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THE EAST ASIAN CRABAPPLE, *MALUS TORINGO* (ROSACEAE), BECOMING INVASIVE IN KENTUCKY AND ACROSSTHE EAST-CENTRAL USA

JULIAN J.N. CAMPBELL
3525 Willowood Road,
Lexington, Kentucky 40517
julian.campbell@twc.com

ABSTRACT

The east Asian crabapple*Malus toringo* has invaded old fields of Hisle Farm Park in Fayette Co., Kentucky. There has been no previous convincingevidence of naturalization by this species in the state and little for elsewhere in North AmericaThe complex unstable taxonomy of *Malus*—with many cultivars—has madetracking of this species difficult. *Malus toringo* is defined here in a broad sense to include*M. sargentii* and *M. sieboldii*. It is possible that invasive spread is concentrated in a limited set of apomictic cultivars and hybrids, including plants known as *M.* ×*zumi*.However, there is now evidence of local invasion from midwestern to mid-Atlantic states, based largely on review of 'gray' literature, review of posted herbarium data, and personal communications.

Malus toringo (Sieb.) Sieb. ex de Vriese, as broadly defined in this paper, is a variable east Asian species of crabapple, including *M. sargentii* Rehder and *M. sieboldii* (Regel) Rehder (Olien 1987; Gu & Spongberg 2003; Dickson 2014; Sutton & Dunn 2021, Ha et al. 2022). Nomenclature here follows the Flora of North America (Dickson 2014) and Weakley et al. (2024).The species typically has white or pink flowers ca. 2 cm across, with 3–4 styles (versus 5 in most other *Malus*), relatively small red or brownish-yellow fruits (ca. 4–8 mm wide)on short pedicels (ca. 1.2–4 cm),leaves with short petioles (ca. 1.5–2.5 cm), the blades folded in bud, relatively narrow and often slightly to deeply lobed, especially on long shoots,and branches often somewhat thorny on vigorous plants. Its leaf lobing and thorniness can sometimes cause confusion in eastern North America with the native species of crabapple (*Malus coronaria* complex) or with hawthorns (*Crataegus*).

This paper summarizes records from Kentucky and some other east-central states that indicate *Malus toringo* is becoming at least locally invasive. An expanded version of this account, with more notes on cultivars, plus illustrations and maps, is posted at my website (Campbell 2024).

Review of taxonomy

Both the east Asian *Malus toringo* and the Siberian *M. baccata* have small fruits with deciduous sepals. In contrast, *M. domestica* [= *pumila*], *M. prunifolia* and the natives of eastern North America (*M. coronaria* etc.) have generally larger fruits with persistent sepals. Larger fruits have probably been selected for dispersal by mammals rather than birds (Spengler 2019; Spengler et al. 2023).*Malus toringo* in its broad sense includes diverse variants distributed from western China to Korea to northern Japan, and there are also close allies that can probably interbreed (Gu & Spongberg 2003): e.g., *M.kansuensis*, *M.toringoides*.Some of these variants are apomictic triploids or tetraploids (Sax 1959). Putative hybrids of M. *toringo* with *M.baccata* known as*Malus*× *zumi*(Matsumura) Rehder have also been widely cultivated. Such putative hybrids have been collected in Ohio as well as more typical *M.toringo* (Vincent & Cusick 1998). Apparent hybrids between *M.toringo* and *M.baccata* are also known within their overlapping native ranges. Moreover, recent analysis of DNA in the native range has indicated that *M.toringo* in its broad sense may be hard to disentangle from *M.baccata* in phylogeny(Cho et al. 2021; Ha et al. 2022). In its stricter sense, *M.toringo* is a largely Chinese diploid (2n = 34) that may be closest to *M.toringoides* (2n = 51, 68) and other Chinese

species. In contrast, some Korean or Japanese segregates of *M.toringo*, often named *M.sargentii* or*M.zumi*, may be closest to *M.baccata* or its allies.

If separated from typical *Malus toringo*, *M.sargentii* (and perhaps some *M.zumi*) may be distinguished as follows (Koidzumi 1934; Fiala 1994; Schuster & Büttner 1995; Dickson 2014; Wilhelm & Rericha 2017): fruits larger on average (up to 10 mm wide), usually becoming dark red with slight bloom (versus often remaining brownish-yellowish); styles 4–5 (versus 3–4); flowers relatively large (up to 2.5 cm wide), with white suborbicular petals (versus white or pink, elliptic); leaves less deeply serrate or lobed (versus often deeply serrate to lobed); branches more horizontally spreading, dense and thorny; plants only up to 2.5–3 m tall (versus 6–10 m); 2n = usually 68 (versus 34).Most plants of the *M.toringo* complex planted in the USA may be referred to *M.sargentii*, but it remains uncertain whether the name*M.sargentii* can be applied to any of the invasive populations noted below.

Sutton & Dunn (2021) have provided further details of taxonomic issues within*Malus toringo*: "This is primarily a diploid, sexual species which readily produces hybrid seed when outcrossed in collections, although triploids and tetraploids also occur... Var. *sargentii* is one of these tetraploids. Fiala's (1994) claim that 'true' *M. toringo* is a yellow-fruited pentaploid, while *M.* × *zumi* (which he most unhelpfully calls *M. sieboldii* (Rehd.) Fiala) is a red-fruited diploid, is made without citing any reference, seems deeply suspect, and has been generally ignored. The status of *M.* × *zumi* (q.v.) is very uncertain; in Japan it has usually been treated as *M. toringo* var. *zumi* (Matsum.) H. Hara, with leaves not or scarcely lobed... ."

Under var. *sargentii*, Sutton & Dunn noted this: "It has often been noted that seedlings from Sargent's Crab are mostly true to type... although this cannot be relied upon. This is a tetraploid plant showing facultative apomixis: almost all its seedlings are tetraploids, genetically identical to the mother (Sax 1959). The fact that it can produce sexual offspring, mostly triploids resulting from crossing with sexual diploid species, explains the existence of cultivars and hybrids such as 'Rosea', a triploid with deeper pink buds raised at the Rochester Parks Department, NY before 1921 (Sax 1959); 'Tina' is an important modern cultivar (see 'Cultivars T-Z'), an open pollinated seedling of var. *sargentii*, which is even more dwarf. Whether or not any of these should be treated as belonging in this variety is debatable. 'Candymint Sargent' with its purple leaves is more obviously a hybrid (see 'Cultivars C')."They continued (under var. *sargentii*): "The horticultural literature has tended to list it as a full species... and there is certainly a case for treating it as an apomictic microspecies in the orbit of *M. toringo*, but botanists have regularly sunk it entirely... A group of similar forms rather than a cultivar, this important garden plant requires a name, so we take a middle course following Cullen et al. (2011)."

Records of naturalization in Kentucky

The only previous record of possibly naturalized *Malus toringo*in Kentucky is a collection of "*sieboldii*" in 1978 by E.W. Chester from Trigg County, where it was "common on open roadside" of Land-Between-the-Lakes (APSC)—but it may have been planted.More recently a self-sown tree, about 7–8 m tall and 15–20 cm dbh, was found in 2015 by the author at the edge of the wild woodland garden that has been established by Dr. D. Svetich of Fayette County. And shortly afterwards, the species was discovered spreading abundantly in nearby old fields and fencerows of the Hisle Farm Park, owned and managed by Lexington-Fayette Urban County Government. A collection has been provided to EKY: *J. Campbell*, 15 Jul 2024, small tree 6 m tall on right of entrance to Hisle Farm Park, Fayette County, Kentucky (at 38.07001, -84.39293). The extent of naturalization by *M.toringo* in Kentucky remains largely unknown. Details of range and habitat have not been presented in recent floristic publications nor even in unpublished reports.There has been almost no documentation of its invasive status or of efforts to control.

The first plantings in Kentucky of *Malus toringo*, as *M.sargentii*, may have been at Bernheim Forest (Johnson 2024): "One of the great treasures of the Bernheim Arboretum is its outstanding Crabapple Collection. This collection greets everyone who visits with its astonishing beauty, just a few short yards inside the entrance. The collection is among Bernheim's earliest, dating back to the 1930s and 1940s, though most planting records for that period were destroyed when the original Bernheim headquarters building burned down. Few, if any, of the original trees likely remain. Some trees have fallen victim to high winds and other severe weather, others succumbed to disease, and still others reached the end of their normal lifespan of 40–60 years." Bernheim Forest (2019) stated this: "The crabapple collection on Crabapple Hill near the main entrance was planted in 1952 and is a part of the original Olmsted plan. Since then, the crabapple collection has been refined to only contain only the most beautiful, disease-resistant specimens." Their current list includes "*M. sargentii*" and "*M. sargentii* Tina." However, there is no evidence yet of significant invasion into nearby old fields or woods (A. Berry, pers. comm.).

The 1978 record of *Malus toringo*from Land-Between-the-Lakesmay well have resulted from plantings by the Tennessee Valley Authority when they managed that area after 1965. The TVA also planted other alien woody species, including several trees of *Pyrus calleryana*, which were finally removed by the US Forest Service at the South Welcome Station in 2018! In Lexington, *M. toringo* (as *M. sargentii* 'Tina' and other cultivars) has been planted at the University of Kentucky Arboretum; there are a few at corner of the parking lot, although one has recently been removed, perhaps due to fire blight. During 2024, J.Slade (pers. comm.) discovered that at least 100 seedlings had spread into this 50-acre arboretum, and they were destroyed. The same or similar cultivars have been planted at several other sites around Fayette County, including large groups in about 1990 near Krogers at Tates Creek Road and Man-O-War Boulevard, in about 2000 at Woodhill Shopping Center, and a few in about 2009 at the northern entrance to Lansdowne-Merrick Park. At that park, seedlings of *M.toringo* are also scattered in unmowed areas, especially at the edge of thickets along the riparian zone. Seedlings appear to be slightly shade-tolerant.

The population of *Malustoringo* at the 280-acre Hisle Farm Park in Fayette County is remarkable. There are 100s or 1000s of plants, which may have originated from a small planting near the pond at northeast corner of the park. The most obvious trees are in fencerows and unmowed edges of the old fields. If unmowed for three or more years, these plants flower and fruit in profusion. In much of the park, south of the railroad, there is a three-year mowing rotation, and *M.toringo* is mixed with other trees and shrubs in the resprouts, especially black walnut, hackberry, Bradford/Callery pear, white mulberry, bush honeysuckle and multiflora rose. The plants are up to 3–4 m tall; they appear to be typical *M.toringo*, not *M.sargentii*. Across the railroad, the old fields are mowed annually in summer, but *M.toringo* has become common in the stubbly growth along with briars and poison ivy etc. The *M.toringo*there suckers laterally and puts up shoots. Management plans for this park remain uncertain. It would be wise to consider the potential problem with *M.toringo* invasion. Where mowing is relaxed, it would be desirable to spot kill all *M.toringo* sprouts before they grow more than a year old. We do not want this species to become a new 'Bradford Pear' but 'Pandora's Box' is now opened! We have limitedplanning and resources for control of invasive species across the landscapes of central Kentucky. But at least small groups of committed managers and volunteers could maintain a few relatively alien-free arboreta, parks and preserves. And we should of course grow much more of the native crabapples.

Records of naturalization elsewhere in North America

The first trees of *Malus toringo* (broadly defined) that were planted within North America appear to have been var. *sargentii*or × *zumi* in 1890–92 at the Arnold Arboretum (Fiala 1994; Dosmann 2009, Sutton & Dunn 2021). The first herbarium collection shown by SERNEC (2024) was from cultivation at the Arnold Arboretum in 1906 (Harvard A), then labeled as *M. sieboldii* var.

calocarpa Rehder.There have been many subsequent records from cultivation. The first collections that indicate self-sown naturalization appear to date from 1977-82 (SERNEC 2024): e.g., by M. Nee in Wisconsin (WIS); W. Lampa in Illinois (MOR); E.W. Chester in Kentucky (APSC); R.L. Angelo in Massachusetts (GH); P.F. Siza in Vermont (VT).

Local abundance of naturalized plants has been indicated after 1990.In Ohio, Vincent and Cusick (1998) reported collections of naturalized *Malustoringo*, *M.zumi*, and other crabapples during the 1990s. After 2010, *M.toringo* has become locally abundant in unmowed fields and fencerows of the 2000-acre Dawes Arboretum and nearby (D. Brandenburg, pers. comm.). In Michigan, a collection made in 2006 by S.C. Garske described a "well-established population along an edge of a wetland in Ontonagon Co." (Reznicek et al. 2011). In Illinois, White (2012) reported dense invasion by seedlings of *M.toringo* at Meadowbrook Park in Urbana: "There are thousands of times more Japanese crab [*toringo*] seedlings than Siberian crab [*baccata*] seedlings, and Japanese crab saplings are perhaps 50 times more common than Siberian crab saplings... In May 2011, I chose an average, representative spot near the big Japanese Crabs along the Wildflower Walk and counted 92 crab seedlings in a square foot. Most of the seedlings died as the growing season progressed, and only a few might survive to the sapling stage, but Japanese Crab obviously can dominate the vegetation if left uncontrolled." J. White (pers. comm.) has also stated this in 2024: "There is a heavy infestation along a railroad in Champaign, a few miles west of Meadowbrook Park in Urbana."Forthe Chicago area, Wilhelm and Rericha (2017) noted this under *M.toringo*: "Far more common than our records indicate; vegetative whips of this species are common in shrubby old fields, pastures, and along hedgerows on fine to coarse textured soils... The American Robin, European Starling, and Hermit Thrush disperse the fruits. Flocks of the first two species can be seen on this crab apple at the end of the summer into autumn." Forest Preserves of Cook County (2021) noted this: "Japanese crab apple (*Malus toringo*) has alreadybeen found in a few Forest Preserves locations and in surrounding communities."

One wonders if crossing between new cultivars in midwestern states has promoted invasion, as indicated in Ohio for *Pyrus calleryana* by Vincent (2005), Culley and Hardiman (2009), and others. The Dawes Arboretum at Newark, Ohio, recently hosted a meeting, "Non-native Crabapple Research Collaborator DocumentationWorkshop" (30 April 2024), led by Shana Byrd and David Brandenburg, who presented information on the extensive invasion by *Malus toringo* (broadly defined) into old fields at the arboretum. Staff here have been observing, researching and attempting to control this invasion for up to a decade, but they have not yet published results.They are using DNA analysis to indicate which cultivars are most invasive.

Continental mapping of *Malustoringo* has been slow to catch up. Kartesz (2024) has included the species in BONAP only after 2010. Other national mapping projects have included it, especially EDDMapS (2024), but with curious inconsistencies —compare displays at <invasiveplantatlas.org>, <invasive.org>, and <eddsmaps.org>. Local impressions within particular states are often interesting; for example, Gilman and Watson (2006) stated that *M.sargentii* has "little invasive potential" in Florida. Ideally, there would be more transparent sharing and comparing of data between different local and global mapping projects. The inadequacy of EDDMapS (2024) to indicate naturalized *M.toringo* is particularly notable given the purpose of this system, established in 2007: "The central focus of the Early Detection and Distribution Mapping System (EDDMapS) is to foster the collection, amalgamation and sharing of these data to show a more complete map of the threat of invasive species and how this issue impacts the nation as a whole" (Wallace et al. 2022).However, there has not been comprehensive synthesis with records in iNaturalist, SERNEC, and BONAP, partly because those other websites sometimes include records of cultivated plants that are not differentiated from records of truly naturalized plants.

Given the concentrations of alien genetic material and breeding programs for crabapples in major arboreta and botanical gardens of North America, it is surprising that so little has been written about potential invasions. One of the few relevant publications is an article by Tietmeyer and Bristol (2002), but their purpose was only "to collect baseline data to assist in the evaluation of the potential invasiveness of this small tree and some of its varieties and cultivars in theChicago region." They reported numbers of viable seeds per fruit but provided no data on numbers of fruits per tree or on actual occurrence of naturalized seedlings across the landscape.There are zero comments on potential invasiveness by alien crabapples in the publications of Fiala (1994), Dosmann (2009), Sax (2011), and the whole 2021 issue of "Malus"—Journal of the International Ornamental Crabapple Society. This journal was revived in 2021 under its new "patron," the China National Botanical Garden (IOCS 2024).

There has not yet been a thorough investigation into the potential role of apomixis, defined as clonal production of seeds from maternal tissue without pollination. It is likely that the reported apomictic reproduction of *M.sargentii* and so-called "*zumi*" has facilitated their invasion (Sax 1959; Olien 1987; Fiala 1994). Several papers have attempted to correlate invasive behavior of woody species in North Temperate regions with functional traits (e.g. Herron et al. 2007; Widrlechner et al. 2009; Boyce 2010; Dehnen-Schmutz 2011; Grotkopp et al. 2010; Pyšek et al. 2014). There has been little to no mention of apomixis in such papers, except for those dealing with *Rubus* (e.g. Clark et al. 2013). However, in a broader global context and covering all vascular plants, there has been much research that indicates a major role for apomixis in some cases of invasive species (e.g. Rambuda and Johnson 2004; Hörandl 2010; Pannell et al. 2015).

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