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A Field Survey of Grapevine Germplasm Susceptible to Eutypa Dieback

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Abstract. **Eutypa dieback of grapevine is a trunk disease that impacts vineyard productivity worldwide. Grape germplasm is typically evaluated for resistance to Eutypa dieback through controlled inoculations in the greenhouse, although the high level of replication required of this approach (40 plants per genotype) can limit the total number of genotypes evaluated. An alternative approach is to evaluate naturally infected genotypes in the field. We rated the incidence and severity of vines with the diagnostic leaf symptoms of Eutypa dieback and the incidence of mortality among such vines of 973 *Vitis vinifera* accessions (planted in duplicate) at the US Department of Agriculture, National Clonal Germplasm Repository in Davis, CA, USA, which is maintained as a living collection for grape research. Across 3 years and spanning a total of 5 years (2011, 2013, and 2015), 120 accessions had leaf symptoms in one or more years ("susceptible accessions"). Courbu blanc [Davis *Vitis* identification tag (DVIT) 2313], Frankenthal blanc (DVIT 2115), and Pinot gris (DVIT 0907) were the only accessions with leaf symptoms each year. Accessions with the most severe leaf symptoms (a rating of 5 points) were Chasselas Napoleon (DVIT 0375) and Queen of the Vineyard (DVIT 0496). We identified susceptible accessions—namely, those related to 'Chasselas' and 'Muscat'—with a shared genetic background, based on a previous single nucleotide polymorphism genotyping effort of the collection. Especially for grapevine, a long-lived perennial that is meant to produce a crop for decades, knowledge of susceptible accessions and their pedigrees can help inform breeding programs and studies on the host response to infection.**

Grapevine is the most valuable and most widely planted fruit crop in the world. Approximately 8,000,000 ha of vineyards are in cultivation worldwide for the production of grapes fermented into wines or distilled into brandy. Grapes are also eaten fresh, dried into raisins, or processed into juice and preserves. Domestication of cultivated *Vitis vinifera* subspecies *vinifera* dates back to between 6000 and 8000 years ago in the Near East, from its wild progenitor *Vitis vinifera* subspecies *sylvestris* (McGovern 2003; This et al. 2006). Although the wine market is dominated by a few cultivars (e.g., 'Cabernet-Sauvignon', 'Pinot noir', 'Sauvignon blanc'), thousands of cultivars exist (Reisch et al. 2012). Genetic diversity in the grapevine germplasm can be used to develop disease-resistant cultivars, thereby minimizing the economic and environmental costs of disease management (Cattonaro et al. 2014), especially for grape diseases that are widespread and for which fungicide applications are a routine practice to minimize disease losses (e.g., Grape powdery mildew).

Among the many diseases of grape, trunk diseases are particularly detrimental because the fungal pathogens reside in the permanent, woody structure of the vine, and these wood infections are chronic. The causal fungi are taxonomically diverse, wood-colonizing species representing different orders in Phylum Ascomycota [e.g., *Eutypa lata* (Class Sordariomycetes, Order Xylariales, Family Diatrypaceae), *Neofusicoccum parvum* (Class Dothideomycetes, Order Botryosphaeriales, Family Botryosphaeriaceae), and *Phaeoacremonium minimum* (Class Sordariomycetes, Order Togniniales, Family Togniniaceae) and Phylum Basidiomycota [e.g., *Fomitiporia polymorpha* (Class Agaricomycetes, Order Hymenochaetales, Family Hymenochaetaaeae)] (Lawrence et al. 2017a). Although the pathogens do not spread systemically throughout the vine, wood infections that are localized near fruiting positions damage the distal shoots, and this impacts both yield and fruit quality. Because of their cumulative negative effects on grape yields over time, the profitable life span of vineyards with trunk diseases is severely reduced (Kaplan et al. 2016).

Eutypa dieback, caused by the fungus *Eutypa lata* (Pers:Fr.) Tul and C. Tul. (syn. *Eutypa armeniacae* Hansf. and M.V. Carter), is one of the best-studied trunk diseases, thanks to the original research of Maurice Carter in South Australia (Carter 1991). In addition to grape, *E. lata* attacks other horticultural crops of economic importance, including almond, apricot, blueberry, cherry, and kiwi (Carter et al. 1983). The pathogen is reported from grape-growing regions around the world (Travadon et al. 2012).

Grapevines are infected by the sexual spores (ascospores) of *E. lata*, which are released during rain events from fruiting bodies (perithecia) produced on a range of woody hosts (Trouillas and Gubler 2010), and are transported by wind to susceptible pruning wounds (Carter 1991). Ascospores germinate within the xylem vessels beneath the cut surface of the wood (Carter 1960). Enzymes and toxic fungal metabolites produced by *E. lata* degrade the wood; the fungus uses structural glucose, xylose of hemicellulose, and starch as nutrients (Rolshausen et al. 2008). Infection is associated with the development of an internal wood symptom known as a lesion or canker, which appears as a dark-brown discolored section of wood, sometimes shaped like a V, radiating from the center of the wood out to the bark (in a cross section of the wood). Wood cankers are thought to result from a combination of the soft-rot type of wood decay caused by *E. lata* and host responses to infection [e.g., phenolic compounds concentrated in the wood near the infection court (Galarneau et al. 2021) and vessel occlusion (Rudelle et al. 2005)]. The leaf symptoms of Eutypa dieback are unique in that the shape of the leaf can change from a typical fan-shaped vein orientation to one in which the veins grow in parallel, resulting in flattened leaves or cup-shaped leaves. The margins of leaves on symptomatic shoots may also be necrotic (brown) and/or tattered. Flower inflorescences, if they form at all on symptomatic shoots, dry completely and die (Moller and Kasimatis 1978). Shoots growing from an infected fruiting position are more and more stunted each year, until the shoots die or no shoots grow from the fruiting position—hence the term dieback. The pathogen does not colonize leaves. Instead, leaf symptoms are thought to be a result of the actions of toxins metabolites produced by *E. lata*, which

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are translocated from infected wood out to the shoots (Lardner et al. 2006).

Grape cultivars vary in susceptibility to Eutypa dieback, based on comparisons of the severity of leaf and/or wood symptoms (Dubos 1987; Moisy et al. 2017; Péros and Berger 1994; Sosnowski et al. 2007a, 2022; Travadon and Baumgartner 2023; Travadon et al. 2013). Some resistant cultivars have a high rate of lignin and suberin deposition in the wood (Munkvold and Marois 1995) or high concentrations of lignin (Rolshausen et al. 2008). The differential expression of genes associated with enzymes of the jasmonic acid, salicylic acid, and phenylpropanoid pathways has been associated with severity of leaf symptoms, in comparisons between resistant and susceptible cultivars (Cardot et al. 2019).

Overall, reports on the resistance of grapevine cultivars to Eutypa dieback, based on field observations of plants under natural levels of disease pressure, are rare and limited to France and Australia (Dubos 1987; Loschiavo et al. 2007; Sosnowski et al. 2022). Unlike controlled inoculations in the greenhouse, field evaluations of cultivar resistance take into account the complex interactions among the pathogen, host, and the environment, which can cause resistant cultivars to show high levels of disease under different environmental conditions (Péros 1995). Phenotypes based on leaf symptoms allow for repeated observations over time, unlike phenotypes based on wood symptoms, which rely on destructive sampling of sections of the woody canopy that take over a year to retrain (canes, spurs, cordons). Furthermore, controlled inoculations in the greenhouse typically require the propagation of a minimum of 40 replicate plants per genotype and an incubation period of up to 1 year postinoculation (Travadon and Baumgartner 2023), which can limit the total number of genotypes examined. Thus, the objective of this study was to rate genetically diverse germplasm accessions originating from around the world—based on the incidence and severity of diagnostic leaf symptoms of Eutypa dieback and the incidence of mortality of symptomatic vines—in the field in the US Department of Agriculture (USDA) grape germplasm collection, in Winters, CA, USA. As this collection was genotyped with single nucleotide polymorphism (SNP) markers previously (Myles et al. 2011), our Eutypa-dieback phenotypes contribute to the further characterization of this important research resource.

Materials and Methods

The USDA–Agricultural Research Service (ARS), National Clonal Germplasm Repository in Davis, CA, USA maintains a publicly available, living collection of 973 domesticated wine and table-grape accessions, which are grown for cultivar evaluation and breeding by USDA scientists, university scientists, commercial nurseries, and horticulturists. The vineyard is located at the Wolfskill Experimental Orchard (WEO), in Winters, CA, USA (lat. 38.50204°N, long. 121.97911°W). At the start of the study, each accession was represented by two adjacent vines, both of which were propagated originally from cuttings taken from the same vine. All accessions are grafted onto St. George rootstock (established in the 1980s; $>$ 25 years old at the time of the survey). The vines are head-trained and cane-pruned, although not with the precision of a commercial vineyard. There are sufficient shoots for researchers to gather leaf and fruit samples, but canopies do not have canes of uniform length or number. Vines are pruned each year in the first 2 weeks of March. Rainfall data for this study, specifically during the rainy season (from 1 Oct to 31 May), were recorded at a California Irrigation Management Information System weather station (cimis.water.ca.gov; Winters #139), located ~100 m from the collection.

Surveys were conducted in early May 2011, 2013, and 2015, when the leaf symptoms of Eutypa dieback are most apparent on new green shoots between budbreak and bloom. Each duplicate vine per accession was examined for the presence of the following diagnostic leaf symptoms of Eutypa dieback: dwarfed, zigzag-shaped internodes; stunted shoots with deformed, cupped leaves that may also have a yellow (chlorotic) or bronzed appearance; leaves with necrotic and tattered margins; and scorched flower inflorescences (Rolshausen et al. 2015). For vines with these leaf symptoms, symptom severity was rated on a scale of 1 to 5 points, as follows: 1 point = normal-size leaves and shoots, but some leaves have necrotic (brown) margins; 2 points = normal shoot length, but some leaves are dwarfed and/or have necrotic margins; 3 points = stunted shoots with dwarfed leaves, but no leaves with necrotic margins; 4 points = stunted shoots with dwarfed leaves, and some leaves dwarfed with necrotic margins; and 5 points = no shoot growth or stunted shoot that grew and then died (Travadon and Baumgartner 2023). The number of symptomatic vines that later died (i.e., incidence of mortality) was recorded. We defined vines with diagnostic leaf symptoms of Eutypa dieback (as just detailed) as susceptible accessions. Other trunk diseases were also present in the vineyard, based on previous isolations of Botryosphaeria-dieback pathogens (*Neofusicoccum mediterraneum*, *N. parvum*) and Phomopsis-dieback pathogens (*Diaporthe ambigua*, *Diaporthe ampelina*) from vines that did not have the diagnostic leaf symptoms of Eutypa dieback, but instead had dead fruiting positions and/or stunted shoots (Fujiyoshi et al. 2021). Vines that had been retrained from the base of the trunk, as evidence that the canopy may have had trunk-disease symptoms previously and was thus retrained, were noted, but were not considered symptomatic of Eutypa dieback unless they also had diagnostic leaf symptoms.

At the start of the study, in May 2011, wood samples were collected from a subset of 20 accessions with leaf symptoms to confirm the presence of *E. lata* at the vineyard site. As the germplasm collection exists to preserve the accessions in perpetuity, it was not possible for us to sample the wood in a way that compromised the collection of leaf and fruit samples for other grape research. Because confirming infection by *E. lata* requires destructive sampling of the wood (and thus destroys all shoots growing distal to the wood that is cut away), samples were collected only from vines that had shoots with leaf symptoms growing from multiple woody parts of the canopy. In this way, we collected a wood sample from which symptomatic shoots grew, without cutting away all of the vine's shoots. From the wood samples, 16 pieces of wood (4 × 4 × 2 mm) were surface-sterilized in 0.6% sodium hypochlorite (pH 7.2) for 15 s, and rinsed twice in autoclaved, distilled water for 30 s per rinse. From the 16 pieces of surface-sterilized wood, two sets of eight pieces were plated onto two petri plates with potato dextrose agar (PDA) amended with tetracycline (1 mg/L), and 1% malt extract agar amended with benomyl 50WP (4 mg/L) and streptomycin sulfate (100 mg/L). Plates were incubated at 25 °C in darkness. Within 2 weeks of incubation, fungal colonies with morphological characteristics of *E. lata* were subcultured onto new PDA plates and further hyphal-tip–purified for identification.

At the end of the survey, we ranked susceptibility further based on the following observations and corresponding scores of a susceptibility index (summing to a total of 10 for the most susceptible): 1) the recurrence of symptoms during the 3 study years (1 point for 1 year, 2 points for 2 years, 3 points for 3 years), 2) the presence of leaf symptoms on both duplicate vines per accession (0 point for one vine, 1 point for both vines), 3) death of at least one of two duplicate vines per accession (0 point for no mortality, 1 point for death of one or both vines, in a survey year after symptoms developed), and 4) leaf symptom severity (ranging from 1 to 5 points, as defined earlier).

Based on SNP genotyping of the *V. vinifera* collection at the WEO, a previous study identified accessions with identical genotypes, parent-offspring relationships, and sibling relationships (Myles et al. 2011). We assume that our records of accession names and their corresponding Davis *Vitis* identification tag (DVIT) numbers (unique identifiers that are searchable in the GRIN-Global database) match those reported by Myles et al. (2011), and that the SNP genotypes for the accessions are accurate. As such, we report identical SNP genotypes and inferred first-order relationships among accessions that developed leaf symptoms (susceptible accessions) during the course of our study. We assume the accuracy of the cultivar names associated with the accessions, but we reference their DVIT numbers throughout, in case cultivar names are not accurate.

Results

Of the 973 wine and table-grape accessions we surveyed, diagnostic leaf symptoms of Eutypa dieback were present in at least 1 of 3 study years for 120 accessions (Table 1). Leaf symptoms were most widespread in

Table 1. Grapevine accessions with leaf symptoms of Eutypa dieback identified as susceptible during field surveys conducted in 2011, 2013, and 2015.[i]

Name[ii]	Accession no.[iii]	Type	Berry skin color[iv]	Origin	Year when leaf symptoms were present (1)/absent (0) 2011	2013	2015	Symptoms present on one (0) or both (1) vines[v]	Leaf symptom severity rating[vi]	Mortality of neither vine (0) or at least one vine (1)[vii]	Susceptibility index rating[viii]
Aromatico (Aromatica)	DVIT 0637	Table, wine	Blanc	Italy	0	0	1	1	4	0	6
Asprorombola	DVIT 0641 (PI 171200)	Table, wine	Blanc	Greece	1	0	0	1	3	0	5
Aurora	DVIT 0345 (PI 136815)	Table	Blanc	Italy	0	1	0	0	4	0	5
Austrian Seedless (a)	DVIT 1650	Table	Blanc	USA	1	0	0	0	3	0	4
Austrian Seedless (a)	DVIT 1325	Table	Blanc	USA	1	0	0	0	3	0	4
B39-63 Mlc	DVIT 1860	Wine	Blanc	Mexico	0	0	1	0	4	0	5
Barbableu	DVIT 0348 (PI 136816)	Table	Noir	Italy	1	0	0	0	3	0	4
Batta (Bhatta Ribba Black)*	DVIT 2545 (PI 364293)	Wine	Noir	India	1	0	0	1	3	0	5
Beli Potok (*V. vinifera* subsp. *sylvestris* hybrid)	DVIT 1841	Wine	Noir	?	0	0	1	1	4	0	6
Bequignol (Bequignol blanc)	DVIT 2113	Wine	Blanc	France	1	0	0	0	4	0	5
Black Ferrara	DVIT 0356	Table	Noir	USA	0	0	1	0	2	0	3
Black Hamburg (Trollinger Rot)	DVIT 1082 (PI 442838)	Table, wine	Rouge	Germany	0	0	1	0	4	0	5
Black Kishmish (Kishmish Chernyi)	DVIT 2055	Table, raisin, wine	Noir	Azerbaijan	1	0	0	0	3	0	4
Blackrose (4n) (Black Rose)	DVIT 2476	Table, wine	Noir	USA	1	1	0	0	3	0	5
Buckland's Sweetwater (Buckland Sweet Water)	DVIT 0363	Table	Blanc	UK	0	0	1	0	4	0	5
Burger (Monbadon)*	DVIT 0674	Wine	Blanc	France	1	0	0	0	4	0	5
Cape Currant*	DVIT 0369 (PI 129649)	Table	Rouge	South Africa	1	0	0	0	4	0	5
Caus × Perla de Csaba (Chaouch Blanc × Csaba Gyoengye)*	DVIT 2308 (PI 264132)	Table	Blanc	Belgium	1	0	0	1	3	0	5
CG 1481 (4n) (Gargiulo 1481)	DVIT 2480	Table	Blanc	Argentina	1	0	0	0	3	0	4
Chaouchi Politiko (Tsaouch Politico)	DVIT 0599 (PI 171340)	Table	Blanc	Greece	1	0	0	0	3	0	4
Chardonnay (b)	DVIT 0816	Table, wine	Blanc	Spain	1	0	0	0	4	0	5
Chasselas des Bouches du Rhone	DVIT 2112	Table	Rose	France	0	0	1	0	4	0	5
Chasselas Hs 14-33/4 (Chasselas H. S.) (c)	DVIT 2310 (PI 306340)	Table	Blanc	?	1	0	0	1	3	0	5
Chasselas Jababert (Chasselas blanc) (c)	DVIT 2120	Table	Blanc	?	1	0	0	1	4	0	6
Chasselas Musque (c)	DVIT 0374 (PI 120492)	Table	Blanc	France	1	0	0	1	3	0	5
Chasselas Napoleon (Bicane)	DVIT 0375 (PI 259000)	Table	Blanc	France	1	0	0	0	5	0	6
Chasselas Rose (c)	DVIT 0376	Table, wine	Rose	France	1	1	0	0	4	1	7
Chasselas Rose Royal (Chasselas Rose) (d)	DVIT 2158	Table, wine	Noir	France	1	0	0	1	3	0	5
Chasselas Tompa (Tompa Mihaly)	DVIT 0378	Table, wine	Blanc	Hungary	1	0	0	1	3	0	5
Chaush White (Chaouch Blanc)*	DVIT 1088 (PI 349732)	Table	Blanc	Turkey	1	0	0	0	3	0	4
Chenin Noir (Pineau d'Aunis)	DVIT 0692	Wine	Noir	France	0	1	0	0	3	0	4
Corbu Blanc (Courbu Blanc)	DVIT 2313	Wine	Blanc	France	1	1	1	1	4	0	8
Criolla Mesa (Criolla Grande Sanjuanina)	DVIT 0385	Table, wine	Noir	Argentina	0	1	0	0	4	0	5
Curisti Mici (Curisti)	DVIT 0703	Table, wine	Rose	Greece	1	0	0	0	4	0	5
Durif	DVIT 0895 (PI 113643)	Wine	Noir	France	1	0	0	1	3	0	5
Ezerjo	DVIT 0715 (PI 105001)	Wine	Blanc	Hungary	1	0	1	0	4	0	6
Ferral Tamara*	DVIT 0406 (PI 157783)	Table, wine	Rouge	Portugal	1	1	0	1	3	0	6
Fileri (Moschofilero)	DVIT 1044 (PI 171346)	Wine	Rose	Greece	1	1	0	0	4	1	7
Frankenthal blanc (Elbling Weiss)*	DVIT 2115	Wine	Blanc	Germany	1	1	1	0	4	0	7
Gamay Bourgogne (Gamay Noir)	DVIT 0734	Wine	Noir	France	0	1	0	0	4	0	5
Gamay Toma (Gamay Noir)	DVIT 2100 (PI 259022)	Wine	Noir	France	1	0	0	1	3	0	5
Ghula Dari	DVIT 2039 (PI 171101)	Table	Blanc	Afghanistan	1	0	0	1	3	0	5
Green Hungarian (Putzscheere)	DVIT 0748	Table, wine	Blanc	Hungary	1	0	1	1	4	0	7
Hermitage (Cinsaut) (d)	DVIT 1099 (PI 344094)	Table, wine	Noir	France	0	0	1	0	4	0	5
Hunisa (Dattier noir)	DVIT 0418	Table	Noir	Iran	1	0	0	1	4	0	6
Husseine (Khusaine Belyi)	DVIT 0420 (PI 171070)	Table	Blanc	Uzbekistan	1	0	1	1	4	0	7
Jurançon blanc	DVIT 1102 (PI 422365)	Wine	Blanc	France	1	0	0	1	3	0	5
Kandahari (Kandahari Sorh)*	DVIT 0429 (PI 171098)	Table	Rouge	Afghanistan	1	0	0	1	4	0	6
Kara Dzhidzhigi (Dzhidzhigi Kara)	DVIT 2322 (PI 349735)	Table	Noir	Turkmenistan	1	0	0	1	4	0	6
Karistino (Karystino)	DVIT 0771 (PI 171245)	Wine	Rose	Greece	1	0	0	0	4	0	5
Khalchili (Raucha Safid)*	DVIT 0431 (PI 171081)	Table	Blanc	Afghanistan	1	0	0	1	3	0	5
Khalili (Xynisteri)	DVIT 2084	Table	Blanc	Cyprus	1	0	1	0	4	0	6
Kishmish Early (Naose)	DVIT 2324 (PI 349739)	Table	Rouge	Afghanistan	1	0	0	1	4	0	6

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Table 1. (*Continued*)

Name[ii]	Accession no.[iii]	Type	Berry skin color[iv]	Origin	Year when leaf symptoms were present (1)/absent (0)			Symptoms present on one (0) or both (1) vines[v]	Leaf symptom severity rating[vi]	Mortality of neither vine (0) or at least one vine (1)[vii]	Susceptibility index rating[viii]
					2011	2013	2015				
Kishmish Sorkh (Kishmish Sorh)*	DVIT 2041 (PI 171073)	Table	Rouge	Afghanistan	1	0	0	1	3	0	5
Lal Sorkh (Lal Sorh)	DVIT 0442 (PI 171072)	Table	Rouge	Afghanistan	0	0	1	0	4	0	5
Lambrusca di Alessandria*	DVIT 0701	Wine	Noir	Italy	1	0	0	0	4	0	5
Lattuario (Lattuario Nero)	DVIT 0445	Table	Noir	Italy	0	0	1	0	4	0	5
Leanoy (Lesnoi Belyi Maraginskii)	DVIT 2641 (PI 247635)	Table, wine	Blanc	Daghestan, Russia	0	0	1	0	4	0	5
Malta Seedless	DVIT 2327 (PI 319205)	Table	Blanc	?	0	0	1	0	2	0	3
Mandilaria	DVIT 0815 (PI 171275)	Wine	Blanc	Greece	1	0	0	1	4	0	6
Memory of Queen Elizabeth (Erzsebete Kiralyne Emleke) (e)	DVIT 0458	Table	Blanc	Hungary	1	0	0	0	3	0	4
Millishun	DVIT 2498	Table	Noir	Pakistan	0	0	1	0	4	0	5
Monukka (Black Monukka)	DVIT 0462	Table	Noir	USA	0	0	1	0	4	0	5
Mortagua (Castelao)*	DVIT 0840	Wine	Noir	Portugal	1	1	0	0	3	1	6
Mureto (Moreto)*	DVIT 0854	Wine	Noir	Portugal	1	0	0	0	4	0	5
Muscat Hamburg	DVIT 0860	Table, wine	Noir	UK	0	0	1	0	4	0	5
Muscat Ottonel	DVIT 0861	Table, wine	Blanc	France	0	0	1	0	3	0	4
Muscat St. Laurent	DVIT 0471	Table	Blanc	France	1	1	0	1	3	1	7
Neeli	DVIT 2514	?	Blanc	Pakistan	1	0	0	1	4	0	6
Oki di Boi	DVIT 0877	Wine	Rouge	Moldova	1	1	0	0	4	0	6
Olho De Pargo (Ahmeur Bou Ahmeur)	DVIT 0589 (PI 157778)	Table	Blanc	Algeria	0	0	1	0	4	0	5
Olmo 030-51	DVIT 1799	Wild	?	Afghanistan	0	0	1	0	2	0	3
Olmo 034-26	DVIT 1805	Wild	Noir	Afghanistan	0	1	1	1	4	0	7
Olmo 035-50 (f)	DVIT 1813	Wild	Blanc	Afghanistan	1	0	0	0	4	0	5
Olmo 035-58 (f)	DVIT 1814	Wild	Blanc	Afghanistan	1	0	0	1	4	0	6
Orange Muscat (Muscat fleur d'oranger) (g)	DVIT 2167	Table, wine	Blanc	France	1	0	0	1	3	0	5
Osteiner	DVIT 2330	Wine	Blanc	Germany	1	0	0	0	3	0	4
Otscha Bala (Ocha Bala)	DVIT 0617 (PI 259077)	Table, wine	Blanc	Uzbekistan	0	0	1	0	1	0	2
Perbos 139	DVIT 2145	Wine	Blanc	France	1	0	0	1	3	0	5
Perla de Csaba (Csaba Gyoengye)	DVIT 2042 (PI 173280)	Table, wine	Blanc	Hungary	1	0	0	1	3	0	5
Perla de Csaba (Csaba Gyoengye)	DVIT 0487	Table, wine	Blanc	Hungary	1	0	0	1	3	0	5
Pinger	DVIT 2649	Table	Rouge	China	1	0	0	0	3	0	4
Pinot gris	DVIT 0907	Wine	Gris	France	1	1	1	1	3	1	8
Pinot Musque (b)	DVIT 1117 (PI 289902)	Wine	Blanc	?	1	0	0	1	3	0	5
Pinot noir	DVIT 0912	Wine	Noir	France	1	1	0	0	4	0	6
Plavac Mali (Pavlac Mali Crni)	DVIT 1119 (PI 422378)	Wine	Noir	Croatia	0	0	1	0	4	0	5
Precoce De Malingre (Malingre Precoce)	DVIT 0490 (PI 189729)	Table, wine	Blanc	France	1	0	0	1	3	0	5
Psevthosirico	DVIT 0592 (PI 171357)	Table	Noir	Greece	1	0	0	0	3	0	4
Queen of the Vineyard (Koenigin Der Weingaerten)	DVIT 0496	Table	Blanc	Austria	1	1	0	1	5	1	9
Red Malaga (Molinera)*	DVIT 0498	Table, wine	Rouge	Spain	1	0	0	1	3	0	5
Red Roumi Tanta	DVIT 2260	Table	Rouge	Turkey	1	0	0	0	3	0	4
Rhazaki De Crete (e)	DVIT 0501 (PI 115784)	Table	Blanc	Greece	1	0	0	0	3	0	4
Rhazaki Mavro (Razaki Mavro)	DVIT 0555 (PI 171320)	Table	Noir	Greece	1	0	1	1	4	0	7
Rizamat	DVIT 2338	Table	Rouge	Uzbekistan	1	1	0	0	4	1	7
Robin Noir	DVIT 0933	Wine	Noir	France	1	1	0	0	2	0	4
Romania	DVIT 0595	Table	?	?	1	1	0	1	3	1	7
Rubired	DVIT 0938	Table, wine	Noir	USA	1	1	0	0	4	0	6
Rulander (Pinot Gris)*	DVIT 0941	Wine	Gris	France	1	0	0	0	3	0	4
Sahebi (Sahibi Gird) (h)	DVIT 0508 (PI 171086)	Table	Rose	Afghanistan	0	0	1	0	4	0	5
Seeded Thompson (h)	DVIT 1334	Table	Blanc	Central Asia	1	0	0	0	2	0	3
Servant*	DVIT 0518	Table, wine	Blanc	France	0	1	1	0	2	0	4
Siar	DVIT 0522 (PI 171085)	Table	Blanc	Afghanistan	1	0	1	1	4	0	7
Sicilien	DVIT 0523	Table, wine	Blanc	France	1	0	0	0	3	0	4
Sidezitis	DVIT 0557 (PI 171254)	Table, wine	Rouge	Greece	1	0	0	0	3	0	4
Stein (Chenin blanc)	DVIT 1127	Wine	Blanc	France	1	0	0	1	4	0	6

(*Continued on next page*)

Table 1. (*Continued*)

Name[ii]	Accession no.[iii]	Type	Berry skin color[iv]	Origin	Year when leaf symptoms were present (1)/absent (0) 2011	2013	2015	Symptoms present on one (0) or both (1) vines[v]	Leaf symptom severity rating[vi]	Mortality of neither vine (0) or at least one vine (1)[vii]	Susceptibility index rating[viii]
Tabyrn	DVIT 0969	Wine	Rose	USA	0	1	1	0	4	0	6
Tamarez (Trinacadeira Das Pratas)	DVIT 0972	Wine	Blanc	Portugal	1	0	0	0	3	0	4
Tannat	DVIT 0973	Wine	Noir	France	1	0	0	0	3	0	4
Teneron	DVIT 0453	Table	Blanc	Italy	1	0	0	1	4	0	6
Terret blanc*	DVIT 0765	Wine	Blanc	France	1	1	0	1	4	1	8
Thompson Seedless (Sultanina) (h)	DVIT 0535	Table, raisin, wine	Blanc	Central Asia	1	0	0	0	4	0	5
Tokay (g)	DVIT 2157	Table, wine	Blanc	Hungary	1	1	0	0	3	1	6
Trieste 4x (4n)	DVIT 1669	Table	Blanc	Italy	0	0	1	0	2	0	3
Tschilaci	DVIT 0539 (PI 114121)	Table	Rouge	USA	1	0	0	0	3	0	4
Unknown	DVIT 0881	Table, wine	Blanc	?	1	1	0	0	3	1	6
Van Der Laan (c)	DVIT 0543	Table, wine	Blanc	Netherlands	1	0	0	0	3	0	4
Vernaccia di San Gimignano	DVIT 1003	Wine	Blanc	Italy	1	0	0	0	3	0	4
Vitis vinifera subsp. *sylvestris*	DVIT 2426	Wild	Noir	Tunisia	1	1	0	1	4	0	7
White Calabrian (Calabre)	DVIT 2391	Table	Blanc	Italy	1	1	0	1	3	1	7
White Tokay (Korithi Aspro)	DVIT 0550	Table, wine	Blanc	Greece	0	0	1	0	4	0	5

[i] Accessions are part of the wine and table-grape collection maintained by the US Department of Agriculture (USDA)–Agricultural Research Service, National Clonal Germplasm Repository, Davis, CA, USA, and are located at the Wolfskill Experimental Orchard in Winters, CA, USA. All accessions are assumed to be *Vitis vinifera* L. subsp. *vinifera*, unless otherwise noted as *Vitis vinifera* L. supsp. *sylvestris*. Accession names, numbers, grape type, berry skin color, and geographic origin are as listed in GRIN-Global, the USDA Germplasm Resources Information Network (www.ars-grin.gov), with details missing from GRIN-Global filled in (when available) from the Vitis International Variety Catalogue (VIVC) (www.vivc.de).

[ii] For accessions that represent cultivars with more than one name, the prime name of the cultivar (i.e., name where the plant material originated) is given in parentheses, according to the VIVC. Accessions with "4n" are tetraploid. Some accession names consist of the breeder's name (Olmo) and/or breeder-collection number (e.g., Olmo 030-51). Accessions with an asterisk were not genotyped with single nucleotide polymorphism (SNP) markers; all remaining accessions without an asterisk were genotyped by Myles et al. (2011). Accessions followed by the same lowercase letter have identical SNP genotypes (Myles et al. 2011).

[iii] Accession numbers are unique identifiers that are searchable in GRIN-Global. DVIT = Davis *Vitis* identification tag.

[iv] Berry skin colors are Blanc = white, Rose = pink, Rouge = red, Gris = gray-red, and Noir = bluish black,? = unknown.

[v] The presence of leaf symptoms on one or both duplicate vines per accession, where 0 = one vine and 1 = both vines.

[vi] 1 point = normal-size leaves and shoots, but some leaves have necrotic (brown) margins; 2 points = normal shoot length, but some leaves are dwarfed and/or have necrotic margins; 3 points = stunted shoots with dwarfed leaves, but no leaves with necrotic margins; 4 points = stunted shoots with dwarfed leaves, and some leaves dwarfed with necrotic margins; and 5 points = no shoot growth or stunted shoot that grew and then died.

[vii] The death of at least one of two duplicate vines per accession, where 0 = no mortality and 1 = death of one or both vines.

[viii] The sum of the contents of the six columns to its left, regarding the incidence and severity of leaf symptoms, and the incidence of mortality of duplicate vines per accessions, ranging from a minimum of 2 (leaf symptoms present in 1 year and a leaf symptom rating of 1) to a maximum of 10 (leaf symptoms present in all 3 years, symptoms present on both vines, leaf symptom rating of 5, and mortality of both vines).

2011 (90 accessions), compared with 2013 (28 accessions) and 2015 (35 accessions). Among the 120 accessions with leaf symptoms in ≥ 1 study years (susceptible accessions), both vines were symptomatic for 46 accessions and both vines of 12 accessions died (all between 2011 and 2013). Of the 90 susceptible accessions in 2011, 63 did not show symptoms again in 2013 or 2015. There were only seven newly susceptible accessions in 2013. Of the 35 susceptible accessions in 2015, 23 were newly susceptible accessions and six had shown symptoms previously in 2011, but not in 2013. Susceptible accessions with the most severe leaf symptoms (a rating of 5 points) were Chasselas Napoleon (DVIT 0375) and Queen of the Vineyard (DVIT 0496). The majority of susceptible accessions had a symptom severity rating of either 3 points (52 of 120 accessions) or 4 points (58 of 120 accessions). Corbu blanc (DVIT 2313), Frankenthal blanc (DVIT 2115), and Pinot gris (DVIT 0907) were the only accessions that had leaf symptoms in all 3 study years.

In 2011, we confirmed the presence of *E. lata* in the vineyard from the few susceptible accessions that also had sufficient canopy growth to allow for sampling (i.e., cutting away) woody tissues without also cutting away all shoot positions. Based on growth of *E. lata* in culture from internal wood cankers visible in these wood samples, the following 20 susceptible accessions were confirmed infected: Austrian Seedless (DVIT 1650), Black Kishmish (DVIT 2055), Chasselas Musque (DVIT 0374), Chasselas Rose (DVIT 0376), Corbu Blanc (DVIT 2313), Frankenthal blanc (DVIT 2115), Ghula Dari (DVIT 2039), Husseine (DVIT 0420), Khalili (DVIT 2084), Muscat St. Laurent (DVIT 0471), Oki di Boi (DVIT 0877), Orange Muscat (DVIT 2167), Pinot gris (DVIT 0907), Queen of the Vineyard (DVIT 0496), Rizamat (DVIT 2338), Seeded Thompson (DVIT 1334), Tannat (DVIT 0973), Thompson Seedless (DVIT 0535), Tokay (DVIT 2157), and White Calabrian (DVIT 2391).

Winter rainfall, starting 18 months before our first set of symptom ratings in May 2011 and up to our last set of symptom ratings in May 2015, was as follows: 58.7 cm (from 1 Oct 2009 to 31 May 2010), 61.2 cm (from 1 Oct 2010 to 31 May 2011), 34.9 cm (from 1 Oct 2011 to 31 May 2012), 35.3 cm (from 1 Oct 2012 to 31 May 2013), 26.5 cm (from 1 Oct 2013 to 31 May 2014), and 34.0 cm (from 1 Oct 2014 to 31 May 2015). Thus, the two winters leading up to our first study year in May 2011 had the greatest total rainfall, which—afterward, in the winter of 2011 to 2012—decreased by half and remained consistently low for four consecutive winters.

The 17 most susceptible accessions were as follows, based on susceptibility index ratings ≥ 7 points (from highest to lowest): Queen of the Vineyard (DVIT 0496), Corbu blanc (DVIT 2313) (Fig. 1), Terret blanc (DVIT 0765), Pinot gris (DVIT 0907), Chasselas Rose (DVIT 0376), Fileri (DVIT 1044), Frankenthal blanc (DVIT 2115) (Fig. 1), Green Hungarian (DVIT 0748), Husseine (DVIT 0420), Olmo 034-26 (DVIT 1805), Rhazaki Mavro (DVIT 0555), Rizamat (DVIT 2338), Siar (DVIT 0522), Muscat St. Laurent (DVIT 0471), Romania (DVIT 0595), White Calabrian (DVIT 2391), and *Vitis vinifera* L. subsp. *sylvestris* (DVIT 2426) (Fig. 1). These 17 highly susceptible accessions had symptom severity ratings ranging from 3 to 5 points.

Fig. 1. Leaf symptoms of Eutypa dieback on susceptible accessions. (**A**) Cup-shaped, dwarfed leaves (some leaves also with brown, necrotic margins) on stunted shoots of Austrian Seedless [Davis *Vitis* identification tag (DVIT) 1650]. (**B**) Dwarfed leaves on stunted shoots of Frankenthal blanc (DVIT 2115). (**C**) Stunted shoots and scorched flower inflorescences of Corbu blanc (DVIT 2313). (**D**) Stunted shoot, with short internodes and zigzag shape, of *Vitis vinifera* L. subsp. *sylvestris* (DVIT 2426).

There were eight sets of accessions with identical SNP genotypes (20 total accessions), among the 120 susceptible accessions (Table 1). The following three pairs of accessions with identical SNP genotypes also share the same berry skin color, identical susceptibility index ratings, and identical leaf symptom severity ratings for leaf symptoms present in the same study year: Austrian Seedless (DVIT 1325) and Austrian Seedless (DVIT 1650), Memory of Queen Elizabeth (DVIT 0458) and Rhazaki De Crete (DVIT 0501), and Olmo 035-58 (DVIT 1814) and Olmo 035-50 (DVIT 1813). The following two pairs of accessions with identical SNP genotypes also share the same berry skin color and identical susceptibility index ratings, but had slightly different leaf symptom severity ratings, and/or leaf symptoms were present in different years and on one vs. both accession vines: Chardonnay (DVIT 0816) and Pinot Musque (DVIT 1117), and Chasellas Rose Royal (DVIT 2158) and Hermitage (DVIT 1099). Orange Muscat (DVIT 2167) and Tokay (DVIT 2157), which share identical SNP genotypes and the same white berry skin color, had different susceptibility index ratings because the latter had leaf symptoms present in more years and mortality was seen in one of two accession vines. Of the eight susceptible 'Chasselas' accessions, four share

the same SNP genotype [Chasselas Hs 14-33/4 (DVIT 2310), Chasselas Jababert (DVIT 2120), Chasselas Musque (DVIT 0374), and Chasselas Rose (DVIT 0376)], along with Van Der Laan (DVIT 0543). Chasselas Hs 14-33/4 (DVIT 2310), Chasselas Jababert (DVIT 2120), Chasselas Musque (DVIT 0374), and Van Der Laan (DVIT 0543) (all of which have the same white berry skin color) had leaf symptom ratings of either 3 or 4 points, with symptoms present in the same study year. Compared with these four accessions of the same SNP genotype, Chasselas Rose (DVIT 0376) (which has a different rose berry skin color, presumably from a genetic mutation that is not associated with an SNP marker) had a greater susceptibility index rating as a result of the presence of leaf symptoms in 2 of 3 study years, and also because mortality was seen in one of two accession vines. Despite identical SNP genotypes and white berry skin color, Seeded Thompson (DVIT 1334) and Thompson Seedless (DVIT 0535) had different leaf symptom ratings (2 and 4 points, respectively). These two accessions share the same SNP genotype with Sahebi (DVIT 0508) (which has a different rose berry skin color), but Sahebi (DVIT 0508) had leaf symptoms in a different year.

Inferred parent–offspring relationships were identified among 11 pairs of susceptible accessions (Table 2). The large set of identical SNP genotypes, including four Chasselas accessions [Chasselas Hs 14-33/4 (DVIT 2310), Chasselas Jababert (DVIT 2120), Chasselas Musque (DVIT 0374), and Chasselas Rose (DVIT 0376)] and Van Der Laan (DVIT 0543) accounted for 4 of the 11 pairs, and is a parent or offspring of Buckland's Sweetwater (DVIT 0363) and Muscat St. Laurent (DVIT 0471), and identical SNP genotypes Orange Muscat (DVIT 2167), Tokay (DVIT 2157), and Perla Di Csaba (DVIT 0487). Chasselas Napoleon (DVIT 0375), which was one of two susceptible accessions with the greatest leaf symptom rating of 5 points, has a parent–offspring relationship with Buckland's Sweetwater (DVIT 0363). Queen of the Vineyard (DVIT 0496), which had the greatest leaf symptom rating of 5 points and was the only susceptible accession with the highest susceptibility index rating of 9 points, has a parent–offspring relationship with identical SNP genotypes Memory of Queen Elizabeth (DVIT 0458) and Rhazaki De Crete (DVIT 0501).

Inferred sibling relationships were identified among nine pairs of susceptible accessions (Table 3). Monukka (DVIT 0462), which accounted for three of nine pairs, is an inferred sibling of Khalili (DVIT 2084) and Lal Sorkh (DVIT 0442), and the identical SNP genotypes of Sahebi (DVIT 0508), Seeded Thompson (DVIT 1334), and Thompson Seedless (DVIT 0535). The highly susceptible accession Queen of the Vineyard (DVIT 0496) is an inferred sibling of Perla Di Csaba (DVIT 0487). The highly susceptible accession Rizamat (DVIT 2338) is an inferred sibling of Lal Sorkh (DVIT 0442) and Tabyrn (DVIT 0969).

Table 2. Susceptible accessions with parent–offspring relationships.[i]

Name	Parent–offspring
Barbableu (DVIT 0348)	Muscat Hamburg (DVIT 0860)
Black Kishmish (DVIT 2055)	Kara Dzhidzhigi (DVIT 2322)
Buckland's Sweetwater (DVIT 0363)	Chasselas Hs 14-33/4 (DVIT 2310)
	Chasselas Jababert (DVIT 2120)
	Chasselas Musque (DVIT 0374)
	Chasselas Rose (DVIT 0376)
	Van Der Laan (DVIT 0543)
Buckland's Sweetwater (DVIT 0363)	Chasselas Napoleon (DVIT 0375)
Chasselas Hs 14-33/4 (DVIT 2310)	Muscat St. Laurent (DVIT 0471)
Chasselas Jababert (DVIT 2120)	
Chasselas Musque (DVIT 0374)	
Chasselas Rose (DVIT 0376)	
Van Der Laan (DVIT 0543)	
Chasselas Hs 14-33/4 (DVIT 2310)	Orange Muscat (DVIT 2167)
Chasselas Jababert (DVIT 2120)	Tokay (DVIT 2157)
Chasselas Musque (DVIT 0374)	
Chasselas Rose (DVIT 0376)	
Van Der Laan (DVIT 0543)	
Chasselas Hs 14-33/4 (DVIT 2310)	Perla Di Csaba (DVIT 0487)
Chasselas Jababert (DVIT 2120)	
Chasselas Musque (DVIT 0374)	
Chasselas Rose (DVIT 0376)	
Van Der Laan (DVIT 0543)	
Hunisa (DVIT 0418)	Red Roumi Tanta (DVIT 2260)
Lal Sorkh (DVIT 0442)	Sahebi (DVIT 0508)
	Seeded Thompson (DVIT 1334)
	Thompson Seedless (DVIT 0535)
Malta Seedless (DVIT 2327)	Sahebi (DVIT 0508)
	Seeded Thompson (DVIT 1334)
	Thompson Seedless (DVIT 0535)
Memory of Queen Elizabeth (DVIT 0458)	Queen of the Vineyard (DVIT 0496)
Rhazaki De Crete (DVIT 0501)	

[i] Inferred from analyses of single nucleotide polymorphism (SNP) genotypes by Myles et al. (2011). Sets of accessions with identical SNP genotypes are grouped together. Accession names and Davis *Vitis* identification tag (DVIT) numbers are as listed in GRIN-Global (www.ars-grin.gov).

Discussion

During 3 years over a 5-year period, we conducted visual observations of the germplasm collection of 973 wine and table-grape accessions maintained at the USDA-ARS National Clonal Germplasm Repository in Winters, CA, USA. Our survey identified 120 accessions with diagnostic leaf symptoms of Eutypa dieback in at least 1 of 3 study years. These field observations in this northern California collection complement previously published surveys conducted in Australian and French vineyards and germplasm collections (Dubos 1987; Sosnowski et al. 2022).

Compared with observations of fungal foliar diseases of grapevine, for which symptoms develop within days or weeks of infection of the leaves (e.g., powdery mildew), the leaf symptoms of Eutypa dieback develop ≥ 1 year after infection of woody tissues. Thus, we do not know when the symptomatic accessions were infected before 2011. The susceptible accessions we examined were each represented by two adjacent vines within the vineyard, and one or both vines of 12 accessions died during the course of the study. Because all vines were subjected to natural infections by ascospores of *E. lata*, it is possible that accessions with more severe symptoms were under a greater level of inoculum pressure. However, all vines were more than 25 years old at the time of the study. Furthermore, there is not, typically, a disease gradient or aggregated spatial pattern of

Table 3. Susceptible accessions with sibling relationships.[i]

Name	Sibling
Chardonnay (DVIT 0816)	Gamay Bourgogne (DVIT 0734)
Pinot Musque (DVIT 1117)	
Chasselas Tompa (DVIT 0378)	Muscat Hamburg (DVIT 0860)
Lal Sorkh (DVIT 0442)	Rizamat (DVIT 2338)
Monukka (DVIT 0462)	Khalili (DVIT 2084)
Monukka (DVIT 0462)	Lal Sorkh (DVIT 0442)
Monukka (DVIT 0462)	Sahebi (DVIT 0508)
	Seeded Thompson (DVIT 1334)
	Thompson Seedless (DVIT 0535)
Perla Di Csaba (DVIT 0487)	Orange Muscat (DVIT 2167)
	Tokay (DVIT 2157)
Perla Di Csaba (DVIT 0487)	Queen of the Vineyard (DVIT 0496)
Rizamat (DVIT 2338)	Tabyrn (DVIT 0969)

[i] Inferred from analyses of single nucleotide polymorphism (SNP) genotypes by Myles et al. (2011). Sets of accessions with identical SNP genotypes are grouped together. Accession names and Davis *Vitis* identification tag (DVIT) numbers are as listed in GRIN-Global (www.ars-grin.gov).

symptomatic vines documented in the literature, but rather symptomatic vines are distributed randomly within a vineyard (Munkvold et al. 1993). Also, eight sets of susceptible accessions with identical SNP genotypes, which are planted in different locations in the vineyard, had identical or similar symptom severity ratings. In other words, it seems unlikely that variable inoculum pressure within the vineyard and during the study years was a limiting factor for *E. lata* infections. As such, we assume that the accessions reported here with leaf symptoms are indeed the most susceptible accessions in the germplasm collection. Because we confirmed *E. lata* infection among 20 susceptible accessions, based on isolations of the pathogen in pure culture from wood samples, spores of the pathogen may originate from within the vineyard, although we did not see stromata in the vineyard. Spores may also originate from nearby apricot accessions or native tree species (e.g., *Salix* spp.), from which we isolated *E. lata* previously (Travadon and Baumgartner 2015).

The variability we found in the incidence of symptom expression among study years (ranging from 28 vines in 2013 to 90 vines in 2011) highlights the importance of conducting multiyear studies when evaluating a phenotype associated with disease resistance/susceptibility. Although *E. lata* causes chronic wood infections, and thus one might expect an infected vine to develop leaf symptoms consistently each year, symptom presence can vary over time (Sosnowski et al. 2007b); symptoms may be present one year and then absent the next. Although disease incidence was less at our study site than that of all study sites examined in all study years by Sosnowski et al. (2007b), we had a similar observation of greater disease incidence (i.e., more susceptible accessions) with greater rainfall in the winter rainy season 18 months before the first set of symptom observations we made in May 2011.

Given the destructive sampling required to reveal the wood symptoms of Eutypa dieback, and the fact that our study site was a living germplasm collection for grape research, we could not sample all 973 accessions each year for the presence/absence of *E. lata*. Although we characterized vines as susceptible accessions based on the diagnostic leaf symptoms of Eutypa dieback, we cannot discount the possibility that they may have also been infected by other pathogens. Indeed, we isolated from other vines in the same vineyard Botryosphaeria dieback pathogens and Phomopsis dieback pathogens, as part of a previous study (Fujiyoshi et al. 2021). These dieback-type trunk diseases share canopy symptoms in common, so we focused on a phenotype specific to Eutypa dieback.

We found 21 sets of susceptible accessions sharing common genetic backgrounds, based on inferred parent–offspring relationships (12 sets) or inferred sibling relationships (nine sets) in analyses of their SNP genotypes, which were published previously (Myles et al. 2011). For example, there were eight susceptible accessions related to 'Chasselas' [Chasselas des Bouches du Rhone (DVIT 2112), Chasselas Napoleon (DVIT 0375), Chasselas Rose Royal (DVIT 2158), and Chasselas Tompa (DVIT 0378); and identical SNP genotypes Chasselas Hs 14-33/4 (DVIT 2310), Chasselas Jababert (DVIT 2120), Chasselas Musque (DVIT 0374), and Chasselas Rose (DVIT 0376)] and four susceptible accessions related to 'Muscat' [Muscat Hamburg (DVIT 0860), Muscat Ottonel (DVIT 0861), Muscat St. Laurent (DVIT 0471), and Orange Muscat (DVIT 2167)]. 'Chasselas blanc' is reported as highly susceptible to Eutypa dieback (Dubos 1987; Moisy et al. 2017; Péros and Berger 1994). Although it is not clear whether the susceptible accessions Muscat St. Laurent (DVIT 0471) and Orange Muscat (DVIT 2167) are identical to clones of cultivars examined in other studies, 'Muscat St. Laurent' and 'Orange Muscat' are offspring of a cross involving a parent 'Chasselas' (Lacombe et al. 2013; Raimondi et al. 2020; Schneider et al. 2008). It is possible that susceptibility of 'Muscat St. Laurent' and 'Orange Muscat' was inherited from the susceptible 'Chasselas' parent, but future studies on the genetics of host resistance to Eutypa dieback should validate this hypothesis. Similarly, 'Muscat Ottonel', resulting from a cross of 'Ingram's Muscat' and 'Chasselas blanc', is reported as susceptible by Dubos (1987). We confirmed the susceptibility of Chasselas Jababert (DVIT 2120, syn. 'Chasselas blanc') and Muscat Ottonel (DVIT 0861); 'Ingram's Muscat' is not part of the collection. The presence of other accessions related to 'Chasselas' and 'Muscat' in the collection that did not develop symptoms suggests that not all cultivars with 'Chasselas' and 'Muscat' parentage are susceptible to Eutypa dieback.

With no leaf symptoms among 90% of the germplasm accessions we surveyed, it is difficult to pinpoint sources of resistance in the *V. vinifera* germplasm, based on our findings. From a comparison of the results of published surveys, some cultivars reported previously as resistant to Eutypa dieback also did not develop leaf symptoms in our survey, albeit among accessions with the same cultivar names (but not necessarily the same genotypes) as those in published surveys. For example, we found no leaf symptoms on accessions of cultivars that are reported as resistant in separate field surveys in France ['Merlot', 'Semillon', and 'Sylvaner' (Dubos 1987)] and in South Australia ['Muscadelle' and 'Ughetta' (Sosnowski et al. 2022)]. In previous controlled inoculations in the greenhouse, we identified Merlot (DVIT 0826) and Primitivo (DVIT 1342, syn. 'Zinfandel') as resistant to Eutypa dieback (Travadon and Baumgartner 2023). Neither Merlot (DVIT 0826) nor Primitivo (DVIT 1342, syn. 'Zinfandel') had leaf symptoms in our survey of the germplasm collection, thereby verifying the results of a phenotyping assay conducted in the greenhouse on plants propagated from cuttings of these exact vines. Similar controlled inoculations have identified the Serbian cultivar Prokupac as resistant to Eutypa dieback (Živković et al. 2023). Indeed, accessions of 'Prokupac' (PI 364249 and PI 245964) present in the germplasm collection did not develop symptoms during our survey.

The comprehension of which accessions are susceptible to Eutypa dieback (and of their pedigree relationships) is essential information for exclusion of susceptible germplasm from future breeding programs. We found that some of the most susceptible accessions had inferred first-order relationships [based on a previous SNP genotyping effort (Myles et al. 2011)] with other susceptible accessions. Furthermore, accessions that we found to be susceptible—Thompson Seedless (DVIT 0535), Lal Sorkh (DVIT 0442), and Queen of the Vineyard (DVIT 0496)—were identified previously as among the most highly connected accessions within the germplasm collection (Myles et al. 2011). We reported previously on the susceptibility of 'Thompson Seedless' compared with other *V. vinifera* cultivars (namely, 'Cabernet Franc'), based on controlled inoculations in the greenhouse (Travadon et al. 2013). Because 'Thompson Seedless' is part of the parentage of most seedless cultivars of table grapes planted in the southern San Joaquin Valley of California, USA (e.g., 'Autumn King', 'Crimson Seedless', 'Scarlet Royal'), our field observations further emphasize the importance of acknowledging disease susceptibility in table-grape breeding programs. After all, Eutypa dieback and other trunk diseases have a significant negative impact on table-grape production in California, USA (Baumgartner et al. 2019), and trunk diseases are also widespread in the other top two grape-producing states in the United States: Washington (Travadon et al. 2022) and New York (Baumgartner et al. 2013; Lawrence et al. 2017b; Rolshausen et al. 2014). Furthermore, knowledge of susceptible germplasm is an important study tool for addressing fundamental research questions of host responses to infection by *E. lata*, at the transcriptomic level (Cardot et al. 2019) and at the biochemical and anatomic levels (Fleurat-Lessard et al. 2013).

References Cited

Baumgartner K, Fujiyoshi PT, Travadon R, Castlebury LA, Wilcox WF, Rolshausen PE. 2013. Characterization of species of *Diaporthe* from wood cankers of grape in eastern North American vineyards. Plant Dis. 97:912–920. https://doi.org/10.1094/PDIS-04-12-0357-RE.

Baumgartner K, Hillis V, Lubell M, Norton M, Kaplan J. 2019. Managing grapevine trunk diseases in California's southern San Joaquin Valley. Am J Enol Viticult. 70:267–276. https://doi.org/10.5344/ajev.2019.18075.

Cardot C, Mappa G, La Camera S, Gaillard C, Vriet C, Lecomte P, Ferrari G, Coutos-Thévenot P. 2019. Comparison of the molecular responses of tolerant, susceptible and highly susceptible grapevine cultivars during interaction with the pathogenic fungus *Eutypa lata*. Front Plant Sci. 10:991. https://doi.org/10.3389/fpls.2019.00991.

Carter MV. 1960. Further studies on *Eutypa armeniacae* Hansf. & Carter. Aust J Agric Res. 44:498–504. https://doi.org/10.1071/AR9600498.

Carter MV. 1991. The status of *Eutypa lata* as a pathogen. Phytopathological Paper 32. Commonwealth Agricultural Bureau, International Mycological Institute, Wallingford, Oxon, UK.

Carter MV, Bolay A, Rappaz F. 1983. An annotated host list and bibliography of *Eutypa armeniacae.* Rev Plant Pathol. 62:251–258.

Cattonaro F, Testolin R, Scalabrin S, Morgante M, Gaspero GD. 2014. Genetic diversity in the grapevine germplasm, p 683–704. In: Tuberosa R, Graner A, Frison E (eds). Genomics of plant genetic resources. Springer, Dordrecht, The Netherlands. https://doi.org/10.1007/978-94-007-7572-5_27.

Dubos B. 1987. Mise au point sur les maladies de deperissement dans le vignoble Francais. Prog Agric Vitic. 104:135–140.

Fleurat-Lessard P, Bourbouloux A, Thibault F, Ménard E, Béré E, Valtaud C, Roblin G. 2013. Differential occurrence of suberized sheaths in canes of grapevines suffering from black dead arm, esca or Eutypa dieback. Trees. 27: 1087–1100. https://doi.org/10.1007/s00468-013-0859-z.

Fujiyoshi P, Lawrence DP, Travadon R, Baumgartner K. 2021. DNA-based detection of grapevine trunk-disease pathogens from environmental spore samples. MethodsX. 8:101494. https://doi.org/10.1016/j.mex.2021.101494.

Galarneau ERA, Lawrence DP, Wallis CM, Baumgartner K. 2021. A comparison of the metabolomic response of grapevine to infection with ascomycete wood-infecting fungi. Physiol Mol Plant Pathol. 113:101596. https://doi.org/10.1016/j.pmpp.2020.101596.

Kaplan J, Travadon R, Cooper M, Hillis V, Lubell M, Baumgartner K. 2016. Identifying economic hurdles to early adoption of preventative practices: The case of trunk diseases in California winegrape vineyards. Wine Econ Policy. 5: 127–141. https://doi.org/10.1016/j.wep.2016.11.001.

Lacombe T, Boursiquot JM, Laucou V, Di Vecchi-Staraz M, Péros JP, This P. 2013. Large-scale parentage analysis in an extended set of grapevine cultivars (*Vitis vinifera* L.). Theor Appl Genet. 126:401–414. https://doi.org/10.1007/s00122-012-1988-2.

Lardner R, Mahoney N, Zanker TP, Molyneux RJ, Scott ES. 2006. Secondary metabolite production by the fungal pathogen *Eutypa lata*: Analysis of extracts from grapevine cultures and detection of those metabolites *in planta.* Aust J Grape Wine Res. 12:107–114. https://doi.org/10.1111/j.1755-0238.2006.tb00049.x.

Lawrence DP, Travadon R, Nita M, Baumgartner K. 2017a. TrunkDiseaseID.org: A molecular database for fast and accurate identification of fungi commonly isolated from grapevine wood. Crop Prot. 102:110–117. https://doi.org/10.1016/j.cropro.2017.08.017.

Lawrence DP, Travadon R, Pouzoulet J, Rolshausen PE, Wilcox WF, Baumgartner K. 2017b. Characterization of *Cytospora* isolates from wood cankers of declining grapevine in eastern North America, with the descriptions of two new *Cytospora* species. Plant Pathol. 66:713–725. https://doi.org/10.1111/ppa.12621.

Loschiavo A, Sosnowski M, Wicks T. 2007. Incidence of Eutypa dieback in the Adelaide hills. Aust New Z Grapegrower Winemaker. April: 26–29.

McGovern PE. 2003. Ancient wine: The search for the origins of viniculture. Princeton University Press, Princeton, NJ, USA.

Moisy C, Berger G, Flutre T, Le Cunff L, Péros J-P. 2017. Quantitative assessment of grapevine wood colonization by the dieback fungus *Eutypa lata.* J Fungi. 3:21. https://doi.org/10.3390/jof3020021.

Moller WJ, Kasimatis AN. 1978. Dieback of grapevines caused by *Eutypa armeniacae.* Plant Dis Rep. 62:254–258.

Munkvold GP, Duthie JA, Marois JJ. 1993. Spatial patterns of grapevines with Eutypa dieback in vineyards with or without perithecia. Phytopathology. 83:1440–1448. https://doi.org/10.1094/Phyto-83-1440.

Munkvold GP, Marois JJ. 1995. Factors associated with variation in susceptibility of grapevine pruning wounds to infection by *Eutypa lata.* Phytopathology. 85:249–256. https://doi.org/10.1094/Phyto-85-249.

Myles S, Boyko AR, Owens CL, Brown PJ, Grassi F, Aradhya MK, Prins B, Reynolds A, Chia J, Ware D, Bustamante CD, Buckler ES. 2011. Genetic structure and domestication history of the grape. Proc Natl Acad Sci USA. 108: 3530–3535. https://doi.org/10.1073/pnas.1009363108.

Péros J-P. 1995. Sensibilité des cépages à l'eutypiose: Le problème du comportement de référence au vignoble. Prog Agric Vitic. 112:61–67.

Péros J-P, Berger G. 1994. A rapid method to assess the aggressiveness of *Eutypa lata* isolates and the susceptibility of grapevine cultivars to Eutypa dieback. Agronomie. 14:515–523. https://doi.org/10.1051/agro:19940804.

Raimondi S, Tumino G, Ruffa P, Boccacci P, Gambino G, Schneider A. 2020. DNA-based genealogy reconstruction of Nebbiolo, Barbera and other ancient grapevine cultivars from northwestern Italy. Sci Rep-UK. 10:15782. https://doi.org/10.1038/s41598-020-72799-6.

Reisch BI, Owens CL, Cousins PS. 2012. Grape, p 225–262. In: Badenes M, Byrne D (eds). Fruit breeding handbook of plant breeding. Springer, Boston, MA, USA. https://doi.org/10.1007/978-1-4419-0763-9_7.

Rolshausen PE, Baumgartner K, Travadon R, Fujiyoshi P, Pouzoulet J, Wilcox WF. 2014. Identification of *Eutypa* species causing Eutypa dieback of grapevine in eastern North America. Plant Dis. 98:483–491. https://doi.org/10.1094/PDIS-08-13-0883-RE.

Rolshausen PE, Greve LC, Labavitch JM, Mahoney NE, Molyneux RJ, Gubler WD. 2008. Pathogenesis of *Eutypa lata* in grapevine: Identification of virulence factors and biochemical characterization of cordon dieback. Phytopathology. 98:222–229. https://doi.org/10.1094/PHYTO-98-2-0222.

Rolshausen PE, Sosnowski M, Trouillas FP, Gubler WD. 2015. Eutypa dieback, p 57–61. In: Wilcox WF, Gubler WD, Uyemoto JK (eds). Compendium of grape diseases, disorders, and pests (2nd ed). American Phytopathological Society Press, Saint Paul, MN, USA.

Rudelle J, Octave S, Kaid-Harche M, Roblin G, Fleurat-Lessard P. 2005. Structural modifications induced by *Eutypa lata* in the xylem of trunk and canes of *Vitis vinifera.* Funct Plant Biol. 32:537–547. https://dor.org/10.1071/fp05012.

Schneider A, Marinoni DA, Crespan M. 2008. Genetics and ampelography trace the origin of Muscat fleur d'oranger. Am J Enol Viticult. 59: 200–204. https://doi.org/10.5344/ajev.2008.59.2.200.

Sosnowski MR, Ayres MR, McCarthy MG, Scott ES. 2022. Winegrape cultivars (*Vitis vinifera*) vary in susceptibility to the grapevine trunk pathogens *Eutypa lata* and *Diplodia seriata.* Aust J Grape Wine Res. 28:166–174. https://doi.org/10.1111/ajgw.12531.

Sosnowski MR, Lardner R, Wicks TJ, Scott ES. 2007a. The influence of grapevine cultivar and isolate of *Eutypa lata* on wood and foliar symptoms. Plant Dis. 91:924–931. https://doi.org/10.1094/PDIS-91-8-0924.

Sosnowski MR, Shtienberg D, Creaser ML, Wicks TJ, Lardner R, Scott ES. 2007b. The Influence of climate on foliar symptoms of Eutypa dieback in grapevines. Phytopathology. 97:1284–1289. https://doi.org/10.1094/PHYTO-97-10-1284.

This P, Lacombe T, Thomas MR. 2006. Historical origins and genetic diversity of wine grapes. Trends Genet. 22:511–519. https://doi.org/10.1016/j.tig.2006.07.008.

Travadon R, Baumgartner K. 2015. Molecular polymorphism and phenotypic diversity in the Eutypa dieback pathogen *Eutypa lata.* Phytopathology. 105:255–264. https://doi.org/10.1094/PHYTO-04-14-0117-R.

Travadon R, Baumgartner K. 2023. Phenotyping grapevine cultivars for resistance to Eutypa dieback. Phytopathol Mediterr. 62:239–253. https://doi.org/10.36253/phyto-14467.

Travadon R, Baumgartner K, Rolshausen PE, Gubler WD, Sosnowski MR, Lecomte P, Halleen F, Peros J-P. 2012. Genetic structure of the fungal grapevine pathogen *Eutypa lata* from four continents. Plant Pathol. 61:85–95. https://doi.org/10.1111/j.1365-3059.2011.02496.x.

Travadon R, Lawrence DP, Moyer MM, Fujiyoshi PT, Baumgartner K. 2022. Fungal species associated with grapevine trunk diseases in Washington wine-grapes and California table-grapes, with novelties in the genera *Cadophora, Cytospora*, and *Sporocadus*. Front Fungal Biol. 3: 1018140. https://doi.org/10.3389/ffunb.2022.1018140.

Travadon R, Rolshausen PE, Gubler WD, Cadle-Davidson L, Baumgartner K. 2013. Susceptibility of cultivated and wild *Vitis* spp. to wood infection by fungal trunk pathogens. Plant Dis. 97:1529–1536. https://doi.org/10.1094/PDIS-05-13-0525-RE.

Trouillas F, Gubler WD. 2010. Host range, biological variation, and phylogenetic diversity of *Eutypa lata* in California. Phytopathology. 100: 1048–1056. https://doi.org/10.1094/PHYTO-02-10-0040.

Živković SP, Vasić TP, Marković JP, Jevremović DR. 2023. Susceptibility of grapevine cultivars to *Eutypa lata* in Serbia. Acta Sci Pol-Hortoru. 22:105–116. https://doi.org/10.24326/asphc.2023.4489.