RCBD design). As a result, only cuttings treated with one of the auxin treatments were in a given flat. Rating of cuttings occurred immediately after the end of each 6-week rooting period.

Experiment 2: Genotypes. Cuttings of *P. ×cistena* and *P. spp*. 'Alderman' were taken every 2 weeks beginning in week 23 (2012; Table 1). Similar to Experiment I, the frequency was reduced to once per mo beginning in week 37 with the final collection occurring in week 49.

Rooting Treatments. Cuttings were physically prepared following the protocol outlined in Experiment I. The scored, proximal ends of the distal and proximal cuttings were then submerged in 3 cm of either 0.00033 M (80 ppm) K-IBA or 0.000236 M (80 ppm) Indole-3-caprioc acid (ICapA) solutions. Cuttings soaking in the auxin solution treatments were then covered with plastic bags and kept at 4° C for 22 h. The same greenhouse and mist system conditions were used as outlined in Experiment I for a 6-week duration, after which rating of cuttings occurred immediately.

Data Collection. Prior to the rooting experiments, the number of nodes and total

cutting lengths were recorded. Following the six-week rooting period, cuttings from Experiments I and II were evaluated for viability, callus formation, root development, and flower or leaf bud break. Root ratings were assessed on a six point scale (0-5): 0 = dead, no callus; 1 = alive, no callus; 2 = callus, no roots; 3 = root initials; 4 = roots; 5 = well-developed, branching root system (Fig. 1). Percent rooting within genotypes for each week was equal to ([the number of cuttings / week that ranked in the 3-5 point scale]/20 replications)*100. Overall cutting health was also noted for the condition of leaves (turgid, limp), leaf abscission, bud break (vegetative or flowering) and extension growth of any shoots into leaves and/or flowers. In the case of leaf and/or flower bud break, we calculated the growing degree day (GDD) accumulations for each rooting week with the Katz et al. (1982) formula using the North Carolina model and the *P. armeniaca* base temperature of 4.4°C (Valentini et al., 2004). Mar. 15 was the date of bud break in 2012 for GDD calculations to begin. For chilling units (CU) accumulation, the Richardson et al. (1974) Utah temperature model was used with the beginning CU start date of 15 Sept. 2012, the date of first frost (Valentini, et al., 2004). No CUs accumulated prior to the start date.

Statistical Analyses. Root rating data from each experiment (I, II) were analyzed with univariate, repeated measures general linear model Analysis of Variance (ANOVA) along with mean separations using Tukey's Honestly Significance Difference (HSD) tests at α=0.05 (Statistical Package for the Social Sciences, SPSS, version 22, University of Chicago, Chicago, IL). Repeated measures was required since root ratings occurred on the same clones and/or ramats repeatedly over time (weeks); the same shoots could not be assessed since none were long enough (i.e. lacking sufficient node numbers) to harvest for the entire duration of either experiment. Rooting data within genotypes were pooled to calculate % rooting but were not statistically analyzed due to the lack of reps.

Results

Experiment I. In the repeated measures ANOVA for root ratings, the main effects

Fig. 1: Cutting rating scale (1-5) for rooting of *Prunus cerasus* 'Meteor'. Numerical scores are 1, 2, 3, 4 or 5, from left to right, representing poor (1) no callus or roots), callus only (2), and callus with increasing quantity of roots (3-5).

genotype ($P \leq 0.001$) and treatment ($P=0.004$) were highly significant whereas cutting position ($P=0.266$) was not. All interactions that included position were not significant ($P>0.074$ Genotype x Position, Treatment x Position, Genotype x Treatment x Position.) The only significant interaction was Genotype x treatment ($P=0.003$). Since cutting position was not significant, the distal and proximal positions were pooled.

Average root ratings for the 0.0041 M K-IBA treatment (control) ranged from 0.0 to 3.6 with the majority of genotypes having ≤ 2.0 (no roots with or without callus) at any given point in the experiment (Table 2). *Prunus* ×*cistena* had significantly higher mean root ratings in weeks 25, 45 and 49 than all other tested genotypes (Table 2). While this still held true in weeks 23 and 41, *P.* ×*cistena* overlapped with 'Westcot' (week 41) or 'Hardygold', 'Meteor', and 'Northstar' in week 23 (Table 2). In weeks 27, 29, 35 and 37, *P.* ×*cistena* overlapped with the majority of tested genotypes. The most divergent root rating responses were found in weeks 31 and 33 where *P.* ×*cistena* did not have the highest rating (Table 2).

Percent rooting for the 0.0041 M K-IBA treatment ranged from 0% to 100% (Table 3). Overall, *P.* ×*cistena* had the highest % rooting in weeks 23, 25, 27, 35, 37, 41, 45, and 49 with average root ratings of 0.6 to 3.6 during these weeks (Tables 2 and 3). However, *P.* ×*cistena* did not root in weeks 31 or 33 when 'Meteor' and 'Alderman' did (week 31 [20%] and week 33 [10%], respectively; Tables 2 and 3). No genotype had any rooting in week 29 with the 0.0041 M K-IBA (Table 3). In any given week, only three (weeks 23, 25, 37, 41, and 49) or four (weeks 45-49) genotypes rooted (Tables 2 and 3).

For the 0.017 M K-IBA, average root ratings ranged from 0.0 to 3.5 (Table 2). *Prunus* ×*cistena* followed a similar response to the

Table 2: Average root ratings (0 to 5 scale) of cuttings from seven *Prunus* genotypes treated with 0.0041 M and 0.017 M K-IBA for each week of collection in Experiment I[z]. Mean separations within treatments and week number, based on Tukey's 5% HSD.

	Mean Root Rating by Week Number										
Genotype	23	25	27	29	31	33	35	37	41	45	49
					0.0041 M KIBA Treatment						
P. ×*cistena*	2.7 a	3.6 a	0.6 ab	1.6 ab	0.6 bc	0.0 c	2.2 a	2.8 a	3.1 a	3.5 a	3.5 a
'Alderman'	1.8 bc	1.9 b	1.0 ab	1.5 ab	1.0 b	1.4 ab	1.6 ab	2.0 ab	1.9 bc	1.0 b	1.0 c
'Superior'	0.7 d	0.4 c	1.0 ab	0.8 b	0.2 c	0.6 bc	0.7 b	1.7 b	2.2 abc	1.2 b	1.7 bc
'Westcot'	1.3 cd	2.0 b	0.0 b	1.3 ab	1.1 b	1.1 ab	1.6 ab	2.8 a	2.4 ab	2.1 b	1.6 bc
'Hardygold'	2.0 abc	1.8 b	1.4 a	1.2 ab	0.0 c	1.3 ab	1.5 ab	2.1 ab	1.5 bc	1.7 b	1.9 b
'Meteor'	2.0 abc	1.6 bc	0.6 ab	1.4 ab	2.2 a	1.7 a	2.0 a	2.0 ab	2.0 bc	2.1 b	2.0 b
'Northstar'	2.1 ab	2.0 b	0.8 ab	2.0 a	2.0 a	1.4 ab	1.2 ab	1.6 b	1.2 c	0.8 b	2.0 b
					0.017 M KIBA Treatment						
P. ×*cistena*	2.9 a	3.5 a	0.2 b	0.2 c	1.4 abc	0.8 abc	0.4 b	2.7 a	3.2 a	2.6 ab	2.9 a
'Alderman'	1.5 bc	1.4 bc	0.0 b	0.3 bc	1.0 abc	0.6 bc	1.5 a	1.8 bc	1.9 bc	1.6 bc	0.9 bc
'Superior'	0.6 c	1.2 bc	1.1 ab	0.9 abc	0.6 bc	0.1 c	0.4 b	1.2 c	1.6 cd	1.1 cd	0.7 c
'Westcot'	1.2 bc	2.6 ab	0.6 ab	2.0 a	0.3 c	1.8 a	2.0 a	2.4 ab	2.8 ab	3.0 a	1.4 bc
'Hardygold'	2.1 ab	1.1 bc	1.5 a	1.5 ab	1.6 abc	0.4 bc	1.6 a	1.9 abc	1.2 cd	1.7 bc	1.4 bc
'Meteor'	3.0 a	0.7 c	0.2 b	2.0 a	2.0 a	1.3 ab	2.0 a	1.9 abc	2.0 bc	2.0 abc	2.0 ab
'Northstar'	2.0 ab	2.0 abc	0.5 ab	1.8 a	1.8 ab	1.3 ab	1.5 a	1.4 c	0.6 d	0.3 d	1.9 abc

[z] Cuttings collected every two weeks beginning 5 June 2012 (week 23) and once a mo. beginning week 11 September 2012 (Week 37) through week 49.

Table 3: Percent rooting for seven *Prunus* genotypes, rooting week[z] and (A) 0.0041 M and (B) 0.017 M K-IBA concentrations in Experiment I.

	% Rooting of *Prunus* Genotypes													
	P. ×*cistena*		'Alderman'		'Superior'		'Westcot'		'Hardygold'		'Meteor'		'Northstar	
Week	A	B	A	B	A	B	A	B	A	B	A	B	A	B
23	80	80	20	10	0	0	0	0	0	10	0	70	10	0
25	80	70	0	0	0	0	40	40	0	0	20	0	0	20
27	10	0	0	0	0	10	0	20	0	0	0	0	0	0
29	0	0	0	0	0	0	0	40	0	10	0	0	0	0
31	0	30	0	0	0	0	0	0	0	0	20	20	0	0
33	0	0	10	0	0	0	0	30	0	0	0	0	0	0
35	0	40	0	0	0	0	10	30	0	0	0	0	0	10
37	70	50	0	0	0	0	50	40	10	10	0	0	0	0
41	90	80	0	0	10	0	30	70	0	0	0	0	0	0
45	90	60	0	0	0	0	40	70	10	0	10	0	0	0
49	100	50	0	0	10	0	10	10	0	0	0	0	0	0

[z] Cuttings collected every two weeks beginning 5 June 2012 (week 23) and once a mo. beginning week 11 September 2012 (Week 37) through week 49.

0.0041 M K-IBA treatment, having a significantly higher root rating than some of the other tested genotypes. However, in weeks 27 and 29, *P.* ×*cistena* had significantly lower root ratings than other genotypes, unlike that found with 0.0041 M K-IBA treatment where this occurred in weeks 31 and 33 (Table 2).

Percent rooting ranged from 0% to 80% for the 0.017 M K-IBA treatment (Table 3). *Prunus* ×*cistena* cuttings treated with 0.017 M K-IBA had a maximum of 80% rooting in weeks 23 and 41 (Table 3) with root ratings of 2.9 and 3.2, respectively (Table 2). In contrast, for the 0.0041 M K-IBA treatment, *P.* ×*cistena* had 80% rooting in weeks 23 and 25 with average root ratings of 2.7 and 3.6, followed by 90% rooting in weeks 41 and 45 with average root ratings of 3.1 and 3.5, and 100% rooting in week 49 with an average root rating of 3.5 (Tables 2 and 3). Even across all genotypes the range of rooting success for 0.017 M K-IBA treatment was smaller (0-80%) than for 0.0041 M K-IBA (0-100%; Table 3). This did not mean that all genotypes had lower percent rooting with 0.017 M K-IBA, such as *P.* ×*cistena* (Tables 3 and 4). For example, 'Westcot' had 0% rooting in weeks 23 and 31, 10% in week 49, and 40% in week 25 for both K-IBA treatments (Table 3). However, 'Westcot' had a significant increase in rooting with 0.017 M K-IBA treatment in weeks 27, 29, 33, 35, 41, and 45 with average root ratings of ≥0.6 (Tables 2 and 3).

Leaf and flower break. Leaf break occurred at the very beginning of Experiment I, as early as weeks 23 with GDD = 837 ('Alderman', *P.* ×*cistena,* 'Superior', and 'Westcot') or week 25 at GDD = 1070 ('Hardygold', 'Meteor', and 'Northstar'; Table 4). This continued sporadically throughout the duration of this experiment with most genotypes; the notable exceptions were 'Alderman', *P.* ×*cistena* and 'Westcot' with one or more cuttings with leaf break occurring continuously in week 33 (GDD = 2208) through 49 (GDD = 2990; Table 4). Flowering occurred as early as week 37, before any chilling units accumulated in *P.* ×*cistena* and 'Westcot', and continued weekly thereafter through the experiment. *Prunus* ×*cistena* and 'Westcot' were the two genotypes with the highest rooting. The other genotypes flowered later in the experiment. 'Alderman began flowering during week 41 at GDD=2944 and CU=69 (Table 4). During week 41, in which

Table 4. Number of *Prunus* genotype cuttings with leaf[z] or flower[z] bud break during or following rooting, based on rooting week[y] number, growing degree day and chilling unit accumulations[x].

	Week number																					
	23		25		27		29		31		33		35		37		41		45		49	
Genotype	L	F	L	F	L	F	L	F	L	F	L	F	L	F	L	F	L	F	L	F	L	F
'Alderman'	3	0	1	0	7	0	0	0	0	0	2	0	11	0	2	0	11	11	13	20	8	29
'Hardygold'	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	6	0	8	4	8	5
'Meteor'	0	0	1	0	0	0	0	0	0	0	2	0	4	0	5	1	0	0	19	0	12	4
'Northstar'	0	0	1	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	2	0	8	6
P. ×*cistena*	1	0	2	0	2	0	2	0	0	0	3	0	4	0	2	1	2	1	25	18	31	25
'Superior'	2	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	2	0	10	6	7	8
'Westcot'	1	0	8	0	3	0	4	0	0	0	9	0	7	0	7	8	6	1	7	7	10	4
Total	7	0	14	0	13	0	7	0	0	0	17	0	30	0	18	10	27	3	84	55	84	81
GDD	837		1070		1256		1669		1965		2208		2441		2695		2944		3028		2990	
CU	0		0		0		0		0		0		0		0		69		449		755	

[z] L refers to leaf (vegetative) bud break and F refers to flower bud break.

[y] Cuttings collected every two weeks beginning 5 June 2012 (week 23) and once a mo. beginning week 11 September 2012 (Week 37) through week 49.

[x] The start date for GDD and CU calculations were 15 March and 15 September, 2012.

GDD=3028 and CU=449 had accumulated, both 'Hardygold' and 'Superior' began flowering (Table 4). Week 49 and onwards, 'Meteor' and 'Northstar' flowered (GDD=2990 and CU=755; Table 4). Leaf break occurred during week 22-25 and required GDD from 837-1070 (Table 4). In contrast, flower break did not occur until week 37 or later. Clearly, GDD for leaf break was much lower and occurred early than flower break (Table 4).

Experiment II. No treatments, genotypes, and cutting position were significant ($P>0.05$) in this experiment. Except for week 41, where one cutting rooted, 'Alderman' had 0% rooting, regardless of cutting position or treatment (Fig. 2). The rooting rates for 'Alderman' were lower than in Experiment I where three cuttings rooted in week 23 (Table 3). In contrast, *P.* ×*cistena*, had ~35% rooting for both cutting positions. Similar to 'Alderman', *P.* ×*cistena* had differing percent rooting from Experiment I. For example, the highest rooting in Experiment II was 85% and occurred in both weeks 23 and 41, rather than just week 41 in Experiment I. In other cases, rooting in week 37 was 60% in Experiment I and 0% in Experiment II. For both genotypes, the majority of cuttings had a rating between 0 and 2 in Experiment II. The proportion of *P.* ×*cistena* cuttings that scored 3 to 5 decreased (Fig. 2).

Discussion

Our study confirmed that previously documented factors that impact rooting of *Prunus* cuttings, e.g. species, genotype, auxin type and concentration, juvenility, time of cutting collection, as well as physiological and environmental conditions (Hartmann et al., 1997; Pijut and Espinosa, 2004; Strauch et al., 1985; Tworkoski and Takeda, 2007) were also true for winter-hardy types. Future studies might find differences over years, but these seven *Prunus* genotypes most likely would remain difficult-to-root. Even though some *Prunus* have escaped cultivation and become invasive in the wild, the likelihood that any of our tested genotypes would regenerate in the wild with adventitious root formation is unlikely (Deckers et al., 2008; Reichard and White, 2001; Vanhellemont et al., 2010). Based on these results, any new *Prunus* cultivar should be tested for all of these identified factors to determine the best

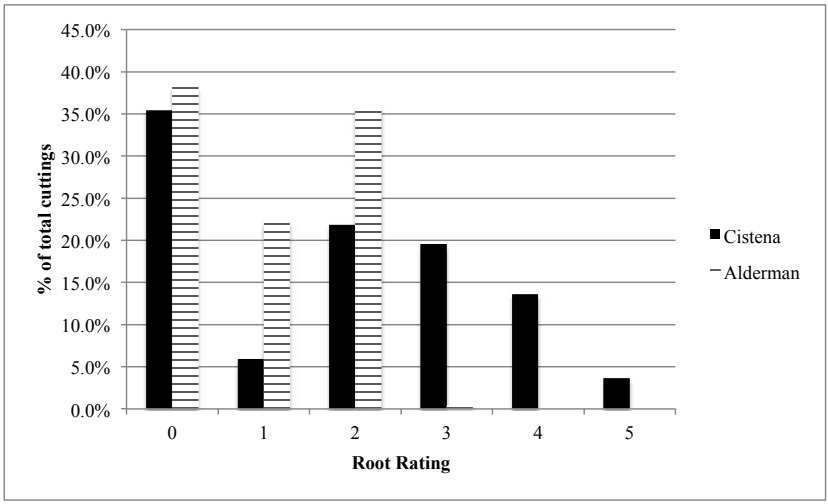

Fig. 2: Percent of cuttings of *Prunus spp.* 'Alderman' and *P.* ×*cistena* using 0.00033 M K-IBA or 0.00033 M ICapA (pooled by treatmeants and dates cuttings were taken in Experiment II); data are separated by root ratings and genotypes.

possible rooting method to mitigate the need for grafting.

Not all of the *Prunus* species or clonal cultivars tested formed adventitious roots when treated with K-IBA. *Prunus* ×*cistena* had the highest % rooting overall, but even this genotype did not root in weeks 29 or 33, and barely rooted at all during certain months of the year. Other types of sand cherries, *P. besseyi* (L.H. Bailey) Gleason and *P. pumila* L., had only an average of 31% rooting (Reighard et al., 1990). The commercially acceptable levels of asexual propagation of *Prunus* via cuttings is ≥60% rooting (Nečas and Krška, 2013). In addition to *P.* ×*cistena*, the only other genotypes with ≥60% rooting were 'Meteor' sour cherry during week 23 and 'Westcot' apricot in week 41 and 45. All other genotypes were consistently below commercially acceptable rooting levels of 60%. This was not unusual for *Prunus* genotypes where scions or rootstocks were difficult to root. Howard (1973) reported 0% rooting for *P. cerasifera* 'Myrobalan B' rootstock with 0 ppm IBA and only 35% 0.024 M (5000 ppm) IBA treatment. Reighard et al. (1990) found that European and Japanese plums (*P. cerasifera, P. domestica, P. institutoa, P. salicina,* and *P. munsoniana*) averaged only 42.5% rooting, whereas American plums (*P. americana, P. angustifolia* Marsh., and *P. hortulana*) were as low as 8.5%. Quantitative and qualitative differences in percent rooting could be the result of a variety of factors including genotypic differences, seasonality, degree of dormancy and maturity through the seasons.

In similar reports (Nečas and Krška, 2013), genotypes had a significant effect on root ratings in all possible respects, such that cultivars within and among species rooted significantly different. In the current study, genotypic effects within species were apparent with *P. armeniaca* 'Hardygold', where rooting was significantly lower than *P. armeniaca* 'Westcot'. Both apricot genotypes had higher percent rooting at 0.017 M K-IBA. Lower % rooting has been reported for *P. armeniaca* rootstocks (Reighard et al., 1990). Staniča et al. (2010) reported significant differences in rooting of *P. armeniaca* rootstocks using 0.0041 M K-IBA. In contrast to *P. armeniaca, P. cerasus* 'Meteor' and 'Northstar' had higher rooting with 0.0041

M K-IBA. The low levels of rooting for sour cherries in our study contrasts with Strauch et al. (1985) who reported that they rooted easily. Both plums (*P. spp.* 'Superior' and 'Alderman') followed the same trends as *P. cerasus*. Similar findings of genotypic differences both within and among species have been reported across the *Prunus* genus, although our findings for some species differ from that of Strauch et al. (1985).

The times of year cuttings were taken affected rooting. However, across the year (weeks), the concentration of K-IBA did not impact root ratings. Seasonality, reflective of the level of maturity (softwood vs. semi hardwood to hardwood cuttings) and degree of growth vs. dormancy has also been significant factors in past research. Strauch et al. (1985) found that cuttings with vigorously growing shoots rooted the worst, while the best were semi-hardwood cuttings. Nečas and Krška (2013) found that the critical factor for rooting of *Prunus* rootstocks was the date of harvest and growth status of cutting material. Reighard et al. (1990) also reported that percent rooting and cutting survival was highly influenced by time of year.

The structural difference between K-IBA and ICpA compounds is the number of carbon side chains; the former has four while the latter has six (Fawcett et al., 1960; Martinez, 2010). While this is the first report of using ICapA to root *Prunus*, it did not significantly affect rooting in either genotype. This was similar to other findings where the type of rooting compound tested had no significant effect (Nečas and Krška, 2013).

Some buds grew between week 23 and 25. No previous reports involving rooting of *Prunus* cuttings harvested during week 23-49 have ever reported the occurrence of such a quick release from dormancy. That this unexpected phenomenon continued sporadically in all genotypes with the exception of 'Westcot', 'Alderman', and *P. ×cistena* indicates this may be uniquely connected with these winter-hardy *Prunus.* Likewise, before the accumulation of any chilling units at week 41, flowering occurred as early as week 37. While GDD for leaf break was much lower and occurred earlier (GDD=837-1070, week 23-25) than for flower break (week 37 onwards; Table 4), neither were expected to occur in this experiment. Since an accumulation of CUs is required for deciduous *Prunus* to overcome endodormancy or rest period (Weinberger, 1967) the occurrence of leaf and flower bud break without any accumulated CUs was novel. For instance, *P. cerasus* 'Montmorency' grown in Michigan (USDA Zone 5-6) requires 954 chilling h to overcome endodormancy and begin growing (bud break) (Anderson et al., 1986; Richardson et al., 1974; Zavalloni et al., 2006). It would be reasonable to expect that winter-hardy *Prunus*, including *P. cerasus* tested herein, would require >954 chilling h since they are USDA Zones 3-4 winter hardy. This was clearly not the case with the seven genotypes tested. Further analyses are warranted to determine GDD and CUs for all *Prunus* hardy in Minnesota and their impact on early bud break in spring and risk of injury by spring frosts.

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