Critical Wind Blowdown Studies for Container Crops Using Cal Tech Wind Tunnel Facilities

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Critical wind blowdown studies were conducted in the Cal Tech wind tunnel with woody ornamental stock in various container sizes and with different plant spacing configurations. The study was conducted to assist in evaluating properties for relocation of a nursery and to determine how plant form, size and plant spacing influence the ability of wind to knock plants down and the wind velocity necessary to do this. Critical wind blowdown velocities ranged from 8.2 mph (3.9 m s^{-1}) for 1 gal (2800 cc) *Lagerstroemia indica* shrubs of 42 in. (106.7 cm) in height to 38 mph (18.1 m s^{-1}) for 5 gal (15,600 cc) *Ilex vomitoria* 'Stoke's Dwarf' bush forms.

INTRODUCTION

A literature search on wind blowdown studies on container stock revealed that no research has been done on the subject. In order to better evaluate properties for relocating Monrovia Nursery, a study was conducted in the Cal Tech wind tunnel with various sizes of container stock and spacing configurations.

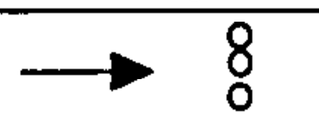
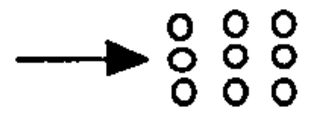
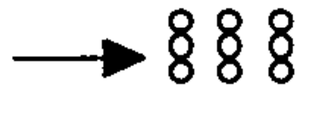
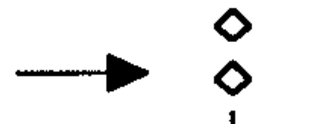
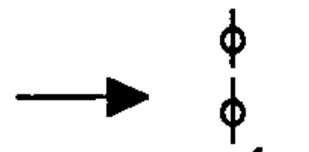
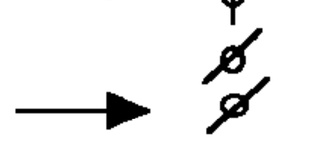
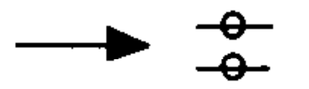
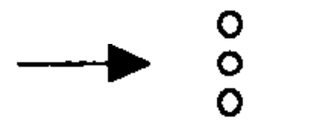
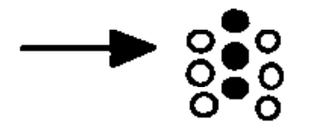
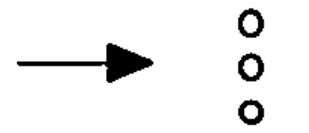
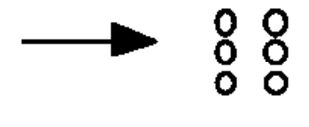
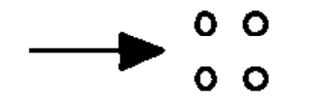
Nurserymen well know the cost and nuisance of picking up stock after it has blown over during windy periods. A knowledge of critical wind blowdown velocities will assist nurserymen in the placement and spacing of stock to minimize blowdown problems.

There are several wind tunnels at Cal Tech and at Jet Propulsion Lab, Pasadena, California. The Cal Tech wind tunnel used for these tests was built in 1928 and is still in use. It was instrumental in testing prototypes of the DC-3 (C-47) and was used until the 1950s by General Motors to test car bodies. The Cal Tech Guggenheim wind tunnel is capable of developing windspeeds of up to 200 mph (94.4 m s^{-1}). A second tunnel built in 1945 and modified in the mid 1950s is capable of developing windspeeds of 1.8 mach.

METHODS AND MATERIALS

Eighteen tests were conducted in the Guggenheim wind tunnel with gradually increasing wind velocities on 1-gal (2.8 liter) and 5-gal (15.6 liter) *Juniperus chinensis* 'Hetzii Columnaris'; 2-gal (6 liter) and 3-gal (10.6 liter) *J. chinensis* 'Robusta Green' in round containers and in 3-gal (10.6 liter) square plastic containers; 5-gal (15.6 liter) *Euonymus japonica* 'Grandifolia' espaliers; 5-gal tree *Magnolia grandiflora*, *Ilex vomitoria* 'Stoke's Dwarf', and *Hibiscus rosa-sinensis* 'Crown of Bohemia'; and 1-gal bush *Lagerstroemia indica*. The plants were arranged in either spaced single or double rows or as tight plants within rows, but spaced rows and with different orientations with respect to the wind. Wind velocities were gradually increased for each set of plants and configurations until the first plant blew down.

Table 1. Critical wind blowdown velocities for plants of different sizes and container arrangements.

Trmt.	Plant	Size & shape	Ht.[1] in.	Dia.[2] in.	Configuration	Wind → Container configuration	Critical blowdown velocity, mph.
1.	*J. chinensis* 'Hetzii Columnaris'	1	42	7	3 - 90° 3" bc		15.4
2.	"	1	42	7	9 - 90/180° 3" bc, 6" br		25.0
3.	"	5	60	12	3 - 90° 10" bc		20.2
4.	"	5	60	12	9 - 90/180° 3 x 3 10" br tbc		23.0 leaning 28.5 blowdown
5.	*J. chinensis* 'Robusta Green'	2	48	10	3 - 90° 10" bc		20.0
6.	"	3 RD	48	9	2 - 90° 10" bc		28.1
7.	"	3 SQ	48	9	2 - 90° 10" bc		25.5
8.	"	3 SQ	48	9	2 - 45° 10" bc		33.3
9.	*E. japonica* 'Grandifolia'	5 ESP	52	42	2 - 90° trellis near touching		9.5
10.	"	5 ESP	52	42	2 - 45°		12.1
11.	"	5 ESP	52	7	2 - 180°		20.2
					2 - 195°		19.6
12.	*M. grandiflora* 'Majestic Beauty'	5 TR	60	25	3 - 90°		15.0
13.	*M. grandiflora* 'Majestic Beauty' ● with *I. vomitoria* 'Stoke's Dwarf' ○	5 TR 5 BU	60 22	25 17	3 - 90° 4"bc 6 - 90° 3 x 2 10"		16.1 outside 17.5 leaning on *Ilex*
14.	*I. vomitoria* 'Stoke's Dwarf'	5 BU	22	17	3 - 90° 10"bc		38.0
15.	*L. indica*	1 BU	42	21	3 - 90° 10"bc		8.2
16.	"	1 BU	42	21	6 - 90/180° bc 3 x 2 tbc,10" br		16.1
17.	*H. rosa-sinensis* 'Crown of Bohemia'	5 BU	48	22	2 - 90° 10"bc		27.9
18.	"	5 BU	48	22	2 x 2 - 90° 10" bc br		23.5

LEGEND:

1. height of container + plant
2. diameter of plant only

10" bc = 10" spacing between container
bc = between containers
br = between rows
tbc = tight between containers
bcr = between containers and rows
deg = container orientation to wind

E. = *Euonymus*
I. = *Ilex*
J. = *Juniperus*
L. = *Lagestromia*
M. = *Magnolia*
H. = *Hibiscus*

RD = round container
SQ = square container
ESP = espalier
TR = tree
BU = bush

RESULTS AND DISCUSSION

A summary of the results are listed in Table 1. The name of the plant is indicated, its size, the size of the container, the shape of the plant and of the container, the plant and row spacing, the configuration of the plants, and the critical wind blowdown velocity.

It is interesting to note that the force required to blow down upright conifers is greater in a block with spaced rows and tight cans within the row, than is required to blow down an isolated row of tight cans of the same plant. Wind flow patterns around plants are very complicated since the plants flex, changing the pattern of turbulence around the plants. In addition, air movement through the plants, influences the pressure zones and the eddies created. Apparently a pressure/turbulence zone is created on the back side of plants in a block which helps reduce blowdown if wind strikes at right angles to the rows. Compare treatments 1 and 2, and 3 and 4.

CONCLUSIONS

1) Square 3-gal containers blow over more easily than round containers if the wind hits the containers broadside. The round containers are more "streamlined aerodynamically." However, if you simulate the streamlining by arranging the square containers so that the wind hits them at 45°, it takes greater force to blow them down than it does the round container plants. (Table 1, treatments 6, 7, and 8).

2) As expected, the espaliers are most vulnerable to blowdown, especially if oriented in a way that greater surface area is exposed to the wind at 90° (Table 1, treatments 9, 10, 11, 12). It takes the same force to blow down an espalier at 180° to the wind as it does to blow down an upright conifer.

3) A much greater force is required to "tip" over magnolia trees interspersed with low bush-type 5-gal plants. The magnolias were prevented from completely tipping over because they leaned on the low growing 5-gal stock within 4 in. of each other.

4) It took the greatest amount of force (38 mph) to blow over 5-gal *I. vomitoria* 'Stoke's Dwarf'. It would probably take a similar force to knock down 5-gal conifer spreaders such as *J. tamariscifolia*, *J. chinensis* var. *procumbens* 'Nana', *J. horizontalis* 'Bar Harbor', etc.

5) It takes twice the force to blow over spaced rows of tight *Lagerstroemia indica*, than it does isolated spaced containers.