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Selecting Coastal Plain Species for Wind Resistance[1]

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Wind damage to urban trees increases with storm intensity, but not all tree species withstand high winds to the same degree, making some trees better choices than others for including in coastal landscapes. A team of scientists at the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) studied 10 hurricanes to determine their effect on the urban forest. One of the major goals of this study was to assemble lists of relative wind resistance for different urban tree species to help communities better prepare for future hurricane seasons by selecting proper species. This fact sheet presents the research and methodology that led to these lists of relative wind resistance. It also discusses in detail the results and additional recommendations for selecting and establishing trees for a healthier and more wind-resistant urban forest.

The Study

In 2004, four hurricanes struck Florida with maximum sustained winds ranging from 169 to 233 km/h (105 to 145 mph). In 2005, Hurricane Dennis struck the Florida panhandle at 193 km/h (120 mph). The impacts of these five hurricanes were widespread. They affected urban areas, agricultural croplands, and Florida's natural ecosystems (Duryea et al. 2007). Since 1992 when Hurricane Andrew struck south Florida, we have been studying the impacts of hurricanes on the urban forest (Duryea et al. 1996). We continued with measurements of hurricane wind damage to urban neighborhoods again in 1995 when two hurricanes struck the Pensacola area (Duryea 1997) and then again in 1998 when Hurricane Georges crossed over the entire island of Puerto Rico. These nine hurricanes with their varied wind speeds gave us the opportunity to study over eighty tree species and their comparable responses to hurricanes. This study reports on the relative wind resistance of southeastern coastal plain species in urban forests (including plant hardiness zones 8 and 9).

Methods

Urban Tree Damage Measurements

Urban tree damage was measured within three to six days following each hurricane that struck the Florida panhandle: Erin, Opal, Ivan, and Dennis (Figure 1). We also report the hurricane response of coastal plain species such as live oak (*Quercus virginiana*) and sabal palm (*Sabal palmetto*) that occur throughout Florida and were impacted by Hurricanes Andrew, Charley, Frances, and Jeanne. Hurricane Andrew results were collected in a survey of 128 homeowners in Dade County, Florida, who reported the impacts of the hurricane on trees in their yards (Duryea et al. 1996). The methodology for the other eight hurricanes was the same and was as follows. Neighborhoods at the point of landfall of the hurricane were randomly chosen on the strong side of the storm. For each neighborhood, all trees in front yards were observed along street transects. (If invited, we also measured trees in backyards.)

Overall, we sampled 100 neighborhoods and 18,200 trees. Each tree's diameter at breast height (for dicots and conifers) or height (for palms) was measured (estimated for height), and then it was determined if the tree was standing, leaning, or had fallen. Leaning trees were those that were leaning because of the storm at less than a 45-degree angle. Fallen trees were either broken at the main stem or lying on the ground. All fallen trees were assessed as either broken or uprooted. Percent survival was calculated for each species using trees that were standing after the hurricane. (Trees were considered not surviving if they had fallen or if they were leaning at less than a 45-degree angle.)

Crowns of all standing trees were first assessed for percent of branch loss and then for leaf loss from the hurricane. For palms, only a percent leaf loss was assessed. Then for dicots and conifers, if a tree had 50% or greater branch loss from the hurricane, it was declared dead, and a new second survival percentage was calculated. This is called the "recalculated survival" throughout this document.

Figure 1. Urban trees were measured following hurricanes striking Florida, the Gulf Coast, and Puerto Rico. For each hurricane, the arrow points to the location of landfall. The maximum sustained wind speed (mph) and year are included.
Image Credit: UF/IFAS, Duryea and Kampf

The Survey

After four hurricanes struck Florida in 2004, we concluded that urban forest professionals in the state were a resource of knowledge about wind resistance. In June 2005, we sent out 240 surveys to arborists, urban foresters, and forest scientists who were members of the International Society of Arboriculture (Florida chapter) or the Florida Urban Forestry Council or who were faculty at the University of Florida. We asked them to rank the wind resistance (high, medium, or low) of those urban tree species they observed after hurricanes. Eighty-five (85) surveys (35%) were returned. We report these numbers and percentages in this publication and then use these ratings along with our measurements and analyses and the scientific literature to formulate wind resistance lists for tree species in urban areas.

Results

Tree Survival and Branch Loss

Tree species in the Southeastern Coastal Plain respond differently to hurricanes. Response of species to Hurricane Ivan in 2004 illustrates differences at 209 km/h (130 mph) wind speeds (Figure 2). Tree species demonstrating the highest survival in these winds were sand live oak (*Quercus geminata*), American holly (*Ilex opaca*), southern magnolia (*Magnolia grandiflora*), live oak, wax myrtle (*Myrica cerifera*), sweetgum (*Liquidambar styraciflua*), crape myrtle (*Lagerstroemia indica*), dogwood (*Cornus florida*), and sabal palm. Dogwood, live oak, sabal palm, sand live oak, and southern magnolia were also the best survivors in Hurricanes Erin and Opal in 1995 (Duryea 1997).

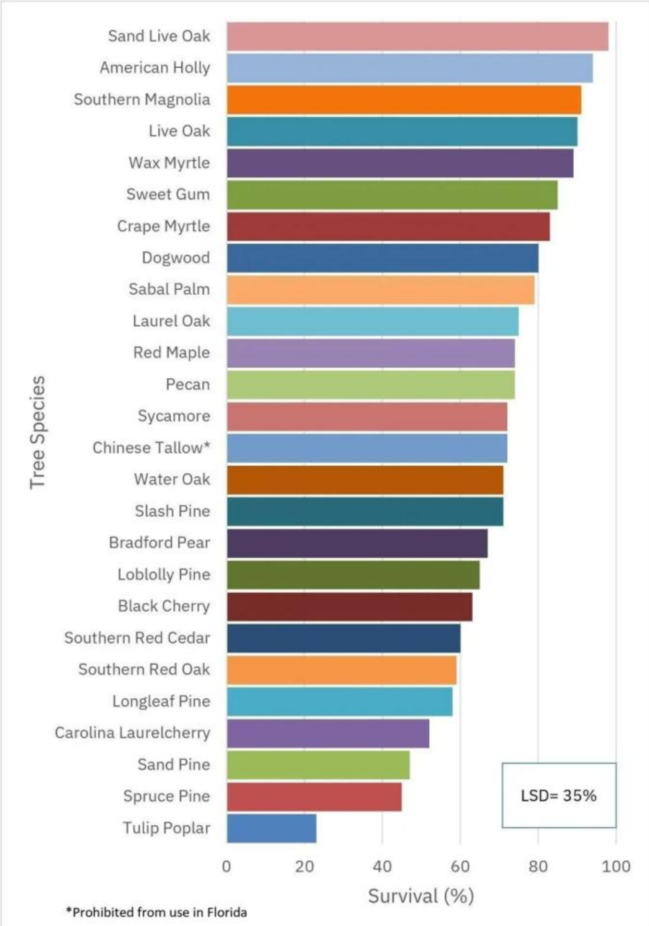

Figure 2. Survival (percentage of trees still standing) of species in Hurricane Ivan, which struck at 209 km/h (130 mph). The LSD (Least Significant Difference) is at the 0.05 level.
Credit: UF/IFAS, Duryea and Kampf

A more detailed look at live oak and sabal palm demonstrates their repeated resilience to hurricane-force winds (Table 1). However, it can also be seen that in south Florida when the winds reached 233 and 265 km/h (145 and 165 mph) in Hurricanes Charley and Andrew, survival of live oak decreased to 78%.

Table 1. Survival for Southeastern Coastal Plain Tree Species After Six Hurricanes.

Tree Species		Survival (%) After Each Hurricane (Wind Speed in km/h)*					
		Erin (137)	Jeanne (193)	Opal (201)	Ivan (209)	Charley (233)	Andrew (265)
Dicots							
Acer rubrum	Red maple	—	—	93	76	—	—
Acer saccharinum	Silver maple	—	—	93	—	—	—
Carya floridana	Florida scrub hickory	—	83	—	—	—	—
Carya illioensis	Pecan	97	—	93	76	—	—
Carya glabra	Pignut hickory	100	—	—	—	—	—
Cinnamomum camphora[a]	Camphor	—	—	—	—	90	—
Cornus florida	Flowering dogwood	100	—	96	81	—	—
Ilex opaca	American holly	—	—	—	95	—	—
Lagerstroemia indica	Crape myrtle	—	—	—	84	—	—
Liquidambar styraciflua	Sweetgum	—	—	93	86	—	—
Liriodendron tulipifera	Tulip poplar	—	—	—	24	—	—
Magnolia grandifolia	Southern magnolia	96	—	97	92	—	—
Magnolia virginiana	Sweet bay magnolia	97	—	—	—	—	—
Myrica cerifera	Wax myrtle	—	—	—	90	—	—
Platanus occidentalis	Sycamore	—	—	92	73	—	—
Prunus caroliniana	Carolina laurelcherry	76	—	74	53	—	—
Prunus serotina	Black cherry	—	—	—	64	—	—
Pyrus calleryana	Bradford pear	—	—	—	68	—	—
Quercus falcata	Southern red oak	—	—	—	60	—	—
Quercus virginiana	Live oak	96	97	95	91	78	78
Quercus geminata	Sand live oak	96	94	96	99	—	—
Quercus laurifolia	Laurel oak	89	94	90	77	85	—
Quercus laevis	Turkey oak	83	—	89	—	—	—
Quercus nigra	Water oak	—	—	—	72	—	—
Sapium sebiferum[a]	Chinese tallow	97	—	83	73	—	—
Monocots-Palms							
Butia capitata	Jelly palm	97	—	—	—	—	—
Sabal palmetto	Sabal/cabbage palm	97	92	100	80	92	93
Washingtonia robusta	Washington palm	—	80	—	—	92	—
Conifers							
Juniperus virginiana var. *silicicola*	Southern red cedar	92	—	60	61	—	—

Tree Species		Survival (%) After Each Hurricane (Wind Speed in km/h)[*]					
		Erin (137)	Jeanne (193)	Opal (201)	Ivan (209)	Charley (233)	Andrew (265)
Dicots							
Pinus clausa	Sand pine	61	4	58	48	—	—
Pinus ellitotii var. *Elliotii* and var. *densa*	Slash pine (and S. Florida slash pine)	95	90 (*densa*)	96	72	79 (*densa*)	73 (*densa*)
Pinus glabra	Spruce pine	—	—	—	46	—	—
Pinus palustris	Longleaf pine	90	—	94	59	57	—
Pinus taeda	Loblolly pine	—	—	82	66	—	—
Taxodium distichum	Baldcypress	—	—	—	—	95	—

[a] Invasive species, prohibited from use in Florida.

[*] Survival is defined as the percentage of trees still standing after the hurricane. Numbers are only presented for tree species having a sample greater or equal to n=20 trees for each hurricane. Least Significant Differences at p=0.05 are 35% for Jeanne, 35% for Ivan, and 30% for Charley. Erin and Opal survival percentages are from Duryea 1997; Andrew survival percentages are from Duryea et al. 1996.

In a statistical comparison of sand live oak, live oak, and laurel oak, laurel oak had poorer overall survival than both live oak and sand live oak in four panhandle Florida hurricanes (p<0.001) (Figure 3). In several publications, live oak, sabal palm, baldcypress (*Taxodium distichum*) and pondcypress (*Taxodium ascendens*) have been ranked at the top of lists for hurricane-related wind resistance (Touliatos and Roth 1971; Swain 1979; Barry et al. 1993).

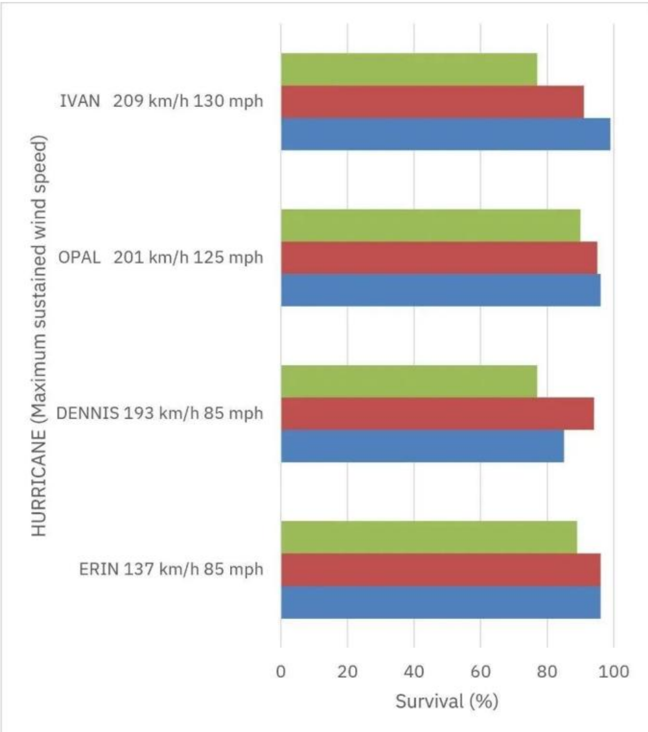

Figure 3. In a statistical comparison of sand live oak, live oak, and laurel oak survival in four Florida panhandle hurricanes, laurel oak survival was significantly less than the other two oaks (p<0.001). There was no difference between sand live oak and live oak survival.
Credit: Duryea and Kampf, UF/IFAS

Branch loss in hurricanes may also be an important measure of trees' resilience (Figure 4). In Hurricane Ivan, southern red cedar (*Juniperus virginiana* var. *silicicola*), sycamore (*Platanus occidentalis*), southern red oak (*Quercus falcata*), and laurel oak lost on average over 25% of their branches. Sweetgum, silver maple (*Acer saccharinum*), sycamore, and southern red cedar were species losing the most branches in Hurricanes Erin and Opal (Duryea 1997). Species with 10% or less branch loss were crape myrtle, loblolly pine (*Pinus taeda*), American holly, and tulip poplar (*Liriodendron tulipifera*).

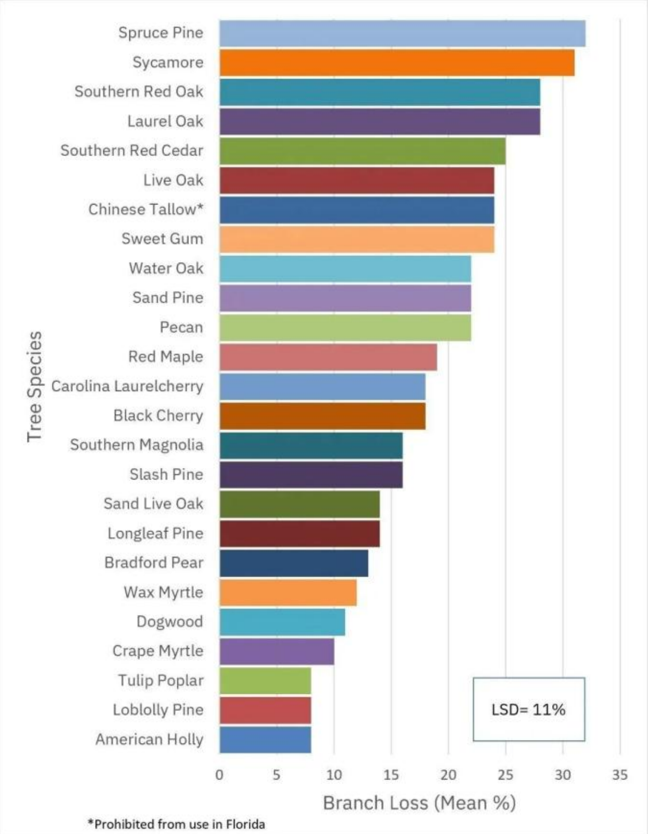

Figure 4. Average branch loss (%) for each tree species in Hurricane Ivan, which struck land at 209 km/h (130 mph). The LSD (Least Significant Difference) is at the 0.05 level.
Credit: Duryea and Kampf, UF/IFAS

When we looked at tree diameter and branch loss, we found that large trees (100–200 cm, 39–79 in diameter) lost the most branches (30%), followed by medium sized trees (50–99 cm, 20–39 in) with 25% loss, smaller trees (20–49 cm, 8–19 in) with 20% loss, and finally the smallest trees (< 20 cm, 8 in), which lost 12% of their branches (p<0.0001). Glizenstein and Harcombe (1988) also found that damage was positively correlated with average stem size in a forest stand. In their review, Everham and Brokaw (1996) summarize that most researchers have found a positive correlation between stem size and wind damage. Webb (1989) found that larger trees were more likely to be damaged directly by the wind compared to smaller trees, which were more likely to be indirectly damaged by other falling trees.

Since trees with large amounts of branch loss from a hurricane may not be considered healthy urban trees, we re-analyzed survival, considering branches lost. As mentioned before, standing trees that had 50% or greater branch loss were called dead and a "new" survival was calculated (named "recalculated survival" henceforth) (Figure 5).

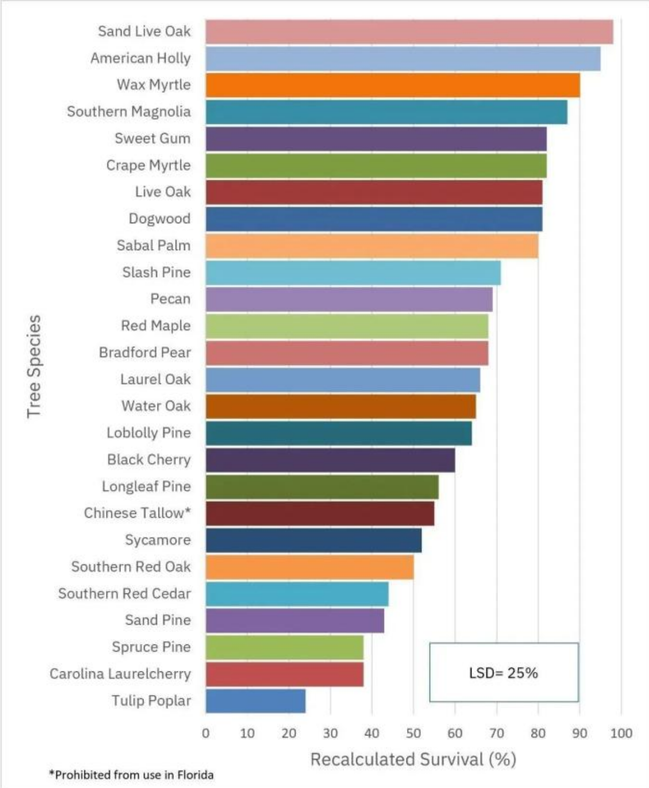

Figure 5. A recalculation of survival (%) after declaring trees with 50% branch loss dead after Hurricane Ivan. The LSD (Least Significant Difference) is at the 0.05 level. Credit: Duryea and Kampf, UF/IFAS

Some species with heavy branch loss had significantly lower recalculated survival. Southern red cedar survival was decreased from 61% to 46% due to heavy branch loss. Sycamore survival was reduced from 73% to 52%. Even live oak trees had significant branch loss, and their survival was decreased from 91% to 81%. When we statistically compared the recalculated survival of oak species after Hurricane Ivan, the ranking from greatest to lowest survival was sand live oak (98% survival), live oak (81%), laurel oak (66%), water oak (*Quercus nigra*) (65%), and Southern red oak (50%) (p=0.0001). A study in South Carolina coastal plain forests after Hurricane Hugo also found that live oak was less damaged than laurel and water oaks (Gresham et al. 1991).

Survival of pine species showed significant differences with greatest survival for slash pine (*Pinus elliottii* var. *elliottii*) (71%), then loblolly (64%), longleaf (*Pinus palustris*) (57%), sand pine (*Pinus clausa*) (43%), and spruce pine (*Pinus glabra*) (38%) (p=0.0014). Three months after Hurricane Ivan, we re-measured pines and found that 2% to 3% of the slash and longleaf standing trees had died, and 56% of the standing sand pine had died. In the southeastern coastal plain forest, longleaf pine was less damaged than loblolly during Hurricane Hugo (12% versus 73% damaged) (Gresham et al. 1991), but a tornado in Texas resulted in equal and intense damage to loblolly, longleaf, and shortleaf (*Pinus echinata*) pines (Glitzenstein and Harcombe 1988). Two conifer species that have shown repeatedly poor performance in our studies during hurricanes are sand pine and southern red cedar (Duryea 1997).

Defoliation

There were distinct species differences in defoliation during Hurricane Ivan. Species like sand live oak, crape myrtle, and dogwood lost an average of 94%, 88%, and 86% of their leaves compared to southern red cedar, wax myrtle, slash pine, longleaf pine, and loblolly pine, which lost 32%, 31%, 29%, 19%, and 11% of their leaves, respectively (LSD=17%).

Leaf loss had a positive relationship ($p<0.0001$) with both survival and recalculated survival (trees with ≥ 50% branch loss excluded), which is to say that losing leaves during the hurricane meant higher survival. Francis and Gillespie (1993), reporting on urban trees in Puerto Rico after Hurricane Hugo in 1989, also found that crown damage appeared to be avoided if the crown surface area was reduced quickly with leaf and twig loss during the hurricane. There are some exceptions to defoliation being a strategy for survival; southern magnolia, American holly, and sabal palm are all excellent survivors, but they only lost 43%, 34%, and 27% of their leaves.

Native and Exotic Trees

In the coastal plain area, exotic tree species made up 8% of the trees in the urban forest. The major exotic species were crape myrtle, Chinese tallow (*Sapium sebiferum*)—a prohibited invasive species, camphor tree (*Cinnamomum camphora*)—an invasive species, Bradford pear (*Pyrus calleryana*), and palms such as pindo palm (*Butia capitata*) and Washington fan palm (*Washingtonia robusta*). As a group, native trees survived the same as exotic trees (73% versus 77%, not significantly different [n.s.]) and lost the same amount of branches (20% versus 15%, n.s.) and leaves (58% versus 60%, n.s.). In contrast, after Hurricane Andrew struck south Florida, native trees survived winds better than non-native trees (Duryea et al. 1996). Other studies have shown trends toward increased wind damage of exotic species in rural plantation forests (King 1945; Everham and Brokaw 1996).

The Survey

Arborists' and urban foresters' ratings of wind resistance for coastal plain species show a strong agreement with our measurements over several hurricanes. Small trees that were awarded high wind-resistance ratings were fringe tree (*Chionanthus virginicus*), dogwood, persimmon (*Diospyros virginiana*), myrtle oak (*Quercus myrtifolia*), sparkleberry (*Vaccinium arboretum*), and the hollies (*Ilex* spp.) (Table 2).

Table 2. Results of Survey of Arborists, Scientists, and Urban Foresters in Florida.*

Scientific Name	Common Name	Wind Resistance						p-value	Total N
		High		Medium		Low			
		N	%	N	%	N	%		
Dicots and Pines									
Acer negundo	Boxelder	1	8	6	50	5	42	n.s.	12
Acer palmatum	Japanese maple	6	50	6	50	0	0	n.s.	12
Acer rubrum	Red maple	12	20	32	52	17	28	0.0049	61
Acer saccharinum	Silver maple	0	0	10	45	12	55	n.s.	22
Acer saccharum subsp. *floridanum*	Florida sugar maple	2	11	11	61	5	28	0.0302	18
Betula nigra	River birch	11	39	16	57	1	4	0.0019	28
Carpinus caroliniana	Ironwood	7	50	6	43	1	7	n.s.	14
Carya glabra	Pignut hickory	11	41	14	53	3	7	0.0131	27
Carya illinoinensis	Pecan	6	21	9	32	13	47	n.s.	12
Carya tomentosa	Mockernut hickory	6	50	6	50	0	0	n.s.	12
Celtis laevigata	Sugarberry	4	15	18	70	4	15	0.0005	26
Celtis occidentalis	Common hackberry	2	18	5	46	4	36	n.s.	11
Cercis canadensis	Red bud	14	48	8	28	7	24	n.s.	29
Chionanthus virginicus	Fringe tree	7	50	5	36	2	14	n.s.	14
Cornus florida	Flowering dogwood	9	60	6	40	0	0	n.s.	15
X *Cupressocyparis leylandii*	Leyland cypress	7	22	11	41	12	37	n.s.	15
Diospyros virginiana	Common persimmon	14	56	9	36	2	8	0.0128	25
Eucalyptus cinerea	Silver dollar eucalyptus	2	13	9	56	5	31	n.s.	16
Eriobtrya japonica[c]	Loquat	9	24	24	63	5	13	0.0004	38
Fraxinus americana	White ash	3	24	5	38	5	38	n.s.	13
Fraxinus pennsylvanica	Green ash	3	24	5	38	5	38	n.s.	13
Ilex cassine	Dahoon holly	34	76	10	22	1	2	0.0001	46

Scientific Name	Common Name	Wind Resistance						p-value	Total N
		High		Medium		Low			
		N	%	N	%	N	%		
Dicots and Pines									
Ilex opaca	American holly	21	75	6	21	1	4	0.0001	46
Ilex vomitoria	Yaupon holly	28	81	7	19	0	0	0.0004	37
Juniperus virginiana var. *silicicola*	Southern red cedar	14	28	18	35	19	37	n.s.	51
Lagerstoemia indica	Crape myrtle	55	83	11	17	0	0	0.0001	66
Liriodendron tulipifera	Tulip poplar	2	8	14	58	8	33	0.0111	24
Liquidambar stryaciflua	Sweetgum	18	43	21	50	3	7	0.0013	42
Magnolia grandiflora	Southern magnolia	45	82	9	16	1	2	0.0001	55
Magnolia virginiana	Sweetbay magnolia	15	42	17	47	4	11	0.0169	36
Magnolia x *soulangiana*	Saucer magnolia	8	44	9	50	1	6	0.0421	18
Morus rubra	Red mulberry	6	23	14	54	6	23	n.s.	26
Myrica cerifera	Wax myrtle	18	33	15	28	21	39	n.s.	54
Nyssa aquatica	Water tupelo	7	58	5	42	0	0	n.s.	12
Nyssa sylvatica	Black tupelo	14	58	9	38	1	4	0.0469	24
Ostrya virginiana	American hophornbeam	8	67	4	33	0	0	n.s.	12
Pinus glabra	Spruce pine	7	54	1	8	5	38	n.s.	13
Pinus elliottii var. *elliottii*	Slash pine	16	25	36	57	11	18	0.0002	63
Pinus palustris	Longleaf pine	23	56	13	32	5	12	0.0017	41
Pinus taeda	Loblolly pine	7	20	19	54	9	26	0.0289	35
Platanus occidentalis	Sycamore	17	38	21	48	6	14	n.s.	44
Prunus angustifolia	Chickasaw plum	12	50	8	33	4	17	n.s.	24
Prunus caroliniana	Carolina laurelcherry	5	16	15	48	11	36	n.s.	31
Prunus serotina	Black cherry	4	18	10	46	8	36	n.s.	22
Pyrus calleryana	Bradford pear	5	21	5	21	14	58	0.0342	24
Quercus alba	White oak	6	55	5	45	0	0	0.0539	11
Quercus falcata	Southern red oak	4	20	15	75	1	5	0.0003	20

Scientific Name	Common Name	Wind Resistance						p-value	Total N
		High		Medium		Low			
		N	%	N	%	N	%		
Dicots and Pines									
Quercus geminata	Sand live oak	36	92	2	5	1	3	0.0001	39
Quercus laevis	Turkey oak	17	47	16	45	3	8	0.0062	36
Quercus laurifolia	Laurel oak	3	4	27	39	39	57	0.0001	69
Quercus michauxii	Swamp chestnut oak	8	50	8	50	0	0	n.s.	16
Quercus myrtifolia	Myrtle oak	13	76	4	24	0	0	0.0290	17
Quercus nigra	Water oak	3	8	14	36	22	56	0.0009	39
Quercus phellos	Willow oak	1	8	8	67	3	25	0.0388	12
Quercus shumardii	Shumard oak	13	52	10	40	2	8	0.0207	25
Quercus stellata	Post oak	5	33	10	67	0	0	n.s.	15
Quercus virginiana	Live oak	64	89	8	11	0	0	0.0001	72
Salix x *sepulcralis*	Weeping willow	2	12	8	50	6	38	n.s.	16
Taxodium distichum	Baldcypress	59	91	6	9	0	0	0.0001	65
Taxodium ascendens	Pondcypress	41	91	4	9	0	0	0.0001	45
Tillia americana	Basswood	5	38	4	31	4	31	n.s.	13
Ulmus alata	Winged elm	15	53	12	43	1	4	0.0030	28
Ulmus americana	American elm	6	30	12	60	2	10	0.0224	20
Ulmus parvifolia	Chinese elm	7	23	11	35	13	42	n.s.	31
Vaccinium arboreum	Sparkleberry	11	85	2	15	0	0	0.0126	13
Palms									
Butia capitata	Pindo, jelly	34	79	7	16	2	5	0.0001	43
Phoenix canariensis	Canary Island date palm	49	89	4	7	2	4	0.0001	55
Phoenix dactylifera	Date palm	33	94	2	6	0	0	0.0001	35
Sabal palmetto	Cabbage, sabal palm	71	99	1	1	0	0	0.0001	72
Washingtonia robusta	Washington fan palm	29	54	16	29	9	17	0.0033	54

Scientific Name	Common Name	Wind Resistance						p-value	Total N
		High		Medium		Low			
		N	%	N	%	N	%		
Dicots and Pines									

[C] Caution: may be used but must be managed to prevent escape in Florida (UF/IFAS, 2018).

* Rankings for wind resistance of southeastern US coastal plain tree species. N is the number of respondents for each species, out of a total of eighty-five experts. P-values from the chi-square test for equal proportions indicate the significance level for one or more of the categories being different from the others; n.s. means that there is no significant difference between the categories of high, medium, and low (p>0.05).

While live oak and sand live oak were rated as high, other oaks such as southern red oak and swamp chestnut oak (*Quercus michauxii*) were rated as medium, and in agreement with our results, laurel and water oaks were rated as having low wind resistance. Although we have consistently seen low survival or heavy branch damage in southern red cedar, the ratings were even for each of the wind-resistance categories in the survey results. However, 91% of the respondents rated baldcypress and pondcypress with high wind resistance (Figure 6). Both cypresses were stated to have the best wind resistance along with live oak and sabal palm after Hurricanes Camille and Frederick struck the Gulf Coast in 1969 and 1979 (Swain 1979).

Figure 6. Baldcypress, a species increasingly planted in urban areas, was ranked as a highly wind resistant tree. Credit: Adobe Stock, Kazu

In the survey, sand pine received a low rating, which is consistent with our results, while the other pines were mostly rated as medium, again consistent with our results. In their summarizing list of wind resistance for forest species, Everham and Brokaw (1996) cite ten studies where loblolly, slash, and longleaf pines are ranked with low to intermediate wind resistance.

Sabal palm received a high wind-resistance rating from 99% of the survey respondents, in agreement with our ratings and those of Swain (1979). Canary Island date palm (*Phoenix canariensis*), which is being planted more frequently in north Florida, received a high rating from 89% of the respondents (Figure 7).

Figure 7. Canary Island date palm, rated as having high wind resistance, is being planted more frequently in north Florida. Credit: Adobe Stock, juerginho

Respondents rated sweetgum's wind resistance as medium to high; in a summary table of wind resistance by Everham and Brokaw (1996), seven studies rated sweetgum as having medium to high wind resistance. Our studies have shown that it survives well but is prone to some branch breakage. In a Texas study after a tornado, sweetgum was listed as one of the best survivors, but also the tree with the most branch damage (Gliltzenstein and Harcombe 1988). In a study after Hurricane Kate in 1985, sweetgum had low mortality (2%) in a southern mixed hardwood forest compared to spruce pine with 34% mortality (Batista and Platt 2003). They note that wind-firmness of sweetgum is likely due to its underground connections, short and stout branches, and leaves with slender, long petioles that readily detach from branches in wind. On gravelly ridges, hillsides, and upland piedmont sites, sweetgum has been noted to develop a particularly strong taproot and is very resistant to wind (Kormanik 1990).

Tulip poplar had very poor survival in Hurricane Ivan (24%). Survey respondents rated it as having medium to low wind resistance. Everham and Brokaw (1996) summarize two studies in their table with high levels of wind damage for tulip poplar in high intensity storms.

Recommendations

Taking our survival and branch loss results from hurricanes and incorporating results from the survey and from the scientific literature, we have developed lists of relative wind resistance for tree species in the southeastern coastal plain (Table 3). These lists should be used with caution, with the knowledge that no species and no trees are completely windproof. In addition, local considerations such as soil, cultural practices, tree age and health, and other urban forest health conditions need to be considered. In addition to hurricane wind speed, other conditions accompanying hurricanes such as precipitation and the speed with which the storms move through an area appear to influence tree response.

Relative Wind Resistance for Southeastern Coastal Plain Tree Species

Wind resistance of southeastern coastal plain species as estimated utilizing the hurricane measurements and the survey results in this study, and the scientific literature cited throughout this publication.

Highest Wind Resistance

DICOTS

Carya floridana, Florida scrub hickory

Cornus florida, dogwood

Ilex cassine, dahoon holly

Ilex glabra, inkberry

Ilex opaca, American holly

Ilex vomitoria, yaupon holly

Lagerstroemia indica, crape myrtle

Magnolia grandiflora, southern magnolia

Podocarpus spp., podocarpus

Quercus geminata, sand live oak

Quercus laevis, turkey oak

Quercus myrtifolia, myrtle oak

Quercus virginiana, live oak

Vaccinium arboreum, sparkleberry

CONIFERS

Taxodium ascendens, pondcypress

Taxodium distichum, baldcypress

Medium-High Wind Resistance

DICOTS

Acer saccharum, Florida sugar maple

Acer palmatum, Japanese maple

Betula nigra, river birch

Carpinus caroliniana, ironwood

Carya glabra, pignut hickory

Carya tomentosa, mockernut hickory

Cercis canadensis, red bud

Chionanthus virginicus, fringe tree

Diospyros virginiana, common persimmon

Fraxinus americana, white ash

Liquidambar styraciflua, sweetgum

Magnolia virginiana, sweetbay magnolia

Magnolia x *soulangiana*, saucer magnolia

Nyssa aquatica, water tupelo

Nyssa sylvatica, black tupelo

Ostrya virginiana, American hophornbeam

Prunus angustifolia, chickasaw plum

Quercus michauxii, swamp chestnut oak

Quercus shumardii, Shumard oak

Quercus stellata, post oak

Ulmus alata, winged elm

Medium-Low Wind Resistance

Dicots

Acer negundo, boxelder

Acer rubrum, red maple

Acer saccharinum, silver maple

Celtis laevigata, sugarberry

Celtis occidentalis, hackberry

Cinnamomum camphora, camphor[a]

Eriobotrya japonica, loquat[c]

Eucalyptus cinerea, silverdollar eucalyptus

Fraxinus pennsylvanica, green ash

Morus rubra, red mulberry

Myrica cerifera, wax myrtle

Persea borbonia, redbay

Platanus occidentalis, sycamore

Prunus serotina, black cherry

Quercus alba, white oak

Quercus phellos, willow oak

Salix x *sepulcralis*, weeping willow

Ulmus americana, American elm

Conifers

Pinus elliottii, slash pine

Pinus palustris, longleaf pine

Pinus taeda, loblolly pine

Lowest Wind Resistance

Dicots

Carya illinoensis, pecan

Liriodendron tulipifera, tulip poplar

Prunus caroliniana, Carolina laurelcherry

Pyrus calleryana, Bradford pear

Quercus falcata, southern red oak

Quercus laurifolia, laurel oak

Quercus nigra, water oak

Sapium sebiferum, Chinese tallow[a]

Ulmus parvifolia, Chinese elm

Conifers

Juniperus virginiana var. *silicicola*, southern red cedar

Cupressocyparis leylandii, Leyland cypress

Pinus clausa, sand pine

Pinus glabra, spruce pine

Palms

Washingtonia robusta, Washington fan palm

Notes

[a] Prohibited from use in Florida.

[b] Invasive and not recommended for use in Florida.

[c] Caution: may be used but must be managed to prevent escape in Florida (UF/IFAS 2018).

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