Differential Tolerance of Eleven *Prunus* Taxa to Root Zone Flooding[1]

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Abstract

Eleven taxa of own-rooted *Prunus* L. were subjected to incremental flooding for 7 weeks to assess relative tolerance to root zone flooding. Rates of net photosynthesis (P_n) decreased gradually as the flooding stress intensified. However, 'Newport' plum maintained higher P_n than any other taxa when root systems were completely submerged. Defoliation of flooded plants ranged from a low of 15% for 'Newport' plum to a high of 100% for 'Canada Red' chokecherry. Following a chilling period, survival of flooded plants ranged from a low of 0% for Carolina cherrylaurel to a high of 100% for 'Newport' plum and 'F-12/1' mazzard cherry. Of the 11 taxa evaluated, 'F-12/1' mazzard cherry and 'Newport' plum had the greatest tolerance to root zone flooding as indicated by high survival rates (100%) and low defoliation (≤27%). 'Newport' plum further demonstrated superior tolerance to flooding compared to other taxa as indicated by a greater capacity to maintain P_n during flooding and subsequent recovery. Carolina cherrylaurel, 'Canada Red' chokecherry, and 'Peggy Clark' Japanese apricot were relatively sensitive to flooding as indicated by low survival rates (≤50%) and considerable defoliation (≥82%). The remaining taxa, including Japanese bushcherry, Sargent, Yoshino, 'Okame', 'Autumnalis' and 'Kwanzan' cherries, were found to be intermediate in tolerance to flooding.

Index words: carbon exchange rate, inundation, landscape plants, photosynthesis, poor drainage, *Rosaceae*, waterlogging.

Species used in this study: Carolina cherrylaurel [*Prunus caroliniana* (Mill.) Ait.]; 'Okame' cherry (*P. incisa* Thunb. x *P. campanulata* Maxim. 'Okame'); 'Canada Red' chokecherry (*P. virginiana* L. 'Canada Red'); 'Autumnalis' Higan cherry (*P. subhirtella* Miq. 'Autumnalis'); 'Peggy Clark' Japanese apricot (*P. mume* Siebold & Zucc. 'Peggy Clark'); Japanese bushcherry (*P. japonica* Thunb.); 'Kwanzan' Japanese flowering cherry (*P. serrulata* Lindl. 'Kwanzan'); 'F-12/1' mazzard cherry (*P. avium* L. 'F-12/1'); 'Newport' plum [((*P. salicina* Lindl. x (*P. americana* Marsh. x *P. nigra* Ait.)) x *P. cerasifera* J.F. Ehrh.)'Newport']; Sargent cherry (*P. sargentii* Rehd.); Yoshino cherry (*P. yedoensis* Matsum.).

Significance to the Nursery Industry

This research demonstrates that there is considerable variation in tolerance to root zone flooding among taxa within the genus *Prunus*. When selecting own-rooted *Prunus* for poorly drained sites, taxa more tolerant of flooding, such as 'Newport' plum should be considered. The superior flood tolerance of 'Newport' plum also suggests the potential for using 'Newport' plum, and/or other myrobalan plums (*P. cerasifera*) and hybrids, as rootstocks or breeding parents for enhancing flood tolerance of Japanese apricot and other compatible taxa. For grafted cherry plants, the rootstock 'F-12/1' mazzard cherry was found to be relatively flood tolerant, it is graft compatible with many of the flowering cherries, and may be a superior rootstock for less flood tolerant cherry taxa growing in poorly drained soils.

Introduction

Compared to many other genera of temperate woody plants, trees in the genus *Prunus* are often found to be intolerant of poor drainage (5, 12). Even in comparisons among rosaceous trees, *Prunus* species are typically found to be relatively sensitive to flooding while pome fruited genera including apple (*Malus* Mill. *spp.*), pear (*Pyrus* L. *spp.*), and quince (*Cydonia* Mill. *spp.*) are tolerant to very tolerant of root zone flooding (1, 4, 14).

In some cases it has been shown that inundation of the root system for as little as 2–5 days can be sufficient to kill certain taxa of *Prunus* including almond (*P. dulcis* Mill.), peach (*P. persica* L.), and grafted sour cherry (*P. cerasus* L. 'Montmorency' on *P. mahaleb* L.) (2, 16). However, there is considerable variation in flood tolerance among closely related plants within the genus *Prunus*. For example, based on a review of literature, Rowe and Beardsell (12) provided a relative ranking of flood tolerance of *Prunus* taxa and classified apricot (*P. armeniaca* L.), mahaleb cherry (*P. mahaleb* L.), mazzard cherry, and peach as being extremely sensitive; Japanese plum (*P. salicina* Lindl.) as being moderately sensitive; and myrobalan plum and European plum (*P. domestica* L.) as being moderately resistant. In a direct comparison of flood tolerance among *Prunus* species, Mizutani et al. (8) found Japanese bushcherry to be most tolerant; Japanese plum and myrobalan plum were tolerant; peach, Japanese apricot, Nanking cherry (*P. tomentosa* Thunb.), and Higan cherry were less tolerant; and apricot was least tolerant. Studies on tolerance of cherry rootstocks to inundation have resulted in general agreement that tolerance to poorly drained soils is greatest for sour cherry, less for mazzard, and least for mahaleb cherry (10).

Conventionally, many of the ornamental *Prunus* are propagated by budding and grafting with flowering cherries often being propagated on mazzard rootstocks (7). Recently, however, many *Prunus* taxa are being propagated from rooted cuttings and in some cases tissue culture. Although this type of propagation can simplify production practices and mini-

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mize problems of graft incompatibility and rootstock suckering, there is little information on the adaptability of many landscape *Prunus* taxa when grown on their own roots.

Plant responses to flooding typically vary with duration, intensity, and plant tolerance of the stress. Reduction in P_n is often found to be an early and sensitive indicator of plant strain in response to flooding (1, 6, 11). Prolonged flooding can result in defoliation and eventually compromise plant growth and survival (5). As a result, measurements of leaf gas exchange, defoliation, and plant survival in response to flooding can provide valuable information on the adaptability of plants to inundation and poorly drained soils. Because many species of *Prunus* are important nursery, landscape, and orchard trees, a better understanding of the flood tolerance of different taxa and their potential suitability as rootstocks would aid in the selection and improvement of more adaptable trees for varied root environments. The objective of this research was to evaluate differential sensitivity of 11 own-rooted taxa of *Prunus* to flooding.

Materials and Methods

Own-rooted plants were propagated by stem cuttings in 1990 and 1991. In March, 1992 trees, 30–46 cm (12–18 in) in height, were standardized to a uniform height and root volume and were potted into 2.8 l (3 qt) containers. Growing medium was perlite:pasteurized loam (1:1 by vol) amended with 0.45 kg dolomite/m^3 (0.75 lbs/yd^3) and were moved into a heated greenhouse. Greenhouse temperatures were maintained at approximate day/night temperatures of 21°C/18°C (70°F/65°F). The experiment was a 11 (taxa) by 2 (flooded and nonflooded) factorial treatment combination arranged in a randomized complete block experimental design with 7–10 replicate plants per factorial combination.

Considering the sensitivity of many *Prunus* species to flooding, an incremental flooding stress was imposed so that plant responses to a progressively increasing stress could be observed. Flooding treatments commenced on May 4, 1992. Flooded plants were placed in individual 4.7 l (5 qt) buckets with sufficient water to submerge the lower half of the root system. After 2 weeks (May 18, 1992) the water level was raised to submerge the lower three fourths of the plants' root systems. On May 25, 1992, 3 weeks after the flooding treatments were initiated, the water level was raised to completely submerge the root system of flooded plants. Flooding was relieved on June 22, 1992 following 3 weeks of incremental flooding and 4 weeks of complete submergence. Plants were maintained for one additional week, with irrigation as needed, until June 29, 1992.

Leaf gas exchange was measured periodically during the period from May 4, 1992 to June 29, 1992, at 3 to 10 day intervals. Rates of P_n and photosynthetically active radiation [PAR(400–700 nm)] were measured between 1030 and 1400 HR with a LI-COR model LI-6200 portable gas exchange system (LI-COR, Lincoln, NB). One leaf (3–5th most recently matured) was measured per plant on each of 5 plants per factorial combination. Gas exchange measurements were taken over a 25 sec period with CO_2 initially at approximately 330 ppm. Supplemental lighting was provided with a halogen lamp to ensure a minimum PAR of 1200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at the leaf surface.

The number of abscised leaves was recorded throughout the flooding period and the week after the stress was relieved. Remaining attached leaves were counted and removed from all plants on June 30, 1992. Trees were then cut back to 46 cm (18 in) in height and placed in a cooler at 6°C (43°F) for 10 weeks to simulate an over-wintering period. Following chilling, plants were moved to a greenhouse maintained at approximate day/night temperatures of 21°C/18°C (70°F/65°F) for six weeks. Survival was assessed on November 2, 1992.

Results and Discussion

Rates of P_n varied as a function of taxon and the flooding treatment, with no interactions, for the first 7 days of the treatment period (Table 1). Flooded plants showed a significant decrease in P_n as early as the first day of flooding when only the lower half of the root system was submerged. On day 1 and day 7 of the flooding treatment, flooded plants showed an average depression in P_n (main effect averaged for all taxa) of 7% and 19%, respectively.

From the 12th day of the treatment period throughout day 57 there was a significant water regime by taxon interaction. Rates of P_n decreased gradually for most plants as the flooding treatment continued and intensified. However, by day 43 of the treatment period, at which time the root systems of flooded plants had been completely submerged for 21 days, P_n was not significantly greater than 0 for any of the flooded taxa except 'Newport' plum. Flooded plants of 'Newport' plum maintained P_n rates significantly higher than any of the other flooded taxa from day 18 to day 50 and was the only flooded taxon that maintained rates of P_n significantly greater than 0 throughout day 50 of the treatment period.

On day 57, one week following de-flooding, P_n of flooded plants were still not significantly greater than 0 for any taxa except 'Newport' plum which had a P_n rate of 6.9 $\mu mol \cdot m^{-2} \cdot s^{-1}$ which was not significantly lower than the P_n of the 'Newport' nonflooded plants that had a mean P_n rate of 9.4 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

One week after the flooding stress was relieved, there was a significant interactive effect between irrigation regime and taxon on defoliation (Table 2). Defoliation of nonflooded plants was minimal (<7%) and was not significantly different among taxa. Defoliation for flooded plants ranged from 15% for 'Newport' plum to 100% for 'Canada Red' cherry (Table 2). Flooded 'Newport' plum, mazzard cherry, and Sargent cherry had significantly lower defoliation as compared with other flooded taxa.

At the end of the treatment period (day 57), many flooded plants were severely defoliated, yet the stem tissue beneath the bark was often green. A cold, dormant period was then provided so that survival could be more clearly distinguished when plants resumed growth following chilling. Survival was 100% for all nonflooded plants regardless of taxon (Table 2). Flooded plants, however, varied from 0 to 100% survival. Carolina cherrylaurel suffered the greatest with 0% survival while 'Kwanzan' cherry, mazzard cherry, and 'Newport' plum had similar survival rates ranging from 90 to 100%. The remaining taxa were intermediate.

Both Japanese bushcherry and 'Peggy Clark' Japanese apricot maintained positive rates of P_n long into the flooding period and following complete submersion of the root system (e.g. day 28, Table 1) indicating considerable tolerance to the stress. However, these plants eventually reached an apparent threshold of tolerance when P_n dropped to near 0 for the remaining period and did not appear to recover as

Table 1. **Net photosynthetic rate (μmol·m^{-2}·s^{-1}) of 11 taxa of *Prunus* measured periodically during 7 weeks of treatment (incremental flooding and nonflooded control) and 1 week following de-flooding.**

	Days of treatment									
Treatment/taxon	**1**	**7**	**12**	**18**	**21**	**28**	**33**	**43**	**50**	**57**
Nonflooded										
Carolina cherrylaurel	18.5^{Z}	18.1	13.9	11.9	11.6	12.0	10.3	9.0	7.5	10.4
'Canada Red' chokecherry	14.5	16.0	11.4	11.6	12.4	13.0	11.6	12.6	8.9	8.4
'Peggy Clark' Japanese apricot	13.9	15.7	14.2	13.0	13.5	13.2	11.4	11.4	8.9	10.4
Japanese bushcherry	14.2	18.0	13.1	10.0	12.1	12.9	11.3	10.0	7.2	8.3
Sargent cherry	13.6	14.3	10.8	9.1	8.8	9.7	8.1	8.6	7.8	10.1
Yoshino cherry	15.8	19.0	15.2	13.6	14.1	13.6	12.8	10.0	8.7	10.5
'Okame' cherry	19.5	20.8	19.6	16.8	19.3	17.2	15.7	15.8	7.4	12.0
'Autumnalis' Higan cherry	18.1	23.2	18.3	18.2	19.8	20.4	19.0	20.0	15.6	15.6
'Kwanzan' Japanese cherry	14.1	16.3	12.5	11.8	11.2	12.1	10.8	10.6	6.1	10.0
'F-12/1' mazzard cherry	17.2	17.4	15.1	12.5	13.1	13.1	14.1	13.1	8.9	13.2
'Newport' plum	16.1	19.2	15.2	14.9	15.0	15.4	14.3	13.5	10.3	9.4
Flooded	**1/2 flooded**			**3/4 flooded**		**submerged**				**recovery**
Carolina cherrylaurel	15.3	14.4	11.1	9.2	6.6	1.5	0.5	0.3	0.1	0.0
'Canada Red' chokecherry	13.0	11.5	5.3	2.2	3.0	0.4	0.0	0.0	0.0	0.0
'Peggy Clark' Japanese apricot	11.9	13.0	9.8	6.8	8.1	4.0	2.2	0.4	0.0	0.0
Japanese bushcherry	13.6	12.9	8.0	6.0	4.1	2.5	1.6	0.5	0.0	1.0
Sargent cherry	14.8	10.0	3.4	2.2	5.5	0.9	1.6	0.5	0.8	1.4
Yoshino cherry	15.3	15.3	13.1	1.9	1.9	0.4	0.7	-0.1	0.1	0.4
'Okame' cherry	19.4	16.2	9.3	6.0	5.9	1.8	0.9	0.2	0.0	0.3
'Autumnalis' Higan cherry	14.8	20.4	12.8	6.5	7.5	1.3	0.6	1.1	0.9	1.8
'Kwanzan' Japanese cherry	13.0	9.9	7.6	3.4	4.0	1.2	1.1	0.3	0.6	0.4
'F-12/1' mazzard cherry	15.8	15.1	8.0	3.6	5.8	2.2	0.3	0.3	0.0	0.6
'Newport' plum	16.4	21.1	14.1	14.4	12.1	12.5	9.3	6.2	4.3	6.9
Statistical analysis										
Treatment	**^{Y}	**	**	**	**	**	**	**	**	**
Taxon	*	**	**	**	**	**	**	**	**	**
Treatment × taxon	NS	NS	**	**	**	**	**	**	**	**
$LSD_{0.05}$	3.3	4.3	3.3	3.5	3.6	2.1	1.9	2.7	2.7	3.0

^{Z}Values are means, n = 5.

^{Y}NS, *, and ** indicate nonsignificant or significant at $P \leq 0.05$ or $P \leq 0.01$, respectively.

indicated by low survival rates. These data suggest, that Japanese bushcherry and 'Peggy Clark' may be relatively tolerant of a less severe flooding stress (shorter duration) than was imposed in this experiment.

Of the 11 taxa evaluated, 'Newport' plum and 'F-12/1' mazzard cherry had the greatest tolerance to root zone flooding as indicated by high survival rates (100%) and low defoliation (≤27%). 'Newport' plum further demonstrated superior tolerance to flooding over all of the other taxa as indicated by a greater capacity to maintain P_n during flooding and subsequent recovery. Other studies have consistently shown that different species of plums, including Japanese and myrobalan plums—two of the parents of the hybrid 'Newport' plum (3), are generally very tolerant to flooding compared to other *Prunus* species (9, 10, 12). The greater flood tolerance of plums appears to result from lower concentrations of cyanogenic glycosides in the roots (13, 15).

Carolina cherrylaurel, 'Canada Red' chokecherry and 'Peggy Clark' Japanese apricot were relatively sensitive to flooding as indicated by low survival rates (≤50%) and considerable defoliation (≥82%). The remaining taxa, including Japanese bushcherry, Sargent, Yoshino, 'Okame', 'Autumnalis', and 'Kwanzan' cherries were found to be intermediate in tolerance to flooding.

When selecting own-rooted taxa or rootstocks of *Prunus* for poorly drained sites, taxa more tolerant of flooding, such as 'Newport' plum, should be considered. For grafted plants, the rootstock 'F-12/1' mazzard cherry is compatible with many of the flowering cherries (7) and may be a superior rootstock for less flood tolerant cherry taxa growing on poorly drained sites. The superior flood tolerance of 'Newport' plum also suggests the potential for using 'Newport' plum, and/

Table 2. **Survival and defoliation of 11 taxa of *Prunus* for plants subjected to incremental flooding over seven weeks and nonflooded controls.**

	Survival (%)		Defoliation (%)	
Taxon	**Control**	**Flooded**	**Control**	**Flooded**
Carolina cherrylaurel	100 a^{z}	0 a	1 a	82 c
'Canada Red' chokecherry	100 a	43 b	1 a	100 d
'Peggy Clark' Japanese apricot	100 a	50 b	7 a	95 cd
Japanese bushcherry	100 a	50 b	1 a	52 b
Sargent cherry	100 a	60 b	1 a	29 a
Yoshino cherry	100 a	60 b	0 a	87 cd
'Okame' cherry	100 a	70 bc	1 a	80 c
'Autumnalis' Higan cherry	100 a	70 bc	2 a	52 b
'Kwanzan' Japanese cherry	100 a	90 cd	0 a	58 b
'F-12/1' mazzard cherry	100 a	100 d	1 a	27 a
'Newport' plum	100 a	100 d	5 a	15 a

^{z}Values are means of 7–10 plants. Means followed by the same letter within a column are not significantly different, $t = 0.05$.

or other myrobalan plums and hybrids, as rootstocks for enhancing flood tolerance of Japanese apricot and other graft compatible scions. Although Japanese apricot is reportedly graft compatible with some plums (7), apparent incompatibilities have been reported with certain Japanese apricot/plum (scion/rootstock) combinations. For example 'Kobai' Japanese apricot/myrobalan plum appear to be compatible while 'White Fast' Japanese apricot/myrobalan plum appear to be incompatible (K. Warren, personal communication; D. Werner, personal communication) indicating that such interspecific grafting should be done with caution. In other cases, flood tolerance of some taxa may be enhanced through breeding. Hybridizing flood sensitive taxa such a Japanese apricot with more flood tolerant taxa such as myrobalan plum (e.g. *P.* x *blireiana*) may serve to retain and combine certain ornamental characteristics of Japanese apricot with greater tolerance to flooding found in the plums.

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