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Index of Invasiveness of Cultivars of *Acer palmatum*

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An independent study project report by The Martha J. Wallace Endowed Plant Propagation Intern (2017-2018)

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Abstract
Recent publications have detected fluctuations in the native ranges of many plant species, as well as indications that invasive species are spreading into areas that were once not suitable for them (Hellmann 2008). *Acer palmatum* is a species whose presence has been documented in the Wissahickon Park and the natural areas around the Morris Arboretum in Philadelphia as well as at the National Arboretum in Washington, D.C. With many cultivars having high seed yields, it is important to look into viability and germination rates as indicators of their invasiveness, as previously researched for *Ailanthus altissima* (Wickert et. al 2017). This project looks to compare these indices among cultivars to produce a recommendation of what cultivars might be better to plant in order to mitigate potential invasive effects.

Disciplines
Horticulture | Plant Breeding and Genetics

Comments
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AUTHOR: **Wayne Schmitt, *The Martha J. Wallace Endowed Plant Propagation Intern***

DATE: **April 2018**

ABSTRACT:

Recent publications have detected fluctuations in the native ranges of many plant species, as well as indications that invasive species are spreading into areas that were once not suitable for them (Hellmann 2008). *Acer palmatum* is a species whose presence has been documented in the Wissahickon Park and the natural areas around the Morris Arboretum in Philadelphia as well as at the National Arboretum in Washington, D.C. With many cultivars having high seed yields, it is important to look into viability and germination rates as indicators of their invasiveness, as previously researched for *Ailanthus altissima* (Wickert et. al 2017). This projects looks to compare these indices among cultivars to produce a recommendation of what cultivars might be better to plant in order to mitigate potential invasive effects.

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INTRODUCTION

Acer palmatum, commonly known as Japanese maple, has hundreds of cultivars that have been disseminated worldwide (Brand 2015). Many of these cultivars originated in Japan, where early descriptions of its cultivation by Ibei Itō date back to 1710 (van Gelderen et. al 2000). Swedish botanists Carl Peter Thunberg and Johan Andreas Murray came upon the species in 1784 on an expedition to Japan, though it is also native to South Korea (Brand 2015; van Gelderen et. al 2000; Hong et. al 2008). Thunberg named it "*palmatum*" for the hand-like shape of its leaves, which is similar to the translation of the Japanese word for maple, "*kaede*," 楓 which derives from "*kaeru te*" (蛙手) meaning "frog hand" (Gogen 2018).

The Japanese maple (at the time known as *Acer polymorphum*) was introduced to the United States in 1862 by Dr. George Rogers Hall and Thomas Hogg on separate but simultaneous trips to Japan (Del Tredici 2017). Dr. Hall's shipment was received in Flushing, New York by Samuel Bowne Parsons of Parsons & Sons Nursery. This delivery included many cultivars of *Acer palmatum*, along with many other first introductions from Japan (Del Tredici 2017). Thomas Hogg's collections were shipped to his brother James, however, both Hall and Hogg worked closely with Parsons as a propagator and distributor (Del Tredici 2017). Hogg has been referred as the official introducer of the cultivars 'Atropurpureum,' 'Dissectum Atropurpureum,' and 'Sanguineum' (Del Tredici 2017).

Three subspecies of *A. palmatum* are currently recognized – subsp. *palmatum*, subsp. *amoenum*, and subsp. *matsumurae* (Vertrees et. al 2007). Among these, seven groups of cultivars are recognized, based on habit and leaf shape:

1. Palmatum – small leaves, coarsely toothed margins, distinct lobes
2. Amoenum – large leaves, finely toothed margins, less distinct lobes
3. Matsumurae – large leaves, coarsely toothed margins, very distinct lobes
4. Linearilobum – narrow leaf lobes
5. Dissectum – deeply divided and dissected leaf lobes
6. Dwarf – less than 6 ½ feet (2m) tall
7. Other – any that do not fit in the pre-mentioned categories.

The specimens used in this study from other gardens have been identified to their group in the work of van Gelderen and Vertrees (Appendix A).

It should be noted that this study includes some specimens that are listed as contested cultivars. Generally, cultivars require propagation by vegetative cuttings to ensure that new individuals are genetic clones retaining the same distinctive qualities as the original (van Gelderen et. al 2000). However, in some cases, seedlings of a cultivar are sold under the same name. In these cases, clones and genetically variable specimens become difficult to distinguish (van Gelderen et. al 2000). Known cultivars exhibiting this issue include *A. palmatum* 'Atropurpureum', 'Dissectum,' 'Dissectum Viridis' (van Gelderen et. al 2000). Anecdotally, individuals sold as *A. palmatum* 'Bloodgood' have also led to suspicion as to being potentially grown from seeds.

The flowering patterns of *Acer palmatum* could have a strong influence on how much seed production varies between cultivars. For example, isolated monoecious specimens of multiple *Acer* species in the Palmata section (e.g. *A. palmatum*, *japonicum*, *circinatum*, etc.) can produce fruits, demonstrating the possibility of self-fertilization (de Jong 1976). On the other hand, some individuals in the same study produced only male flowers for several years (1966-1971), which would have prevented the production of fruits on these individuals (de Jong 1976). In the future, more studies are required on the variation of flowering in *A. palmatum* to analyze its effect on the pollination and fruiting differences between cultivars.

As for the dispersal patterns of the Japanese maple, studies conducted in Japan have found the mean dispersing distance of a viable seed to be approximately 41m (Wada et. al 1997). Seedlings were dispersed about 14.3 m from conspecific (of the same species) adults, while older saplings were found with a mean dispersal distance of 34 m from conspecific adults. These observations suggest that older juveniles find growing conditions more favorable farther away from trees of their own species (Wada et. al 1997). This variable was actually shown to be more conducive to dispersal than light availability or canopy gap (Wada et. al 1997). Such a correlation could lead to quick dispersion through non-native habitats.

The purpose of this study is to determine the invasiveness risk of *A. palmatum*. In the woods around the Morris Arboretum, in the neighboring Wissahickon Park, as well as in the woods around the National Arboretum, naturalized *A. palmatum* trees are beginning to escape from cultivated into natural areas. The goal of this study is to find cultivars that will produce less seeds (and/or with lower viability), thus decreasing the potential for dispersal of this non-native species. We hope that future data sets may profit from the methodology outlined here.

METHODS

All *Acer palmatum* accessions from the Morris Arboretum were sampled. In addition, to assess available populations outside the Morris Arboretum, a list of the top selling cultivars from five nurseries was compiled to optimize sampling efficiency (Appendix A).

At the Morris Arboretum, there are 74 accessioned plants of *Acer palmatum*, with 38 unique cultivars. Starting in August, each accession was sampled with three replicates, two weeks between each sampling. Notes were made if the tree was too tall and too many seeds were out of reach (skewing a random sample), if there were triple samaras (Figure 1), or if there were too few seeds to perform a cut test (Table B). Seed production was indexed and seed viability was calculated using the methods described below. In October, when the seeds had ripened, seeds were collected for germination trials following the method detailed below.

In addition to the Morris Arboretum, plants were surveyed at the United States National Arboretum (USNA), Brooklyn Botanic Garden (BBG), and New York Botanical Garden (NYBG) in the month of September. Lists of their accessioned *Acer palmatum* specimens as well as maps to help locate them were obtained from the gardens' curators. Using this information, table templates were created to record data for this study using the following parameters: accession number, species and cultivar, location, seed production index, seed viability percent, and notes (Table A). Assisting in tree locating and data acquisition were Deanna Curtis at NYBG, Joe Meny at USNA, and Karen Kongsmai and Rowan Blake at BBG.

Seed Production Index

Unlike other studies that used an absolute count on the number of seeds produced, this study ranks seed production on a relative scale of 1 to 10 (Wickert et. al 2017). Due to limited time and a large number of individuals, it would not have been possible to count the seeds produced by every plant. An initial broad assessment of each plant's condition and corresponding seed production was performed at the Morris Arboretum to serve as a basis for this index. Two weeks later these trees were indexed in relation to one another using the aforementioned relative scale, 1 being too few seeds to sample from (<20 seeds on the whole tree), and 10 being the most amount of seeds possible (between 30 to 50 seeds on every branch). This scale was also used at the other gardens comparing each tree to all those seen previously, as the trees at the Morris Arboretum provided a thorough range of seed production levels. The index was then averaged among individuals for each replicate (for those at Morris). Afterwards, the cultivars were averaged from all individuals sampled both within the Morris Arboretum and at other gardens.

Seed Viability Test

After indexing the seed level, cut tests were performed to assess the percent seed viability of each individual. Cut tests were performed as follows: seeds were picked from all points on the tree, noting if the tree was too tall to reach some of the seeds, to obtain randomized samples. Using pruners, each seed was cut in half. Green or white solid embryos were considered viable. If the seed had been aborted, was empty, or contained brown and rotting tissue inside, it was considered not viable (Appendix B). For most individuals, 20 seeds were tested, but for those with triple samaras (Figure 1) a sample size of 25 was used, given the odd number of seeds. Viability was calculated as the percent of viable seeds out of the number of seeds sampled. Then, viability across replicates and across cultivars was averaged.

Figure 1: Triple Samara

Germination Trials

A set of individuals from the Morris Arboretum were selected for germination trials to represent the four combinations of seed production and viability (low or high viability, low or high seed production). However, a cultivar with low production, high viability could not be found at the Morris Arboretum and thus were not included in this survey (Table C). In addition, the following individuals not found at Morris Arboretum were included in seed collection: a 'Bloodgood' cultivar found in neighboring Chestnut Hill, a naturalized *A. palmatum* specimen found in the nearby Wissahickon Park and a 'Skeeter's Broom' from USNA (the only seed-producing individual of that cultivar). Approximately sixty seeds were collected from each individual (when sixty seeds were available). Following the standard stratification procedure for *Acer palmatum*, seeds were warm stratified in moist perlite for a week to imbibe water and then moved into the fridge for three months where they were cold stratified at temperatures between 34-45°F to break their dormancy (Dirr 2010). The seeds were sown in a Fafford 3B mixture with an antifungal treatment of *Trichoderma* in late January/early February and placed in a propagation greenhouse that has a bottom heat system set to 68°F (20°C), fog, and supplementary HID lighting until midnight. This room also receives supplemental light between one hour after dawn and one hour after disk, whenever the sunlight output does not exceed 200Wm^{-2}. Germination success rates were calculated by the number of plants germinated divided by the number of seeds sown (Wickert et. al 2017).

RESULTS

Index and Viability

One of the interesting findings in this data was the correlation between viability and seed index, which showed a positive linear trend defined by a Pearson Coefficient of 0.797 (Figure 2). A few cultivars were found with no seeds or low viability. However, further samples will be necessary to produce statistically significant data, as this project took place over only one growing season, and was limited to less than three individuals in many cases.

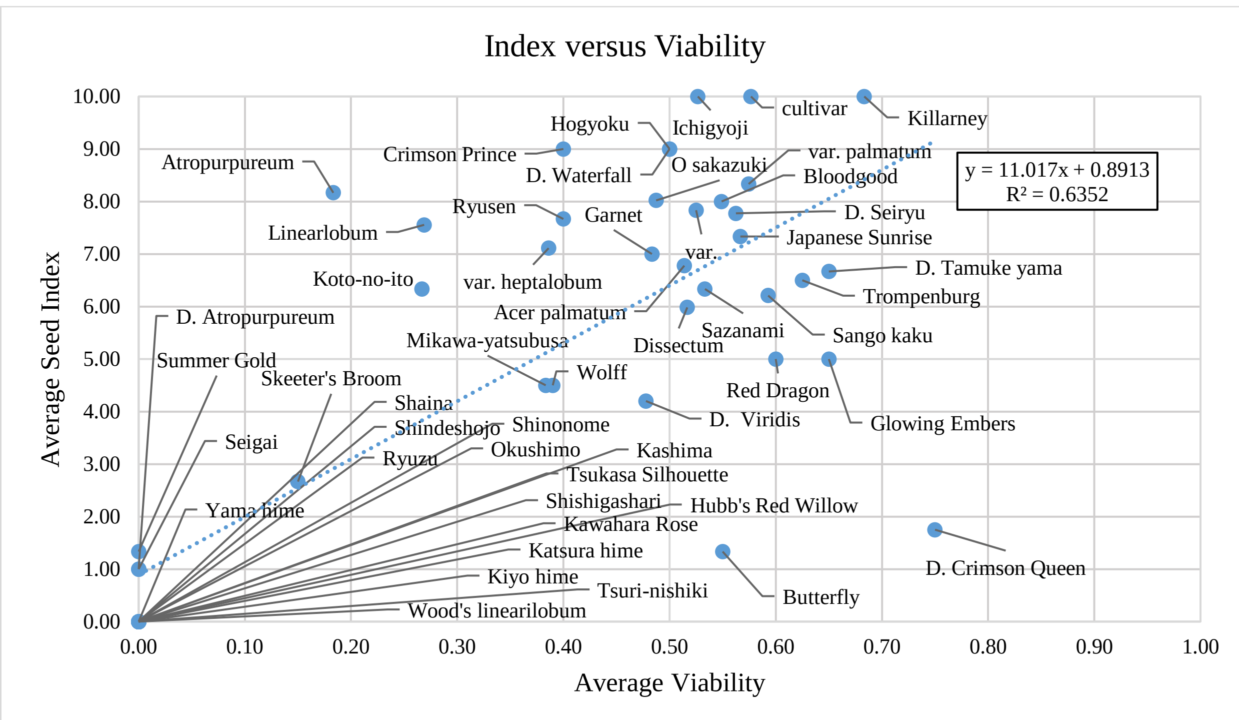


Figure 2: Seed Production Index vs Viability

By multiplying the viability percentage by the index, a composite score was created to determine a potential index of invasiveness, with the underlying assumption that increasing seed production along with increased fertility produces a compounding effect in a plant's capacity to escape cultivation. These results can be seen in Figure 3 for all cultivars with seed production, where number of individual trees tested is seen above each corresponding bar.

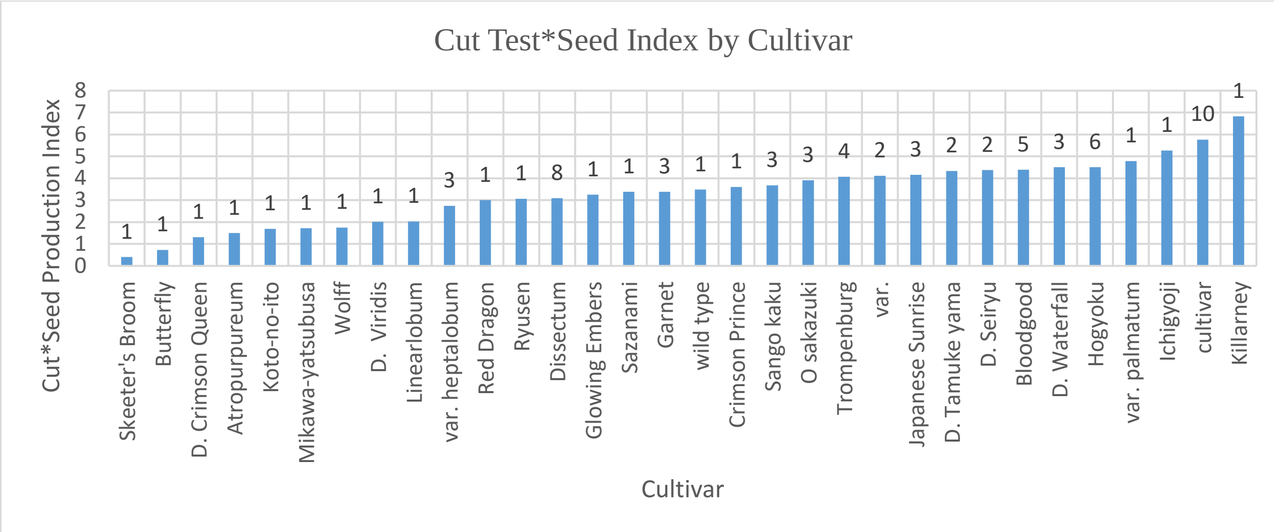


Figure 3: Viability Ratio Multiplied by Seed Productions

<u>Plant Collections Network</u>

With the help of the Acer Multi-Site Collections Network, data was compiled from six gardens: University of British Columbia Botanical Garden, the Dawes Arboretum, the Arnold Arboretum, the Morton Arboretum, Atlanta Botanical Garden, and Cornell Botanic Gardens. Qualitative ratings such as “heavy,” “very few,” or “none” were converted to quantitative numerical ratings on the scale created by this study and placed onto a graph. Figure 4 displays the seed production data received from the Collections Network with the number of individual trees surveyed above each bar (Figure 4). This data is kept separate from the data collected during this study as it is from varied sources that followed no standardized method of collection.

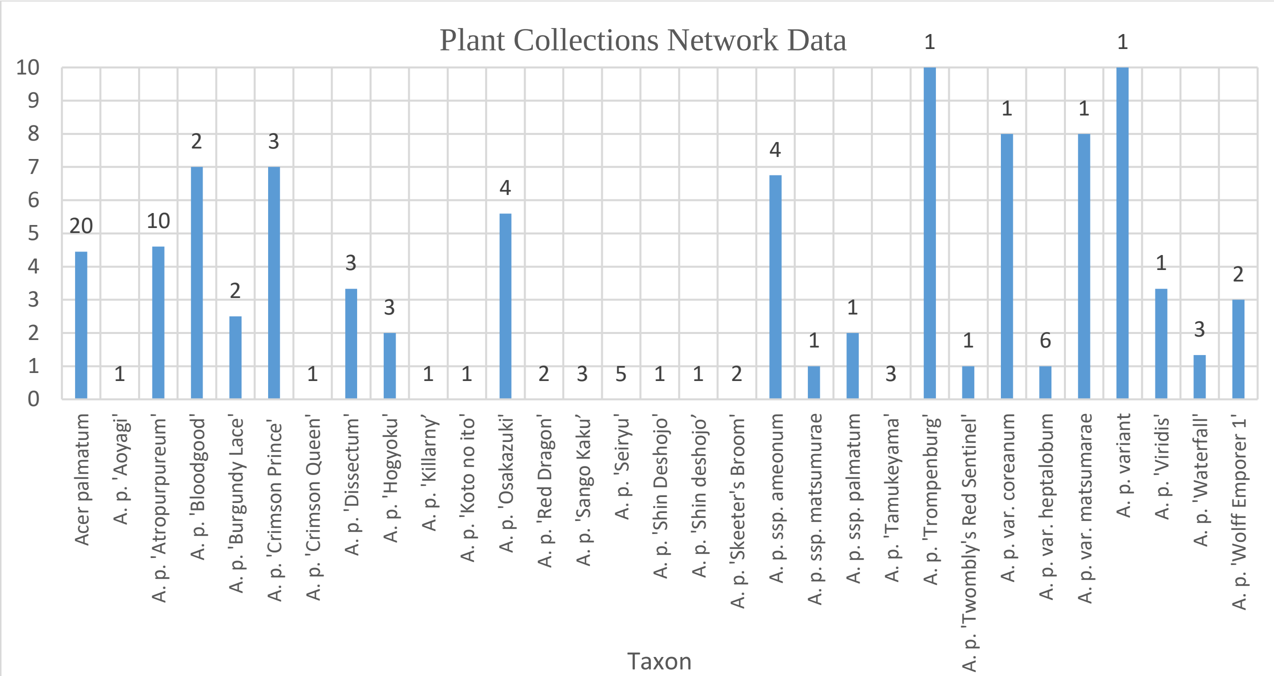
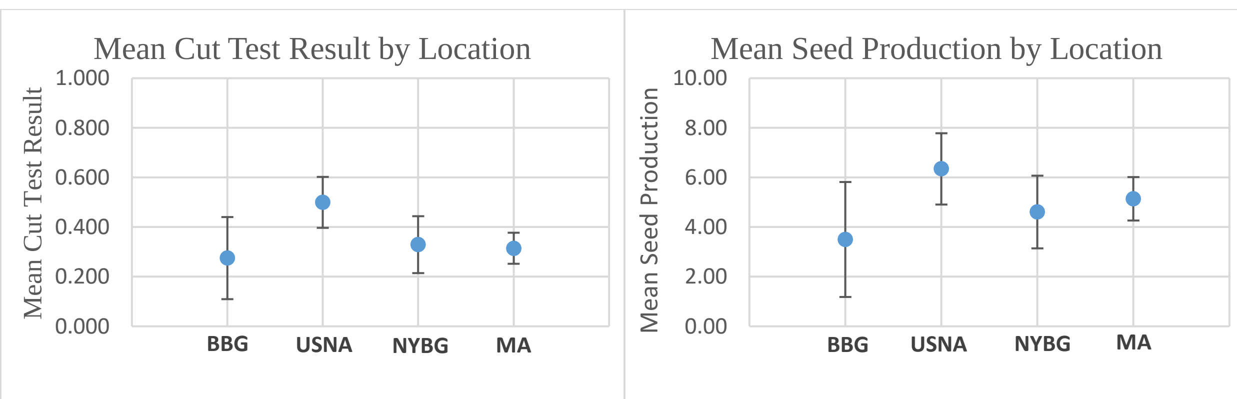


Figure 4: Plant Collection Network Data

Data Sorted by Location

For those sites visited, an ANOVA was done to determine if location had an influence on seed production or viability. Using this analysis, a higher mean cut test result and seed production was observed at the USNA, corresponding to the southernmost data collection point. Results from the cut test mean results indicate that the effect of location was statistically significant with p=0.017, although results using seed production data are not as strong with p = 0.16.



Figures 5 and 6: Location-based data

Germination Trials

The number of seeds that germinated was divided by the number of seeds propagated and then plotted as shown in Figure 7. The quantities of seeds for each individual are shown above each bar. Some seeds did not see any germination (e.g. 'Seigai', 'Atropurpureum', and

‘Waterfall’), although looking at the viability ratios adds some context (Figure 7). For instance, ‘Seigai’ only had two seeds on the entire tree and ‘Atropurpureum’ had notably low viability rates. On the other hand, ‘Viridis’, ‘Waterfall’, and ‘Killarney’ showed low to no germination compared to their moderate to high viability. The viability for ‘Summer Gold’ and ‘Seigai’ could not be measured, as the individual did not produce enough seeds to test.

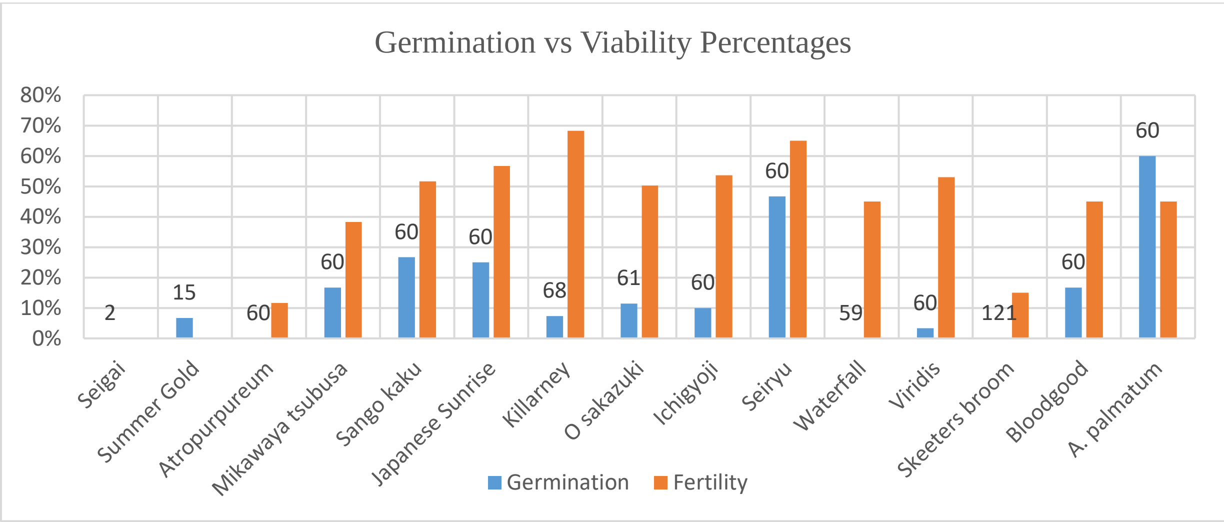


Figure 7: Germination and Viability Results

DISCUSSION

Cultivars

As seen in Figure 2, two kinds of cultivars stand out: (1) those with low seed production and viability; and (2) those with low viability who were also shown to have low germination in propagation trials, such as ‘Skeeter’s Broom’, ‘Summer Gold’, and ‘Atropurpureum’ cultivars (Figure 8). It is should be noted that there was a limitation on sample sizes for individual plants. Additionally, it cannot be ruled out that an individual plant could have lower or higher seed production based on depending on its environmental conditions. That said, some cultivars with sample sizes greater than three produced no seeds, including ‘Skeeter’s Broom’, ‘Shishigashira’, ‘Shaina’, and ‘Tsuri-nishiki’. Further tests are required to confirm these results. Nevertheless, these cultivars are the most promising in terms of low seed production and viability of those sampled.

Confirming our expectations, the naturalized *Acer palmatum* specimen found in Wissahickon Park featured the overall highest germination rate, surpassing the observed viability ratio. This could explain how it has been spreading quickly through the forests, and it is possible that selection has caused these naturalized specimens to germinate better than cultivated ones.

In future studies, it might be important to look at the germination of *A. palmatum* compared to native species. In a study done on an invasive grass in Brazil, *Eragrostis plana*, it was found that in comparison to native species, *E. plana* demonstrated earlier germination times (Guido et. al 2017). Additionally, plants may be better suited to their areas of introduction and gain competitive advantage by decreasing dormancy time, adjusting to temperature differences, and releasing allelopathic agents to inhibit others (Udo et. al 2017; Guido et. al 2017). Such factors should be included in follow up research on *A. palmatum*'s risk of invasiveness.

A study on the invasive *Ailanthus altissima* has shown a large span of reproductive viability, producing fertile seeds for up to a century of its lifespan (Wickert et. al 2017). The importance of long-term observation of seed production will add data on how different cultivars may produce more seeds in a lifespan compared to others, or for different timelines of maturity, as it is possible that some cultivars are sexually mature before others.

Weather

Since this study only considers a single growing season, weather conditions for the year may have influenced the observed seeding patterns. Weather data in the year of 2017 can be found in Appendix C as compared to the averages of 1981-2010 for the localities of New York (measured from LaGuardia Airport), Philadelphia (measured at the Philadelphia Airport), and Washington, D.C. (measured at the Ronald Reagan Airport). This data was acquired from Weather Underground, The National Weather Service, US Pest, and Climate Smart Farming.

With increasing effects of climate change, one would expect this area to receive warmer temperatures, more GDD, and less predictable rainfall, which could greatly affect the production of seeds by *Acer palmatum* (Badh 2011; Hellman et. al 2008). Nevertheless, a study on the effects of weather on seed production did not show strong correlations of these variables in other tree species such as *Acer platanoides*, *Quercus robur*, and *Carpinus betulus*, excluding heavy rainfall during flowering, which has the potential to hinder wind and insect pollination (Wesołowski et al. 2015). Multi-year samples should be considered for future analyses of *A. palmatum* as different species may reveal higher susceptibility to weather conditions.

CONCLUSION

This study highlighted promising cultivars for containing invasiveness of the non-native species *A. palmatum*, in which individuals show low seed production and seed viability. These cultivars should be further investigated to confirm whether these features are observed irrespective of region and season, and in order to investigate other variables such as precipitation or isolated events (e.g. a storm or pest causing flower damage). These cultivars include the following:

- Skeeter's Broom: witch's broom cultivar, only 1/3 individuals with seeds, low viability
- Shishigashira: no seeds found on 8 individuals
- Shaina: dwarf cultivar, no seeds found on 3 individuals
- Tsuri-nishiki: no seeds found on 3 individuals, all individuals were in Morris Arboretum
- Koto-no-ito: low seed production, low seed viability on 2 individuals

Using the methodology described here, staff members at the Morris Arboretum as well as at other institutions can continue developing this work to produce a more thorough picture of the variables influencing seed production in these cultivars of *Acer palmatum* and how these variables might be affected by the changing climate. Future studies into sex expression, flowering phenology, flower anatomy across cultivars and specimens could provide further insights for understanding variation in seed production.

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TABLES

***Table A**: Data Collected from Morris Arboretum*

Accession	cultivar	color	color	color	Cut test 8/28/2017	Cut test 9.11.2017	Cut test 9/25/2017	Index 8/28/2017	Index 9/11/2017	Index 9/25/2017	Notes 8/28/2017	Notes 9.11.2017	Notes 9/25/2017
1996-075*A		g	g/r	g/b	30%	50%	32%	7	9	8	tall tree	tall tree	tall, tri-sam
1998-256*A		g	g	g	50%	35%	55%	4	7	7	tall tree	tall tree	tall
2010-012*A		g	g	g/b	55%	60%	50%	7	7	7			tall
2012-055*A		g	g	g	75%	55%	65%	6	6	6			tall
2013-003*A		g	g	b/g	15%	28%	25%	9	9	10		tri-sam	
1932-0701*A	'Atropurpureum'	g	g/b	b/g	5%	10%	20%	8	8	6			
1982-003*A	'Butterfly'							0	0	0	poor condition		
2016-264*A	cultivar	g/r	r/g	r/g	60%	65%	48%	10	10	10	Tall tree	tri-sam	tall, tri-sam
1932-0025*A	'Dissectum'	g/r	g	g	55%	85%	70%	9	9	9		partial tri-sam	
1954-0129*A	'Dissectum'	g	g/r	g/r/b	55%	60%	45%	8	8	8	partial tri-sam		
1954-0130*A	'Dissectum'	g	g	g/b	55%	30%	10%	8	5	6			
1954-0246*A	'Dissectum'	g	g/r	g	20%	15%	50%	8	9	9			
1954-1145*A	'Dissectum'	g	g	g/r/b	85%	60%	70%	8	8	8			
1976-164*A	'Dissectum'	g/r	g	g/b	55%	40%	50%	9	9	8			
1978-140*A	'Dissectum'												
1978-143*A	'Dissectum'	g	g	g/b	50%	65%	55%	8	7	8			
1985-051*A	'Dissectum'		g	g/b		40%	60%	-	2	2			
2011-003*A	'Dissectum'	g		g	55%			2	-	1	all on north side		too few (2)
2001-046*A	'D. Atropurpureum'	g/r	r	r				1	1	1	too few (4)	too few (6)	too few (2)
2006-037*A	'Dissectum Viridis'	g	g	g				1	1	1	too few (12)	too few (10)	too few (4)
2006-037*B	'Dissectum Viridis'	g	g	g	50%	65%	45%	8	8	8			
~~2017-031*A~~	~~'Dolly Hill'~~										~~Dead~~	~~Dead~~	~~Dead~~
1983-020*A	'Garnet'	r/g	r/g	r/g	55%	45%	45%	7	6	8			
1932-1235*A	var. heptalobum	g	r/g	r/g	55%	45%	55%	8	10	10			
1976-181*A	var. heptalobum	g	g	g	35%	45%	45%	7	9	9			
1990-054*A	var. heptalobum	g/r	g/r	r/g	55%	45%	30%	9	10	10			
2009-008*A	var. heptalobum	r/g	r/g	r/g	50%	40%	36%	8	9	10			tri-sam
2009-008*B	var. heptalobum	g/r	r/g	r/g	52%	52%	55%	5	6	6	tri-sam	tri-sam	
2017-070*A	var. heptalobum												
2017-032*A	'Hubb's R Willow'												
1986-135*A	'Ichigyoji'	g/r	r/g	r/g	52%	64%	45%	10	10	10	tri-sam	tri-sam	

1986-135*B	‘Ichigyoji’	r/g	r/g	r/g	60%	40%	55%	10	10	10			
2006-137*A	‘Japanese Sunrise’	y	y	y	65%	60%	45%	8	7	7			
2003-025*A	‘Kashima’												
2016-063*A	‘Katsura Hime’												
2016-107*A	‘Kawahara Rose’												
1982-002*A	‘Killarney’	g	g/r	g/b	60%	60%	85%	10	10	10			
2010-096*A	‘Kiyohime’										poor condition		
1932-3236*A	‘Linearilobum’	g	g	g/b	35%	15%	15%	7	8	9	Tall tree	tall tree	
2010-022*A	‘Linearilobum’	g/r	g	g	55%	52%	55%	7	8	8			
2010-022*B	‘Linearilobum’	g/r	g	r/g	0%	0%	15%	7	7	7			
2006-138*A	‘Mikawa-yatsubusa’	g	g	g				1	1	1	too few (2)	too few (2)	too few (4)
2016-261*A	‘Mikawa-yatsubusa’	g	r/g	g/r	50%	25%	40%	7	9	8			
2010-175*A	‘Okushimo’												
1981-368*A	‘Osakazuki’	r/g	r/g	r/g	36%	55%	60%	7	10	10	tri-sam		
1981-368*B	‘Osakazuki’	r/g	r/g	r/g	45%	60%	55%	10	10	10			
1981-368*C	‘Osakazuki’	r/g	r/g	r/g	50%	60%	40%	10	10	10			
1932-1255*A	var. palmatum	g/r	g	g/b	50%	70%	55%	7	7	7	tall, poor condition		tall
1947-516*A	var. palmatum	g/r	g	g/r	72%	50%	70%	8	9	9	tri-sam		tall
1976-165*A	var. palmatum	g	g	g	45%	50%	55%	10	9	9	partial tri-sam	tall tree	tall
2011-091*A	‘Ryusen’	g	g	g	55%	15%	50%	8	7	8			
2015-111*A	‘Ryuzu’												
1979-078*A	‘Sango Kaku’	g	g	y	75%	65%	80%	10	7	9		tall tree	
2006-034*A	‘Sango Kaku’	g/y	y/g	y	60%	40%	55%	7	7	7			
1986-139*A	‘Sazanami’	g	g	g	60%	40%	60%	6	6	7			
1947-521*A	‘Seigai’		g/y	g/b				-	1	1	poor condition	too few (8)	too few (2)
1988-079*A	‘Seiryu’	g	g	g/b	65%	65%	65%	8	6	7			
2006-139*A	‘Shaina’												
2017-071*A	‘Shinonome’												
2008-085*A	‘Skeeter’s Broom’												
2009-022*A	‘Skeeter’s Broom’												
2015-023*A	‘Summer Gold’	g/b	g	g/b				2	1	1	too few (12)	too few (10)	too few (10)
2013-052*A	‘Tsukasa Silhouette’												
1932-2701*A	‘Tsuri-nishiki’												
1986-140*A	‘Tsuri-nishiki’												
2017-069*A	‘Tsuri-nishiki’												
54-1151*A	var.	g	g/r	g	55%	48%	52%	6	5	7			tri-sam

78-148*A	var.	g	g	g	50%	60%	50%	9	10	10			
2005-058*A	'Waterfall'	g	g	g	40%	35%	60%	9	9	9		multi tri-sam	
2013-050*A	(Wood's linearilobum)												
2009-023*A	'Yama hime'												

Colors: dominant color first/secondary color(s) after

g = green
r = red
b = brown
y = yellow

Notes: too few (x), x =number of seeds on individual
Tri-sam means there was a triple samara collected
Tall tree means that many seeds were out of reach

***Table B**: Data Collected from outside Morris Arboretum*

Accession #	Cultivar	Cut test	Seeding Index	Source
1664/95*A	‘Bloodgood’	25%	10	NYBG
1569/96*B	‘Crimson Queen’	0%	0	NYBG
503/97*B	‘Crimson Queen’	0%	0	NYBG
1184/2015*A	‘Crimson Prince’	40%	9	NYBG
328/2016*A	‘Glowing Embers’	65%	5	NYBG
1680/2004*B	‘Koto-no-ito’	32%	5	NYBG
719/2016*A	‘Koto-no-ito’	8%	7	NYBG
422/2007*A	‘O sakazuki’	60%	6.1	NYBG
1274/2011*A	‘Red Dragon’	60%	5	NYBG
1469/95*A	‘Sango kaku’	50%	8	NYBG
1008/96*A	‘Sango kaku’	75%	8	NYBG
2397/2004*A	‘Sango kaku’	55%	8	NYBG
908/2012*A	‘Seiryu’	45%	7.1	NYBG
330/2016*A	‘Shaina’	0%	0	NYBG
1569/2004*A	‘Shishigashari’	0%	0	NYBG
349/2014*A	‘Shishigashari’	0%	0	NYBG
1156/2015*A	‘Shishigashari’	0%	0	NYBG
339/2017*A	‘Shishigashari’	0%	0	NYBG
1630/2004*C	‘Tamuke yama’	70%	2	NYBG
1160/2015*A	‘Tamuke yama’	80%	9	NYBG
1173/2015*A	‘Trompenburg’	60%	9	NYBG
424/2007*A	‘Viridis’	0%	1	NYBG
685/2008*A	‘Viridis’	20%	7	NYBG
1283/2005*A	‘Wolff’	30%	2	NYBG
1187/2015*A	‘Wolff’	48%	7	NYBG
670835	‘Bloodgood’	30%	5	BBG
930488	‘Bloodgood’	55%	10	BBG
950286	‘Butterfly’	55%	4	BBG
620399	‘O sakazuki’	30%	5	BBG
188	‘Sango kaku’	50%	4	BBG
X10498	‘Sango kaku’	0%	0	BBG
334	‘Seiryu’	55%	7	BBG
620421	‘Shishigashira’	0%	0	BBG
670457	‘Shishigashira’	0%	0	BBG
670457B	‘Shishigashira’	0%	0	BBG
44082-H	Acer palmatum	45%	7	USNA
44082-J	Acer palmatum	65%	6	USNA
65148-H	Acer palmatum	80%	7	USNA

67610-H	Acer palmatum	75%	8	USNA
67610-J	Acer palmatum	55%	3	USNA
71460-H	Acer palmatum	25%	7	USNA
29088-H	D. 'Crimson Queen'	75%	7	USNA
64708-H	D. 'Seiryu'	60%	10	USNA
31616-J	D. 'Tamuke yama'	45%	9	USNA
15637-H	D. 'Viridis'	70%	4	USNA
64720-H	D. 'Waterfall'	55%	9	USNA
62965-H	'Atropurpureum'	25%	9	USNA
64698-H	'Bloodgood	68%	8	USNA
38164-H	'Bloodgood'	90%	9	USNA
38164-J	'Bloodgood'	75%	7	USNA
38164-L	'Bloodgood'	60%	5	USNA
38164-P	'Bloodgood'	56%	8	USNA
38164-T	'Bloodgood'	45%	8	USNA
~~58268-H~~	~~'Butterfly'~~	~~DEAD~~	~~DEAD~~	~~USNA~~
32495-H	'Hogyoku'	50%	9	USNA
69610-H	'Koto-no-ito'	40%	7	USNA
73671-H	'Sango-kaku'	60%	6	USNA
79299-L	'Shaina'	0%	0	USNA
79955-H	'Shindeshojo'	0%	0	USNA
42389-H	'Shishigashira'	0%	0	USNA
64696-H	'Skeeter's Broom'	15%	8	USNA
58273-H	'Trompenburg'	65%	4	USNA
N/A	Acer palmatum	45%	7	Wissahickon Park, PA
N/A	'Bloodgood'	45%	10	Chestnut Hill, PA

Table C: *Germination Trials*

Cultivar	**Relative Viability**	**Relative Index**	**Germination Rate**
Seigai	Unknown	Very Low	
Summer Gold	Unknown	Very Low	
Atropurpureum	Low	High	
Mikawaya tsubusa	Low-Moderate	Low-Moderate	
Sango kaku	Moderate-High	Moderate-High	
Japanese Sunrise	Moderate-High	High	
Killarney	Very High	Very High	
O sakazuki	Low-Moderate	High	
Ichigyoji	Moderate-High	Very High	
Seiryu	Moderate-High	High	
Waterfall	Moderate	High	
Viridis	Low-Moderate	Low-Moderate	
Skeeter’s broom	Low	Low	

APPENDICES

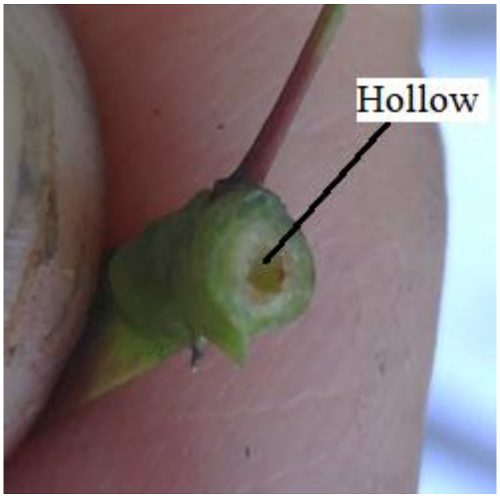
***Appendix A**: Top 23 Bestselling Cultivars*

Cultivar	Group
Acer palmatum[2, 3]	Green Palmatum
Acer palmatum ‘Aoyagi’ [4] aka Ukon	Green Palmatum
Acer palmatum ‘Atropurpureum’ [3, 4]	Red Palmatum
Acer palmatum ‘Bloodgood’[1, 2, 3, 4, 5]	Red Palmatum
Acer palmatum ‘Butterfly’[1]	Variegated Palmatum
Acer palmatum ‘Crimson Prince’[2]	Red Matsumurae
Acer palmatum ‘Glowing Embers’[2]	?
Acer palmatum ‘Hogyoku’[1]	Green Amoenum
Acer palmatum ‘Koto No Ito’[1]	Green Linearilobum
Acer palmatum ‘O sakazuki’[4]	Green Amoenum
Acer palmatum ‘Sango kaku’[1, 2, 3, 4]	Green Palmatum
Acer palmatum ‘Shaina’[3, 4]	Red Palmatum/Dwarf
Acer palmatum ‘Shin Deshojo’ [3]	Green Palmatum
Acer palmatum ‘Shishigashira’[1, 2, 3]	Green Palmatum
Acer palmatum ‘Skeeter’s Broom’[1]	Red Dwarf
Acer palmatum ‘Trompenburg’ [4]	Red Matsumurae
Acer palmatum ‘Wolff’/‘Emperor 1’[1, 3, 4]	Red Matsumurae
Acer palmatum dissectum ‘Crimson Queen’[2, 4, 5]	Red Dissectum
Acer palmatum dissectum ‘Red Dragon’[1, 3]	Red Dissectum
Acer palmatum dissectum ‘Seiryu’[1, 2, 3]	Green Dissectum
Acer palmatum dissectum ‘Tamukeyama’[1, 2, 3, 5]	Red Dissectum
Acer palmatum dissectum ‘Viridis’[1, 2]	Green Dissectum
Acer palmatum dissectum ‘Waterfall’[4]	Green Dissectum

1. Andy Schenck (Sam Brown’s Nursery, Inc.)
2. J F. Frank Schmidt & Son Co.
3. Heritage Seedlings & Liners, Inc.
4. Monrovia Nursery Co.
5. Colibraro Landscaping and Nursery, Inc.

***Appendix B**: Viable and Not Viable Seeds*

Viable Seed



Not Viable Seeds

***Appendix C**: Weather Data from the 2017 Growing Season*

Philadelphia, PA

- Annual mean temperature 58°F (2.1°F above average)
- 40.5 inches of rain (average)
- 3990 Growing Degree Days (GDD), (400 GDD above average)

Washington, D.C.

- Annual mean temperature 61°F (3°F above average)
- 35.54 inches of rain (4 inches below normal)
- 4974 GDD (1000 GDD above average)

New York City, NY

- Annual mean temperature 58°F (2.5°F above average)
- 42.2 inches of rain (2.5 inches below average)
- 4272 GDD (1000 GDD above average)