

POPULATION ECOLOGY STUDY OF *EPIFAGUS VIRGINIANA* (L.) W.P.C. BARTON (BEECHDROPS) IN CENTRAL INDIANA

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ABSTRACT. *Epifagus virginiana* (Beechdrops) is a holoparasitic plant that is obligate on the roots of *Fagus grandifolia* (American Beech) throughout mesic forests in the Midwest. This parasite has a coefficient of conservatism of 8, indicating it requires high-quality plant communities and tolerates little disturbance. *Epifagus virginiana* resembles twigs, producing inconspicuous flowers from August to October. An unexpectedly large population of this species, comprised of 886 plants growing on 17 *F. grandifolia* trees, was found in Hougham Woods Biological Field Station (HWBFS) in Johnson County, Indiana. Plants were morphologically similar to descriptions in literature, with an average height of 16.1 cm and many were commonly observed growing in association with large *Fagus grandifolia* trees (DBH > 40 cm). A statistic previously undocumented was that these plants had cleistogamous and chasmogamous flowers in a 20:1 ratio. Chasmogamous flowers in this population proved sterile. However, since each cleistogamous flower produced an average of 827 seeds, the *E. virginiana* population in HWBFS displays a very large reproductive potential for the coming years. Monitoring this population could provide a way to assess the health of this forest remnant.

Keywords: *Epifagus virginiana*, beechdrops, beech trees, *Fagus grandifolia*, mesic woods, root parasite

INTRODUCTION

Epifagus virginiana (L.) W.P.C. Barton is a holoparasitic plant that lacks chlorophyll (Porcher & Rayner 2001; Tsai & Manos 2010; Weakley et al. 2012; Yatskievych 2013) and is an obligate parasite interacting solely with the roots of *Fagus grandifolia* Ehrh. (Deam 1940; Brooks 1960; Gleason & Cronquist 1991; Yatskievych 2000; Mohlenbrock 2002; Jones 2005; Rhoads & Block 2007; Tsai & Manos 2010; Homoya 2012; Abbate & Campbell 2013). These plants grow in mesic, eastern deciduous forests, occupying the same range as their host (Thieret 1969; Smith 1994; Chapman et al. 1998, 2008; Yatskievych 2000; Porcher & Rayner 2001; Tsai & Manos 2010; Homoya 2012; Abbate & Campbell 2013). Both plants have a coefficient of conservatism of 8, indicating they grow in high-quality plant communities and tolerate little disturbance (Rothrock 2004).

Epifagus virginiana is a member of the Orobanchaceae or Broomrape family. Traditionally, species in this family were non-green, root parasites that relied entirely on deciduous host trees. These herbaceous plants were characterized by having small, scale-like leaves, irregular

flowers, and fruit capsules that produced an abundance of small seeds (Radford et al. 1968; Jones 2005). However, today, Orobanchaceae also includes hemiparasitic species and is comprised of 89 genera and 2061 species (Bennett & Mathews 2006). These species are distributed worldwide, but are most predominant throughout the Mediterranean, Southern Africa, the Himalayas, and North America (Bennett & Mathews 2006).

Most botanists describe *Epifagus virginiana* as an annual (Thieret 1969; Yatskievych 2013; Porcher & Rayner 2001; Tsai & Manos 2010; Abbate & Campbell 2013); however, they have also been reported as a perennial (Homoya 2012; Weakley et al. 2012). These non-showy, brown, twig-like plants are 10–15 cm tall (Yatskievych 2000; Homoya 2012) with branches bearing alternate scale-like leaves and two types of flowers (Homoya 2012) (Fig. 1). *Epifagus* flowers from August to October (Gleason & Cronquist 1991; Chapman et al. 1998, 2008; Mohlenbrock 2002; Jones 2005; Homoya 2012; Yatskievych 2013); however, the dried plant stalks persist throughout winter (Porcher & Rayner 2001).

The open, chasmogamous flowers (1 cm) of *Epifagus* are tubular, having four purple and white petals and are located on the upper portion of the stem (Radford et al. 1968; Homoya 2012;

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Figures 1–3.—*Epifagus virginiana*. 1. Entire plant. 2. Chasmogamous flower. 3. Cleistogamous flower. (Photos 1 & 2 by Kay Yatskievych; photo 3 by Charles de Mille-Isles (2011).)

Abbate & Campbell 2013) (Fig. 2). These flowers are considered to be sterile (Radford et al. 1968; Gleason & Cronquist 1991; Porcher & Rayner 2001; Homoya 2012; Weakley et al. 2012; Yatskievych 2013). Occasionally, however, long-tongued bees and ants have been observed visiting them, possibly attracted to a nectary found near

the ovary of the chasmogamous flower. Infrequently, these flowers produce fruits and seeds (Abbate & Campbell 2013). Normally, chasmogamous flowers are few in comparison to the self-fertile, closed cleistogamous flowers.

Cleistogamous, closed, spike-like flowers (4–6 mm) are found near the base of the plant and

produce seeds (Radford et al. 1968; Jones 2005; Homoya 2012; Yatskiyevych 2013) (Fig. 3). The small, dust-like seeds are washed deep into the soil, in close proximity to *F. grandifolia* roots (Porcher & Rayner 2001; Jones 2005). These roots release a chemical, signaling the seeds to germinate in spring (Porcher & Rayner 2001; Jones 2005; Grafton 2008).

Epifagus virginiana, which is found throughout southern Indiana counties (Fig. 4), is scattered throughout northern Indiana (Deam 1940; Yatskiyevych 2000) with a recent new record for Johnson County (specimen #155310 housed in Friesner Herbarium (BUT) at Butler University). As high quality forests are degraded by habitat fragmentation, invasive species, and anthropogenic disturbances, the high quality sites where *F. grandifolia* and *E. virginiana* occur are at high risk for declining populations. There is also a lack of information about this relatively inconspicuous species and its population ecology. The objectives of this research are to establish baseline information about the size and locations of *E. virginiana* within Hougham Woods Biological Field Station (HWBFS) in Johnson County, Indiana, to determine the size and morphological characteristics of these plants, to examine the reproductive potential of the *Epifagus* population, and to examine host tree size and location.

METHODS

Study site.—HWBFS is a 12 ha relatively flat, mesic forest that was donated to Franklin College in 2006. Dominant canopy species include *Acer saccharum* Marshall, *F. grandifolia*, and *Quercus* spp. (Smith & Heikens 2014). The forest is located in Johnson County east of Franklin, Indiana in the Tipton Till Plain Section of the Central Till Plain Natural Region (Fig. 4). In this region, soil types are often neutral silt and silty clay loams (Homoya et al. 1985; Smith & Heikens 2014). HWBFS is surrounded by agricultural field and an industrial park, and has experienced disturbances, including selective cutting and wind throw (Smith & Heikens 2014). Despite these disturbances, a few species with high coefficients of conservatism, such as *F. grandifolia* and *Aplectrum hyemale* (Muhl. ex Willd.) Torr., persist in the forest.

From September to November 2013, *E. virginiana* and their associated host trees were located, flagged, and numbered in HWBFS and marked using GPS. The locations were mapped using

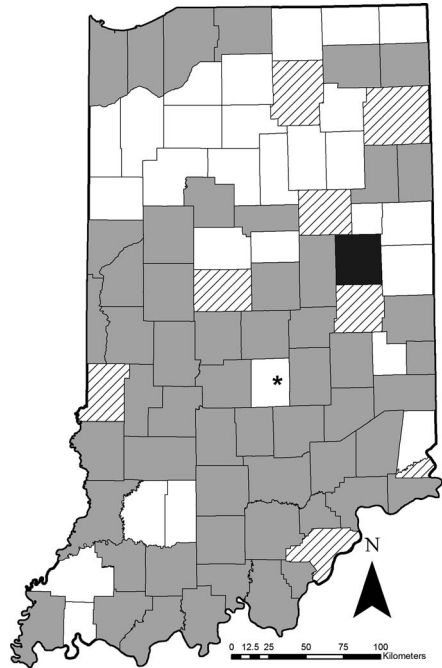


Figure 4.—Distribution of *Epifagus virginiana* in Indiana. Light shading indicates distribution from BONAP (2014), hashing indicates new records in several counties (K. Yatskiyevych Per. Comm.), dark shading indicates the Delaware County Record (Ruch et al. 1999 specimen BSUH 8227), and the star indicates the county record for Johnson County.

ArcGIS software. To establish baseline data on the size of *Epifagus* plants, large populations (≥ 40 plants) were randomly sampled (all plant numbers ending in 2) and measured for the following morphological characteristics: plant height (cm), number of branches, number of chasmogamous and cleistogamous flowers, and distance (cm) to nearest host tree. In small populations (< 40 plants), this data was gathered for all plants. In total, 225 plants were examined.

Twenty plants from the entire population were randomly selected for seed production. The 10th capsule from the bottom of the plant was examined if the capsule was intact. The capsules were weighed, then opened and the seeds were weighed and counted.

To investigate chasmogamous flowers, in the largest population (470 plants), 32 plants were randomly selected and examined for chasmogamous and cleistogamous flower ratios. In addition, 50 plants were randomly selected from the three largest populations to determine if seeds

Table 1.—Morphological characteristics and seed production in *Epifagus virginiana* in 2013 in Hougham Woods Biological Field Station, Franklin, IN. (n = 225).

	Mean	Range	Standard deviation
Height (cm)	16.1	4.3 – 40.0	7.3
Distance from Host Trunk (cm)	195.0	18 – 912	5.1
Number of Branches	6	1 – 40	6.9
Number of Flowers	61	3 – 471	80.6
Capsule Weight (mg)	14.00	8.00 – 20.80	0.0
Seeds	6.18	1.00 – 12.00	0.0
Number of Seeds	827	188 – 1799	344.6
Weight per Seed (μg)	7.38	3.89 – 10.74	1.81×10^{-6}

were produced in chasmogamous flowers. Plants taller than 25 cm were examined because chasmogamous flowers were not found on plants shorter than 16 cm.

In the summer of 2014, all *Fagus* trees in HWBFS were flagged and marked using GPS. The trees were grouped into the following DBH (cm) size classes arbitrarily: 0-10, 11-20, 21-30, 31-40, 40+ cm. Host trees were examined for number of *Epifagus* plants, average height (cm), and average distance to host trunk (cm). *Epifagus* plants were assumed to parasitize the nearest *Fagus* tree. Minitab 17 was used for the Pearson Correlations.

RESULTS AND DISCUSSION

In 2013, 886 *Epifagus* plants were found growing on 17 host trees in the interior of HWBFS. The 225 *Epifagus* plants that were measured in HWBFS were larger (16.1 cm) than the size documented in Indiana (10–15 cm) (Yatskievych 2000) (Table 1); however, the observed heights were similar to ranges reported throughout the Midwest (15–60 cm) (Chapman et al. 1998, 2008; Porcher & Rayner 2001; Homoya 2012; Weakley et al. 2012). Distances between *Epifagus* and their host trunks varied widely (Table 1). Large variations were also discovered when examining the morphological characteristics of the plants, i.e., number of branches and number of flowers (Table 1). Plants had multi-branched stems averaging 6 stems and 61 flowers per plant. Flower totals varied from 3 to 471 per plant (Table 1).

Epifagus is reported as producing an abundance of small seeds (Radford et al. 1968; Jones 2005; Homoya 2012; Yatskievych 2013) and the results from this study are consistent with this (Table 1). In 2013, 20 cleistogamous flowers from 20 different plants produced approximately 16,500 seeds with an average weight of 7.38 μg

per seed (Table 1). The large number of seeds per cleistogamous capsule, combined with the high cleistogamous flower presence per plant (Table 2), suggests that the overall *Epifagus* population in HWBFS has a high reproductive potential. Chasmogamous flowers occurred in much smaller numbers per plant and were limited to larger plants (Table 2). While these flowers have been reported as being pollinated and producing seeds (Abbate & Campbell 2013), this study supports the more common findings that these flowers are sterile (Radford et al. 1968; Gleason & Cronquist 1991; Porcher & Rayner 2001; Homoya 2012; Weakley et al. 2012; Yatskievych 2013). In an examination of 50 chasmogamous flowers from large *Epifagus* (average height 29.4 cm), no seeds were discovered. The ratio of cleistogamous to chasmogamous flowers in this study was 20:1.

In 2014, 415 *Fagus* trees were located throughout HWBFS, 17 of which were associated with *Epifagus* populations (Table 3). The majority of *Epifagus* were associated with trees in the 40+ DBH size classes and none were found in the smallest size class of 0-10.9 cm (Table 3). Also, the largest *Epifagus* populations were supported by trees that had a DBH of 40+ cm. However, there was not a significant ($p \leq 0.05$) correlation

Table 2.—Presence of chasmogamous and cleistogamous flowers on *Epifagus virginiana* in 2013 in Hougham Woods Biological Field Station, Franklin, IN. (n = 32).

Plant height (cm)	Flower type	
	Chasmogamous	Cleistogamous
5.0 – 10.9	0	12
11.0 – 15.9	0	34
16.0 – 20.9	3	68
21.0 – 25.9	8	114
26.0 – 30.9	18	249

Table 3.—Host tree metrics and *Epifagus virginiana* association in Hougham Woods Biological Field Station, Franklin, IN. DBH = diameter at breast height.

DBH (cm)	<i>Epifagus virginiana</i> population size	Mean height of plants (cm)	Mean distance from host trunk (cm)
13.3	13	15.0	89.7
14.9	2	16.2	254.2
16.1	16	15.3	185.6
17.1	1	18.2	237.2
18.9	7	13.0	242.3
20.6	1	17.4	276.1
24.3	3	19.3	36.2
33.7	3	7.9	43.2
36.5	34	15.9	191.4
39.9	1	16.5	295.6
46.4	190	19.9	267.0
48.6	18	15.6	57.5
48.8	23	10.1	75.7
55.8	18	17.1	220.1
57.9	40	15.5	139.9
61.5	15	24.6	286.5
63.5	470	16.0	281.7

between tree size and size of the *Epifagus* population ($R^2 = 0.47$, $p = 0.053$). This lack of a significant correlation may be due to the shortest *Epifagus* plants being associated with trees that were 33.7 and 48.4 cm DBH, respectively. It appears that factors other than tree size impact *Epifagus* growth. There was also a lack of a significant correlation between mean height of *Epifagus* and tree size ($R^2 = 0.18$, $p = 0.47$), or tree size and distance of *Epifagus* from the host trunk ($R^2 = 0.10$, $p = 0.71$). It is possible that large *Fagus* trees produce an abundance of chemicals that trigger *Epifagus* germination (Porcher & Rayner 2001; Jones 2005; Grafton 2008). It is unknown if younger trees are more resistant to *E. virginiana*, if it takes a number of years for above ground stems to form, or what environmental factors impact germination.

In conclusion, the large population of *E. virginiana* at HWBFS has a high reproductive potential due to its abundance of plants, number of flowering plants, and number of seeds per capsule. Additional research is needed to determine the impact of chemicals released by the host species on germination and how environmental conditions impact *Epifagus* population sizes. The abundance of *E. virginiana* and *F. grandifolia*, is one indicator that HWBFS is a relatively high-

quality forest remnant and the continued monitoring of these populations in HWBFS may be one way to determine the quality of the forest overtime.

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