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PHORADENDRON LEUCARPUM SUBSP. *LEUCARPUM* (VISCACEAE) AT PERRYVILLE BATTLEFIELD STATE HISTORIC SITE, BOYLE COUNTY, KENTUCKY

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ABSTRACT

A survey for American mistletoe (*Phoradendron leucarpum* subsp. *leucarpum*) was conducted during 2006, 2015, 2016, and 2018 on 300-ha of the Perryville Battlefield State Historic Site (PBSHS) core battlefield area. Vegetation is of scattered mesophytic to subxeric deciduous woodlands among non-indigenous grasslands in rolling to steep hilly terrain of the Hills of the Bluegrass Ecoregion. A total of 102 mistletoe-infected host trees from eight facultative calciphilous tree species were documented: *Juglans nigra*, *Ulmus americana*, *Prunus serotina*, *Fraxinus americana*, *Celtis occidentalis*, *Robinia pseudoacacia*, *Maclura pomifera*, and *Acer saccharum*. Sixty-three mistletoe-infected trees were recorded within a 26-ha wooded grove of the PBSHS Museum and Visitor Center Headquarters and Interpretive Trail Markers 1–11. A significant determining factor for current scarcity of mistletoe at PBSHS includes the severe effects of extended mean minimum low winter temperatures of 2014–2015.

A preliminary field survey of American mistletoe [*Phoradendron leucarpum* (Rafinesque) Reveal & M.C. Johnston subsp. *leucarpum*] was made in 2006 to Perryville Battlefield State Historic Site (PBSHS) within the Hills of the Bluegrass Ecoregion of northwestern Boyle County, Kentucky. Mistletoe was vouchered from six host tree species within the wooded grove at the PBSHS Museum and Visitor Center Headquarters. This 2006 reconnaissance was the basis for a research survey of mistletoe-infected host trees in a 26-ha core battlefield area of the Museum and Visitor Center wooded grove and adjoining 274-ha PBSHS core battlefield area (Kentucky State Parks 2020) during 2015, 2016, and 2018. Our PBSHS study is a continuation of mistletoe surveys in east-central Kentucky to determine host tree specificity within the Inner Bluegrass, Hills of the Bluegrass, Outer Bluegrass, and Knobs-Norman Upland Ecoregions of Woods et al. (2002) and the effects of extended mean minimum low 2014–2014 winter temperatures on mistletoe.

Physical features of PBSHS

Perryville State Battlefield Site was established on October 8, 1954 (Noe 2001), and it was redesignated as Perryville Battlefield State Historic Site by the Kentucky Division of Parks on May 22, 1999, to preserve and protect the historic American Civil War site. In 1960, PBSHS was recognized as a National Historic Landmark (Noe 2001).

The 300-ha core battlefield area is a central tract within the total 580-ha of PBSHS land. The perimeter of the 580-ha area, counterclockwise, encompasses the Museum and Visitor Center (37.674362° -84.970594°) bordered by KY 1920 (Battlefield Road), north to KY 1331 (Whites Road),

west to KY 1314 (Hayes-May Road) south to Doctor's Fork Creek, south-southeast to KY 1920, and back north to the Museum and Visitor Center entrance (Kentucky State Parks 2020). Elevations range from 270 m above sea level at the Museum and Visitor Center to 285 m at the Russell House down to 247 m at Doctor's Fork Creek where it empties into the Chaplin River (Cressman 1974).

Perryville Battlefield State Historic Site is situated in the Interior Low Plateau Physiographic Province entirely within the Hills of the Bluegrass (Woods et al. 2002), or Eden Shale Hills (Campbell 2003). Geology of the Hills of the Bluegrass is composed of Upper Ordovician calcareous shale, siltstone, and limestone. Holocene shale, limestone cobbles, and aggregate alluvium occur along major streams (Carey et al. 2006). Bedrock at PBSHS consists of Garrard Siltstone and Clays Ferry Limestone, Middle and Upper Ordovician shale, siltstone, and Lexington limestone with shale, siltstone, and limestone surface outcrops (Cressman 1974; Carey et al. 2006).

Upland residual soils are an intermixed mosaic of 11 soil units in the PBSHS area (Craddock 1983; Soil Survey Staff 2019). Eden, Lowell-Faywood-Eden, and Eden-Lowell soil associations are acid to moderately alkaline, well-drained, deep soils on gently rolling to steep hilly terrain underlain by weathered shale, siltstone, and limestone, or just limestone (Craddock 1983). These three soil associations comprise the majority of the PBSHS uplands (Soil Survey Staff 2019). Caleast-McAflee-Maury soil series are slightly acid to mildly alkaline, well-drained, deep to shallow soils, on level to steep hills underlain by limestone or limestone surface outcrops. Newark-Nolin series are deep, poorly to well-drained, slightly acid to neutral silt loams on alluvial floodplains along intermittent creeks and Doctor's Fork (Craddock 1983).

Braun (1950) described forest vegetation of the broad Interior Low Plateau Province as Western Mesophytic Forest, a mosaic of eastern Oak-Hickory (*Quercus-Carya*) Forest and Mixed Mesophytic Forest. The deciduous forest land-cover classes of the Hills of the Bluegrass are largely restricted to scattered woodlands and woodlots of Oak-Ash-Elm (*Quercus-Fraxinus-Ulmus*) Forest with upland terrain dominated by large tracts of disturbed non-indigenous grassland for crops, hay, and pasture (Campbell 1987). Woods et al. (2002) described vegetation of the Hills of the Bluegrass Ecoregion as mixed Oak-Hickory-Ash (*Quercus-Carya-Fraxinus*) Forest on mesic terrain with Oak-Hickory-Red Cedar (*Quercus-Carya-Juniperus*) stands on subxeric hilly terrain.

American mistletoe biology

Using the name established by Reveal & Johnston (1989) for American mistletoe, *Phoradendron leucarpum*, and accepting entities and taxonomic ranks of Kuijt (2003), Abbott and Thompson (2011) provided a new set of subspecies combinations for *P. leucarpum*. Weakley (2020) follows this nomenclature.

Phoradendron leucarpum subsp. *leucarpum* is the only subspecies native to the eastern USA. The distribution of American mistletoe, clockwise, is eastern Texas and Oklahoma, Arkansas, southern Missouri, Tennessee, and Kentucky, north alongside the Ohio River of southern Illinois, Indiana, Ohio, to West Virginia, east to Maryland and Delaware and southward throughout the Mid-Atlantic and Gulf Coastal States back to Texas (Kuijt 2003; Mallams & Mathiasen 2010). American mistletoe is a southern intraneous geographical species primarily within the southern USA distribution (Thompson & Jones 2001). Mistletoe extends more than 160 km north of PBSHS in east-central Kentucky.

Eastern USA host tree studies

Kuijt (2003) reported 77 mistletoe host tree species for the eastern USA from herbarium specimen data. Overlease and Overlease (2005) recorded 41 host tree species in an extensive mistletoe field study of the distribution, abundance, and host species in the eastern USA.

Kentucky mistletoe studies

Reed and Reed (1951) listed 24 host trees for 76 Kentucky counties from American mistletoe observations and specimen collections. Statewide, the five mistletoe-infected hosts they observed in decreasing order of occurrence were black walnut (*Juglans nigra*), blackgum (*Nyssa sylvatica*), American elm (*Ulmus americana*), black locust (*Robinia pseudoacacia*), and honey locust (*Gleditsia triacanthos*). Overlease and Overlease (2005) observed 16 host tree species among 557 host trees in Kentucky. They reported black walnut comprised 44% of the total followed by silver maple (*Acer saccharinum*), American elm, black locust, black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), hackberry (*Celtis occidentalis*), sugar maple (*Acer saccharum*), and Osage-orange (*Maclura pomifera*).

Braun (1943) stated mistletoe was widely distributed in Kentucky and listed 32 counties among several host trees. Wharton and Barbour (1973) reported mistletoe in Kentucky on black walnut, American elm, hackberry, black locust, honey locust, and other trees. Campbell et al. (2020) mapped 119/120 Kentucky counties based on R.L. Thompson's vouchers from his statewide survey of American mistletoe.

Kentucky Bluegrass mistletoe studies

Wharton and Barbour (1991) referred to the "Kentucky Bluegrass" as the total area of Ordovician outcrops within the Inner Bluegrass, Hills of the Bluegrass, and Outer Bluegrass Physiographic Regions. Braun (1943) reported mistletoe was especially abundant in the Bluegrass Region (Inner Bluegrass, Hills of the Bluegrass, Outer Bluegrass) on several hardwood tree species. Coulter (1877) observed American elm and black walnut as the dominant mistletoe-infected trees in Louisville, Jefferson County, in the Outer Bluegrass. Willis (1873) noted mistletoe in Bourbon County in the Inner Bluegrass on Ohio buckeye (*Aesculus glabra*), honey locust, bur oak (*Quercus macrocarpa*), and black locust. Schneck (1884) found mistletoe to be common on black walnut and black cherry in the Kentucky Bluegrass Region. Garman (1913) reported black walnut as the most common mistletoe host in the Kentucky Bluegrass followed by black locust and American elm. In the Ordovician Kentucky Bluegrass, Reed and Reed (1951) observed the principal mistletoe-infected hosts were black walnut followed by American elm, black locust, honey locust, hackberry, maples (*Acer* spp.), Osage-orange, white ash, and black cherry in descending order. Within the Inner Bluegrass ecoregion, Wharton and Barbour (1991) stated mistletoe was present on several tree species with black walnut the most common and elms (*Ulmus* spp.) and hackberry occasionally infected.

Eight American mistletoe surveys have been published from 1992–2010 within the Inner Bluegrass, Hills of the Bluegrass, Outer Bluegrass, Knobs-Norman Uplands, and Eastern Highland Rim ecoregions of Woods et al. (2002). A total of 33 mistletoe host woody plants have been documented (31 trees, a shrub, a vine) in those mistletoe surveys (Thompson 1992; Thompson & Noe, Jr. 2003; Thompson 2005; Thompson & Poindexter 2005; Thompson et al. 2008; Taylor & Thompson 2009; Thompson & Rivers Thompson 2009; Thompson & Evans 2010).

METHODS

We conducted our survey of *Phoradendron leucarpum* subsp. *leucarpum* in fall of 2006 and the winter and spring of 2015, 2016, and 2018 within the 300-ha PBSHS core battlefield area. Nikon Monarch (8 x 25 power) binoculars were used to identify signs of mistletoe infestation on infected host trees, e.g., branch cankers or swellings, stem clumps, clusters, brooms, shoots, and limb die-back. Each host tree was scored according to a Mistletoe Infestation Scale (MIS) from external obvious signs (Thompson et al. 2008; Thompson 2014): light-infestation (1–10 clusters), moderate-infestation (11–30), heavy-infestation (31–100), and extensive-infestation (>101). Mistletoe *infestations* are external visible signs to an internal *infection* response in host trees.

Mistletoe vouchers with host tree twigs were gathered from 25 different infected trees with a 12 m extendible fiberglass linesman pole. At the PBSHS Headquarters wooded grove, 21 mistletoe vouchers were collected from eight representative trees from one to four times to observe infestation and freeze data effects. Specimens were dried, mounted, labeled, and deposited in the Berea College Herbarium (BEREA). Tree nomenclature follows Jones (2005).

RESULTS AND DISCUSSION

We observed 102 mistletoe-infected host trees from eight facultative calciphilous species at PBSHS (Table 1). Black walnut accounted for over 41% of the host trees with the following in descending order of occurrence: American elm, black cherry, white ash, hackberry, black locust, Osage-orange, and sugar maple (Table 1). Sixty-three (61.76%) of 102 mistletoe-infected trees were documented within a 26-ha wooded grove of the PBSHS Museum and Visitor Center Headquarters, and Interpretive Markers 1–11 (Table 1).

In previous articles involving mistletoe from Boyle County, Garman (1913) reported mistletoe on black walnut among several other counties, Reed and Reed (1951) observed black walnut, Osage-orange, black locust, and American elm as host trees, and Braunrieter (2015) collected mistletoe without designating a host tree species.

Table 1. *Phoradendron leucarpum* host occurrence at Perryville Battlefield State Historic Site (2018).

Host Trees	HQ*	Areas**	Trees	Clumps	% Trees
Juglans nigra L	19	23	42	472	41.18
Ulmus americana L.	12	4	16	194	14.71
Prunus serotina Ehrh.	10	4	14	28	13.73
Fraxinus americana Marsh.	10	1	11	41	10.78
Celtis occidentalis L.	7	3	10	57	9.80
Robinia pseudoacacia L.	1	4	5	7	4.90
Maclura pomifera (Raf.) Schneid.	3	1	4	13	3.72
Acer saccharum Marsh.	1	0	1	5	0.98
Total Species = 8	63	39	102	817	100.00

*HQ=PBSHS Headquarters wooded grove (26-ha.)
**Areas=Other PBSHS lands (474-ha.).

In the following six east-central Kentucky mistletoe studies, we followed delineation for the "Kentucky Bluegrass" (Wharton & Barbour 1991) as comprising the Inner Bluegrass, Hills of the Bluegrass, Outer Bluegrass, and the Knobs-Norman Uplands of Woods et al. (2002). These six mistletoe studies include the survey at PBSHS (Table 2) among the dominant host tree sp ecies in respective order of occurrence, percentage, and Woods et al. (2002) ecoregion(s).

The most common host trees in all six mistletoe surveys were *Juglans nigra* (JUNI), *Ulmus americana* (ULAM), and *Prunus serotina* (PRSE), although the overall order of host tree incidence varied with the particular ecosystems; geological substrate, soils, vegetation, tree dominance or codominance, and area size, among other variables (Table 2). In east-central Kentucky mistletoe surveys, the same eight host tree species at PBSHS were among those documented for Garrard County (Thompson & Poindexter 2005); city of Berea (Thompson et al. 2008); Jessamine County (Thompson & Evans 2010), and seven of eight hosts at the Lexington-Blue Grass Army Depot (Thompson 1992).

Table 2. Six east-central Kentucky *Phoradendron leucarpum* host occurrence studies.

County & Site	Tree Species	Total Trees	Major Hosts*	%	Ecosystem(s)**
Boyle Co. PBSHS Thompson et al. (2020)	8	102	JUNI, ULAM, PRSE	70.36	HB
Robertson Co. Thompson (2005)	7	45	JUNI, ULAM	73.30	HB
Jessamine Co. Thompson & Evans (2010)	10	1403	JUNI, PRSE, ULAM	89.10	IB
Garrard Co. Thompson & Poindexter (2005)	12	1740	JUNI, PRSE, ULAM	80.46	IB, HB, OB, KN
Madison Co. LBGAD Thompson (1992)	14	1837	PRSE, JUNI, ULAM	86.76	OB
Madison Co. Berea Thompson et al. (2008)	22	2320	PRSE, JUNI, ULAM	70.64	OB, KN

*Tree Codes: JUNI=*Juglans nigra*; PRSE=*Prunus serotina*; ULAM=*Ulmus americana*.
**Ecosystems: IB=Inner Bluegrass; HB=Hills of the Bluegrass; OB=Outer Bluegrass; KN=Knobs-Norman Uplands (Woods et al. 2002).

PBSHS mistletoe infestation dynamics

The four ecoregions of east-central Kentucky (Inner Bluegrass, Hills of the Bluegrass, Outer Bluegrass, and Knobs-Norman Uplands) have associated and comparable features in geology, topography, substrate-derived soils, existing mesophytic forest, and culturally disturbed vegetation (Woods et al. 2002). Most of the infected hardwood host trees are facultative calciphilous (calcicolous) in these ecoregions. Calcicolous host trees thrive best in predominantly alkaline calcareous medium or limestone-based soils (Reed & Reed 1951; Thompson & Rivers Thompson 2009; Thompson & Evans 2010).

At PBSHS, as in previous studies, most mistletoe-infected trees were older, taller and typically with full canopy crowns and in wooded groves, or solitary and scattered trees of open upland habitats, e.g., fence rows, fields, pastures (Thompson 1992; Thompson & Noe, Jr. 2003; Thompson & Poindexter 2005; Thompson & Evans 2010). Frugivorous birds congregate or flock among the largely open wooded grove at the PBSHS Museum and Visitor Center Headquarter, not unlike other surveys of avian allurement for mature host trees in towns and small cities, to feed, perch, and roost (Thompson & Noe, Jr. 2003; Thompson & Poindexter 2005; Thompson et al. 2008).

The Mistletoe Infestation Scale was recorded for the eight host trees selected from the wooded grove at PBSHS Museum and Visitors Center Headquarters (Table 3). A total of 21 representative annotated voucher specimens were collected from these eight host trees.

Our American mistletoe study at PBSHS reports consequences of two severe cold winters, 2014 and 2015, over a 12-year period (2006–2018). Observations and one to four mistletoe specimens were collected from the same eight host tree species (Table 3). A *Juglans nigra* changed from heavy-infestation (*06-749*; *15-34*; *16-14*) to extensive-infestation (*18-353*) approaching mortality from 2006 to 2018. Black walnut was the major infected tree with the most visible signs (Tables 1, 3). An *Ulmus americana* scored moderate (*06-333; 15-38; 16-07*) to heavy-infestation (*18-354*) over the same period. American elm was the second most infected tree with visible signs from light to heavy infestation (Tables 1, 3). The *Prunus serotina* exhibited light-infestation (*06-754*; *15-33*; *16-13*) with an increase of new clusters (*18-355*), while the other black cherries at PBSHS had few clumps or one or two cankers. An old mature *Fraxinus americana* exhibited only light-infestation (*06-752, 15-39*) with large gnarled, clavate swellings. Shoot and limb die-

back were evident in all 11 white ashes observed (Tables 1, 3). Hackberry had light-infestation (*06-733; 15-36; 18-356*) in all 10 hackberries at PBSHS. A single black locust showed light-infestation with one large branch canker (*06-750*) and mistletoe never recovered from winter freezes. Four of the five black locust at PBSHS contained only one or two clumps for eight total (Tables 1, 3). An Osage-orange had light-infestation with four clumps (*15-35*) and added a new cluster (*18-355*). Four infected Osage-orange trees possessed a total of 13 clumps. The tall mature sugar maple had only light-infestation (*15-42*) with five branch clumps (Tables 1, 3).

Table 3. Eight host tree species at PBSHS Museum Headquarters wooded grove in sequence by species, MIS infestation values, dates, collector's initials and numbers.

Standard Label Data: BOYLE COUNTY: *Phoradendron leucarpum* (Raf.) Rev. & M.C. Johnst. subsp. *leucarpum.* Perryville Battlefield State Historic Site (PBSHS), 1825 Battlefield Road (KY 1920), Museum and Visitors Center, and Monument Headquarters. Elev. 265–272 m, ca. 37.674557°, -84.970594°: Hemiparasitic on:

1 *Juglans nigra*, ~15 m tall tree, heavy-infestation, ~60–70 clumps and cankers, 29 Oct 2006, *RT & KR 06-751*; ~40+ clumps, clusters, limb cankers, 13 Apr 2015, *RT & CT 15-34*; heavy-infestation, 70–80 clumps, cankers, limb die-back, 17 Mar 2016, *RT & ND 16-14*; extensive-infestation trending toward tree mortality due to infection, >100+ clumps, gnarled limb cankers, branch die-back, 1 Dec 2018, *RT & ND 18-353.*

2 *Ulmus americana*, ~14 m tree, moderate-infestation, ~35–40 small clusters, 29 Oct 2006, *RT & KR 06-749*; 20–25 scattered clumps, 13 Apr 2015, *RT & CT 15-38*; heavy-infestation, ~35–40 clumps, 17 Mar 2016, *RT & ND 16-07*; ~15 m tree, ~60–70 clusters scattered on limbs and trunk, 1 Dec 2018, *RT & ND 18-354*.

3 *Prunus serotina*, ~9–10 m tall, light-infestation, 2 small clusters on one of five black cherries planted in a row infected, 29 Oct 2006, *RT & KR 06-754;* 2 clusters, 13 Apr 2015, *RT& CT 15-33*; 3 small clusters, 17 Mar 2016, *RT & ND 16-13*; 4–6 new growth clumps and three more cherries infected, 1 Dec 2018, *RT & ND 18-355.*

4 *Fraxinus americana*, ~17–18 m tall, light-infestation, 6–7 clavate, knobby cankers and sparse old broom shoots, in an old ash among other infected white ashes, 29 Oct 2006, *RT & KR 06-752*. 3–4 severe old clavate cankers and broom shoot dieback, no new shoots, 13 Apr 2015, *RT & CT 15-39*.

5 *Celtis occidentalis*, ~12 m tall, light-infestation, 3–5 clumps; three other infected hackberry in a row, 29 Oct 2006, *RT & KR 06-753;* 2–4 clumps, 13 Apr 2015, *RT & CT 15-36*; 6–7 small clusters, 1 Dec 2018, *RT & ND 18-356.*

6 *Robinia pseudoacacia*, ~16 m tall, light-infestation, one large limb canker and broom shoots; broom shoots shattered after 2015 freezes, not recollected, 29 Oct 2006, *RT & KR 06-750.*

7 *Maclura pomifera*, ~15 m tall, light-infestation, 3–4 large clumps; two additional Osage-orange trees infected, 13 Apr 2015, *RT & CT 15-35*; 5–6 clumps, a new limb cluster collected, 1 Dec 2018, *RT & ND 18-357*.

8 *Acer saccharum*, ~18–19 m tall, light-infestation, 5 small clumps at top of sugar maple; no additional new signs evident, not recollected, 13 Apr 2015, *RT & CT 15-42*.

Collector's initials: RT=Ralph L. Thompson; KR=Katrina Rivers Thompson; CT=Craig A. Thivierge; ND=Gary Neil Douglas.

The incidence of mistletoe-infected trees tended to be in close proximity to other host trees at the PBSHS Headquarters wooded grove. This aggregated (clumped) spatial distribution likely results from ornithophily (Thompson & Noe, Jr. 2003; Thompson & Poindexter 2005; Gougherty 2013; Thompson 2014). Coder (2008) noted variable incidence of mistletoe in forested communities was due in part to the availability of host trees and attributes of bird behavior for dispersal, establishment, and spread.

Low winter temperature and duration factors

The duration of low winter temperature has been reported as the major factor influencing the incidence, abundance, and northern distribution of American mistletoe in the eastern USA (Spooner 1983; Coder 2008). Medley (1993) listed mistletoe as hemiparasitic on a large number of trees throughout Kentucky with rare to common abundance based on cyclic severity of winters. Clark and Weckman (2008) reported mistletoe throughout Kentucky with incidence very common southward but increasingly rare northward.

Spooner (1983) reported that mistletoe reaches its northern distribution limits in southern Ohio and produced evidence the main reason for the northern limits of mistletoe corresponded to the mean minimum January temperature of -4.5° C. Coder (2008) stated the minimum December daily temperature of -3.9° C was the limiting factor in the northern range of American mistletoe, while the western expansion of American mistletoe was restricted by 63.5 cm annual precipitation.

Several American mistletoe studies in the USA document effects of low winter temperature and its duration on the prevalence, external mistletoe death, and eventual endophyte recovery with range increases during warmer temperatures: Illinois (Schneck 1884; Fuller 1955; Thompson 2014); Indiana (Deam 1932); Kentucky (Coulter 1877; Garman 1913; Shacklette 1937; Thompson 2005; Thompson et al. 2008); Ohio (Braun 1961; Spooner 1983); and, Oklahoma (Gould 1901). Other studies of *Phoradendron* spp. on low winter temperature effects, duration, and distribution and have been recorded for Arizona and New Mexico (Bray 1910; Lightle et al. 1964) and California (Bray 1910; Wagener 1957).

Boyle County and most of Kentucky is located within the 6b (-17.8° C to -20.6° C) USDA Plant Hardiness Zone Map (USDA, ARS 2012). Recent extended 2014 and 2015 low mean minimum temperatures duration in days through January, February, and March 2014–2015 (Table 4), were a primary limiting factor for the scarcity of mistletoe at PBSHS. The 2014–2015 low mean minimum temperatures at PBSHS (Table 4) were comparable to the low temperatures of mistletoe survival recorded for other *Phoradendron* spp. survival studies (Wagener 1957; Lightle et al. 1964), and the Plant Hardiness Zone Map for Kentucky (USDA, ARS 2012).

Table 4. Minimum, mean minimum, and days at minimum (° C) in Marion Co., Kentucky* (Midwest Regional Climate Center 2020).

Year	Time Period	Minimum	Mean Minimum	Days at Minimum
	1/02–1/09	-20.0	-15.1	3
	1/21–1/31	-21.1	-16.0	4
2014	2/05–2/18	-14.4	-8.6	2
	2/24–3/06	-10.0	-8.0	4
2014--2015	12/30–1/03	-7.8	-6.9	2
	1/05–1/21	-17.2	-8.7	4
	1/27–2/07	-11.1	-7.0	10
2015	2/11–2/21	-27.8	-15.7	2
	2/23–3/03	-12.8	-9.8	2
	3/05–3/08	-21.1	-19.6	3
	3/28–3/30	-6.7	-6.5	3

*Marion County, is the closest weather station to Boyle County with a contiguous eastern border.

Dead and dying external mistletoe signs (brittle leaves, stems, and shoots) fragmented and sloughed off after January, February, and March of 2014 and especially during 2015. The mistletoe internal endophyte haustoria system produced new mistletoe growth during 2016–2018 in the majority of host trees. Conversely, new mistletoe signs did not reappear in a few trees, e.g., a white ash (*15-36*), a black cherry (*16-43*), a black locust (*06-750*), and an American elm (*16-15*).

American mistletoe is sparse and rarely present in the northern Kentucky counties. Mistletoe distribution in the Ohio River Valley typically follows the -4.5° C mean January isotherm mapped by Spooner (1983). The 6a (-20.6° C to -23.3° C) USDA Plant Hardiness Zone Map covers those areas where mistletoe terminates in the southern parts of the states north of the Ohio River (Spooner 1983; Mallams & Mathiasen 2010; Thompson 2014).

Schneck (1844) recorded -17.8° C as a critical temperature for survival of *Phoradendron leucarpum* at Mt. Carmel, Illinois. Thompson (2005) noted the low January 1996 temperature of -22.1° C caused extensive mistletoe die-back in Robertson County, Kentucky. In northern California, Wagener (1954) reported low minimum temperatures below -17.8°C over a seven day period from -18.8° C to -25.5° C (*m*= -19.5° C), killed all external and endophyte systems in dense mistletoe (*Phoradendron densum* Torrey ex Trelease). Comparably, Lightle et al. (1964) reported a low temperature range of -12.7° C to -18.8° C (*m*= -15.3° C) at seven stations over a two-day period caused severe cold injury to mesquite mistletoe (*Phoradendron californicum* Nuttall) in southern Arizona. Based partly on Table 4 data, the mean January isotherm map of the Ohio River Valley (Spooner 1983), and the 6b zone (-17.8° C and -20.6° C), mean annual minimum temperature of the USDA Plant Hardiness Zone Map (USDA, ARS 2012), the critical minimum low temperature of American mistletoe severe injury or death in Kentucky may be estimated at -18.0° C to -21.0° C, or lower.

American mistletoe in east-central Kentucky is well within its natural geographical range. The northern range is limited to the Ohio River Valley (Braun 1961; Spooner 1983). Mild winter temperatures during 2016–2020 (Midwest Regional Climate Center 2020) within the 6b Plant Hardiness Zone have been advantageous to American mistletoe establishment, growth, and proliferation in most host trees at Perryville Battlefield State Historic Site and throughout Kentucky.

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