

Effect of Leaf Removal on Shoot Decay of Various Cultivars of *Plumeria rubra* (Apocynaceae), Part I

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Because of their handsome, fragrant, and showy flowers, plumerias or frangipani are among the most highly esteemed shrubs and small trees in tropical and subtropical regions of the world. They have an ardent, world-wide following of collectors and growers who breed, select, propagate, and cultivate these handsome plants for landscape and personal adornment.

A horticultural practice among some plumeria growers and collectors is to defoliate the plants in late fall or winter, manually removing and disposing of the leaves. This practice is done for a variety of reasons, including to help control some diseases, like foliar rust, and overwintering pests, such as leafhopper (Hodel et al. 2017), to reduce wind loads and subsequent blow over of plants during windy times of the year, and/or to prepare plants for indoor storage in cold-winter areas. While no research-based information supports this practice for disease and pest management, the act of removing leaves from the stems before they are naturally ready to senesce and drop can create wounds that could facilitate pathogen entry and cause shoot decay.

Indeed, many plumeria plants in the “Grove” at the Los Angeles County Arboretum and Botanic Garden in Arcadia, California, about 20 km northeast of Los Angeles, which is one of the largest public collections of plumerias in the United States, typically suffer from various shoot decays each spring (**Fig. 1**). In fact, removal of decaying shoots in the spring to prevent even more damage later in the summer is one of the most critical, annual practices in the “Grove.” Because winter leaf removal on plumerias is frequently practiced in the “Grove,” we devised a two-part study to determine what impact, if any, this practice has on the development of shoot decay.

Materials and Methods

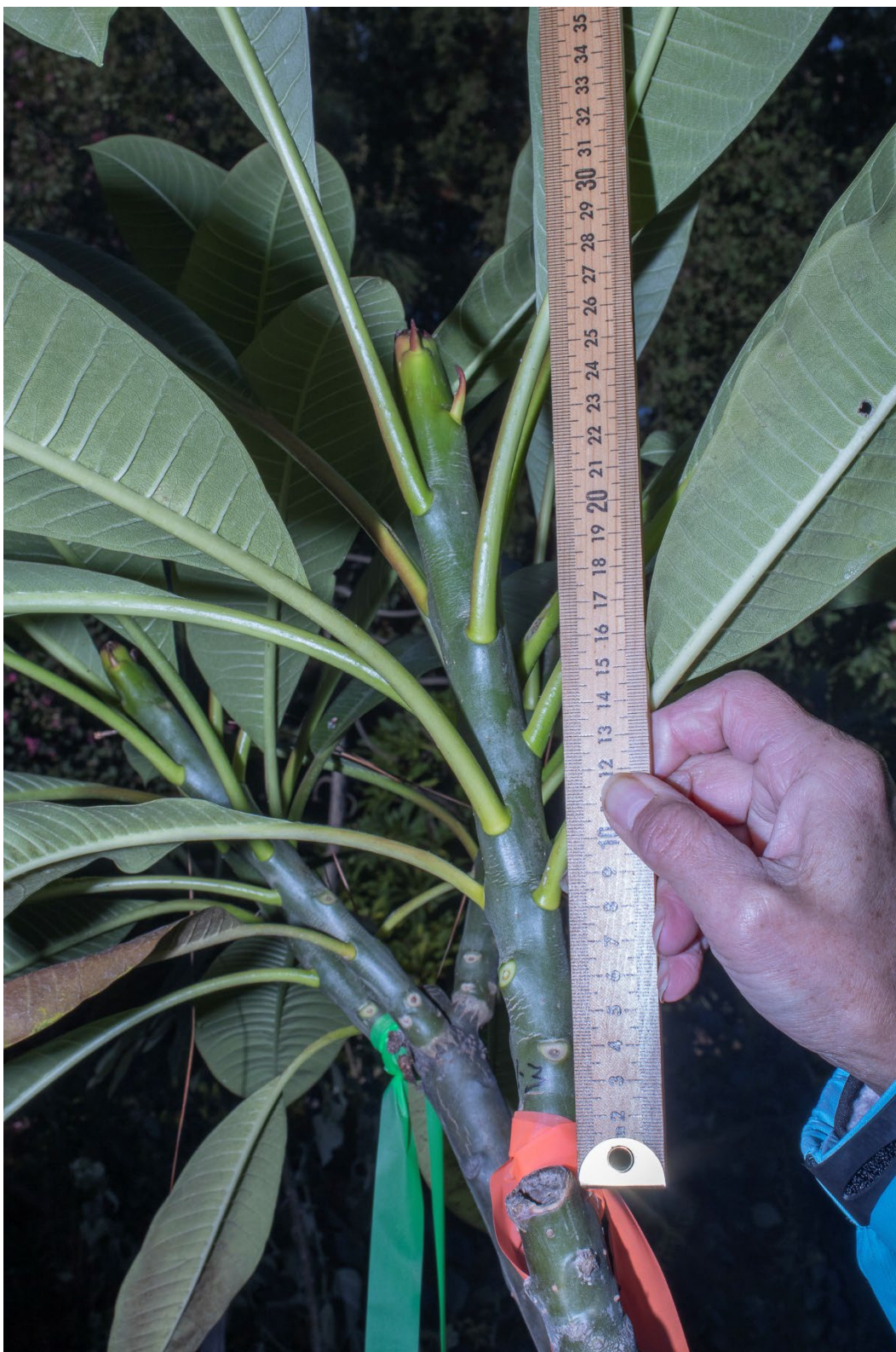
In December, 2021, we selected 16 plants comprising various cultivars (varieties) of *Plumeria rubra* in the “Grove” on Tallac Knoll at The Los Angeles County Arboretum and Botanic Garden in Arcadia. The Arboretum, which is at 34°N latitude has a Mediterranean climate with warm to hot, rainless summers and cool to mild, typically moist winters although global warming is leading to decreasing rain and increasing temperatures and aridification. Average annual rainfall is about



1. Shoot tip decay, here on ‘Pink Cloud’, is an annual problem in the plumeria “Grove” at the Los Angeles County Arboretum and Botanic Garden, Arcadia.



2. ‘Indian Ivory’, here leafless in the winter, is the typical size of the plumeria trees used in this leaf removal study.



3. We measured overall shoot length and shoot length produced in 2021 for each selected shoot, here on 'Red Candy Stripe'.



4. On three shoots per tree, leaves were hand stripped, here on 'Red Candy Stripe'.

450 mm, nearly all occurring from November to March. The plumerias must be irrigated during rainless times of the year. Typical summer maximum day temperatures are in the low to mid 30s C while winter night minimums are 2 to 6 C. Because of its elevation, Tallac Knoll is likely the most frost- and freeze-free location at The Arboretum but still experiences a few nights every winter where temperatures dip to 0 C or slightly lower although patchy cover provided by trees offers some cold protection. The soil is a well-structured sandy loam.

We mostly randomly selected the 16 plants, but included three cultivars that co-author Donnellan and Arboretum staff noted were unusually susceptible to shoot decay, including ‘Hollywood Pink’, ‘Nebel’s Rainbow’, and ‘Pink Cloud’. The 16 plants comprised 15 cultivars (we had two plants of ‘Nebel’s Rainbow’). The plants were mostly two to five m in height and width although a few were one to two m in height and width (**Fig. 2**). All were obtained as potted plants, mostly from 2010 to 2015.

In December, 2021, on each of the 16 plants, we randomly selected, tagged, and marked nine shoots, and measured overall shoot length (comprising several years of growth), shoot length and diameter for 2021 (shoot length and diameter produced in 2021 only) (**Fig. 3**), and quantity of leaves per shoot. On these nine shoots, we randomly stripped the leaves from three (**Fig. 4**), cut the leaves from three (**Fig. 5**), and left the leaves on of the remaining three. In February and May 2022, we recorded the position (tip or lateral) and extent of decay on the selected shoots.

We determined means and medians of overall shoot length, 2021 shoot length and diameter, and quantity of leaves, and mean extent of shoot decay, if any. Representative samples of decayed shoots were analyzed to determine which pathogens, if any, were present. We classified the decayed shoots into three categories: 1) shoot tip; 2) black tip; and 3) lateral.

1). As the name suggests, shoot tip decay occurs at the shoot tip and typically works proximally down the shoot over time, often decaying the entire shoot, which can be to 50 cm long or more (**Fig. 6**). 2). In contrast, black tip decay, also on the shoot tip, appears to move very little proximally down the stem, only a few cm, and new growth typically appears proximally of it rather early in the growing season. Black tip decay typically occurs later in the spring, just as new leaves are beginning to push out (**Fig. 7**), than do shoot tip decay and lateral decay, and some varieties, like ‘Nebel’s Rainbow’, seem especially susceptible to it. In its early stages at least, black tip decay initially has rather distinctive symptoms: the shoot tip, while black as in other decays, mostly retains its natural shape and does not shrivel or become deformed significantly as in other decays, and remains “full,” smooth, solid, and glossy (**Fig. 8**). Later, affected shoots do tend to shrivel and become deformed as the decay progresses. 3). Lateral decay initiates well proximally of the shoot tip, leaving the tip initially healthy, and typically works distally up and proximally down the shoot, in some cases, destroying the entire shoot (**Fig. 9**).



5. On three shoots per tree, leaves were cut off, here on 'Red Candy Stripe'.



6. Shoot tip decay, here on 'Hollywood Pink', is an annual problem, especially on some cultivars.



7. Black tip decay tends to occur later in the spring, just as new leaves begin to push out, here on 'Nebel's Rainbow' #1. The fungus *Dothiorella* spp. is a potential pathogen.



8. Black tip decay has rather specific, distinctive, initial symptoms, here on 'Nebel's Rainbow' #1. The fungus *Dothiorella* spp. is a potential pathogen.



9. Shoot lateral decay, here on “Pink Cloud”, occurs proximally of the tip and progresses up and down the shoot.

Results

Means and medians for overall shoot length, 2021 shoot length and diameter, and quantity of leaves per shoot in December, 2021, and mean extent of shoot tip decay and shoot lateral decay in May, 2022, are reported in **Table 1**. Black tip decay occurred on several shoots of ‘Nebel’s Rainbow’ #1 but not on shoots included in our study (**Figs. 7–8**) (see end of this section for additional information).

Cultivars with mean overall longest shoots were Rachel’s Cloud’ (50.9 cm), ‘Indian Ivory’ (39.2 cm) and Hollywood Pink (38.6 cm) while those with the shortest shoots were Serenade’ (23.9 cm), Apricot’ and ‘Celadine’ (both 24.7 cm), ‘NO ID’ #3 (24.8 cm), and ‘Nebel’s Rainbow’ #2 (25.2 cm).

Cultivars with the mean longest shoots produced in 2021 were ‘Rachel’s Cloud’ (24.0 cm), ‘Hollywood Pink’ (20.9 cm), ‘Nelly’s White’ (18.9 cm), Serenade’ (18.6 cm), and ‘NO ID’ #2 (18.1 cm) while those with the shortest shoots produced in 2021 were ‘Celadine’ (4.4 cm) and ‘Apricot’ (6.0 cm).

Cultivars with the mean largest shoot diameter in 2021 were ‘Apricot’ (2.6 cm) and ‘Hollywood Pink’ and ‘Nebel’s Rainbow’ #1 (both 2.5 cm) while those with the smallest diameter were ‘Pink Cloud’ and ‘Tai Surprise’ (both 2.0 cm) and ‘Nebel’s Rainbow’ #2 and ‘NO ID’ #1 (both 2.1 cm).

Cultivars with the greatest mean quantity of leaves per shoot were ‘Rachel’s Cloud’ (25.8), ‘Hollywood Pink (24.3), ‘NO ID’ #3 (17.2), ‘Mr. Ambassador’ (16.7), ‘Nelly’s White’ and ‘Serenade’ (both 16.4), and ‘NO ID’ #2 (16.2) while those with the fewest leaves were ‘Celadine’ (5.8), ‘Nebel’s Rainbow’ #2 (9.0), ‘Apricot’ (9.9), and ‘Red Candy’ (10.3).

By far, three cultivars showed the most extensive mean shoot tip and shoot lateral decay. These were ‘Hollywood Pink’ (14.6 and 0 cm, respectively), ‘Nebel’s Rainbow’ #1 (9.1 and 1.2 cm, respectively), and ‘Pink Cloud’ (8.8 and 1.1 cm, respectively) (**Table 1**). One cultivar had 5 cm of combined shoot decay, three had between 0.7 and 1.2 cm of shoot decay, and nine had none at all.

The three cultivars with the most extensive shoot tip and shoot lateral decay tended to have the decay on shoots with one or the other of the two leaf removal treatments (**Table 2**). ‘Hollywood Pink’ had three shoot tips with decay, all on the shoots where leaves were stripped off (**Fig. 10**). ‘Nebel’s Rainbow’ #1 had two shoot tips with decay, both on shoots where leaves were stripped off (**Fig. 11**) and two shoots with lateral decay, both on shoots where the leaves were cut off. ‘Pink Cloud’ had four shoot tips with decay, two were on shoots where the leaves had been stripped off (**Fig. 12**), one was on a shoot where the leaves had been cut off (**Fig. 13**), and one was on a shoot where the leaves were not removed (**Fig. 14**). Also, ‘Pink Cloud’ had one shoot

Table 1. Mean and median overall shoot length (cm), shoot length produced in 2021 (cm), shoot diameter in 2021 (cm), and quantity of leaves per shoot (December 2021), and mean extent of shoot tip and shoot lateral decay on 16 cultivars of *Plumeria rubra*, May 2022, at the Los Angeles County Arboretum and Botanic Garden, Arcadia, California.

Cultivar	Accession No.	Overall shoot length.	Shoot length 2021.	Shoot diam.	Quantity of leaves per shoot	Extent of shoot tip decay.	Extent of shoot lateral decay.
'Apricot'	20100322*1						
	mean	24.7	6.0	2.6	9.9	0	0
	median	25.0	6.0	2.5	10.0		
'Celadine'	20100328*1						
	mean	24.7	4.4	2.3	5.8	0	0
	median	25.0	3.5	3.5	6.0		
'Hollywood Pink'	20100337*1						
	mean	38.6	20.9	2.5	24.3	14.6	0
	median	35.0	22.0	2.5	26.0		
'Indian Ivory'	20150024*1						
	mean	39.2	13.5	2.3	11.4	0	0
	median	38.0	12.5	2.4	13.0		
'Mr. Ambassador'	20160089*1						
	mean	30.4	9.7	2.4	16.7	0	0
	median	29.0	8.0	2.5	17.0		
'Nebel's Rainbow' #1	20110307*1						
	mean	33.8	7.6	2.5	14.3	9.1	1.2
	median	34.0	8.0	2.5	14.0		
'Nebel's Rainbow' #2	20160693*1						
	mean	25.2	8.2	2.1	9.0	2.1	0
	median	21.0	6.0	1.9	10.0		
'Nelly's White'	20100329*1						
	mean	32.6	18.9	2.4	16.4	0	0
	median	31.0	22.0	2.4	14.0		
'No ID' #1	20100311*1						
	mean	32	7.1	2.1	13.9	0.6	0.6
	median	24.0	6.0	2.0	13.0		

Table 1, continued.

Cultivar	Accession No.	Overall shoot length.	Shoot length 2021.	Shoot diam.	Quantity of leaves per shoot	Extent of shoot tip decay.	Extent of shoot lateral decay.
'No ID' #2	20100330*1						
	mean	32.8	18.1	2.2	16.2	5.0	0
	median	35.0	17.0	2.2	16.0		
'No ID' #3	20110303*1						
	mean	24.8	7.8	2.4	17.2	0	0
	median	17.0	7.0	2.3	16.0		
'Pink Cloud'	20100362*1						
	mean	28.6	13.0	2.0	12.7	8.8	1.1
	median	25.0	11.0	2.0	14.0		
'Rachel's Cloud'	20150149*1						
	mean	50.9	24.0	2.3	25.8	0	0
	median	48.0	24.0	2.4	25.0		
'Red Candy'	20150139*1						
	mean	27.3	15.6	2.2	10.3	0	0
	median	28.0	16.0	2.2	11.0		
'Serenade'	20170318*1						
	mean	23.9	18.6	2.3	16.4	0	0
	median	25.0	16.0	2.3	16.0		
'Tai Surprise'	20150152*1						
	mean	26.8	7.3	2.0	11.9	0	0.7
	median	26.0	7.0	2.0	10.0		

with lateral decay where the leaves had been cut off. In summary, in these three cultivars, nine shoots stripped of leaves had seven with tip decay; nine shoots with the leaves cut off had one with tip decay and three with lateral decay; and nine shoots where the leaves were not removed had one shoot with tip decay.

Lab analyses of nine samples with several types of decay isolated one potential fungal pathogen, *Phomopsis* spp., on 'Nebel's Rainbow' #1 from a shoot tip where leaves had been stripped off (**Fig. 15**) (**Table 3**). We did not perform Koch's Postulates to confirm that this potential pathogen was causing the decay. The remaining eight samples were from shoots where leaves had been stripped or cut off and no primary pathogens were detected. A secondary pathogen, *Fusarium* spp., though, was isolated in two of these eight samples, one on "NO ID" #1 where the leaves had been stripped off and another on 'Pink Cloud' where the leaves had been cut off.



10. Shoot tip decay on 'Hollywood Pink' where leaves were stripped from the shoot.



11. Leaves were stripped off on this shoot of 'Nebel's Rainbow' #1, and decay initially developed around the leaf scars.



12. Shoot tip decay on 'Pink Cloud' where leaves were stripped off the shoot.



13. Shoot tip decay on 'Pink Cloud' where leaves were cut f from the shoot.



14. Shoot tip decay on 'Pink Cloud' where leaves were not removed from the shoot.

Table 2. Effect of leaf removal by stripping and cutting and no leaf removal on shoot tip and shoot lateral decay (cm) on three cultivars of *Plumeria rubra* at the Los Angeles County Arboretum and Botanic Garden, Arcadia, California, May 2022.

Cultivar.	Accession No./ Leaf Removal Treatment.	Shoot tip decay (cm).	Shoot lateral decay (cm).
'Hollywood Pink'	20100337*1		
	Stripped.	35.0	0
	Stripped.	48.0	0
	Stripped.	48.0	0
	Cut.	0	0
	Cut.	0	0
	Cut.	0	0
	No removal.	0	0
	No removal.	0	0
	No removal.	0	0
'Nebel's Rainbow' #1	20110307*1		
	Stripped.	48.0	0
	Stripped.	0	0
	Stripped.	34.0	0
	Cut.	0	0
	Cut.	0	3.0
	Cut.	0	8.0
	No removal.	0	0
	No removal.	0	0
	No removal.	0	0
'Pink Cloud'	20100362*1		
	Stripped.	0	0
	Stripped.	15.0	0
	Stripped.	32.0	0
	Cut.	0	10.0
	Cut.	0	0
	Cut.	10.0	0
	No removal.	0	0
	No removal.	22.0	0
	No removal.	0	0



15. The fungus *Phomopsis* spp. was isolated from this decayed shoot where the leaves had been stripped off.

Table 3. Lab analyses for pathogens of four cultivars of *Plumeria rubra* showing several types of shoot decay, at the Los Angeles County Arboretum and Botanic Garden, Arcadia, California, May 2022.

Cultivar.	Accession No.	Leaf removal treatment.	Type of Decay.	Potential pathogen.
'Hollywood Pink'	20100337*1	Stripped.	Tip.	None.
'Nebel's Rainbow' #1	20110307*1	Stripped.	Tip.	<i>Phomopsis</i> spp. (Fig. 15)
		Stripped.	Lateral.	None.
		Cut.	Lateral.	None.
'NO ID' #1	20100311*1	Stripped.	Lateral.	None.
		Stripped.	Tip.	None.
		Stripped.	Tip.	None but secondary <i>Fusarium</i> spp.
'Pink Cloud'	20100362*1	Cut.	Lateral.	None, but secondary <i>Fusarium</i> spp.
		Cut.	Lateral.	None.

Another potential fungal pathogen, *Dothiorella* spp., was detected on several shoots with black tip on 'Nebel's Rainbow' #1 (Figs. 7–8). Because these shoots were not included in our study, they are excluded from the analyses.

Discussion and Conclusions

These preliminary data suggest that the practice of leaf removal might be responsible for more shoot tip and shoot lateral decay in the *Plumeria rubra* cultivars 'Hollywood Pink', 'Nebel's Rainbow' #1, and 'Pink Cloud' than simply allowing the leaves to remain on the shoot until they fall away naturally. Stripping or cutting the leaves off without allowing them to fall away naturally can cause wounds on the shoots, which can facilitate entry of decay-causing primary and secondary pathogens (Figs. 16–17). Also, when leaves are retained on the shoot, they might offer protection against early and mid-winter shoot cold damage; thus, shoots devoid of leaves might be more susceptible to cold damage. Cold damage itself can lead to entry of primary or secondary pathogens.



16. Stripping the leaves off the shoot can leave wounds where decay can become established, here on 'Hollywood Pink'. See Fig. 17.



17. Cutting off leaves allows the remaining petiole stub to abscise and fall away naturally and wounds are less like to occur, here on 'Hollywood Pink'.

Unfortunately, these preliminary data had an insufficient quantity of data points to analyze for treatment statistical significance; however, the study showed at least three cultivars where leaf removal tended to lead to shoot decay. Thus, we selected two of these cultivars, ‘Hollywood Pink’ and ‘Nebel’s Rainbow’ #1, for a second, more in-depth part of this study in 2022–2023. We excluded the third cultivar, ‘Pink Cloud’, from the second part of the study because the plant was so tall that shoot treatments and data collection would have necessitated a ladder and been exceedingly difficult if not dangerous.

Literature Cited

Hodel, D. R., L. M. Ohara, and G. Arakelian. 2017. A new and serious leafhopper pest of *Plumeria* in southern California. *PalmArbor* 2017-5: 1–19.

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Publication Date: 15May 2023.

PalmArbor: <http://ucanr.edu/sites/HodelPalmsTrees/PalmArbor/>

ISSN 269083245

Editor-In-Chief: Donald R. Hodel

Hodel Palms and Trees: <http://ucanr.edu/sites/HodelPalmsTrees/>