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Susceptibility of Crape Myrtles to Cercospora Leaf Spot in Georgia

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***Abstract.* *Lagerstroemia* (crape myrtle) is a genus of horticulturally important shrub or small flowering trees in landscapes across the southeast United States. Crape myrtles are impacted by the disease Cercospora leaf spot (*Pseudocercospora lythracearum*), which causes defoliation and reduces the value of affected plants in the nursery. Crape myrtle cultivars were rated over 6 months from June to November for Cercospora leaf spot incidence in 2021 and 2022 in Blairsville [US Department of Agriculture (USDA) zone 7b] and Watkinsville (USDA zone 8a), Georgia. Differences in disease development were noted between years. The cultivars most resistant to Cercospora leaf spot are Apalachee, Muskogee, Natchez, and Miami. 'Ozark Spring', 'Victor', 'Dynamite', and 'Pink Velour' had the greatest level of leaf spotting and premature defoliation. *Lagerstroemia indica* × *fauriei* hybrids were correlated with higher resistance to Cercospora leaf spot than *L. indica*. *Lagerstroemia limii* × *indica* hybrids demonstrated high susceptibility to Cercospora leaf spot. Hybrids of dark-foliage *L. indica* and *L. subcostata* were more resistant than dark-foliage *L. indica* plants. Resistance to Cercospora leaf spot was inconsistent among species, with some populations having individuals with very high and very low resistance. Hybridization of *L. indica* with *L. fauriei* and *L. subcostata* yields the highest likelihood of creating a crape myrtle resistant to Cercospora leaf spot.**

Lagerstroemia (crape myrtle) is a horticulturally important genus in the southeastern United States, accounting for more than $69 million in sales in 2019 [US Department of Agriculture (USDA), National Agricultural Statistics Service 2019]. More than 50 crape myrtle species have been reported (Cabrera 2004; Liu et al. 2013), but fewer than 10 are cultivated for ornamental use (Parajuli 2023). The most common species for ornamental use are *Lagerstroemia indica* L. and *Lagerstroemia fauriei* Koehne (Wang et al. 2011). *L. indica* is a large shrub or small tree ranging from 3 to 9 m in height and 4.5 to 7.5 m in canopy spread (Dirr 2002). *L. indica* produces 15- to 20-cm flower panicles that are showy with various colors (Dirr 2002). *L. fauriei* is a tree that can grow from 10 to 15 m in height and 7.5 to 10 m in canopy spread (Creech 1985). *L. fauriei* produces flowers in small panicles which bloom only once per season (Wang et al. 2011). Starting in the 1960s and through the 1980s crosses between *L. indica* and *L. fauriei* were made at the USDA National Arboretum to improve resistance to powdery mildew (Egolf 1986, 1987a, 1987b, 1990a, 1990b; Einert and Watts 1973). The resulting cultivars are among the most popular selections in production today. Hybridization between *L. indica* and *L. fauriei* imparts valuable traits, such as powdery mildew resistance and exfoliating bronze bark (Pounders et al. 2007). Several *L. indica* and *L. fauriei* hybrid cultivars are resistant to Cercospora leaf spot (Hagan et al. 1998). *Lagerstroemia limii* Merr. is also resistant to Cercospora leaf spot (Hagan et al. 1998; Parajuli 2023).

Crape myrtles are valued for their large, long-lasting inflorescence, exfoliating bark and few pest and maintenance problems. One of these pest problems is Cercospora leaf spot caused by *Pseudocercospora lythracearum* (Liu and Guo 1992) (syn. *Cercospora lythracearum*; Heald and Wolf 1911). *Pseudocercospora* species are an anamorph, or asexual state, of *Mycosphaerella* (Park et al. 2017). The sexual *Mycosphaerella* stage of *P. lythracearum* has not been described. Although Cercospora leaf spot does not cause plant mortality, this disease negatively affects the beauty and the value of crape myrtle in the nursery and landscape (Hagan et al. 1998). Cercospora leaf spot can be controlled using bimonthly fungicide applications, but resistant cultivars are the preferred control method (Hagan and Arkidge 2013).

Cercospora leaf spot is characterized by brown, round to irregular lesions on the leaves and becomes apparent in August or September, depending on the USDA zone and cultivar (Hagan et al. 1998). During warm, wet conditions, leaf spottings, and premature defoliation increases from August to October (Chappell et al. 2012). Weather plays a prominent role in Cercospora leaf spot development. Rainy weather; heavy dews; and warm, cloudy weather accelerate disease development (Hagan 2001). On a susceptible plant, lesions spread through the canopy, turning leaves yellow and red before defoliating before leaf senescence (Chappell et al. 2012).

Several studies of Cercospora leaf spot impacts on various crape myrtle species and cultivars have been performed (Baysal-Gurel 2017; Chappell et al. 2012; Hagan 2001; Parajuli et al. 2023). However, disagreement remains about how some popular cultivars react to Cercospora leaf spot. Cercosopra leaf spot has been reported on *Lagerstroemia indica*, *L. fauriei*, *L. limii*, and *L. subcostata* (Baysal-Gurel 2017; Chappell et al. 2012; Parajuli et al. 2023). Interspecific hybrids can be made among some of these species (Pooler 2003) and are a focus of breeding programs to introduce new traits in crape myrtle cultivars (Pounders et al. 2007). A few dark-foliage crape myrtle cultivars have also been evaluated for Cercospora leaf spot susceptibility. Dark-foliage crape myrtles, introduced in 2009, have become popular with consumers (Pounders et al. 2013). Here, *Lagerstroemia* species and hybrids for their reaction to Cercospora leaf spot and to determine their resistance in the Piedmont and Blue Ridge regions of Georgia.

Materials and Methods

Study sites. A block of 41 commercially available *Lagerstroemia* cultivars in Blairsville, GA, USA (34.8761°N, 83.9584°W) at the Georgia Mountain Research and Education Center and two blocks of *Lagerstroemia* selections at the University of Georgia Horticulture Farm in Watkinsville, GA, USA (33.8629°N, 83.4088°W) were observed. Two or three replications of each cultivar were included in that planting at Blairsville.

At the Blue Ridge Mountain site in Blairsville [549 m elevation, USDA hardiness zone 7b (USDA 2023)], the plot comprised four rows of trees, 10 to 15 years of age, spaced 4.6 m apart. Cultivars were randomized within the rows.

The Watkinsville area in the Piedmont region of Georgia comprised a breeding program of *Lagerstroemia* (*indica* × *fauriei*) × *subcostata, L. limii, L. indica, L. indica* × *subcostata,*

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L. indica × *limii, L. limii* × *indica,* and *L.* [(*indica* × *fauriei*) × *subcostata*) × *limii*)] plants. Plants were established between 2010 and 2019 at the University of Georgia Horticulture Farm in Watkinsville [220 m elevation, USDA hardiness zone 8a (USDA 2023)]. Selections of *Lagerstroemia* (*indica* × *fauriei*) × *subcostata* were replicated once, whereas all others were single-plant evaluations. The *L. subcostata* breeding lines were from a seed source in Taiwan, and the *L. limii* selections were received as seed from South Korea.

Crape myrtle plants were observed bimonthly for leaf spotting and defoliation due to Cercospora leaf spot in Blairsville from 7 Jun 2021 to 11 Nov 2021 and from 12 Jul 2022 to 21 Oct 2022 and in Watkinsville from 1 Jul 2021 to 18 Nov 2021 and 16 Jun 2022 to 27 Oct 2022.

Disease evaluations. A disease rating scale of 0 to 9 was created based on the Horsfall-Barratt scale (Horsfall and Barratt 1945) to rate the amount of disease observed on the crape myrtles. The ratings were a quality scale corresponding to the percentage of leaves with spots and defoliated leaves, such that 0 = 0% of leaves affected, 0 = 0%, 1 = 1% to 5%, 2 = 5% to 10%, 3 = 10% to 15%, 4 = 15% to 20%, 5 = 20% to 25%, 6 = 25% to 40%, 7 = 40% to 60%, 8 = 60% to 80%, 9 = 80% to 100% (Horsfall and Barratt 1945). Cultivars were given a rating of low, medium, or high resistance to Cercospora leaf spot based on the area under the disease progress curve (AUDPC). High resistance was defined as less than 150 AUDPC in 2021 and 40 AUDPC in 2022, moderate resistance between 150 and 350 AUDPC in 2021 and 40 and 150 AUDPC in 2022, and low resistance was defined as above 350 AUDPC in 2021 and 150 AUPDC in 2022 in the Blairsville plot (Table 1).

Data in Table 2 were analyzed using a *t* test, and data in Tables 3 and 4 were analyzed using a one-way analysis of variance and in the statistical programming language R (R Core Team 2021). The plugin epifitter (Alves and Del Ponte 2021) was used to calculate the AUDPC $Ak = \sum_{i=1}^{N_i-1} \frac{(y_i + y_i + 1)}{2}(t_{i+1} - t_i)$. Tukey's honestly significant difference test was used for mean comparison (alpha = 0.05). The R package multcompView (Graves et al. 2024) was used to visualize mean comparisons in Table 3.

Results

Cercospora leaf spot appeared naturally in late June in Watkinsville and late July in Blairsville. The disease intensified from initial spot development to peak at different times depending on the cultivar or seedling selection at each study location. Crape myrtle accessions are highly susceptible to Cercospora leaf spot and had peak leaf spot incidence in late August to September in Watkinsville and mid-September in Blairsville before defoliating shortly after. In each year, highly resistant selections retained most of their leaves until the first freeze each year, after which they defoliated.

Table 1. Disease resistance rankings as indicated by area under the disease progress curve (AUDPC) values of 43 commercial crape myrtle (*Lagerstroemia*) cultivars to Cercospora leaf spot (*Psuedocercospora lythracearum*). Data collected from Blairsville, GA, USA study location unless noted.

Cultivar	Parentage	Resistance[i]	2021 AUDPC[ii]	2022 AUDPC
Byers Red	*L. indica*	Moderate	361	84
Byers White	*L. indica*	Low	465	154
Carolina Beauty	*L. indica*	Moderate	265	47
Catawba	*L. indica*	Moderate	357	65
Centennial	*L. indica*	Moderate	282	136
Centennial Spirit	*L. indica*	Low	455	346
Dynamite	*L. indica*	Low	560	438
Ebony Embers[iii]	*L. indica*	Low	707	574
Ebony Flame[iii]	*L. indica*	Low	707	539
Hardy Lavender	*L. indica*	Moderate	241	158
Hope	*L. indica*	Moderate	267	130
Ozark Spring	*L. indica*	Low	546	416
Pink Velour	*L. indica*	Low	564	439
Potomac	*L. indica*	Moderate	286	70
Powhatan	*L. indica*	Moderate	334	140
Raspberry Sundae	*L. indica*	Low	415	264
Red Rocket	*L. indica*	Moderate	292	102
Regal Red	*L. indica*	Moderate	386	112
Seminole	*L. indica*	Moderate	331	58
Velmas Royal Delight	*L. indica*	Moderate	275	158
Victor	*L. indica*	Low	567	341
William Toovey	*L. indica*	Moderate	316	119
Acoma	*L. indica* × *fauriei*	Moderate	269	46
Apalachee	*L. indica* × *fauriei*	High	47	0
Biloxi	*L. indica* × *fauriei*	Moderate	272	49
Choctaw	*L. indica* × *fauriei*	High	106	10
Comanche	*L. indica* × *fauriei*	Moderate	126	130
Hopi	*L. indica* × *fauriei*	Moderate	412	144
Lipan	*L. indica* × *fauriei*	High	80	32
Miami	*L. indica* × *fauriei*	High	140	10
Muskogee	*L. indica* × *fauriei*	High	78	16
Natchez	*L. indica* × *fauriei*	High	92	21
Osage	*L. indica* × *fauriei*	High	97	28
Pecos	*L. indica* × *fauriei*	Moderate	260	98
Pocomoke	*L. indica* × *fauriei*	Moderate	222	100
Sioux	*L. indica* × *fauriei*	High	70	38
Tonto	*L. indica* × *fauriei*	High	126	24
Tuscarora	*L. indica* × *fauriei*	Moderate	176	49
Tuskegee	*L. indica* × *fauriei*	Moderate	183	49
Wichita	*L. indica* × *fauriei*	Moderate	205	77
Yuma	*L. indica* × *fauriei*	Moderate	172	49
Zuni	*L. indica* × *fauriei*	Moderate	129	35

[i] High resistance = less than 150 AUDPC in 2021 and 40 AUDPC in 2022, moderate resistance = between 150 and 350 AUDPC in 2021 and 40 and 150 AUDPC in 2022, low resistance = above 350 AUDPC in 2021 and 150 AUPDC in 2022.

[ii] AUPDC is calculated by summing the trapezoids created between each successive observation throughout the season. AUDPC is a relative statistic, therefore AUDPC values of a cultivar should not be compared with a different cultivar in a different year.

[iii] Observed at the University of Georgia Horticulture Farm in Watkinsville, GA, USA. Marketed under the trade name Black Diamond®.

Blairsville. Cultivars showed differing levels of susceptibility to Cercospora leaf spot (Table 1). Less Cercospora leaf spot in 2022 compared with 2021 (Table 1). *Lagerstroemia indica* × *fauriei* cultivars had a significantly lower AUDPC than *L. indica* cultivars (Table 2). The AUDPC was 57.3% lower in the *L. indica* × *fauriei*

Table 2. Area under the disease progress curve (AUDPC) of *Lagerstroemia indica* (n = 22) and *L. indica* × *fauriei* (n = 20) cultivars naturally infected with Cercospora Leaf Spot (*Psuedocercospora lythracearum*) in 2021 and 2022 in Blairsville, GA, USA (USDA Zone 7b).

	Avg AUDPC ± standard error			
Parentage	2021	Range	2022	Range
L. indica	408 ± 30[i] a[iii]	241–567	222 ± 36 a	47–574
L. indica × *fauriei*	163 ± 20[ii] b	47–412	50 ± 9 b	0–144
Mean of all plants	291	47–567	140	0–574

[i] AUDPC over 350 in 2021 and 150 in 2022 is highly susceptible.

[ii] AUDPC under 150 in 2021 and 40 in 2022 is highly resistant.

[iii] Numbers followed by the sample letter are significantly different from each other at $P < 0.05$ using a *t* test.

Table 3. Area under the disease progress curve (AUDPC) for *Lagerstroemia* species and hybrids naturally infected with Cercospora leaf spot (*Pseudocercospora lythracearum*) in Watkinsville, GA, USA (USDA Zone 8a).

Parentage[i]	No. of entries	2021 AUPDC ± *SE*[ii]	2022 AUPDC ± *SE*
L. indica	4	707 ± 23 bc[iii]	632 ± 50 abc
L. indica × *subcostata*	50	441 ± 33 bc	357 ± 32 bc
L. indica × *subcostata* (F_2)	13	448 ± 32 bc	449 ± 31 abc
L. indica × *subcostata* (F_3)	3	189 ± 83 bc	189 ± 83 cd
L. indica × *limii*	19	598 ± 28 b	598 ± 30 a
L. (*indica* × *fauriei*) × *subcostata*	20	339 ± 49 c	116 ± 20 d
L. [(*indica* × *fauriei*) × (*subcostata*)] × *limii*	11	444 ± 53 bc	456 ± 54 abc
L. limii	5	505 ± 108 bc	519 ± 115 abc
L. limii × *indica*	13	1260 ± 151 a	603 ± 45 a
L. limii × (open pollinated)	3	616 ± 77 bc	613 ± 111 ab
L. (*limii* × open pollination) × *indica*	5	581 ± 55 bc	503 ± 104 abc
L. (*limii* × open pollination) × [(*indica* × *fauriei*) × *subcostata*)]	17	332 ± 29 c	380 ± 33 bc

[i] Observed plants were selected from breeding lines.

[ii] Mean AUDPC of all observed entries in group.

[iii] Numbers followed by the sample letter are significantly different from all others that do not share a sample letter. Means were compared using analysis of variances. Sample letters were generated using a multiple paired comparisons visualization of a Tukey's honestly significant difference test.

SE = standard error.

cultivars in 2021 and 73.7% lower in 2022 compared with *L. indica* cultivars. Individual cultivars were differentially affected by disease each year. The four cultivars most resistant to Cercospora leaf spot were Apalachee, Muskogee, Natchez, and Miami, whereas cultivars Ozark Spring, Victor, Dynamite, and Pink Velour were most susceptible to this disease.

Watkinsville. Cercospora leaf spot differentially affected *Lagerstroemia* species in 2021 and 2022 (Table 3). Similar levels of season-long leaf spotting and defoliation were observed in both years for all species and hybrids except *L. limii* × *indica* and *L.* (*indica* × *fauriei*) × *subcostata*, both exhibiting greater disease in 2021. Few species had AUDPC values significantly different from those of other species. The observed difference could be due to the high variance among the species groups. Dark-foliage *L. indica* × *L. subcostata* hybrids showed less disease in 2021 and 2022 compared with the dark-foliage *L. indica* selections (Table 4).

Discussion

For 2 years 42 cultivars in Blairsville, GA, USA, and 13 groups of species and hybrids in Watkinsville, GA, USA, were evaluated for season-long leaf spotting and premature defoliation. Cercospora leaf spot susceptibility was quantified by calculating the AUDPC, a measure of disease severity over time. *L. indica* × *fauriei* cultivars had significantly lower AUDPC values than *L. indica* cultivars in Blairsville. Before the current study, two studies have assessed the relationship between *L. indica* × *fauriei* hybridization and Cercospora leaf spot. Parajuli et al. (2023) found that *L. indica* × *fauriei* hybrids generally had a lower AUDPC values in *L. indica* cultivars. Still, there was wide variation among the susceptibility of *L. indica* × *fauriei* cultivars. Our study supports this finding, although we observed less season-long disease development within *L. indica* × *fauriei* cultivars. Parajuli et al. (2023) observed that *L. indica* × *fauriei* 'Acoma' was among the most susceptible cultivars, whereas in our study, only moderate susceptibility was observed. Here, we found no *L. indica* × *fauriei* cultivars with high susceptibility, but only low and moderate susceptibility. Additionally, our study observed no *L. indica* cultivars with high resistance to Cercospora leaf spot. *L. indica* 'Dynamite' was observed to be the most susceptible cultivar evaluated, confirming the same observation from Parajuli et al. (2023). Parajuli et al. (2023) also observed that pure *L. fauriei* cultivars were resistant to Cercospora leaf spot, and this trait was consistent among all observed plants. Hagan et al. (1998) also observed that *L. fauriei* was resistant to Cercospora leaf spot. Our study did not include pure *L. fauriei* selections. Hagan et al. (1998) observed no correlation between *L. indica* × *fauriei* cultivars and resistance, with *L. indica* × *fauriei* cultivars showing similar levels of disease compared with *L. indica* cultivars. Our results disagree with the conclusion of Hagan et al. (1998) that *L. indica* × *fauriei* cultivars are not more resistant to Cercospora leaf spot than *L. indica.* The difference in results between our study and Parajuli et al. (2023) and Hagan et al. (1998) could be due to evaluation methods and location. Hagan et al. (1998) evaluated each cultivar once per year in late August or early September in the lower Coastal Plain of Alabama, USA, whereas Parajuli et al. (2023) evaluated cultivars throughout the entire progression of disease development using AUDPC to determine plant susceptibility on the Cumberland Plateau of Tennessee, USA.

Table 4. Average area under the disease progress curve (AUDPC) for dark-foliage *Lagerstroemia indica* cultivars and their crosses by *L. subcostata* infected naturally with Cercospora Leaf Spot (*Psuedocercospora lythracearum*) in Watkinsville, GA, USA in 2021 and 2022.

Selection	2021 Mean AUDPC ± *SE*	2022 Mean AUDPC ± *SE*
Dark-foliage *L. indica*	707 ± 19 a[i]	556 ± 33 a
Dark-foliage *L. indica* × *subcostata*	441 ± 33 b	358 ± 32 b

[i] Numbers followed by the sample letter are significantly different from each other at $P < 0.05$ using a *t* test.

SE = standard error.

Additionally, study location could impact the timing of disease onset and intensification due to differing levels of rainfall and humidity between locations. During warm, wet conditions, leaf spottings and defoliation may rapidly intensify from August to October (Chappell et al. 2012). Although there were no differences in total rainfall between locations (∼48 cm) in 2021, rainfall was 64% less in Blairsville in 2022 compared with Watkinsville (Supplemental Tables 1 and 2). Between 2021 and 2022, total rainfall decreased 165% in Blairsville and 59% in Watkinsville. In Aug 2021, in Blairsville, there was 34 cm of rainfall compared with 8.9 cm in Aug 2022 (Supplemental Table 1). Parajuli et al. (2023) also observed that Cercospora leaf spot disease could vary yearly based on rainfall distribution during the growing season.

In addition to Cercospora leaf spot, crape myrtles are also affected by the fungal disease powdery mildew, caused by *Erysiphe australiana* (McAlpine) Braun and Takamatsu. Previously, the high resistance of *L. fauriei* and *L. indica* × *fauriei* to powdery mildew was reported (Chappell et al. 2012; Egolf 1986; Hagan et al. 1998). However, based on our findings and Parajuli et al. (2023), *L. indica* × *fauriei* hybridization does not impart as much resistance to Cercospora leaf spot as powdery mildew. Similar results were reported by Hagan et al. (1998).

There are some trade-offs associated with cross-breeding *L. indica* by *L. fauriei.* The main disadvantages are reduced flower size, inflorescence size, and less vibrant flower color, as *L. fauriei* has small petals with pale colors. The valuable traits associated with crossing *L. indica* × *L. fauriei* are bronze exfoliating bark along with resistance to powdery mildew and Cercospora leaf spot. The most susceptible *L. indica* plants still have horticultural value because the flowers of many cultivars are larger with more vibrant color than those of the *L. indica* × *fauriei* cultivars during the flowering months before Cercospora leaf spot is severe. Further improvements can be made to flower size and color by continued interspecific hybridization among other *Lagerstroemia* species.

Thirteen groups of *Lagerstroemia* species and hybrids were evaluated in Watkinsville for Cercospora leaf spot susceptibility in

2021 and 2022. Few significant differences exist between these groups, with two notable standouts, *L. limii* × *indica* in 2021 being very susceptible and *L.* (*indica* × *fauriei*) × *subcostata* being very resistant in 2022. The lack of significant differences was likely due to the wide variation in AUDPC values observed in each group. For example, the *L. indica* × *subcostata* group contained CANR-1 with an AUDPC of 693, a plant with severe disease completely defoliated by September, and CANR-7 with an AUDPC of 112, a plant that retained most of its leaves until the first frost each year. Variation was seen among almost every group except for *L. indica*, *L. limii* × *indica*, and *L. indica* × *limii*. These three groups had consistently high Cercospora leaf spot susceptibility among all individuals. Parajuli et al. (2023) found few significant differences between different species, finding that *L. indica* was significantly more susceptible than all other evaluated hybrids and species, including *L. subcostata L. limii*, and *L. indica* × *fauriei* × *limii*. Our study was unable to confirm these relationships. Parajuli et al. (2023) observed resistance in their *L. limii* population. Resistance to Cercospora leaf spot was not seen in our *L. limii* population, suggesting that resistance may not be consistent across an entire species.

Two dark-foliage cultivars, Ebony Embers and Ebony Flame, susceptible to Cercospora leaf spot were crossed in 2018 with *L. subcostata* selections and established in Watkinsville. These F_1 individuals were selected based on powdery mildew resistance and dark foliage. The *L. indica* × *subcostata* selections from this cross had significantly better resistance to Cercospora leaf spot than both 'Ebony Embers' and 'Ebony Flame'. On the basis of this finding and the discovery that *L.* (*indica* × *fauriei*) × *subcostata* hybrids were resistant to Cercospora leaf spot in 2022 support the idea that hybridization with *L. subcostata* is a source of disease resistance in crape myrtle cultivars. This is further supported by Parajuli et al. (2023), who observed resistance to Cercospora leaf spot in *L. subcostata* selections, and by Rinehart et al. (2015) and Wang et al. (2023), who observed a genetic similarity between *L. fauriei* and *L. subcostata*.

No crape myrtle selections of *L. indica*, *L. indica* × *fauriei*, and *L.* (*indica* × *fauriei*) × *subcostata* proved immune to Cercospora leaf spot, with all selections showing varying levels of leaf spottings and premature defoliation. Study results may guide breeders in selecting species and landscapers in selecting cultivars with resistance to Cercospora leaf spot. Previous studies have been conducted in the northern and southern United States, but this is the first study with disease comparisons in the Piedmont and Blue Ridge Mountain regions of Georgia, USA.

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