Comparative Densities of Beech Scale, Cryptococcus fagisuga, (Hemiptera: Eriococcidae) in the Country of Georgia and Massachusetts (USA), Parts of its Native and Invaded Ranges, on two Species of Beech

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COMPARATIVE DENSITIES OF BEECH SCALE, *CRYPTOCOCCUS FAGISUGA,* (HEMIPTERA: ERIOCOCCIDAE) IN THE COUNTRY OF GEORGIA AND MASSACHUSETTS (USA), PARTS OF ITS NATIVE AND INVADED RANGES, ON TWO SPECIES OF BEECH

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Abstract

The Caucasus Mountains in the country of Georgia are part of the native range of beech scale (*Cryptococcus fagisuga*) and Massachusetts (United States) is part of the invaded range of this species. As background to determine if the native range of this scale might be a source of natural enemies useful for correcting the ecological damage caused by beech scale in North America to America beech (*Fagus grandifolia*) comparative scale densities were measured in both locations in natural forest stands of *F. grandifolia* in Massachusetts and *F. orientalis* in Georgia. Average diameter at breast height (DBH) and health values were also compared. Scale densities were found to be 45.4-fold higher per unit area of bark in Massachusetts on *F. grandifolia* than in the country of Georgia on *F. orientalis*. Also, *F. orientalis* trees at sample sites in Georgia were 2.9-fold larger in DBH and much healthier that were *F. grandifolia* trees in Massachusetts. These data suggest that either *F. orientalis* is more resistant to beech bark disease than *F. grandifolia* or key natural enemies found in Georgia are missing in Massachusetts, or both. Cage exclusion studies are underway, separate from results reported here, to separate the effects of tree resistance and natural enemies.

Key Words: potential for biological control, beech scale native range, *Fagus* spp., *Cryptococcus*

Resumen

Las montañas del Cáucaso en el país de Georgia son parte del área de distribución natural de la escama del haya (*Cryptococcus fagisuga*), y el estado del Massachusetts (Estados Unidos) es parte del rango geográfico invadido por esta especie. Para determinar si el área nativa de esta escama podría ser una fuente de enemigos naturales útiles para corregir el daño ecológico causado por esta especie a la haya americana (*Fagus grandifolia*), se midieron y compararon las densidades de la escama en áreas de bosques naturales de *F. grandifolia* en Massachusetts y *F. orientalis* en Georgia. También se comparó el promedio del diámetro a la altura del pecho DAP y la sanidad de los arboles. Se encontró que la densidad de escamas por unidad área fue 45.4 veces mayor en la corteza de *F. grandifolia* en Massachusetts que en la corteza de *F. orientalis* en Georgia. Además, los árboles muestreados en Georgia (*F. orientalis*) fueron 2.9 veces más grandes en términos de DAP y mucho más sanos que *F. grandifolia* en Massachusetts. Estos datos sugieren que *F. orientalis* es más resistente a la enfermedad de la corteza del haya que *F. grandifolia,* que los principales enemigos naturales que se encuentran en Georgia no están presentes en Massachusetts, o ambas cosas. Otros estudios utilizando técnicas de exclusión con jaulas están en marcha para separar los efectos de la resistencia de los árboles de los efectos causados por los enemigos naturales.

Palabras Clave: potencial para control biologico, área de distribución natural de la escama del haya, *Fagus* spp., *Cryptococcus*

American beech (*Fagus grandifolia* Ehrhart) in North America are in a highly degraded state in much of the northeastern United States and eastern Canada due to beech bark disease, which is caused by an invasive scale, *Cryptococcus fagisuga* Lindinger (Hemiptera: Eriococcidae), and 2 fungal plant pathogens, i.e., *Neonectria faginata* [Lohman et al.] Castl. & Rossman and *Neonectria ditissima* (formerly *galligena*) (Tul. & C. Tul.) Samuels & Rossman (Castlebury et al. 2006). Of the 2 *Neonectria* species, the newly described *N. faginata* is known only from North America, while *N. ditissima* is known from both North America and Europe (Castlebury et al. 2006). The status of *Neonectria* species in the country of Georgia is unknown; surveys were conducted in southeastern Europe but have not detected *N. faginata* (Mihál et al. 2009).

The beech bark epidemic in North America began in the Canadian Maritimes about 1890 (Hewitt 1914), and moved steadily west and south in the 20th century (Hawboldt 1944; Houston 1994a). The disease is not yet present in all parts of the range of American beech, but now extends west to Michigan (O'Brien et al. 2001) and south, discontinuously, in the Appalachian Mts to North Carolina (Houston 1994b). The Halifax Public Garden in is believed to have initiated the epidemic by importing scale-infested European beech seedlings (*Fagus sylvatica* L.) (Hewitt 1914) from Europe, where the scale has been recorded since 1832 (Fries 1832). Whether or not Western Europe is the native home of this scale has been debated, and indeed Gwiazdowski et al. (2006), based on haplotype diversity of the COI gene, have suggested that the native range lies further to the east. Specifically, southern Europe (Bulgaria), through Turkey and the Caucasus Mountains region were suggested to be the native range by Gwiazdowski et al. (2006). They further suggest that the original host of the scale is oriental beech (*F. orientalis* Lipsky). This origins hypothesis assumes that the scale transferred from *F. orientalis* to *F. sylvatica* either where the range of these trees overlap in southeastern Europe, or the scale was moved long distance into the range of *F. sylvatica* when oriental beech was taken to Western Europe. While details of this anthropic movements of *F. orientalis* are unknown, records do show it had reached Britain by 1880 (Bean 1976).

The known range of beech scale includes eastern North America (clearly an invaded region), western and central Europe (likely part of the invaded range), eastern Europe and parts of western Asia (all parts of the likely native range). Beech scale is unknown from South and East Asia, but in the boundary area when Western Asia and Europe meet, the scale has been recorded from Iran, Turkey, and the Caucasus Mts. region (including Georgia) (Adeli and Soleimanì, 1976), where it infests *F*. *orientalis*. The geographical ranges of the species of beech infested with beech scale are distinct, *F. grandifolia* being restricted (apart from human movement) to North America, while *F. sylvatica* is found in Europe, and *F. orientalis* occurs from southeastern Europe to Iran (Peters, 1997). *Fagus sylvatica* and *F. orientalis* have some area of overlap in southeastern Europe (Bulgaria).

Species invasions in which native plants are attacked, frequently are based on the formation of a new association between the invading insect and a congener of its native host plant. Also, during such invasions, it is common for natural enemies associated with the invader in its native range to fail to co-invade the new region. Classical biological control, therefore, has often been used successfully to suppress the density of such invaders (Van Driesche et al. 1996; Yasnosh & Japoshvili 1998; Van Driesche et al. 2008). However, because the invader typically feeds on a new host in the invader range, which may potentially have a lower level of host resistance, escape from natural enemies and lowered host defense, which are both potential causes of higher pest density, are confounded as potential explanations.

As part of an effort to determine if the Caucasus Mts forests are a potential source of natural enemies able to provide biological control of beech scale in North America, we have begun surveys for natural enemies in the country of Georgia (hereafter referred to solely as Georgia). As part of that larger effort, we measured beech scale populations in Massachusetts (part of invaded range) and in Georgia (part of native range) to determine the degree of difference in beech scale density between this sites. Those data are reported here.

Materials and Methods

Site Selection

The areas to be compared were western Massachusetts (near the University of Massachusetts in Amherst), part of the North American invaded range, and sites in Georgia, selected from various parts of the country.

In Massachusetts, 3 sites were examined, 1 in Amherst in the Connecticut River Valley and 2 sites west of the Connecticut River in a heavily forested, hilly region. All sites were stands of mixed deciduous forests with varying concentrations of beech. Beech density at sites was not determined but beech was most common at the Winsor, Massachusetts (Notchview) site; about 50% of trees being beech. At the other 2 sites, beech was a minor component (< 20% of all trees). Other details of sites are presented in Table 1.

Seven sites were selected throughout Georgia (Fig. 1): (1) Lagodekhi, along the northeast border of Georgia (stand almost 90% of beech), (2) Gombori, in northeast Georgia, (almost 100% beech), (3) Algeti, in central Georgia, west of the capital, Tbilisi (mixed forest with about 35% beech), (4) Bakuriani, in south central Georgia (90% of beech), (5) Kharagauli/Sakhadi, also in south central Georgia (95% of beech), (6) Shaori, in north central Georgia (99% beech), and (7) Sataplia, in north central Georgia (with 95% of beech).

Scale Counting Procedure

In Massachusetts, where scales are abundant and easily visible from a short distance, the critical process in tree selection was not to bias tree selection based on impressions about tree health or numbers of scale present. To prevent bias, in Massachusetts we used the following means of selecting trees. First, the general area to be sampled was located and then all beech trees visible were

TABLE 1. REGIONS IN THE COUNTRY OF GEORGIA AND MASSACHUSETTS (USA) WHERE BEECH SCALE DENSITY SAMPLING WAS DONE IN 2011.

Site #	Region	Site name	Coordinates	Altitude range (m)	Habitat
		MASSACHUSETTS			
1	Windsor	Notchview Reservation (The Trustees of Reservations)	N 42°50'36" W 73°02'78"	650	Beech-dominated hardwood forest
2	Amherst	Pulpit Hill Conservation Area	N 42°38'03" W 72°51'98"	90	Beech as minor component in mixed hardwood forest
3	Chesterfield	Chesterfield Gorge area (US Army Corps of Engineers)	N 42°23'35" W 72°52'48"	435	Beech in riparian hardwood strip along Westfield River
		GEORGIA			
1	western Georgia in the Great Caucasus Mts in the region of Racha	Shaori	N 42°23'23.27" E 43°02'20.04"	1235	Beech forest
2	northeast Georgia in the Great Caucasus Mts.	Gombori	N 41°52'28.68" E 46°21'38.41"	1760	Beech forest or mixed with *Carpinus* or *Acer*
3	western Georgia on the Likhi Ridge joining the Greater and Lesser Caucasus, in the region of Imereti	Sataplia	N 42°04'56.72" E 43°28'02.91"	454	Mixed wide leave forest
4	south of Tblisi in the lesser Caucasus near Tetritskaro	Bakuriani	N 41°44'05.27" E 43°30'40.61"	1811	Mixed with coniferous forests
5	northwest border of Georgia	Lagodekhi	N 41°51'01.50" E 46°17'23.69"	700	
6	western Georgia on the Likhi Ridge joining the Greater and Lesser Caucasus, in the region of Imereti	Kharagauli/sakhadi	N 42°18'50.36" E 42°40'40.57"	918	Mixed wide leave forest
7	south of Tblisi in the lesser Caucasus in the region of Tetritskaro	Algeti	N 41°41'45.01" E 44°20'36.29"	1140	Mixed with coniferous forests

Fig. 1. Map of Georgia with sites marked where density sampling of beech scale (*Cryptococcus fagisuga*) was conducted: (1-7). (1) Lagodekhi, (2) Gombori, (3) Algeti, (4) Bakuriani, (5) Kharagauli, 6) Shaori, (7) Sataplia.

sampled in order of nearness to the originally sampled point, working outward in all directions (Winsor and Amherst), or where sites were linear (along a river) (Huntington, Knightville Dam area), progressing consistently along the unpaved dirt road paralleling the river. In each case, the canopy was scanned to detect beech foliage and each beech tree as it was located was then sampled. Only 2 categories of trees were rejected: (1) beeches that were completely dead, with no live branches at all and (2) trees that were too small for the 10 by 10 cm sampling frame to fit flatly on one side of the trunk. In practice this meant that trees with a DBH (diameter at breast height) of less than above 12 cm were rejected, although this varied a bit due to the shape of the tree trunk. Three samples were taken on each of 30 trees per site selected in this manner. The process of placing the sampling frame on the trunk was haphazard and without regard to scale density. All samples were taken in the bottom 1.5 m of the trunk, with one sample generally being placed each in the upper, middle and lower part of that section. Samples were taken from any face of the tree.

In Georgia, all beech trees at the chosen sites were sampled if they were at least 10 cm in DBH, taking trees in the order they were encountered until 30 trees had been sampled. Sample locations on trees were selected randomly by walking around a tree, counting to 10 and then putting the sampling frame on the trunk at a spot between 40 and 150 cm above the ground.

Tree Health and Other Measures

At all sites, in both Massachusetts and Georgia, the DBH of all sample trees was recorded and each sample tree's health and scale-infestation status was classified into a 5 level scale, based on the condition of the canopy and degree of cankering of trunk: 1 = a healthy tree, 2 = trees with some cankers on bark, 3 = trees with many cankers, 4 = badly cankered trees, 5 = dying trees. From sample data, we calculated both the average number of scales per 1002 cm^2 at each site (averaging over the 90 samples, 3 for each of 30 trees) and the percentage of scale-infested trees at a site. In addition, in Georgia only, the percentage of trees infested with scale was noted based on a visual examination of the whole lower trunk (bottom 2 m).

Results

We found that scales were 45.4 times more abundant in Massachusetts on *F. grandifolia* than in Georgia on *F. orientalis* (average of 63.6 scales in Massachusetts per 100 cm^2 vs. 1.4 in Georgia) (Table 2). Beech trees were 2.9 times larger in DBH in Georgia than Massachusetts (46.5 cm DBH in Georgia vs 16.2 cm in Massachusetts). Trees were healthier in Georgia (rating 1.0 = "healthy" based on 210 trees assessed) compared to trees in Massachusetts, which were classified on average as having "many cankers" (rating of 3.2 based on 90 trees).

Discussion

We found that beech scales are common in Georgia, being present on 88% of all sampled beech trees (caveat: sites selected were ones where at least some beech scale was known to be present) and were widespread, being found in all parts of

TABLE 2. COMPARISON OF BEECH SCALE DENSITIES (PER 100 CM^2), TREE HEALTH, AND DIAMETER AT BREAST HEIGHT, FOR THREE SITES IN WESTERN MASSACHUSETTS (USA) AND SEVEN SITES IN THE COUNTRY OF GEORGIA IN AUGUST, 2011.

Town/site	Sample date	Scales/ 100 cm^2	% stand infested[1]	% sampled trees infested[2]	DBH (cm)	Health (1-5)[3]
		MASSACHUSETTS				
1. Windsor (Notchview TTOR)	Aug 8	90.7	—	100%	19.6	3.3
2. Amherst	Aug 8, 9	15.7	—	93%	9.8	2.2
3. Chesterfield	Aug 17	84.5	—	100%	19.2	4.0
Average		**63.6**		**98%**	**16.2**	**3.2**
		GEORGIA				
1. Shaori	Aug 29	0.6	35%	57%	52.3	1.0
2. Gombori	Aug 24	2.7	100%	80%	58.9	1.1[4]
3. Sataplia	Aug 28	1.1	99%	60%	37.4	1.0
4. Bakuriani	Aug 27	1.7	99%	57%	37.6	1.0
5. Lagodekhi	Aug 24	0.5	99%	53%	49.7	1.0
6. Kharagauili/Sakhadi	Aug 28	0.9	85%	50%	53.7	1.0
7. Algeti	Aug 26	2.7	99%	40%	35.7	1.0
Average		**1.4**	**88%**	**57%**	**46.5**	**1.1**

[1]Percent stand infested is an estimate of the proportion of all trees in the stand infested with beech scales. This data was collected only in Georgia.

[2]Percent sampled trees infested is the percentage of the trees sampled for scale density (selected at random in the stand) on which scale was detected within the three 100 cm^2 samples taken on the lower 2 m of trunk

[3]Health classes assessed visually, using the following categories: 1 = healthy , 2 = some cankers on bark, 3 = many cankers, 4 = badly cankered, 5 = dying

[4]One tree with 3.5 ranking.

the country examined. However, scale densities on *F. orientalis* in Georgia were very low (typically just a few scale per tree, but with 5% of trees or so with up to 100 or so scales per tree). Also, trees in Georgia were mostly old growth (most sampling being done in long standing reserves or parks), with large sizes (average DBH of sampled trees being 46.5 cm, but with many trees having DBH values > 80 cm). Finally, beech trees in Georgia were in uniformly good health.

In contrast, in Massachusetts *F. grandifolia* beech trees were much smaller (average only 16.2 cm DBH for sampled trees), sicker (healthy category 3.2), with extensive bark cracking, and heavily infested by scales. While trees currently extant in Massachusetts are smaller in DBD than trees in Georgia, this is a consequence of beech scale attack, and does not reflect greater susceptibility of younger trees to beech bark disease. While beech bark disease is capable of killing young trees, its effects are most intense in trees 25 cm DBH or greater (Mize and Lea 1979).

While the work reported here on comparative densities at the 2 study locations was done only in late summer, beech scale is univoltine in both Massachusetts and the country of Georgia, and densities are greatest in the fall of the year, after scale reproduction. In Georgia, studies are being conducted throughout the growing season, at many locations. At no time or place were densities found during the first survey year (2011) that were even 5% of those seen in Massachusetts.

Our data suggest either that American beech trees are much less resistant to beech scale than oriental beech, that key pathogens are missing in Georgia, or that important natural enemies are missing in North America that are found in Georgia. Also, in theory, the population of beech scale in North America might simply be more aggressive in attacking its host than is the same scale in Georgia. However, we lack comparative data on this point and so cannot assess the importance of this possibility, which could only be studied in quarantine. To estimate the relative importance of innate tree resistance versus the hypothesis of missing natural enemies in North America, further comparative work is underway in Massachusetts and the country of Georgia.

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