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Seed Germination as a Metric of Invasive Potential in Winter-Hardy *Prunus*

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Abstract

Invasive species threaten the survival of native flora through the alteration of the structure and processes of natural communities. After species are introduced to a new location, seed germination is vital for the formation of diverse, self-sustaining populations. In this study we measured seed germination of a selection of winter-hardy *Prunus* fruit types of apricot, tart cherry, and plum genotypes. This experiment examined seed germination requirements parsed by fruit type, genotype within fruit type, environment, and scarification. Higher germination percentages were observed in the greenhouse compared to the field. Scarification was dependent on genotype within a fruit type and germination environment. From this study we concluded that most genotypes examined will not become invasive due to low and/or inconsistent germination. Apricots had high overall germination whereas tart cherries were lower. The plums had variable germination percentages but progeny from the plum genotypes 'Hazel', 'Whittaker', 'South Dakota', and 'Hennepin' had high germination, indicating the potential to become invasive.

Prunus, a large and economically important genus in the Rosaceae, includes many species with lengthy and rich histories of human cultivation (Das et al., 2011; Griffiths, 1994; Potter, 2012; Wen et al., 2008). Although fruit production is the most prominent use of many of the cultivated species in this genus, others serve functions as landscape plants, for timber production, and medicinal use (Potter, 2012). However, few of these species can be successfully cultivated in USDA zones 3 and 4 because of low midwinter temperatures and flower damage during spring frosts (Andersen and Weir, 1967; Taylor, 1965). Even winter-hardy species are often short lived and fail to produce consistent fruit crops (Andersen and Weir, 1967). In northern climates, breeding programs in the 1900s focused on releasing winter-hardy genotypes that had relatively good fruit quality and produced viable pollen to ensure fruit set (Andersen and Weir, 1967). These goals were accomplished through the hybridization of high quality fruiting species (e.g. *P. domestica* L.) with native, winter-hardy species like *P. americana* Marsh., which often had poor quality and astringent fruit (Andersen and Weir, 1967). Although a number of winter hardy genotypes have been released, little is known about their invasive potential.

Baskin and Baskin (1998) theorized that mechanical dormancy might not be separate from physiological dormancy as some species overcome dormancy through a period of cold stratification without scarification. However, *Prunus* seeds overcome mechanical and deep physiological dormancy to germinate through scarification (Baskin and Baskin, 1998; Hartmann et al. 1997). Scarification leads to variable effects on germina-

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tion in *Prunus*. For *P. americana*, *P. cerasus* L., and *P. persica* Batsch., scarification was shown by Chen et al. (2007), Grisez et al. (2008) and Kristiansen and Jenson (2009) to increase both the percent and rate of germination. In *P. domestica* L. and *P. angustifolia* Marsh., scarification did not alter germination percentage or rate (Grisez et al. 2008; McMahon et al. 2015).

Physiological dormancy is overcome through a long period of moist, cold stratification (Baskin and Baskin, 1998; Westwood, 1993). However, in some *Prunus* species, moist and warm stratification increased seed germination (Baskin and Baskin, 1998; Chen et al. 2007; Grisez et al. 2008; Westwood, 1993). *Prunus armeniaca* L. requires 50 days of cold stratification whereas other species such as *P. domestica* and *P. cerasus* require 90 or 90-150 days, respectively (Jauron, 2000; Grisez et al. 2008; Seeley and Damavandy, 1985). As stratification period lengthens, germination is often higher. For example, germination in *P. persica* begins after 56 days of cold stratification and continues to until 84 days at an increasing rate (Martınez-Gómez and Dicenta, 2001).

The spread of invasive species is often the result of human activities including agriculture, horticulture, and forestry (Reichard and White, 2001; Vanhellemont et al. 2009). Many winter-hardy *Prunus* genotypes have been cultivated since the early 1900s (Andersen and Weir, 1967; Brooks and Olmo, 1997). Some *Prunus* species have escaped cultivation and become invasive. For example, *P. serotina* Ehrh., a species native to North America, has escaped cultivation in parts of Europe and become invasive (Deckers et al. 2005). Phartyal et al. (2009) estimated that 44% of mature seed of the invasive species *P. serotina* germinated *in situ*. *Prunus americana* has also demonstrated high invasive potential as it is adapted to a variety of habitats and is spread across a wide geographic range (Francis, 2004). Whether other *Prunus* species and genotypes will become invasive is not known.

These examples from *Prunus* provide a basis to study whether winter-hardy *Prunus* have invasive potential. Kolar and Lodge (2001) define the first stage in invasiveness as the transport of the species into a new environment. Once present in the new environment, a viable population establishes itself and becomes reproductive (Kolar and Lodge, 2001). Thus, seed germination and seedling establishment are important to understand invasiveness. The objective of our study was to determine winter-hardy *Prunus* seed germination as it relates to invasive potential.

Materials and Methods

Genotypes and Seed Collection. We examined three fruit types of *Prunus* for germination of open pollinated seed including 28 *Prunus* winter-hardy genotypes (Table 1). Fruit type was defined as apricot, tart cherry, or plum. Although there are two types of tart cherries, amarelle and morello genotypes (Brown et al. 1989), all tart cherries were classified under one category for the purposes of this experiment. In 2012, all apricot, tart cherry, and plum fruits were collected from trees at the University of Minnesota research plots in Excelsior, MN (44°52’06.4” N lat., -93°38’00.5” W long.) during weeks 25-26 and 31-34. Week number is defined as the number of weeks from the first week of the year beginning 1 Jan.

Experimental Design. For each genotype, 48 seeds were randomly chosen and divided into two groups of 24 each. One group was mechanically scarified with a hammer hard enough to crack the stony endocarp (pit); the endocarps were left in place when the seeds were sown. Three seeds per pot (11.43 x 11.43 cm Jumbo Junior pots, Belden Plastics, St. Paul, MN) were planted in BM2 germination mix (Berger, Quebec Canada) for the greenhouse or pasteurized field soil (Waukegin silt loam) collected from the University of Minnesota St. Paul campus (44°59’17.8” N lat., -93°10’51.6” W long.) for the field. The pots, rather than individual seeds, were considered experimental units.

Table 1. Fruit type, species, and genotype names for *Prunus* germplasm tested in the germination experiment. All seed was collected at the University of Minnesota research plots in Excelsior, MN in 2012.

Fruit Type	Species	Genotype
Apricot	*P. armeniaca* L.	'Moongold'
		'Sungold'
		'Westcot'
Tart Cherry	*P. cerasus* L.	'Bali'
		'Mesabi'
		'Meteor'
		'N81755'
		'Suda'
Plum	*P. americana* L.	'Hazel'
	P. besseyi x *P. hortulana* L.	'Compass'
	P. domestica L.	'Mount Royal'
		'Opal'
		'Stanley'
		'Todd'
	P. munsoniana Wright and Hedrick	'Whittaker'
	P. nigra Aiton	'Bounty'
	Prunus spp. L.	'Alderman'
		'Gracious'
		'Hennepin'
		'La Crescent'
		MN598
		'Monitor'
		'Pipestone'
		'Redcoat'
		'South Dakota'
		'Superior'
		'Tecumseh'
		'Toka'
		'Underwood'
		'Winona'

After planting, a warm stratification treatment was applied to all pots at 20-25°C (day/night) in darkness for two weeks beginning week 41 in 2012. Pots were monitored and watered as necessary for the duration of warm stratification. After warm stratification, 4 pots of each treatment were divided for the greenhouse or field environments. Pots for the greenhouse environment were placed in a cooler (5°C; complete darkness) for a 112-day period of cold stratification, week 43, 2012 – week 7, 2013. During the cold stratification period, pots were monitored for seed germination and hand-watered as necessary. Pots for the field were covered with fine netting to prevent rodents and other herbivores from destroying the seeds. These pots were planted in a randomized complete block design into the field at the University of Minnesota Saint Paul, MN (44°59'18.4"N,

-93°10’21.5”W) in week 43, 2012. Pots in the field were buried with the soil level of the pots equal to the field soil level. As a result, about 2.5 cm of the rim for each pot was above the soil line. Pots in the field were overwintered. Average monthly soil temperature (10.2 cm depth) and the number of days with average temperatures above and below 0°C per month during this experiment were calculated from average soil temperatures at the University of Minnesota St. Paul Climatological Observatory (44°59’25.1” N long., -93°10’35.2” W lat.; Minnesota DNR, 2016; Table 2).

When the cold stratification period in the cooler was completed, pots were placed in a randomized complete block design in the greenhouse. The average day/night temperature for the greenhouse environment was 17.8°C. Germination was monitored for a seven-week period. A seed was considered germinated once the plumule was observed above the soil surface (Huntzinger, 1971). The week each seed germinated was denoted using different colored toothpicks placed next the seedling for each week of germination assessment. The average number of weeks for germination for each pot was calculated by: summing the number of weeks to germination for all germinated seedlings and then dividing by the number of seedlings that germinated in the pot. If a seed did not germinate, it was not used to calculate average number of weeks for germination.

In the spring of 2013, the pots in the field were monitored for germination *in situ*. Starting when the first seedling’s pumule became visible, germination for all pots was monitored for seven weeks. Nongerminated seeds were evaluated for decay at the germination period. Average number of weeks to germination for individual seedlings was recorded with the same methodology as in the greenhouse.

Data Analyses. The statistical package R, version 3.3.3 (2017-03-06), was used for statistical analyses. Data within a fruit type (i.e. apricot, tart cherry, and plum) were analyzed using univariate, linear model type III analysis of variance (ANOVA). Block was considered a fixed effect nested within germination environment. Germination percentage data was transformed using arcsine square root transformation and all analyses, except for correlations, used the transformed data. To correct for non-constant variance (heteroscedasticity), White’s correction for heteroscedasticity was used. If the genotype x germination environment x scarification interaction was significant, genotype means within a given environment and scarification treatment were compared using Tukey’s Honest Significant Difference test (HSD) at a significance $\alpha \leq 0.05$. If genotype x scarifica-

Table 2. Average monthly soil temperature (°C) from Oct. 2012 to May 2013 at 10.2 cm depth and number of days with average soil temperatures below and above 0°C. Temperature data were recorded at the University of Minnesota Saint Paul campus (Minnesota DNR, 2016).

Month	Year	Avg. Temp.	Days below 0°C	Days above 0°C
Oct.	2012	10.5	0	31
Nov.	2012	3.3	6	24
Dec.	2012	0.4	3	28
Jan.	2013	-1.9	27	4
Feb.	2013	-1.9	28	0
March	2013	-0.3	29	1
April	2013	3.6	5	15[z]
May	2013	13.8	0	31

[z] Temperature probe failed to record ten days in April.

tion, or the genotype x germination environment x scarification treatment interactions were significant, single degree of freedom linear contrasts were used to compare non-scarified and scarified seed germination within a genotype. Germination percentage data within a fruit type were compared using Spearman correlations ($\alpha \leq 0.05$) between field and greenhouse environments.

Results

Apricots. The main effects of germination environment ($p<0.001$) and cultivar ($p<0.05$) significantly affected % germination in the apricot fruit type. Scarification did not have a significant effect ($p=0.096$). The environment x cultivar interaction ($p<0.05$) was significant. All other interactions were not significant: environment x block ($p=0.71$), environment x scarification ($p=0.29$), cultivar x scarification ($p=0.42$), and environment x cultivar x scarification ($p=0.98$). Since the environment x cultivar interaction was significant, cultivar means were calculated and compared within a germination environment across scarification treatments. Average % germination was higher in the greenhouse environment (70.8%) than in the field (37.5%, Table 3); nongerminated seeds had decayed. Average germination in the greenhouse ranged from 91.7% to 45.8% with 'Moongold' and 'Sungold' differing significantly from 'Westcot' (Table 3). In the field environment, mean germination rates ranged from 66.7% to 20.8% with 'Sungold' differing significantly from 'Moongold' and 'Westcot' (Table 3). 'Sungold' had the highest germination in both environments. Regardless of the environment, most apricot seed germinated by the end of week 2 (data not shown).

Tart cherries. Within the tart cherry fruit type, main effects of the greenhouse and field environments ($p=0.45$), cultivar ($p=0.36$), and scarification (0.06) did not significantly affect germination. The interactions environment x block ($p=0.89$), environment x cultivar ($p=0.51$), environment x scarification ($p=0.46$), cultivar x scarification ($p=0.30$), and environment x cultivar x scarification ($p=0.14$) were also not significant. In both environments, germination of tart cherry genotypes was $\leq 33.3\%$ with no significant variation among genotypes (data not shown). Average % germination across environments, tart cherry cultivars, and scarification treatments was 4.3% (data was pooled for all main effects and, thus, is not shown). All nongerminated seeds had decayed. On average, all tart cherry seeds germinated by week 2, 2013 (data not shown), similar to apricots.

Plums. Within the plum fruit type, main effects of cultivar ($p<0.001$) and scarification treatment ($p<0.001$) had significant effects on % germination whereas environment ($p=0.14$) did not. The interactions environment x block ($p=0.55$) and environment x scarification ($p=0.80$) were not significant whereas environment x cultivar ($p<0.001$) and environment x cultivar x scarification ($p<0.05$) were significant. Since the environment x cultivar x scarification interaction was significant, average % germination among genotypes were examined within an environment x scarification treatment combination. Averages for non-scarified seed of

Table 3. Average % seed germination after cold stratification for apricot seeds (pooled across non-scarified and scarified treatments) in the greenhouse and field environments.[z]

Cultivar	Greenhouse	Field
'Moongold'	91.7 a	20.8 b
'Sungold'	75.0 a	66.7 a
'Westcot'	45.8 b	25.0 b
Mean	70.8	37.5

[z] Means within columns followed by common letters do not differ at the 5% level by Tukey's HSD.

Table 4. Average percent seed germination after cold stratification for non-scarified and scarified plum seeds in the greenhouse and field environments.

	Greenhouse		Field	
Cultivar	Non-scarified[z]	Scarified[z]	Non-scarified[z]	Scarified[z]
'Hazel'	25.0 cdef	50.0 ab	75.0 a*[y]	16.7 ab*[y]
'Compass'	33.3 bcdef*[y]	83.3 ab*[y]	50.0 abc*	8.3 ab*
'Mount Royal'	41.7 abcdef	25.0 ab	0.0 d	0.0 b
'Opal'	100.0 a	75.0 ab	0.0 d	8.3 ab
'Stanley'	33.3 bcdef	25.0 ab	0.0 d	0.0 b
'Todd'	41.7 abcdef	58.3 ab	16.7 bcd	8.3 ab
'Whittaker'	58.3 abcdef	91.7 a	41.7 abcd	41.7 ab
'Bounty'	41.7 abcdef	75.0 ab	66.7 a*	33.3 ab*
'Alderman'	16.7 def*	58.3 ab*	0.0 d	16.7 ab
'Gracious'	16.7 def*	58.3 ab*	16.7 bcd	33.3 ab
'Hennepin'	83.3 abc	50.0 ab	58.3 ab	66.7 a
'La Crescent'	91.7 ab	91.7 a	16.7 bcd	16.7 ab
'MN 598'	25.0 cdef	50.0 ab	0.0 d	0.0 b
'Monitor'	25.0 cdef	33.3 ab	0.0 d*	33.3 ab*
'Pipestone'	41.7 abcdef	50.0 ab	0.0 d	16.7 ab
'Red Coat'	8.3 ef	41.7 ab	0.0 d*	33.3 ab*
'South Dakota'	75.0 abcd	75.0 ab	75.0 a*	33.3 ab*
'Superior'	8.3 ef*	75.0 ab*	0.0 d	16.7 ab
'Tecumseh'	8.3 ef	16.7 b	0.0 d	0.0 b
'Toka'	66.7 abcde	66.7 ab	58.3 ab*	25.0 ab*
'Underwood'	25.0 cdef	50.0 ab	0.0 d	8.3 ab
'Winona'	0.0 f*	75.0 ab*	8.3 cd	8.3 ab
Mean	39.4	58.0	22.0	19.3

[z] Means within columns followed by common letters donot differ at the 5% level.
[y] An asterisk refers to a significant difference ($p<0.05$) within a genotype and germination environment across scarification treatments.

plum genotypes ranged from 0.0% for 'Winona' to 100.0% for 'Opal' with a pooled average of 39.4% (Table 4). The range in mean germination of scarified plum seeds in the greenhouse was 16.7% for 'Tecumseh' to 91.7% for 'La Crescent' and 'Whittaker' (Table 4). The main effect means for scarified seed was 55.7% and 39.4% for non-scarified seed (Table 4). There were significant differences for % germination between non-scarified and scarified seed for 'Alderman', 'Compass', 'Gracious', 'Superior', and 'Winona' ($p<0.05$; Table 4). All nongerminated seeds had decayed.

In the field environment, average germination percentages for non-scarified seed ranged from 0.0% for 'Alderman', MN598, 'Monitor', 'Mount Royal', 'Opal', 'Pipestone', 'Red Coat', 'Stanley', 'Superior', 'Tecumseh', and 'Underwood' to 75% for 'Hazel' and 'South Dakota' (Table 4). Average % germination for scarified seed ranged from 0.0% for MN598 and 'Tecumseh' to 66.7% for 'Hennepin' (Table 4). Main effect means for non-scarified and scarified plum seed were 22.0% and 19.3%, respectively (Table 4). There were significant differences for % germination between non-scarified and

scarified seed for 'Bounty', 'Compass', 'Hazel', 'Monitor', 'Red Coat', 'South Dakota', and 'Toka' (Table 4).

Correlations. The only significant correlation between % germination in the greenhouse and field was for plums ($r=0.19$, $p<0.05$, data not shown). The remaining Spearman correlation coefficients were not significant ($p>0.05$; data not shown).

Discussion

Successful germination is the first step towards establishing a self-sustaining population and, as a result, species with higher % germination compared to native species may be more likely to become invasive (Hock et al. 2015). In our experiment, seed germination across environments for apricots was high whereas tart cherries were low. The plum genotypes we studied had variable germination, which is perhaps due to the diverse genetic background (Table 1). Some plum genotypes like *P. americana* 'Hazel', *P. munsoniana* 'Whittaker', and Japanese-American hybrids 'South Dakota', and 'Hennepin' had high seed germination across both environments and scarification treatments. In contrast, *P. domestica* 'Mount Royal' and *P. spp.* 'Monitor' had variable germination percentages across environments and scarification treatments. In comparison to native species, genotypes with higher % germination across environments could potentially become invasive compared to genotypes with low germination (Hock et al. 2015).

Inbreeding depression could potentially provide an explanation for why low % germination among tart cherry genotypes was observed. Most tart cherry genotypes are self-compatible but naturally outcrossing and thus, inbreeding depression is possible in tart cherry progeny (Lansari and Iezzoni, 1990; Krahl et al. 1991). According to Baskin and Baskin (2015), inbreeding has a variable effect on germination; in some cases, inbreeding depression has a negative relationship with germination. Lansari et al. (1994) states that inbreeding depression in almond (*P. dulcis* Miller) can result in reduced seed germination. Inbreeding depression in the tart cherry genotypes tested could have played a role in the lower germination observed. Even though most tart cherry genotypes had low % germination, germination still occurred, thus not eliminating the potential to become invasive. Other factors that may affect a genotype's invasive potential include crop load, seed dispersal mechanism, and seedling establishment (Bullock et al. 2002; Deckers et al. 2008). According to Deckers et al. (2008) the invasive *P. serotina* has inconsistent crop loads but its avian dispersal system makes it highly effective at spreading throughout the landscape. Tart cherries are often consumed completely or damaged by birds (Lindell et al. 2012). The potential for seed dispersal via birds coupled with good stand establishment may result in higher invasive potential.

Germination can be impeded at many steps in the process. The uptake of water initiates germination (Chong et al. 1994). Hard seed coats or stony endocarps can prevent or reduce water uptake (Chong et al. 1994; Hartmann et al. 1997). The endocarp of stone fruits prevents the expansion of the embryo so no radical emergence can occur (Hartmann et al. 1997). These seed types often need to be cracked or softened through scarification to initiate water uptake and thus, germination (Chong et al. 1994; Hartmann et al. 1997). In our experiment, endocarps of seeds were mechanically scarified prior to planting. Scarification had a significant effect on germination of plum seed in both the greenhouse and field environments. However, scarification significantly increased % germination of some plum genotypes in the greenhouse but decreased germination in some plum genotypes in the field. In most cases, germination of non-scarified seed and scarified seed was similar in the field. A potential reason for this is the freeze-thaw cycle. According to Chong et al. (1994), scarification of the seed can result through the freeze-thaw action of the soil. During the overwintering period in our field experiment, the soil at a 10.2 cm

depth oscillated above and below 0°C (Table 2). Scarification via freezing and thawing of the soil in the field could have been sufficient to crack the endocarp of non-scarified seeds and resulted in similar germination between non-scarified and scarified seed of most plum genotypes.

Kristiansen and Jenson (2009) observed greater germination for *P. cerasus* seeds with the endocarp removed whereas Grisez et al. (2008) reported that after 90 days of cold stratification, *P. armeniaca* seeds achieved 95% germination with an intact endocarp. McMahon et al. (2015) observed no significant difference for germination between non-scarified and scarified *P. angustifolia* seed and reasoned that the lower percentages of seeds germinating could have been caused by inadequate endocarp removal. For example, when Kristiansen and Jenson (2009) removed the entire endocarp from *P. cerasus* seed, there was a significant positive effect on germination. However, scarification did not have a significant effect on germination in both the apricot and tart cherry fruit types. In greenhouse and field environments of our study, scarification significantly affected plum germination. However, within most plum genotypes germination was not significantly affected by scarification in both environments. For most genotypes in our study, the combination of warm and cold stratification may have sufficiently overcome dormancy and eliminated the need for scarification. Higher germination was observed for scarified seed in most plum genotypes in the greenhouse whereas lower germination was observed for scarified seed in the field environment. Scarification of some plum genotypes' seed prior to planting in the field could have resulted in lower germination because scarification may have resulted in higher susceptibility of seeds to disease and other environmental pressures (i.e. temperature fluctuations) not present in the greenhouse. For most genotypes, there was not a significant difference for average number of weeks for germination between non-scarified and scarified seed. Germination percentages were similar and most seeds germinated within three weeks, thus indicating that some genotypes do not require scarification for successful germination.

Chong et al. (1994) states that moisture is the most important factor for initiation of seed germination and lack of consistent moisture during germination can result in drying of the seed leading to failed germination and potentially seed death. Across fruit types, we observed higher percent seed germination in the greenhouse than the field. In the greenhouse, pots were consistently monitored and watered whereas in the field watering ceased once the field soil froze and did not begin again until the soil thawed. Inconsistent moisture in our field soil could have resulted in lower germination across fruit types.

Lockley (1980) recorded a significant positive correlation between greenhouse and field for germination and seedling emergence of *P. virginiana* L., leading to the conclusion that germination in the greenhouse was indicative of germination in the field. If the environments in our germination experiment were correlated, germinated seed in the greenhouse could be predictive of germination under field conditions. This would be a useful tool for quickly screening multiple genotypes. However, we found that within most species there was no significant correlation for % germination between the two environments. There was a significant positive correlation between environments for the plums. However, this correlation coefficient was low ($r<0.20$) and, thus, germination in the greenhouse environment may not be an accurate predictor of field response. Further investigation is required.

Conclusions

Although successful germination is an important step in the invasion process, many factors contribute to the invasive potential of a species including vigor of seedlings, tendency to vegetatively propagate, herbivore pressure, crop load, and seed dispersal mech-

anisms (Deckers et al. 2008; Kolar and Lodge, 2001; Siemann and Rogers, 2001). As a result, high % germination does not necessarily mean that a genotype will become invasive. Many of the *Prunus* genotypes examined in this study will probably not become invasive due to poor and/or inconsistent germination. According to Brooks and Olmo (1997) tart cherry genotypes like 'Meteor' tended to be productive and bear regularly. On average, a 10 to 20-year-old tart cherry tree ('Montmorency') produces 36 kg to 45 kg of fruit (MeNsope, 2009). Seed production differences between years could greatly influence invasive potential, particularly since apricots do not set a fruit crop consistently across years due to early spring frosts during the bloom period (Hoover and Zins, 1998; Hoover et al., 2015). Even with relatively low germination, high fruit yields could result in large numbers of propagule units and thus, could potentially result in a moderate number of seedlings. Progeny from the plum genotypes *P. americana* 'Hazel', *P. munsoniana* 'Whittaker', and the hybrids 'South Dakota' and 'Hennepin' exhibited high germination across environments and years, indicating the potential to become invasive. Further research would be necessary to determine seedling stand establishment of these plums as well as the effects of enhanced fruit yield and/or germination differences across years in all tested genotypes.

Even though some genotypes examined in this experiment exhibit characteristics indicative of the potential to become invasive, escapes from cultivation by these genotypes have not yet been documented. Horticultural practices like mowing, tilling, hand pulling, and the application of herbicides can control the spread invasive species (Beasley and Pijut, 2010; Culley and Hardiman, 2007). As a result of these practices, horticulturalists may inadvertently be preventing the escape of *Prunus* genotypes into surrounding environments. However, winter-hardy *Prunus* genotypes may become invasive if present in an abandoned field or in a circumstance where horticultural control practices are not applied, as has occurred with the invasive, ornamental Pyrus *calleryana* Decne in parts of the United States (Culley and Hardiman, 2007; Taylor et al. 1996). Another potential reason that these genotypes have not escaped cultivation is that these genotypes are not extensively cultivated in the landscape. This lack of cultivation results in a low number of propagules that could potentially develop self-sustaining populations.

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