Field Performance of Buxus Cultivars and Selections Against Boxwood Leafminer and Boxwood Blight

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Abstract

Boxwood (*Buxus* L. spp. Buxaceae) are popular landscape plants in the United States, with traditionally low maintenance requirements, glossy evergreen foliage, and deer resistance. *Buxus sempervirens* 'Suffruticosa' (English boxwood) and *B. sempervirens* (American boxwood) were the most popular *Buxus* taxa planted for hundreds of years. But in the 1970s and 1980s, 'Suffruticosa' lost popularity due to boxwood decline, and many commercial nurseries began to search for new cultivars. However, many of the popular new varieties, such as 'Justin Brouwers', 'Green Beauty', 'Green Mountain', and 'Green Velvet' were very susceptible to boxwood leafminer (*Monarthropalpus flavus* Schrank). In 2011 boxwood blight, caused by the fungus *Calonectria pseudonaviculata*, was identified in the eastern United States and Oregon. Based on early reports that both leafminer and blight were variety-specific, Saunders Brothers Inc., a wholesale nursery in Virginia specializing in boxwood, began field trials to search for cultivars with natural resistance to boxwood leafminer and boxwood blight. Reported here are field evaluations of 146 cultivars in leafminer trials and 75 cultivars and selections in blight trials. In these trials, cultivars 'Peergold', 'Cole's Dwarf', 'SB 108', 'SB 300', and 'Wee Willie' and selections SB17 and 9-00-174 had low susceptibility (resistance) to both blight and leafminer.

Species used in this study: *Buxus harlandii* Hance; *B. microphylla* Seibold & Zucc.; *B. microphylla* var. *japonica* D. Anberg; *B. sempervirens* L.; *B. sinica* var. *insularis* (Nakai) M. Cheng; *Calonectria pseudonaviculata* (Crous, J.Z. Groenew. & C.F. Hill); L. Lombard, M.J. Wingf. & Crous, 2010; *Monarthropalpus flavus* (Schrank). *Buxus* nomenclature according to Batdorf, 2021.

Index words: Resistance screening, *Buxus*, *Calonectria pseudonaviculata*, *Monarthropalpus flavus*.

Significance to the Horticulture Industry

Boxwood, particularly in the Eastern United States, are one of the most popular ornamentals grown for landscape use because of their clean geometric shapes, year-round deep green foliage, and deer resistance. Nurseries choose cultivars based on their insect and disease resistance, attractiveness, grower friendliness, and other factors. Attractiveness and grower friendliness can be quite subjective, but insect and disease resistance are usually measurable. Boxwood leafminer, *Monarthropalpus flavus*, and boxwood blight, *Calonectria pseudonaviculata* are serious problems that can cause defoliation, disfiguration, and possibly death of susceptible boxwood and require management to maintain plant appearance and survival. Host resistance to both of these problems is the best solution for long-term management. Of 146 cultivars in leafminer trials and 75 cultivars and selections in blight trials with Saunders Brothers Inc., seven cultivars showed resistance/ low susceptibility to both blight and leafminer: cultivars 'Peergold', 'Cole's Dwarf', 'SB 108', 'SB 300', and 'Wee Willie' plus selections SB17 and 9-00-174. Other cultivars tested have resistance to one or the other, and may be useful in regions where that particular issue is not present, or have traits useful in future boxwood breeding programs. We leave it to the nursery or garden grower to subjectively evaluate attractiveness and grower friendliness.

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Introduction

Since colonial days, boxwood have been one of the most popular landscape plants used in the United States. Their popularity stems from their disease, insect and deer resistance, relatively low maintenance requirements, glossy-green evergreen foliage, and ease of propagation. *Buxus sempervirens* 'Suffruticosa' (English boxwood) and *B. sempervirens* (American boxwood) were the most popular taxa planted for hundreds of years. Before widespread nursery production began in the late 1900s, these two *B. sempervirens* taxa were commonly propagated and dispersed from many backyard gardens.

But in the 1970s and 1980s, *B. sempervirens* 'Suffruticosa' specimens slowly began dying in many landscapes. The terminology used to describe this dieback was "boxwood decline", which was the slow death of the plant, usually one limb at a time over several years. If one replanted another *B. sempervirens* 'Suffruticosa' into the same site, that plant might persist for a few years, but would eventually succumb to the same issues. The decline disease complex has been associated with the fungus *Sesquicillium buxi* (J.C Schmidt in Link) W. Gams,

parasitic nematodes and cultural and environmental conditions (Batdorf 2005).

As a result of these problems, many commercial nurseries began to search for new boxwood cultivars. Cultivars that became very popular in the late 1900s and early 2000s were *B. sempervirens* 'Justin Brouwers', *B. microphylla* var. *japonica* 'Green Beauty', *Buxus* 'Green Mountain', and *Buxus* 'Green Velvet'. However, these cultivars quickly showed extreme susceptibility to the boxwood leafminer (*M. flavus*), a gall midge, especially in hardiness Zone 6 and warmer, but also sometimes in cooler climates.

Although easy to control with neonicotinoid insecticides, boxwood leafminer (LM) can cause severe defoliation and even death of susceptible cultivars if not properly controlled. Additionally, the neonicotinoid class of insecticides is under scrutiny for effects on pollinating insects. In the search for cultivars that have natural resistance to the boxwood leafminer, there was very little published data before 2001, when d'Eustachio and Raupp (2001) reported different levels of infestation among nine cultivars.

In addition to the problems with the boxwood leafminer, in 2011 boxwood blight, caused by the fungus *Calonectria pseudonaviculata*, was identified in North Carolina and Connecticut (Ivors et al. 2012) and Oregon (Douglas 2012). This disease had already been in Europe since its first identification in the United Kingdom was in 1994 (Henricot and Culham 2002), and there was early evidence that boxwood blight, like the boxwood leafminer, was variety-specific (Ganci et al 2013).

In 2008, Saunders Brothers Inc., a Virginia wholesale nursery specializing in boxwood with a strong history of cultivar evaluation (Saunders 2011), began research to identify boxwood cultivars with natural resistance to boxwood leafminer and boxwood blight, and are attractive and easy to grow, with low maintenance requirements in both nurseries and landscapes. Their search for boxwood blight-resistant cultivars intensified after the discovery of boxwood blight in North Carolina in 2011. Ganci et al. (2013), Ganci (2014), Shishkoff (2014), and LaMondia and Shishkoff (2017) have reported varietal differences in susceptibility to blight; additionally, a meta-analysis was performed by Kramer et al. 2020 that systematically evaluated blight ratings among several studies. A preliminary boxwood leafminer report was published (Dunn and Saunders 2014). Here we describe several field and greenhouse trials for the ongoing search for boxwood cultivars resistant to both boxwood leafminer (summarized in Table 1) and boxwood blight (summarized in Table 8). This was not a comprehensive study of blight susceptibility of all popular cultivars because many of the named cultivars in the LM trials had already been tested and documented as susceptible or resistant to boxwood blight (Ganci et al. 2013) before the current screening trials were initiated in 2015.

Materials and Methods

Boxwood leafminer trials, Piney River, VA. In 2008, 2011, 2014 and 2019 boxwood leafminer (LM) trial plantings were established in fertile Hayesville loam soil near Piney River, VA. The plantings were bordered by pine (*Pinus* spp.) trees in rows parallel to the boxwood rows, and pine needles provided a natural mulch. All trials were established as parallel rows or single rows with plants arranged in a randomized complete block design. The test plants were planted in naturally fertile soil and watered as needed to establish plant growth. There was no supplemental fertilizer applied. Weeds near the plants were controlled mechanically, and in the center aisles they were controlled with glyphosate applied with a backpack sprayer. Heavily infested 0.9 m (3 ft) tall *B. sempervirens* 'Inglis' boxwood were already growing on either side of the test plants as source plants for uniform LM infestation. Cultivars and selections in the LM trials, respective *Buxus* species and plant source are summarized with 3-yr grand mean leafminer count data in Table 1.

Assessment of boxwood leafminer susceptibility. LM susceptibility is based on the number of larvae per leaf present in heavily infested leaves on a selected number of sprigs per plant. Samples were collected in October-November each year and were processed by selecting the most heavily infested leaf per sprig and removing the lower epidermis to count the larvae under 20X magnification. Data were analyzed using Proc GLM of Statistical Analysis Software (SAS Institute, Cary, NC). Means were separated using the Waller-Duncan K-ratio t-test ($p=0.05$).

2008 field boxwood leafminer trial. In early Apr 2008, 24 cultivars were planted in an isolated field adjacent to existing rows of heavily infested 'Inglis' boxwood (Table 2). There were five single-plant replicates of each test cultivar in a randomized complete block experimental design, spaced at 1.2 m (4 ft) in the rows and 1.5 m (5 ft) between rows. Larvae per leaf were counted on the most heavily infested two leaves on three shoots per plant in November 2008 and the most heavily infested leaf on four shoots per plant in November 2009 and 2012.

2010 field boxwood leafminer trial. In April 2010, 13 cultivars were planted adjacent to existing rows of heavily infested 'Inglis' plants (Table 3). There were five single-plant replicates of each test cultivar in a randomized complete block experimental design, spaced at 1.2 m (4 ft) in the rows and 1.5 m (5 ft) between rows. Larvae per leaf were counted on the most heavily infested leaf on each of four sprigs per plant in Nov 2010-2012.

2011 field boxwood leafminer trial. In March 2011, 57 cultivars were planted adjacent to existing rows of heavily infested 0.9-1.2 m (3-4 ft) tall 'Inglis' boxwood plants spaced at 1.2 m (4 ft) (Table 4). There were five replicates of each test plant in a randomized complete block experimental design spaced at 1.2 m (4 ft) in the rows and 1.5 m (5 ft) between rows. Larvae per leaf were counted on the most heavily infested leaf on each of four sprigs per plant in Nov 2011-2013.

2014 field boxwood leafminer trial. In early April 2014, 31 cultivars were planted in an isolated field adjacent to existing rows of heavily infested 'Inglis' boxwood plants (Table 5). There were five single-plant replicates of each

Table 1. Summary of boxwood leafminer larval counts, 2008-2021, Piney River, VA.

Boxwood cultivar/selection	Confirmed or presumed *Buxus* species	Plant source or believed origin [z]	Leafminer larvae per leaf [y, x]					
			Field trial					Greenhouse trial,
			2008-2010	2010-2012	2011-2013	2014-2016	2019-2021	2014-17
Most resistant (least susceptible) to leafminer damage								
Buddy	*sempervirens*	PVN		0.00 a				
K-74	*sempervirens*	SAV			0.00 a			
K-96	*sempervirens*	SAV			0.00 a			
K-106	*sempervirens*	SAV			0.00 a			
Richard	*harlandii*	SBI-Ukn			0.00 a			
Harlandii sp.	*harlandii*	SBI-Ukn			0.00 a			
Morris Dwarf Variegated	*microphylla* var. *japonica*	SBI- Mut				0.00 a		
Natchez	*sempervirens*	PVN				0.00 a		
Unraveled	*microphylla* var. *japonica*	SBI-Ukn				0.00 a		
11-00-492	Likely *sempervirens* seedling	WN						0.00 a
Russian Blue	*sempervirens*	SBI-Ukn				0.03 a		
Vardar Valley	*sempervirens*	SBI-Ukn	0.04 a					
Nana	*sinica var. insularis*	SBI-Ukn	0.06 ab				0.08 a	
Morris Midget sport	*microphylla* var. *japonica*	SBI-Mut				0.07 a		
Hohman's Dwarf	*microphylla*	SBI-Ukn			0.10 ab			
SB17	Likely *sinica*	SBI-Ukn			0.15 ab			
Wee Willie [w]	*sinica* var. *insularis*	MN				0.17 a		
Grace Hendrick Phillips Sport 1	*microphylla* sport	SBI-Mut				0.20 ab		
Franklin's Gem	*sinica* var. *insularis*	SBI-Ukn			0.25 a-c			
Fineline	*sempervirens*	PVN				0.25 ab		
Suffruticosa	*sempervirens*	SBI-Ukn	0.28 a-c					
Argentea	*sempervirens*	SBI-USNA				0.55 a-c		
Argenteo-Variegata	*sempervirens*	SAV			0.60 a-d			
Monrue [w]	*sempervirens*	MN		0.63 ab				
Grace Hendrick Phillips	*microphylla*	SBI-Ukn	0.64 a-d					
GB-27	*sempervirens*	RG				0.66 a-c		
GB-80	*sempervirens*	RG			0.67 a-e			
Newport Blue	*sempervirens*	DA			0.67 a-c			
Green Pillow	*microphylla*	SBI-Ukn	0.68 a-d					
Thomas Jefferson [w]	*sempervirens*	SBI-PC		0.73 ab				
Morris Dwarf	*microphylla* var. *japonica*	SBI-Ukn	0.76 a-d			0.10 ab		
SB 300 [w]	*sinica*	SBI- Mut					0.78 ab	
GB-12	*sempervirens*	RG			0.80 a-f			
SB 108 [w]	*microphylla* seedling	SBI-PC		2.08 a-c			0.90 b	
Peergold [w]	*microphylla*	SBI-Ukn		0.90 ab				
West Ridgeway	*sempervirens*	SBI-Ukn			0.93 a-g			
Grace Hendrick Phillips Sport 2	*microphylla* sport	SBI-Mut				1.10 a-d		
Jim Stauffer	*microphylla* var. *japonica*	SBI-Ukn	1.12 a-e					
Cole's Dwarf [w]	*microphylla*	CN		2.04 a-c	1.13 a-h			
Wintergreen (Big Leaf)	*microphylla*	SBI-Ukn	1.13 a-e					
Jensen	*sempervirens*	SBI-Ukn	1.15 a-e					
9-00-174	Likely *harlandii* seedling	WN						1.20 ab
Moderately susceptible cultivars and selections								
11-00-526	Unknown	WN						1.30 ab
Longwood	*sempervirens*	SBI-Ukn				1.50 a-e		
Ohio Winter Gem	Unknown	SBI-PC			1.50 a-i			
Bob Dunn	*sempervirens*	SBI-PC		1.59 a-c				
Rotundifolia	*sempervirens*	SBI-Ukn	1.58 a-e					
Memorial	*sempervirens*	WN				1.70 a-f		
Chloe	*sempervirens*	PVN			1.70 a-j			
K-7	*sempervirens*	SAV			1.83 a-j			
Route 50	*sempervirens*	WN		1.88 a-c				
Elegantissima	*sempervirens*	SBI-Ukn	1.89 b-e					
Fastigiata	*sempervirens*	SBI-Ukn	1.89 b-e					
AGRU-80	*sempervirens*	SBI-Ukn				1.90 a-f		
1-98-83	Likely *sempervirens*	WN						1.90 ab
Morris Midget	*microphylla var. japonica*	SBI-Ukn	1.98 c-e					
11-00-489	Likely *harlandii* seedling	WN						2.05 ab
10-00-329	Likely *sempervirens* seedling	WN						2.13 ab
Dee Runk	*sempervirens*	SBI-PC	2.15 d-f					
GB-57	*sempervirens*	RG				2.27 a-f		
Natchez Sport (Bennett)	*sempervirens*	SBI-Mut			2.30 a-k			
Wanford Page	*sempervirens*	SBI-PC			2.33 b-l			
GB-24	*sempervirens*	RG			2.37 b-l			
10-00-398	Likely *harlandii* seedling	WN						2.40 a-c
K-91-1	*sempervirens*	SAV			2.53 c-m			
Myosotidifolia	*sempervirens*	SAV			2.57 d-m			
8-00-120	Likely *harlandii* seedling	WN						2.58 a-c
Hermann von Schrenk	*sempervirens*	SBI-Ukn				2.63 a-f		
Halifax American	*sempervirens*	SBI-PC			2.65 d-m			
1-98-96	Likely *sempervirens* seedling	WN						2.65 a-c
Liberty	*sempervirens*	SAV			2.70 d-n			
Blauer Heinz	*sempervirens*	SBI-PC			2.70 d-n			
McCracken	*sempervirens*	SAV			2.75 d-n			
8-00-84	Likely *harlandii* seedling	WN						2.75 a-c
AGRU 88	*sempervirens*	LG			2.77 d-n			
Sempervirens	*sempervirens*	SBI-Ukn	2.79 e-g					
Small Leaf Wintergreen	Likely *sinica*	SBI-PC		2.80 b-d				
Berlin	*sempervirens*	SBI-Ukn				2.83 a-f		
GB-17	*sempervirens*	RG			2.90 d-o			
Hugh Crump Upright	*sempervirens*	SBI-PC			2.90 d-o			
Zehrung	*sempervirens*	DA			2.97 e-o			
Mary Gamble	*sempervirens*	SBI-Ukn				2.97 a-f		

Table 1. Continued.

Asheville	*sempervirens*	DA			3.00 f-o			
GB-38	*sempervirens*	RG				3.00 a-f		
Holland	*sempervirens*	SBI-Ukn				3.10 a-f		
GB-26	*sempervirens*	RG				3.15 a-f		
Tom Norvelle	*sempervirens*	SBI-PC			3.17 g-p			
9-00-203	Likely *harlandii* seedling	WN						3.20 a-d
Highlander [w]	*sempervirens*	CN		3.26 cd				
Aurea Maculata	*sempervirens*	SAV			3.27 h-p			
Handsworthii	*sempervirens*	SBI-PC				3.30 a-f		
Robbuxupt [w]	*sinica* var. *insularis*	SBI-Ukn		3.31 cd				
GB-46	*sempervirens*	RG				3.33 a-f		
Meyer Columnar	*sempervirens*	SBI-Ukn				3.40 b-g		
Henry Shaw	*sempervirens*	SAV			3.53 i-q			
Pullman (Fiore)	*sempervirens*	DA			3.60 i-q			
Aurea Pendula	*sempervirens*	SBI-Ukn				3.63 c-g		
9-00-216	Likely *harlandii* seedling	WN						3.63 a-d
Pier Cove	*sempervirens*	DA			3.73 i-q			
Woodland	*sempervirens*	WN			3.73 i-q			
1-00-794	Likely *microphylla* seedling	WN						3.75 a-d
Black American	*sempervirens*	SBI-PC			3.77 i-q			
Highly susceptible cultivars and selections								
Latifolia Aurea Maculata	*sempervirens*	SAV			3.80 i-q			
Justin Brouwers	*sempervirens*	SBI-Ukn	3.85 f-h					
Rochester	*sempervirens*	DA			3.87 j-r			
Morrison Garden	*sempervirens*	DA			3.87 j-r			
11-00-519	Likely *harlandii* seedling	WN						3.90 a-e
GB-28	*sempervirens*	RG			3.93 j-s			
Northern New York	*sempervirens*	SAV			4.00 j-s			
GB-20	*sempervirens*	RG				4.13 d-g		
Green Mound	*Buxus* hybrid	SN	4.14 gh					
GB-40	*sempervirens*	RG				4.20 d-g		
K-24	*sempervirens*	SAV			4.30 k-t			
Abilene	*sempervirens*	DA			4.33 k-t			
John Baldwin	*microphylla*	SBI-Ukn	4.38 gh					
Green Beauty	*microphylla* var. *japonica*	SBI-Ukn	4.47 g-i					
GB-48	*sempervirens*	RG				4.50 e-g		
Denmark	*sempervirens*	SAV			4.50 k-t			
8-00-113	Likely *harlandii* seedling	WN						4.53 a-e
Green Mountain	*Buxus* hybrid	SN	4.59 g-i					
Northern Emerald	*microphylla*	SBI-Ukn		4.60 de				
K-144	*sempervirens*	SAV			4.63 l-t			
GB-51	*sempervirens*	RG			4.73 m-t			
Latifolia Maculata	*sempervirens*	SBI-Ukn			4.80 m-t			
Variegata	*sempervirens*	SBI-PC			4.83 m-t			
Angustifolia	*sempervirens*	SBI-Ukn				4.90 fg		
Beehive	Unknown	SBI-Ukn			4.97 n-t			
Green Velvet	*Buxus* hybrid	SN	5.02 hi				3.44 c	
GB-41	*sempervirens*	RG			5.20 o-t			
Ohio	*sempervirens*	DA			5.43 p-t			
2-98-289	Likely *sempervirens* seedling	WN						5.58 b-f
9-00-254	Likely *sempervirens* seedling	WN						5.60 b-f
K-26	*sempervirens*	SAV			5.70 q-t			
3-99-139	Likely *sempervirens* seedling	WN						6.03 b-f
Cliffside	*sempervirens*	SAV			6.17 r-t			
Glencoe	*Buxus* hybrid	CBG	6.30 ij					
Pullman	*sempervirens*	DA			6.57 t			
1-98-125	Likely *sempervirens* seedling	WN						7.55 c-g
8-00-117	Unknown	WN						8.18 d-g
Inglis	*sempervirens*	SBI-Ukn	7.32 j	6.50 e		6.73 g		9.23 e-g
Green Gem	*Buxus* hybrid	SN			9.37 s-t			
1-2-172	Likely *sempervirens* seedling	WN						10.10 f-h
1-98-76	Likely *sempervirens* seedling	WN						11.43 gh
2-99-95	Likely *sempervirens* seedling	WN						12.78 gh
3-99-158	Likely *sempervirens* seedling	WN						15.03 h
2-98-276	Likely *sempervirens* seedling	WN						15.28 h

[z]Source codes: CBG=Chicago Botanic Garden, Glencoe IL. CN=Cole's Nursery, Pipestem WV. DA=Dawes Arboretum, Newark OH. GN=Greenleaf Nursery, Park Hill OK. JNPS=JN Plant Selections, Milwaukee WI. LG=Longwood Garden, Kennett Square PA. MN=Monrovia Nursery, Monrovia CA. PVN=Pine View Nursery, Leitchfield, KY. RG=Boxwood collection trip to Republic of Georgia in 2001. SAV=State Arboretum of Virginia, Boyce VA. SBI-Mut=Saunders Brothers Inc., (SBI) collection, Piney River VA - Mutation found at SBI.SBI-PC= Saunders Brothers, Inc., Piney River VA. SBI acquired from private collection. SBI-Ukn=Saunders Brothers, Inc., Piney River VA. Original source unknown. Often many years in SBI collection. SN=Sheridan Nurseries, Ontario, CAN. USNA= United States National Arboretum, Washington DC. WN=Woodland Nursery, Salisbury MD. WWN=Willoway Nursery, Avon, OH.

[y]Means of five replications except field trial 2019-2021 which was four replications. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05). Color code for leafminer susceptibility: Green- varied degrees of resistance; Yellow- moderately susceptible; red- highly susceptible. Blue indicates inconsistent reactions that affect reliable positioning of the cultivar.

[x]See Tables 2–7 for complete infestation ratings during the years each trial was in progress.

[w]Current cultivar tradenames and patent numbers: Cole's Dwarf=Little Missy USPP 24703; Glencoe=Chicagoland Green™; Golden Dream USPP 16052; Green Gem USPP 3736; Highlander USPP 22978; Monrue= Green Tower™, USPP 15243; Peergold=Golden Dream USPP 16052; SB 108=NewGen Independence® USPP 32421; SB 300=NewGen Freedom® USPP 28888; Thomas Jefferson=Piney Mountain® USPP 23869; Robbuxupt=Uptight™ USPP 21390P2; Wee Willie USPP 17007.

Table 2. Larvae counts for the 2008 boxwood leafminer trial, Piney River, VA. Ratings 2008-2010.

Boxwood cultivar/ selection	Larvae/leaf [z] 2008	2009	2010	Grand mean
Vardar Valley	0.12 a	0.00 a	0.00 a	0.04 a
Nana	0.07 a	0.10 a	0.00 a	0.06 ab
Suffruticosa	0.07 a	0.70 a	0.08 ab	0.28 a-c
Grace Hendrick Phillips	0.33 ab	0.35 a	1.25 a-d	0.64 a-d
Green Pillow	0.03 a	0.45 a	1.55 a-e	0.68 a-d
Morris Dwarf	0.67 a-d	0.80 a	0.80 a-c	0.76 a-d
Jim Stauffer	0.17 a	1.90 ab	1.30 a-d	1.12 a-e
Wintergreen	0.13 a	0.55 a	2.70 c-f	1.13 a-e
Jensen	0.37 a-c	2.65 a-d	0.44 ab	1.15 a-e
Rotundifolia	1.43 a-e	1.85 ab	1.45 a-d	1.58 a-e
Fastigiata	2.23 d-g	1.20 a	2.25 b-e	1.89 b-e
Elegantissima	2.17 c-f	2.30 a-c	1.20 a-d	1.89 b-e
Morris Midget	1.74 a-e	1.95 ab	2.25 b-e	1.98 c-e
Dee Runk	1.40 a-e	2.35 a-c	2.70 c-f	2.15 d-f
Sempervirens	0.93 a-d	4.35 b-e	3.10 d-g	2.79 e-g
Justin Brouwers	2.80 e-g	4.90 c-e	3.85 e-h	3.85 f-h
Green Mound	2.07 b-f	5.75 ef	4.60 f-h	4.14 gh
Green Gem	3.10 e-g	4.30 b-e	5.55 hi	4.32 gh
John Baldwin	3.13 e-g	4.05 b-e	5.95 h-j	4.38 gh
Green Beauty	2.00 b-e	4.45 b-e	6.95 ij	4.47 g-i
Green Mountain	0.57 a-d	8.00 fg	5.20 g-i	4.59 g-i
Green Velvet	3.86 f-h	5.25 de	5.95 h-j	5.02 hi
Glencoe	4.00 gh	9.30 g	5.60 hi	6.30 ij
Inglis	5.07 h	8.85 g	8.05 j	7.32 j

[z]Annual data means of five replications, counts of the heaviest infested leaf on each of six shoots per replication. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

test cultivar in a randomized complete block experimental design, spaced at 1.2 m (4 ft) in the rows and 1.5 m (5 ft) between rows. Larvae per leaf were counted on the most heavily infested leaf on each of four sprigs per plant in Nov 2014-2016.

2019 field boxwood leafminer trial. In March 2019, four cultivars were planted spaced at 1.2 m (4 ft) in a single row adjacent to existing rows of the 2010 planting (Table 6).

Table 3. Larvae counts for the 2010 planting leafminer trial, Piney River, VA. Ratings 2010-2012.

Boxwood cultivar/ selection	Larvae/leaf [z] 2010	2011	2012	Grand mean
Buddy	0.00 a	0.00 a	0.00 a	0.00 a
Munrue	1.50 bc	0.13 ab	0.25 ab	0.63 ab
Thomas Jefferson	1.20 a-c	0.50 a-c	0.50 a-c	0.73 ab
Peergold	0.00 a	0.90 a-c	1.80 d-f	0.90 ab
Bob Dunn	0.35 ab	2.35 b-d	2.06 d-f	1.59 a-c
Route 50	1.90 c	2.65 cd	1.10 b-d	1.88 a-c
Cole's Dwarf	0.06 a	2.50 cd	3.56 gh	2.04 a-c
SB 108	0.15 a	3.95 de	2.15 ef	2.08 a-c
Small Leaf Wintergreen	4.35 d	2.80 cd	1.25 c-e	2.80 b-d
Highlander	2.25 c	4.83 de	2.70 fg	3.26 cd
Robbuxupt	2.06 c	3.44 d	4.44 h	3.31 cd
Northern Emerald	2.30 c	5.85 e	5.65 i	4.60 de
Inglis	–	9.10 f	3.90 h	6.50 e

[z]Averages of five replications, and the heaviest infested leaf on each of four shoots per replication.

Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

Table 4. Larvae counts in 2011-2013 for the 2011 boxwood leafminer trial, Piney River, VA.

Boxwood cultivar/ selection	Larvae/leaf [z] 2011	2012	2013	Grand mean
K-74	0.0 a	0.0 a	0.0 a	0.00 a
K-96	0.0 a	0.0 a	0.0 a	0.00 a
K-106	0.0 a	0.0 a	0.0 a	0.00 a
Richard	0.0 a	0.0 a	0.0 a	0.00 a
Harlandii sp.	0.0 a	0.0 a	0.0 a	0.00 a
Hohman's Dwarf	0.0 a	0.0 a	0.3 a-c	0.10 ab
SB17	–	0.0 a	0.3 a-c	0.15 ab
Franklin's Gem	–	0.4 ab	0.1 ab	0.25 a-c
Argenteo-Variegata	–	0.8 a-d	0.4 a-c	0.60 a-d
GB-80	0.9 a-c	0.4 ab	0.7 a-e	0.67 a-e
Newport Blue	1.2 a-e	0.5 a-c	0.3 a-c	0.67 a-c
GB-12	1.0 a-d	0.6 a-c	0.8 a-e	0.80 a-f
West Ridgeway	0.8 a-c	0.6 a-c	1.4 a-i	0.93 a-g
Cole's Dwarf	0.0 a	1.5 a-f	1.9 a-k	1.13 a-h
Ohio Winter Gem	0.4 ab	1.9 a-i	2.2 c-m	1.50 a-i
Chloe	0.8 a-c	1.7 a-h	2.6 e-p	1.70 a-j
K-7	2.1 a-g	1.6 a-f	1.8 a-j	1.83 a-j
Natchez Sport (Bennett)	2.8 a-i	3.0 d-l	1.1 a-g	2.30 a-k
Wanford Page	1.9 a-f	2.5 b-l	2.6 d-o	2.33 b-l
GB-24	3.3 b-j	2.8 c-l	1.0 a-f	2.37 b-l
K-91-1	3.5 b-j	2.8 c-l	1.3 a-h	2.53 c-m
Myosotidifolia	2.6 a-i	4.8 a-e	0.3 a-c	2.57 d-m
Halifax American	–	1.2 a-f	4.1 m-s	2.65 d-m
Liberty	2.2 a-h	2.6 b-l	3.3 h-q	2.70 d-n
Blauer Heinz	2.6 a-i	2.8 c-l	–	2.70 d-n
McCracken	–	0.9 a-e	4.6 p-s	2.75 d-n
AGRU 88	5.4 i-o	1.6 a-g	1.3 a-h	2.77 d-n
GB-17	4.1 d-k	4.0 h-m	0.6 a-d	2.90 d-o
Hugh Crump Upright	–	2.8 c-l	3.0 f-q	2.90 d-o
Zehrung	3.6 c-j	2.3 a-k	3.0 f-q	2.97 e-o
Asheville	4.6 f-l	2.4 b-l	2.0 a-k	3.00 f-o
Tom Norvelle	4.1 e-k	1.8 a-f	3.6 j-r	3.17 g-p
Aurea Maculata	4.8 f-m	3.1 e-l	1.9 a-k	3.27 h-p
Henry Shaw	4.6 f-l	3.0 h-m	3.0 f-q	3.53 i-q
Pullman (Fiore)	4.3 e-k	3.4 f-l	3.1 g-q	3.60 i-q
Pier Cove	5.2 g-n	3.0 d-l	3.0 f-q	3.73 i-q
Woodland	5.3 h-o	2.8 c-l	3.1 g-q	3.73 i-q
Black American	6.4 j-q	2.2 a-j	2.7 e-p	3.77 i-q
Latifolia Aurea Maculata	6.0 j-p	2.2 a-i	3.2 h-q	3.80 i-q
Rochester	6.1 j-p	3.0 d-l	2.5 d-n	3.87 j-r
Morrison Garden	4.5 f-l	3.4 f-l	3.7 j-s	3.87 j-r
GB-28	6.1 j-p	2.6 b-l	3.1 g-q	3.93 j-s
Northern New York	7.6 l-q	2.3 a-k	2.1 b-l	4.00 j-s
K-24	6.9 k-q	3.1 d-l	2.9 f-q	4.30 k-t
Abilene	5.4 i-o	3.5 f-l	4.1 m-s	4.33 k-t
Denmark	–	3.3 e-l	5.7 st	4.50 k-t
K-144	8.8 p-q	3.4 f-l	1.7 a-j	4.63 l-t
GB-51	7.9 m-q	3.6 f-l	2.7 e-p	4.73 m-t
Latifolia Maculata	–	2.5 b-l	7.1 t	4.80 m-t
Variegata	7.2 k-q	4.0 g-l	3.3 i-q	4.83 m-t
Beehive	9.5 q	3.0 d-l	2.4 d-m	4.97 n-t
GB-41	8.3 n-q	4.3 i-m	3.0 f-q	5.20 o-t
Ohio	9.1 p-q	3.3 e-l	3.9 k-s	5.43 p-t
K-26	8.4 o-q	4.6 j-m	4.1 l-s	5.70 q-t
Cliffside	9.3 q	4.6 k-m	4.6 o-s	6.17 r-t
Pullman	7.8 m-q	6.3 m	5.6 r-t	6.57 t
Green Gem	9.4 q	4.8 lm	4.5 n-s	9.37 s-t

[z]Averages of five replications, and the heaviest infested leaf on each of four shoots per replication. Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

Table 5. Larvae counts in 2014-2016 for the 2014 boxwood leafminer trial, Piney River, VA.

Boxwood cultivar/ selection	Larvae/leaf [z] 2014	2015	2016	Grand mean
Morris Dwarf Variegated	0.0 a	0.0 a	0.0 a	0.00 a
Natchez	0.0 a	0.0 a	0.0 a	0.00 a
Unraveled	0.0 a	0.0 a	0.0 a	0.00 a
Russian Blue	0.1 ab	0.0 a	0.0 a	0.03 a
Morris Midget Sport	0.1 ab	0.1 a	0.0 a	0.07 a
Morris Dwarf	0.0 a	0.3 a	0.0 a	0.10 ab
Wee Willie	0.0 a	0.5 a-c	0.0 a	0.17 a
Grace Hendrick Phillips Sport 1	0.2 ab	0.4 a	0.0 a	0.20 ab
Fineline	0.3 ab	0.2 a	0.0 a	0.25 ab
Argentea	0.7 a-c	0.4 a	–	0.55 a-c
GB-27	1.0 a-d	0.7 ab	0.3 a-c	0.66 a-c
Grace Hendrick Phillips Sport 2	1.9 a-e	0.5 a	0.9 a-e	1.10 a-d
Longwood	2.7 a-g	1.0 a-c	0.8 a-e	1.50 a-e
Memorial	3.2 b-g	0.6 a-c	1.3 a-e	1.70 a-f
AGRU-80	3.4 c-h	0.4 a	–	1.90 a-f
GB-57	6.6 h-j	0.0 a	0.2 ab	2.27 a-f
Hermann von Schrenk	7.3 ij	0.2 a	0.4 a-d	2.63 a-f
Berlin	5.8 g-j	1.7 a-d	1.0 a-e	2.83 a-f
Mary Gamble	3.6 c-h	2.8 a	2.5 b-e	2.97 a-f
GB-38	5.6 g-j	0.5 a	2.9 ef	3.00 a-f
Holland	5.1 f-i	2.6 c-e	1.6 a-e	3.10 a-f
GB-26	–	3.5 d-f	2.8 d-f	3.15 a-f
Handsworthii	2.2 a-f	1.3 a-c	6.4 g	3.30 a-f
GB-46	4.8 e-i	2.5 b-e	2.7 c-f	3.33 a-f
Meyer Columnar	5.8 g-j	1.0 a	–	3.40 b-g
Aurea Pendula	4.1 d-h	5.3 f	1.5 a-e	3.63 c-g
GB-20	5.2 f-i	4.1 ef	3.1 ef	4.13 d-g
GB-40	10.6 k	0.4 a	1.4 a-e	4.20 d-g
GB-48	–	4.0 ef	5.0 fg	4.50 e-g
Angustifolia	–	4.0 ef	5.8 g	4.90 fg
Inglis	8.6 jk	5.2 f	6.4 g	6.73 g

[z]Averages of five replications, counts of the heaviest infested leaf on each of four shoots per replication. Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

There were four single-plant replicates of each cultivar in a randomized complete block experimental design. Larvae per leaf were counted on the most heavily infested leaf on each of six sprigs per plant in Oct-Nov 2019-2021.

2014-2017 greenhouse boxwood leafminer trial. In April 2014, 26 cultivars and selections were potted into 100% pine bark potting mix in 4 L (1 gal) pots in an isolation greenhouse that was covered with white polyethylene with

Table 6. Larvae counts in 2019-2021 for the 2019 boxwood leafminer trial, Piney River, VA.

Boxwood cultivar/ selection	Total larvae/leaf [z] 2019	2020	2021	Grand mean
Nana	0.00 a	0.00 a	0.25 a	0.08 a
SB 300	0.04 a	0.75 a	1.54 b	0.78 ab
SB 108	0.09 a	0.79 a	1.83 b	0.90 b
Green Velvet	2.67 b	3.91 b	3.75 c	3.44 c

[z]Four replications. Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

Ratings of the most heavily infected leaf on each of six shoots per plant, sampled 21 Oct, 2019, 5 Nov 2020, and 9 Nov 2021.

Table 7. Larvae counts in 2014-2017 for the 2014 boxwood leafminer greenhouse trial.

Boxwood selection	Larvae/leaf [z] 2014	2015	2016	2017	Grand mean
11-00-492	0.0 a	0.0 a	0.0 a	0.0 a	0.00 a
9-00-174	0.7 ab	1.0 a-c	2.4 a-c	0.7 ab	1.20 ab
11-00-526	3.5 a-e	0.1 a	1.4 a-c	0.2 a	1.30 ab
1-98-83	3.0 a-e	2.7 b-e	0.8 ab	1.1 a-c	1.90 ab
11-00-489	0.0 a	1.5 a-c	4.4 c-f	2.3 a-c	2.05 ab
10-00-329	1.6 a-c	1.6 a-c	3.8 b-e	1.5 a-c	2.13 ab
10-00-398	3.5 a-e	0.5 ab	3.5 -d	2.1 a-c	2.40 a-c
8-00-120	1.7 a-c	2.2 a-d	3.1 a-d	3.3 a-d	2.58 a-c
1-98-96	4.5 b-f	2.7 b-e	2.0 a-c	1.4 a-c	2.65 a-c
8-00-84	0.0 a	1.1 a-c	7.1 e-h	2.8 a-c	2.75 a-c
9-00-203	2.4 a-d	1.0 a-c	6.3 d-g	3.1 a-c	3.20 a-d
9-00-216	3.0 a-e	0.6 ab	7.4 f-h	3.5 b-d	3.63 a-d
1-00-794	2.4 a-d	1.9 a-c	6.4 d-g	4.3 c-e	3.75 a-d
11-00-519	5.0 c-f	1.9 a-c	6.1 d-g	2.6 a-c	3.90 a-e
8-00-113	0.0 a	2.5 b-e	13.2 ij	2.4 a-c	4.53 a-e
2-98-289	6.0 d-f	4.5 ef	4.4 c-f	7.4 ef	5.58 b-f
9-00-254	1.6 a-c	2.9 c-e	10.1 hi	7.8 f	5.60 b-f
3-99-139	12.0 h	1.5 a-c	4.2 b-f	6.4 d-f	6.03 b-f
1-98-125	6.6 ef	5.9 fg	8.3 gh	9.4 f	7.55 c-g
8-00-117	0.7 ab	7.4 g	16.0 jk	8.6 f	8.18 d-g
Inglis	–	4.6 ef	14.6 j	8.5 f	9.23 e-g
1-2-172	8.0 fg	4.3 d-f	18.4 k	9.7 f	10.10 f-h
1-98-76	10.6 gh	7.1 g	13.9 j	14.1 g	11.43 gh
2-99-95	11.4 gh	7.1 g	16.4 jk	16.2 g	12.78 gh
3-99-158	3.6 a-e	7.5 g	25.2 l	23.8 h	15.03 h
2-98-276	1.6 a-c	7.4 g	23.3 l	28.8 i	15.28 h

[z]Averages of five replications, counts of the heaviest infested leaf on each of four shoots per replication. Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

50% shading from about 1 November to 10 May in successive years. During the warm months, the greenhouse was covered only with 55% shadecloth. Plants were fertilized with Osmocote 18-6-12, an eight to nine month release product that was incorporated in the pine bark mix at the rate of 4.0 $kg \cdot m^{-3}$ (8.0 $lbs \cdot yd^{-3}$), and they were watered as needed. Five replications of test plants were arranged with heavily infested 'Inglis' boxwood plants in a randomized complete block experimental design (Table 7). The temperature was somewhat warmer in the greenhouse than outdoor ambient, stimulating development of the LM several weeks early in early-mid April. Larvae per leaf were counted on the most heavily infested leaf on each of four sprigs per plant in November each year, 2014-2017.

Methods for boxwood blight trials, Low Gap, NC. In 2015, 2018 and 2020 blight trial plantings were established in creek-bottom land with fertile Colvard and Suches loam soil (pH 6.2-6.7) at Low Gap, NC. The location had been a former nursery with boxwood blight prevalent throughout the site in 2011 through 2015. Because the trial site is situated in a creek bottom, it has very little air movement, is prone to heavy dews, and is very slow drying, all of which make it an ideal site for boxwood blight trials. All trials were established and conducted in a randomized complete block design. The test plants were fertilized with Osmocote Plus 15-9-12, 9 g per plant after planting. They were mulched with mixed hardwood mulch applied after planting in 2015, but the 2018 and 2020 plantings were not

Table 8. Boxwood blight defoliation ratings in four field trials, 2016-2020, Low Gap, NC.

Boxwood cultivar/selection	Confirmed or presumed *Buxus* species	Plant source or believed origin [z]	% of plant defoliated in final trial rating [y, x]			
			14 Nov 2017	7 Nov 2018	7 Nov 2020	
					Trial 1	Trial 2
Most resistant (least susceptible) to blight						
SB19-03	*harlandii* sport	SBI-Mut	--	--	0.0 a	--
RLH-BI [w]	*sinica*	GN	--	--	0.0 a	--
Peergold [w]	*microphylla*	SBI-Ukn	--	5.9 a	--	--
11-0-489	Likely *harlandii* seedling	WN	2.8 ab	8.6 ab	--	--
TM110	Likely *harlandii* seedling	NC	0.5 a	10.9 ab	1.3 ab	--
Wee Willie	*sinica* var. *insularis*	MN	--	15.0 a-d	--	--
SB 108 [w]	*microphylla* seedling	SBI-PC	1.8 a	15.3 a-c	5.0 a-e	--
SB 300 [w]	*sinica*	SBI-Mut	--	16.9 a-d	1.8 ab	--
Cranberry Creek	*Buxus* hybrid	WWN	--	16.5 a-d	--	--
SB17	Likely *sinica*	SBI-Ukn	0.3 a	20.3 b-e	--	--
TM102	Likely *microphylla*; variegated	NC	1.3 a	24.4 b-e	--	1.3 a
TM108	Likely *microphylla*; variegated	NC	0.6 a	31.3 d-f	--	4.3 a
Cole's Dwarf [w]	*microphylla*	CN	2.0 ab	--	--	--
10-00-398	Likely *harlandii* seedling	WN	3.5 ab	--	--	--
8-00-113	Likely *harlandii* seedling	WN	4.0 ab	--	--	--
9-00-254	Likely *sempervirens* seedling	WN	4.3 ab	--	--	--
9-00-174	Likely *harlandii* seedling	WN	6.0 ab	--	--	--
8-00-84	Likely *harlandii* seedling	WN	7.3 ab	--	--	--
1-98-96	Likely *sempervirens* seedling	WN	7.5 ab	28.8 c-f	--	--
8-00-117	Unknown	WN	16.3 bc	--	--	--
SB19-08	*sinica* mutation	SBI-Mut	--	--	3.0 a-d	--
Green Beauty	*microphylla* var. *japonica*	SBI-Ukn	23.8 cd	11.9 ab	3.8 a-d	3.5 a
TM20-08	*microphylla* sport	NC	--	--	--	5.0 a
SB17-01	*sinica*; variegated sport of SB 300	SBI-Mut	--	--	3.8 a-c	--
SB19-04	Unknown	SBI-Mut	--	--	6.3 a-d	--
SB19-05	*sinica*	SBI-Mut	--	--	7.5 a-e	--
SB19-07	*sinica*	SBI-Mut	--	--	8.8 a-f	--
Robert Micro	Likely *microphylla*	SBI-Mut	--	--	9.3 a-f	--
M613B	Sheridan hybrid seedling	JNPS	--	--	10.0 a-e	--
Select E	Sheridan hybrid seedling	JNPS	--	--	10.0 a-d	--
Select I	Sheridan hybrid seedling	JNPS	--	--	11.3 b-g	--
SB19-02	*sinica*	SBI-Mut	--	--	11.8 b-g	--
Moderately susceptible to blight						
TM112	Likely *microphylla*	NC	26.3 c-e	--	--	--
10-00-329	Likely *sempervirens* seedling	WN	36.7 d-f	--	--	--
11-00-492	Likely *sempervirens* seedling	WN	38.8 d-f	--	--	--
Green Mountain	*Buxus* hybrid	SN	--	--	20.0 c-g	--
SB19-01	*sinica*	SBI-Mut	--	--	21.3 d-h	--
Gregem [w]	*microphylla* var. *japonica*	GN	--	--	22.5 e-h	--
SB19-06	*sinica*	SBI-Mut	--	--	31.3 f-i	--
M616C	Sheridan hybrid seedling	JNPS	--	--	32.5 g-j	--
Grejade [w]	*microphylla* var. *japonica*	GN	--	--	33.8 g-j	--
Prostrate #4	Sheridan hybrid seedling	JNPS	--	--	34.8 g-j	--
BWC	Sheridan hybrid seedling	JNPS	--	--	47.5 h-j	--
TM20-07	*microphylla* sport	NC	--	--	--	45.0 b
TM20-09	*sempervirens*	NC	--	--	--	51.3 bc
TM20-10	Likely *sempervirens* seedling	NC	--	--	--	56.3 bc
Green Velvet	*Buxus* hybrid	SN	45.0 d-f	23.1 b-e	51.3 fg	67.5 cd
Hohman's Dwarf	*microphylla*	SBI-Ukn	--	38.1 ef	--	--
8-00-120	Likely *harlandii* seedling	WN	--	40.9 ef	--	--
Lil One	*microphylla*	SBI-Mut	--	48.8 f	--	--
TM109	Likely *sempervirens*	NC	46.3 ef	--	--	--
1-00-794	Likely *microphylla* seedling	WN	46.7 d-f	--	--	--
TM106	Likely *sempervirens*	NC	50.0 f	--	--	--
TM111	Likely *sempervirens*	NC	55.0 fg	--	--	--
1-98-83	Likely *sempervirens*; upright	WN	4.8 ab	82.3 gh	--	--
TM101	*sempervirens* seedling	NC	8.5 ab	92.0 hi	--	--
Thomas Jefferson [w]	*sempervirens* seedling	SBI	60.0 f-h	--	--	--
Robert Tall	Likely *sempervirens* seedling	SBI-PC	--		60.0 j	--

Table 8. Continued.

Highly susceptible to blight						
TM20-02	Likely *microphylla*	NC	--		--	67.5 cd
TM107	Likely *microphylla,* variegated	NC	72.5 g-i	--	--	--
New Boxwood	*sempervirens* sport	SBI-PC	--	70.0 g	--	--
Buddy	*sempervirens*	PVN	--	71.9 g	--	--
TM104	Likely *sempervirens* seedling	NC	75.0 g-i	--	--	--
3-99-158	Likely *sempervirens* seedling	WN	80.0 hi	--	--	--
TM20-06	Likely *sempervirens*	NC	--	--	--	81.3 de
Vardar Valley	*sempervirens*	SBI-Ukn	--	85.1 hi	--	--
UR BH	*sempervirens* seedling	SBI-PC	--		88.5 k	--
TM20-05	Likely *microphylla*	NC	--	--	--	88.8 ef
TM20-03	Likely *sempervirens*	NC	--	--	--	91.5 ef
TM20-04	Likely *microphylla*	NC	--	--	--	94.5 ef
Grace Hendrick Phillips	*microphylla*	SBI-Ukn	--	87.9 hi	--	--
TM105	Likely *sempervirens* seedling	NC	83.3 i	--	--	--
Suffruticosa	*sempervirens*	SBI-Ukn	85.0 i	91.4 hi	90.0 k	96.0 f
TM103	Likely *sempervirens* seedling	NC	87.5 i	--	--	--
Chloe	*sempervirens*	PVN	--	96.9 i	--	--

[z]Source codes: CN=Cole's Nursery, Pipestem WV. GN=Greenleaf Nursery, Park Hill OK. JNPS=JN Plant Selections, Milwaukee WI. MN=Monrovia Nursery, Monrovia CA. NC=North Carolina private collection. PVN=Pine View Nursery, Leitchfield, KY. SBI-Mut=Saunders Brothers Inc., (SBI) collection, Piney River VA - Mutation found at SBI. SBI-PC= Saunders Brothers, Inc., Piney River VA. SBI acquired from private collection. SBI-Ukn=Saunders Brothers, Inc., Piney River VA. Original source unknown. Often many years in SBI collection. SN=Sheridan Nurseries, Ontario, CAN. WN=Woodland Nursery, Salisbury MD. WWN=Willoway Nursery, Avon, OH.

[y]Means of four replications. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

Color code for blight susceptibility: Green- having varying degrees of resistance; Yellow- moderately susceptible;

red- highly susceptible. Blue indicates inconsistent reactions that affect reliable positioning of the cultivar.

[x]See Tables 10–13 for additional infection and defoliation ratings during the years the trials were in progress.

[w]Current cultivar tradenames and patent numbers: Cole's Dwarf=Little Missy USPP 24703; Glencoe=Chicagoland Green™; Golden Dream USPP 16052; Gregem=Baby Gem™ USPP 21159; Grejade=Baby Jade™ USPP 26656; Green Gem USPP 3736; Highlander USPP 22978; Monrue= Green Tower™, USPP 15243; Peergold=Golden Dream USPP 16052; RLH-BI=Emerald Knoll™ USPP 24443; SB 108=NewGen Independence® USPP 32421; SB 300=NewGen Freedom® USPP 28888; Thomas Jefferson=Piney Mountain® USPP 23869; Robbuxupt=Uptight™ USPP 21390P2; Wee Willie USPP 17007.

Table 9. Rainfall, mean monthly temperatures, and boxwood blight infection risk, Low Gap, NC. Apr-Oct 2016-2020.

	Weather data [z]		Blight infection risk criteria [y]	
Year/ month	Rainfall total (in.)	Mean temp. (F) Maximum/ Minimum	Days with high risk of infection	Daily mean Blight risk index
2016 Apr	2.11	72.1/40.9	0	41.2
May	4.80	75.8/51.9	1	185.3
Jun	2.30	86.8/58.3	6	285.7
Jul	3.33	90.1/64.7	7	386.0
Aug	5.05	86.6/65.5	11	471.0
Sep	2.90	84.3/59.9	5	329.7
Oct	2.00	74.2/46.8	1	127.3
2017 Apr	8.96	76.3/47.3	5	222.3
May	9.39	80.0/52.1	4	205.3
Jun	2.31	85.2/57.1	5	270.9
Jul	3.55	89.9/63.3	8	350.8
Aug	3.46	85.7/61.4	7	344.6
Sep	4.46	81.2/53.5	7	341.6
Oct	8.29	75.5/44.4	7	260.6
2018 Apr	7.93	70.5/37.6	0	24.0
May	9.29	83.0/57.6	10	358.2
Jun	6.77	88.2/60.9	8	367.4
Jul	8.17	87.9/62.8	11	422.3
Aug	7.99	86.7/62.2	15	496.8
Sep	9.36	84.4/64.2	22	685.4
Oct	8.74	73.1/46.2	8	265.1
2019 Apr	5.72	75.4/43.6	0	95.3
May	4.03	84.1/54.9	2	219.7
Jun	9.14	84.5/58.3	7	335.8
Jul	3.71	90.1/63.7	8	384.7
Aug	3.54	88.3/61.3	10	404.5
Sep	0.43	88.8/58.2	3	245.6
Oct	9.05	76.7/47.3	3	201.7
2020 Apr	8.84	71.6/39.5	0	30.5
May	11.18	74.6/47.7	8	281.7
Jun	4.59	84.6/58.6	5	312.6
Jul	6.82	90.4/64.2	9	375.4
Aug	13.88	87.8/64.5	9 (+12) [x]	442.4
Sep	4.04	80.1/55.4	9 (+8) [x]	395.3
Oct	10.08	75.6/44.9	3	179.8

Date of first high risk infection period of the year: 2016- 21 May; 2017- 22 Apr; 2018- 17 May; 2019- 6 May; 2020- 23 May.

[z]Data sources for temperature and rainfall: https://mesonet.agron.iastate.edu/sites/monthlysum.php?station=RAVN7&network=NC_DCP.

[y]Boxwood blight risk criteria: http://uspest.org/risk/boxwood_app?sta=RAVN7.

Model documentation: Coop, 2020.

[x]Extended wetting using microsprinklers added about 20 high infection days in Aug-Sept 2020.

mulched. Weeds near the plants were controlled mechanically, and in the center aisles they were controlled with glyphosate, applied with a back-pack sprayer. The 2015 and 2018 plantings were watered with a garden hose as needed to establish plant growth and with minimal irrigation after establishment. In 2020, irrigation for plant growth and to create wetting periods for infection was applied with micro-sprinklers on 31 cm (1 ft) risers to boxwood plants 13-20 cm (5-8 in) tall. Natural rainfall, mean monthly temperatures, and natural boxwood blight infection risk data for April-October 2015-2020 (Table 9) were obtained from a weather station located 4.8 km (3 mi) from the test site. Cultivars and selections in the blight trials, and their *Buxus* species and plant source are summarized with plant defoliation data in Table 8. This was not a comprehensive study of all popular cultivars. Many of the named cultivars in the earlier LM trials (Table 1) were not included in the currently reported boxwood blight trials (Table 8) because they had already been tested and documented as susceptible or resistant to boxwood bight (Ganci 2014, Ganci et al 2013). Selections were based on the Ivors' studies and other observations – by 2015 many cultivars had already been screened, deemed susceptible (or highly resistant), and were not included in further evaluation. Thus, of the 75 plants included in our blight trial plantings in 2015, 2018, and 2020, 58 were new un-named selections.

2015 planting boxwood blight trial (Trial 1, 2017 ratings). Thirty-two cultivars and selections were placed adjacent to plants in an existing row of moderately blighted 1.2-1.5 m (4-5-ft) tall *B. sempervirens* boxwood inoculum source plants spaced at 2.4 × 2.4 m (8 × 8 ft) (Table 10). Four test plants were placed on the corners of each of the inoculum source boxwood plants 0.6 m (2 ft) from the inoculum source plant. There were four replicates of each test plant arranged in a randomized complete block experimental design. Percentage of leaves with infection and percent of plant defoliated were rated on 15 September 2016 and 20 June, 30 August, and 14 November 2017.

2018 trial boxwood blight trial. In April 2018, another planting involving 24 cultivars and un-named selections was established in rows adjacent to the 2015 trial planting (Table 11). Prior to planting, the area was chisel-plowed, disked and rototilled. The experimental and planting design were similar to the 2015 trial, but new *B. sempervirens* boxwood plants, rather than existing plants, were placed at a 2.4 by 2.4 m (8 ft by 8 ft) spacing as inoculum source plants. The inoculum source plants were all of a single strain of *B. sempervirens* boxwood typical in North Carolina. Early in the growing season, the source plants were uniformly inoculated by sprinkling the tops of the plants with 44 ml (3 tbls) of diseased leaf debris retained from infected plants in 2017. There were four test plants placed around each source plant and four replicates of each test plant in a randomized complete block experimental design. Percentage of leaves with infection and percent of plant defoliated were rated on 6 Jul, 23 August, and 7 November 2018. The Fall of 2018 presented the "perfect storm" for boxwood blight with extreme amounts of rain and wetting, and the 7 November data showed the most severe defoliation seen in the trial area in four years.

2020 boxwood blight trials (Trials 1 and 2). Two more plantings, involving 28 and 14 cultivars and selections, were planted April 2020 in a previous trial site (2020 Trials 1 and 2, Tables 12 and 13). In this trial area, following severe blight in 2018, the land had been chisel-plowed and disked in the Fall of 2018, and much of the debris was removed, but many leaves were naturally scattered through soil tillage throughout the 2020 plot areas. In the 2020 plantings, the goal was to complete testing on all varieties in just one growing season by mist-irrigating to promote artificial infection periods with extended wetting in the evening. Test plants were small, mostly 13-20 cm (5-8 in.)

Table 10. Boxwood cultivar/selection performance in the boxwood blight field trial 1, Low Gap, NC, 2016-2017. Sorted by defoliation 14 Nov 2017.

	% leaves infected or % of plant defoliated on indicated date [z]											
	% leaves with infection						% of plant defoliated					
	2017				15 Sep		2017					
Boxwood cultivar / selection	20 Jun		30 Aug		14 Nov		2016		20 Jun		30 Aug		14 Nov	
SB17	0.0	a	0.0	a	0.8	a	0.0	a	0.5	ab	0.0	a	0.3	a
TM110	0.3	a	0.0	a	1.5	a	6.3	ab	0.6	ab	0.0	a	0.5	a
TM108	0.4	a	1.8	a-c	1.3	a	0.3	a	1.3	ab	2.5	a-c	0.6	a
TM102	0.1	a	1.3	a-c	1.5	a	0.3	a	1.0	ab	1.3	ab	1.3	a
SB 108	0.8	ab	0.8	ab	4.0	ab	1.5	ab	1.4	a-c	0.0	a	1.8	a
Cole's Dwarf	0.0	a	0.0	a	1.3	a	0.0	a	0.9	ab	0.0	a	2.0	ab
11-00-489	1.0	ab	0.3	ab	5.3	ab	4.0	ab	0.1	a	0.5	a	2.8	ab
10-00-398	3.5	ab	5.5	a-d	4.0	ab	0.3	ab	1.3	ab	0.0	a	3.5	ab
8-00-113	1.0	ab	0.0	a	6.3	a-c	8.3	a-c	0.2	a	0.0	a	4.0	ab
9-00-254	0.3	a	0.0	a	5.3	ab	2.5	ab	6.7	a-c	16.7	a-d	4.3	ab
1-98-83	0.1	a	1.3	a-c	7.0	a-c	–		0.9	ab	0.5	a	4.8	ab
9-00-174	0.5	ab	0.0	a	21.0	c-f	0.0	a	0.0	a	0.0	a	6.0	ab
8-00-84	0.5	ab	0.3	ab	9.3	a-c	0.0	a	0.1	a	0.0	a	7.3	ab
1-98-96	0.1	a	1.0	a-c	8.8	a-c	1.5	ab	0.1	a	0.0	a	7.5	ab
TM101	0.1	a	0.8	a-c	9.8	a-c	28.8	c-g	4.0	a-c	0.0	a	8.5	ab
8-00-117	0.4	a	0.3	ab	17.5	b-d	7.5	ab	2.8	a-c	0.0	a	16.3	bc
Green Beauty	0.4	a	8.8	a-e	17.5	b-f	11.8	a-e	1.8	a-c	3.0	a-d	23.8	cd
TM112	6.5	ab	27.5	d-f	25.0	d-g	33.8	d-g	9.0	b-d	18.8	de	26.3	c-e
10-00-329	8.5	ab	10.7	a-e	35.0	d-h	66.7	h	3.7	a-c	4.0	a-d	36.7	d-f
11-00-492	4.8	ab	16.5	a-e	26.3	d-g	16.8	b-f	3.3	a-c	11.3	a-e	38.8	d-f
Green Velvet	1.4	ab	17.5	b-f	35.0	d-h	8.3	a-d	6.1	a-d	7.5	a-d	45.0	d-f
TM109	2.6	ab	14.3	a-e	37.5	f-i	52.5	gh	5.3	a-c	18.8	c-e	46.3	ef
1-00-794	0.5	ab	0.0	a	21.7	c-f	25.0	a-f	19.2	d	16.7	b-e	46.7	d-f
TM106	0.8	ab	2.5	a-c	40.0	f-i	42.5	f-h	11.3	cd	15.0	c-e	50.0	f
TM111	1.0	ab	12.5	a-d	31.3	d-h	20.0	b-f	2.4	a-c	11.3	a-d	55.0	fg
Thomas Jefferson	2.3	ab	21.3	c-f	51.3	h-j	41.3	e-h	2.4	a-c	12.5	b-e	60.0	f-h
TM107	1.5	ab	18.8	a-e	36.3	e-h	35.0	e-h	51.3	e	60.0	g	72.5	g-i
TM104	10.3	ab	15.0	a-e	60.0	i-k	40.0	f-h	10.6	b-d	20.0	c-e	75.0	g-i
3-99-158	0.3	a	7.5	a-d	30.0	d-h	10.0	a-c	4.0	a-c	5.0	a-d	80.0	hi
TM105	12.2	bc	30.0	d-f	43.3	g-i	46.7	gh	17.5	d	30.0	ef	83.3	i
Suffruticosa	44.5	d	35.0	ef	67.5	k	91.8	i	74.4	f	70.0	g	85.0	i
TM103	33.3	cd	50.3	f	62.5	jk	56.3	gh	38.1	e	47.5	fg	87.5	i

[z]Means of four replications. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

tall, and the liners were planted 17 April 2020. There were four replicates of each test plant in a randomized complete block design with 0.9 m (3 ft) between plants in the row and 1.2 m (4 ft) between rows. A complete replication occupied one row. The test plants were not mulched. A Micro-Sprinkler irrigation system was installed at the time of planting and the plants were thoroughly watered in and watered on an as-needed basis throughout the summer. The irrigation system (Netafim Ltd., Tel Aviv, Israel), which delivered 44.3 L (11.7 gal) per hr from 31-cm (1-ft) risers centered between all plants in the row and controlled by TBOS/TBOSII control modules (Rainbird Corp., Tucson AZ), was run 2 min per hr every hr from 1900-2300 hr every evening from early August to 30 September 2020. Natural inoculum in the area was supplemented with boxwood blight-infected leaf and shoot debris with 75 mL (5 tbls) of debris placed into the center of each plant 30 May and 24 July 2020. Percentage of leaves with infection and percent of plant defoliated were rated on 3 September, 9 October, and 6 November 2020.

Results and Discussion

Boxwood leafminer trials, Piney River, VA. LM susceptibility ratings of 146 cultivars and selections represent 3-yr means, based on counts of the number of larvae per leaf (Table 1). Column means are analyzed statistically for those entries in that trial, but they are grouped in the table by number of larvae per leaf to indicate relative susceptibility across all the trials. The table is color-coded to indicate degrees of resistance/ low susceptibility, moderate susceptibility, and high susceptibility. The most LM-resistant cultivars showed no damage or little significant damage, while moderately susceptible ones showed some visible damage, and highly susceptible ones showed severe damage. By using the term "resistance" we do not intend to imply "immunity", but susceptibility low enough that control measures can be reduced compared to moderately susceptible ones.

There is a wide range in susceptibility shown, from no larvae or few larvae per leaf to more than 15 larvae per leaf over four years of a greenhouse trial (Tables 1 and 7). This indicates strong resistance or little resistance to reproduction in a cultivar. Forty-two cultivars showed resistance/ low susceptibility with no larvae to fewer than 1.2 larvae per leaf, 44 were highly susceptible with more than 3.8 larvae, and 60 cultivars were moderately susceptible, ranging from 1.3 to 3.77 larvae/leaf (Table 1). Named cultivars that were free of any LM infestation included

Table 11. Boxwood cultivar/selection performance in boxwood blight field trial 2, Low Gap, NC, 2018. Sorted by defoliation 7 Nov 2018.

	% infection or defoliation on indicated date [z]											
	% leaves with infection						% of plant defoliated					
Bxwood cultivar/selection	6 Jul		23 Aug		7 Nov		6 Jul		23 Aug		7 Nov	
Peergold	0.6	a-c	0.5	a	19.5	a	2.0	a-c	1.0	ab	5.9	a
11-0-489	0.9	a-e	6.0	d-g	30.6	a-e	4.4	a-d	4.5	b-d	8.6	ab
TM110	1.4	a-e	0.9	ab	30.3	a-e	3.3	a-c	1.6	a-c	10.9	ab
Green Beauty	0.0	a	1.4	a-c	25.3	ab	1.0	a	1.6	a-c	11.9	ab
Wee Willie	4.8	d-g	5.0	c-g	19.4	a	13.4	ef	13.8	ef	15.0	a-d
SB 108	0.3	ab	1.1	ab	47.5	c-g	1.1	a	1.1	a	15.3	a-c
Cranberry Creek	1.0	a-d	2.5	a-d	27.5	a-c	2.5	a-c	3.4	a-d	16.5	a-d
SB 300	3.3	b-f	1.5	a-c	33.1	a-f	1.3	ab	1.6	a-c	16.9	a-d
SB17	4.1	c-g	3.5	b-d	30.0	a-d	11.6	d-f	7.9	d-f	20.3	b-e
Green Velvet	8.9	fg	9.9	e-g	46.3	b-g	14.3	ef	9.5	d-f	23.1	b-e
TM102	1.6	a-e	2.5	a-d	30.6	a-e	5.6	b-e	3.4	a-d	24.4	b-e
1-98-96	2.1	a-e	3.6	b-e	26.3	a-c	4.0	a-c	4.4	b-d	28.8	c-f
TM108	0.5	a-c	2.3	a-d	35.6	a-f	5.0	a-d	5.8	cd	31.3	d-f
Hohman's Dwarf	22.8	ij	9.9	fg	55.0	f-h	36.5	hi	14.9	ef	38.1	ef
8-00-120	1.8	a-e	6.0	d-g	41.9	b-g	5.9	c-e	4.1	b-d	40.9	ef
Lil One	2.8	b-f	1.8	a-d	50.6	d-h	5.8	b-e	3.5	a-d	48.8	f
New Boxwood	18.1	hi	12.0	g	65.0	hi	18.1	fg	14.9	f	70.0	g
Buddy	31.9	j	29.8	ij	53.1	d-h	43.4	i	39.4	g	71.9	g
1-98-83	0.8	a-e	4.6	c-g	64.4	g-i	2.4	a-c	4.8	cd	82.3	gh
Vardar Valley	21.3	ij	20.0	hi	38.1	a-f	35.0	hi	35.0	g	85.1	hi
Grace Hendrick Phillips	2.8	a-e	4.1	b-f	79.4	i	3.5	a-c	3.1	a-d	87.9	hi
Suffruticosa	29.1	ij	34.5	j	57.3	gh	31.9	gh	60.0	h	91.4	hi
TM101	4.6	e-g	3.3	b-d	63.1	gh	15.3	f	6.8	de	92.0	hi
Chloe	9.8	gh	19.4	h	53.1	e-h	27.5	gh	40.6	g	96.9	i

[z]Means of four replications. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

'Buddy', 'Richard', *B. harlandii* , 'Morris Dwarf Variegated', 'Natchez', and 'Unraveled'. Selections K-74, K-96, and K-106 were also free of infestation. *Buxus sempervirens* 'Inglis', included as a highly susceptible standard and LM source plant, ranged from 6.5 to 9.2 larvae per leaf over four trials. Other highly susceptible, named cultivars were 'Green Gem', 'Green Velvet', 'Glencoe' (a selected hybrid from Chicago Botanic Garden), 'Pullman', 'Cliffside', 'Ohio', 'Latifolia Maculata', 'Justin Brouwers', 'Rochester', 'Morrison Garden', 'Northern New York', 'Green Mound', 'Abilene', 'John Baldwin', 'Green Beauty', 'Denmark', 'Green Mountain', 'Northern Emerald', 'Latifolia Maculata', 'Variegata', 'Angustifolia', and 'Beehive'.

Among species performance, 14 of the 19 cultivars in *B. microphylla*/*microphylla* var. *japonica* grouping were in the least susceptible group, but three from this group were highly susceptible. Five of the seven representatives of *B. sinica*/*sinica* var. *insularis* species grouping were also in the most resistant/ least susceptible group, including 'Nana', 'SB17', 'Wee Willie', 'Franklin's Gem', and 'SB 300'. Among the *B. harlandii* representatives, 'Richard' and *B. harlandii* sp. were very resistant and 9-00-174 was quite resistant, but six selections thought to be *B. harlandii* seedlings were moderately susceptible, and two appeared to be highly susceptible. Among the species *B. microphylla*/*microphylla* var. *japonica, B. sinica*/*sinica* var. *insularis*, and *B. harlandii*, there appears to be good potential for sources of LM resistance for a controlled breeding program.

The 100 *B. sempervirens* cultivars and likely *sempervirens* seedlings ranged across the spectrum of LM susceptibility from highly resistant ('Buddy') to highly susceptible ('Inglis' and five numbered selections). The male parent of numbered seedling selections is not known, so it is possible that a male parent of another species imparted resistance (or susceptibility) to the *sempervirens* seedling offspring.

We noted generally higher levels of infestation in the greenhouse trial, and that might be due to less wind in the environment, making the conditions more favorable for mating and egg-laying by the weak-flying adult leafminers.

Our data are quantitative for the number of larvae within sampled leaves, and it is not known exactly how the observed resistance to LM reproduction is brought into play. Qualitative observations during the evaluations indicate that there may be examples of several proposed mechanisms (d'Eustachio and Raupp 2001). Some cultivars appear to have fewer oviposition sites in their leaves than others, suggesting that they may be less attractive to the egg-laying adults or that they may not be in a tender growth stage for oviposition when the adults are active. Larvae seem to develop more slowly in leaves of some boxwood cultivars than in others, perhaps because of a lack of some needed nutrient or growth factor. Some varieties seem to form more dense tissues around the larvae, perhaps walling them off from the tender parenchyma cells that they need to feed upon. It also is possible that some varieties/species might produce phytochemicals that are toxic to the larvae.

These trials, involving 146 cultivars and selections, were conducted mostly in one field which had been naturally-infested primarily from one LM population source; however, populations in other locations might affect some

Table 12. Boxwood cultivar/selection performance in boxwood blight field trial 3, Low Gap, NC, 2020. Sorted by defoliation 6 Nov 2020.

Boxwood cultivar/ selection	% infection or defoliation on indicated date [z]			
	% leaves with infection		% of plant defoliated	
	9 Oct	6 Nov	9 Oct	6 Nov
SB19-03	7.3 a-c	1.8 ab	2.5 ab	0.0 a
RLH-BI	4.0 ab	0.0 a	1.8 a	0.0 a
TM110	11.8 a-f	8.0 a-d	3.0 ab	1.3 ab
SB 300	3.5 a-c	7.5 a-d	2.8 ab	1.8 ab
SB19-08	4.3 a-c	14.3 b-e	2.3 ab	3.0 a-d
SB17-01	6.0 a-c	7.5 a-c	3.3 ab	3.8 a-c
Green Beauty	3.0 a	10.5 b-e	1.8 a	3.8 a-d
SB 108	7.8 a-d	27.5 d-g	4.5 ab	5.0 a-e
SB19-04	12.8 a-f	25.0 c-g	9.3 a-c	6.3 a-d
SB19-05	12.5 a-f	37.5 fg	6.8 a-c	7.5 a-e
SB19-07	7.5 a-d	22.5 c-g	4.3 ab	8.8 a-f
Robert Micro	22.5 c-g	21.3 c-g	8.0 a-c	9.3 a-f
M613B	3.0 a	12.5 b-e	3.5 ab	10.0 a-e
Select E	8.8 a-e	13.8 b-e	7.5 a-c	10.0 a-d
Select I	7.5 a-d	17.5 c-f	3.0 ab	11.3 b-g
SB19-02	12.5 a-f	11.3 b-e	4.3 ab	11.8 b-g
Green Mountain	35.0 f-i	20.5 c-g	25.5 c-e	20.0 c-g
SB19-01	30.0 d-h	13.8 b-f	11.8 a-d	21.3 d-h
Gregem	33.8 e-i	23.8 c-g	16.3 b-e	22.5 e-h
SB19-06	25.0 b-g	42.5 g	15.5 a-d	31.3 f-i
M616C	45.0 g-j	28.8 d-g	31.3 de	32.5 g-j
Grejade	16.8 a-f	33.8 e-g	6.0 a-c	33.8 g-j
Prostrate #4	55.0 h-j	20.0 c-g	25.5 c-e	34.8 g-j
BWC	42.5 g-i	43.8 g	37.5 e	47.5 h-j
Green Velvet	60.0 i-k	37.5 fg	37.5 e	51.3 ij
Robert Tall	50.0 h-j	42.5 g	31.3 de	60.0 j
UR BH	67.5 jk	74.8 h	71.3 f	88.5 k
Suffruticosa	75.8 k	87.5 h	72.5 f	90.0 k

[z]Means of four replications. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

Table 13. Boxwood cultivar/selection performance in boxwood blight field trial 4, Low Gap, NC, 2020. Sorted by defoliation 7 Nov 2020.

Boxwood cultivar/ selection	% infection or defoliation on indicated date [z]			
	% leaves with infection		% of plant defoliated	
	9 Oct	6 Nov	9 Oct	6 Nov
TM102	2.3 a	4.3 a	1.3 a	1.3 a
Green Beauty	7.0 ab	10.0 ab	3.0 a	3.5 a
TM108	5.3 ab	5.0 a	2.3 a	4.3 a
TM20-08	21.8 bc	47.5 c-e	3.0 a	5.0 a
TM20-07	45.0 de	51.3 c-e	22.5 b	45.0 b
TM20-09	27.5 cd	17.5 ab	21.0 b	51.3 bc
TM20-10	70.0 fg	28.8 b-d	32.5 b	56.3 bc
Green Velvet	57.5 ef	70.0 e-g	25.0 b	67.5 cd
TM20-02	60.0 ef	17.5 ab	20.0 b	67.5 cd
TM20-06	75.0 gh	52.5 d-f	55.0 cd	81.3 de
TM20-05	82.5 gh	25.0 bc	60.0 cd	88.8 ef
TM20-03	81.3 gh	72.5 fg	57.5 cd	91.5 ef
TM20-04	86.3 gh	80.0 g	65.0 cd	94.5 ef
Suffruticosa	87.5 h	84.5 g	75.0 d	96.0 f

[z]Means of four replications. Column mean separation by Waller-Duncan K-ratio t-test (p=0.05).

of these cultivars differently, and reactions in different geographical locations might differ, and different environmental conditions could affect apparent susceptibility. Our findings that *B. sempervirens* 'Vardar Valley' and 'Suffruticosa' are LM-resistant agree with d'Eustachio and Raupp (2001) and Raupp et al (2004), who stated that these cultivars are quite resistant. We have found numerous exceptions to the general statement of Batdorf (2005) that most cultivars of *B. sempervirens* and *B. microphylla* are susceptible to LM as highly resistant *B. sempervirens* cultivars included 'Buddy', 'Russian Blue', 'Vardar Valley', 'Natchez', 'Fineline' 'Suffruticosa' and several others. Resistant *B. microphylla* cultivars included 'Hohman's Dwarf' ('Compacta'), 'Grace Hendrick Phillips', 'Green Pillow', 'Peergold', 'Cole's Dwarf' 'Big Leaf Wintergreen' and the *B. microphylla* seedling 'SB 108'. Our replicated trial results are in general agreement with casual field observations of the authors, the national boxwood trials (Saunders 2011), and observations reported in the *Boxwood Bulletin* (American Boxwood Society) and in landscape variety plantings such as the American Boxwood Society Memorial Garden, State Arboretum of Virginia, Boyce, VA. The replicated trials reported here provide data that document those field observations and have greatly expanded the number of boxwood genotypes for which we have such information. Such data and other observations form the basis of the LM ratings in the *Boxwood Guide* (Saunders Brothers 2020). These data also provide a useful basis for selection of potential LM-resistant parents useful in breeding new boxwood cultivars now and into the future.

Boxwood blight trials, Low Gap, NC. Boxwood blight (BB) defoliation ratings of 75 cultivars and selections are summarized in Table 8. Ratings of percent leaves infected and percent defoliation were conducted at several times throughout the growing season in each of four trials, and those complete data are presented in Tables 10 through 13. Because we view defoliation effects to be more detrimental to horticultural appearance and plant health in the landscape than percent of leaves with infection, we emphasize defoliation ratings rather than percent infection in our overall evaluation. Also, data listing the percent of leaves infected would be skewed by defoliation because it is impossible to conclusively determine percent of leaves with infection after leaves are no longer attached. Data in Table 8 represent the most severe defoliation after increases in blight severity late in the season. Table 8 is color-coded to indicate degrees of resistance and low susceptibility, and moderate and high susceptibility. By using the term "resistance" we do not intend to imply "immunity", but susceptibility low enough that control is improved compared to moderately susceptible ones. The most BB-resistant cultivars showed little or no defoliation, moderately susceptible ones would show readily apparent symptoms with some defoliation, while highly susceptible ones could suffer extremely detrimental, life-threatening defoliation. Plants that died following heavy defoliation were rated as 100% defoliated in subsequent evaluations. We recognize that with boxwood there is some natural shedding of leaves over time, but did not see that as a factor

in the defoliation ratings of the young, actively growing trial plants, and that defoliation in our trial ratings was primarily due to the effects of blight.

Table 8 column means are analyzed statistically for the entries in that trial, but they are grouped in the table by percent defoliation to indicate relative resistance and susceptibility across all of the trials. Cultivars 'Green Beauty', 'Green Velvet', and 'Suffruticosa' were included as standards in each trial to represent the more resistant, moderately susceptible and highly susceptible groups, respectively.

Based on a boxwood blight infection risk model (Coop 2020), there were great differences in natural disease pressure from year to year. Of the three years in which BB data were collected, 2018 was the most favorable for natural disease development, with June-October rainfall of 104.1 cm (41.0 in.) and 64 predicted high-risk infection days (Table 9); 2017 June-October rainfall was only 56.1 cm (22.1 in.) with 34 high risk infection days, while 2020 had June-October rainfall of 100 cm (39.4 in.) and 35 natural infection days. (Use of microsprinklers to extend wetting periods in 2020 likely added 12 high infection days in August and 8 days in September beyond those reported in Table 9, which were based on data from the remote weather station). Based on the boxwood blight risk model (Coop 2020), natural mean daily blight infection risk index for June-October for 2017, 2018 and 2020, respectively, was 313.7, 447.4, and 341.1.

A wide range in susceptibility was evident in each of the four trials, from little defoliation to almost complete defoliation of 'Suffruticosa' boxwood. The standard for low susceptibility, *B. microphylla* var. *japonica* 'Green Beauty', performed as expected, ranging from 3.5% defoliation in 2020 to 23.8% defoliation in 2018 (Table 8). Thirty-two of 75 cultivars and selections showed some degree of resistance in one or more trials, usually with less than 20% defoliation when the susceptible standard 'Suffruticosa' ranged from 85-96% defoliation. Twenty-four cultivars were moderately susceptible, ranging from 20 to 60% defoliation in trials when 'Green Velvet' ranged from 23.1 to 67.5% defoliation. However, two selections placed in this group, 1-98-83 and TM101, had shown inconsistent reactions, 4.8 and 8.5% defoliation, respectively, in 2017, but 82.3 and 92.0% in 2018. Results with 'Green Beauty', 'Green Velvet' and 'Suffruticosa' as standards in our field trials fit well with the susceptibility spectrum range noted in potted plant trials (Ganci et al 2013, LaMondia and Shishkoff 2017) and in a meta-analysis approach that included detached leaf assays (Kramer et al 2020).

Among species reactions, partial resistance was offered by seven of the eight numbered *B. harlandii* seedlings and one sport. Nine of the 11 representatives of *B. sinica*/*sinica* var. *insularis* species grouping were also in the resistant group, including RLH-BI, 'Wee Willie', 'SB 300' and SB17. Fourteen of the 28 *B. microphylla/ microphylla* var. *japonica* seedlings, sport selections and named cultivars were in the resistant group, including 'Peergold', 'SB 108', 'Cole's Dwarf', and 'Green Beauty'; however, five from these species groupings were highly susceptible. The group of boxwood seedlings with Sheridan hybrid parentage (a potential source of winter hardiness), included three selections with low susceptibility (M613B, Select I, and Select E), and three that were moderately susceptible.

The group of 25 *B. sempervirens* candidates offered the least potential source of blight resistance, with only two that were resistant and 23 that were moderately or highly susceptible. Highly susceptible *B. sempervirens* named cultivars included 'Suffruticosa', 'Buddy', 'Vardar Valley', and 'Chloe'.

It should be noted that 58 of the 75 candidates in the blight trials are numbered selections of seedlings or sports. As noted earlier, many of the named cultivars in the earlier LM trials (Table 1) were not included in the currently reported blight trials (Table 8) because they had already been tested and documented as susceptible or resistant (Ganci 2014, Ganci et al 2013). Ganci (2014) found that 43 *B. sempervirens* cultivars were more susceptible than cultivars of other species. Among those least susceptible to blight were *B. harlandii* 'Richard', *B. sinica* var. *insularis* 'Nana', *B. microphylla* 'Golden Dream' ('Peergold') and *B. microphylla* var. *japonica* 'Green Beauty' (Ganci et al. 2013), and these have been listed as such in the *Boxwood Guide* (Saunders Brothers 2020).

Ganci (2014) studied possible components of partial resistance to boxwood blight in *Buxus* cultivars and attributed the high susceptibility of *B. sempervirens* to its shorter required incubation and latent periods, larger lesion area, and high disease severity. The components of resistance in *B. sinica* var. *insularis* 'Nana', *B. harlandii*, and *B. microphylla* var. *japonica* 'Green Beauty' included their minimal disease severity and their longer incubation and latent period requirements (Ganci 2014). Further identification and verification of BB resistance in other commercial cultivars has been documented (Ganci et al 2013, Ganci 2014, Shishkoff 2014, and LaMondia and Shishkoff, 2017, Kramer et al. 2020).

Seven boxwood cultivars and selections in these trials have been identified as having both blight and leafminer resistance: 'Peergold', 'Cole's Dwarf', 'SB 108', 'SB 300', 'Wee Willie', 'SB17' and 9-00-174. Two entries are shown be to resistant to blight but susceptible to LM: 'Green Beauty' and 9-00-254. Four cultivars were shown to be resistant to LM but susceptible to blight: 'Buddy', 'Vardar Valley', 'Grace Hendrick Phillips' and 'Suffruticosa'. Except for one greenhouse leafminer trial, all of these leafminer and blight trials were conducted under realistic field conditions as opposed to laboratory evaluation.

As part of an ongoing effort to develop new boxwood cultivars with blight and boxwood leafminer resistance, six selections offer good boxwood blight resistance and await further evaluation for LM resistance and other characteristics: SB19-03, RLH-BI, 11-0-489, TM102, TM108 and TM110. Resistance of boxwood to both boxwood leafminer and boxwood blight offers distinct advantages in managing them, such as avoiding the cost and risks of insecticide and fungicide use and freedom from the concerns of application timing, coverage, and residual control. As pesticides become more tightly regulated, plant resistance offers means to continue planting boxwood in

home landscapes and public garden areas where insecticide or fungicide use may be more restricted or avoided.

Cultivar resistance is fundamental to integrated sustainable management of boxwood insect and disease pests, and selection and breeding of new cultivars resistant to boxwood leafminer and boxwood blight is an important endeavour now and into the future. Among the seven cultivars and selections identified in these trials as having both blight and leafminer resistance, five are available commercially as trademarked and/or patented cultivars: *B. microphylla* 'Peergold' ('Golden Dream', USPP 16052); 'Cole's Dwarf' (*B. microphylla* 'Little Missy', USPP 24703); *B. microphylla* seedling 'SB 108' (NewGen Independence®, USPP 28888); *B. sinica* 'SB 300' (NewGen Freedom®, USPP 32421); *B. sinica* var. *insularis* 'Wee Willie', (USPP 17007). These cultivars offer a variety of attractive and useful shapes, sizes, leaf textures and colors (Saunders Brothers. 2020). Selections 'SB17' (likely *B. sinica*) and 9-00-174 (likely *B. harlandii*) are not currently available commercially.

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