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RESPONSE OF RABBITEYE BLUEBERRIES TO FLOODING

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Abstract. **The response of 'Woodard' rabbiteye blueberry (*Vaccinium ashei* Reade) to 0, 5, 15, 25, and 35 days of flooding was studied under field conditions during spring and summer of 1984. Flooding 35 days decreased leaf area both spring and summer, and shoot growth in the spring, while summer shoot growth decreased after 25 days of flooding. Percent fruit set and yield of flooded bushes decreased after 25 days, while the number of flower buds decreased with 5 or more days of flooding compared with unflooded plants. Generally, plant size, vigor, and yield appeared to be adversely affected after ca. 25 days of flooding. Flooding symptoms included wilting of immature leaves and stems, followed by reddening or chlorosis of mature leaves, leaf abscission, and stem die back.**

Flooding is periodically a problem for Florida blueberry growers. Many plantings are on flatwoods soils which are characterized by poor drainage and high water tables. Flooding may occur due to the presence of a hardpan causing poor drainage, which can lead to a perched water table after heavy rains. Growers have observed reduced plant vigor, yields, and in some instances death due to flooding.

Flooding tolerance varies within and among plant species (6). Survival following flooding ranges from 1 to 2 days for tobacco (9), 5 to 20 days for peach (1,11), 14 to 58 days for rabbiteye blueberries (5), 12 months for apple (1), up to 20 months for various *Pyrus* species (1), and indefinitely for various willow (1,2), tupelo, and ash species (7).

Soil oxygen depletion occurs within a few hr to a few days depending upon the soil type, soluble organic matter content, nutrient content, microbial activity, and environmental conditions (8,10). Oxygen depletion is primarily due to microbial and plant respiration and physical displacement of soil air upon initial wetting of a dry soil (8,10). The oxygen diffusion rate (ODR) through water is approximately 10,000 times slower than through air and may not be rapid enough to meet microbial and plant root demands (8,10). Nutrient availability and soil structure change during flooding and toxins and gasses accumulate (10).

Although containerized rabbiteye blueberries are moderately flood tolerant, little work has been done to determine the tolerance of bushes grown in the field. Our objectives were to determine the effect of various flooding durations on growth and development of rabbiteye blueberries under field conditions in Florida.

Materials and Methods

Three-year-old 'Woodard' rabbiteye blueberry bushes were planted in the field in Feb. at the IFAS Horticulture Unit in Gainesville, Florida. A 30 × 30 ft field plot of Myakka fine sand was disced and leveled prior to planting. Planting holes (5.3 ft^3) spaced 6 × 6 ft were lined with 6 mil plastic. Treatments consisted of flooding for 0, 5, 15, 25, and 35 days during the spring (Mar.-Apr.) or summer (Aug.-Sept.) growth periods. Treatments were laid out in a completely randomized design with 1 plant/plot and 3 plots/treatment/season. Plants were flooded using a garden hose at irregular intervals so as to maintain 3 to 5 cm of standing water in treatment plots. Flooding treatments were released by puncturing the plastic lined planting holes.

Summer soil oxygen status was determined in 3 plots/treatment at 6- and 12-inch soil depths with a Jensen Instruments Oxygen Diffusion Ratemeter (Model C) using platinum electrodes. Leaf area was determined for all plants at termination of the spring (July) and summer (Nov.) treatments with a LI-COR leaf area meter (Model LI-3000). All new shoots arising from 3 main stems/plant were measured with a ruler to determine shoot growth. Flower counts were made and percent fruit set determined for plants from the spring treatment (Feb.--Mar.) and flower bud development was determined on all shoots of plants treated in the summer (11 Nov.).

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Results and Discussion

Soil oxygen. Oxygen diffusion rates (ODR) in flooded plots decreased to approximately 0.25 $\mu g\ cm^{-2}\ min^{-1}$ within 2 days of flooding and remained below those of the unflooded plots throughout the study (Fig. 1). Similarly, a rapid decline in ODR has been shown to occur in many flooded soils (10). The increase in ODR of plots released from flooding was very slow, with initial ODR values not being attained for 100 days.

Plant roots require a minimum amount of oxygen for growth (12). For example, barley roots require a minimum ODR of 0.15 $\mu g\ cm^{-2}\ min^{-1}$, while ODR values for sugar beet roots ranged from 0.13 to 0.23 $\mu g\ cm^{-2}\ min^{-1}$ (12). Cline and Erickson (4) reported a reduction in pea plant height below 0.58 $\mu g\ cm^{2}\ min^{-1}$. Flooded plots in this study were within the ODR range (0.1 to 0.3 $\mu g\ cm^{-2}\ min^{-1}$) reported to inhibit or retard root (8,12) and shoot growth (4) for other plants.

Leaf area. Total leaf areas declined in spring and summer with 15 days or more of flooding, but did not decrease significantly until after 35 days (Table 1). The decrease can be attributed to immature leaf wilting and increased abscission of mature leaves with flooding duration. Area of individual leaves declined in spring but not in summer. A decrease or cessation of leaf expansion due to flooding also occurred in apple (3), corn (13), paper birch, sycamore, and wheat (8).

Shoot growth. The effect of flooding on shoot growth during the spring was variable; however, after 35 days shoot growth decreased 60% compared to control values (Table 2). Summer shoot growth declined 43 to 61% after 25 and 35 days of flooding, respectively (Table 2). Similarly, flooding reduced shoot elongation in apple, quince, various *Pyrus* species (1), and containerized rabbiteye

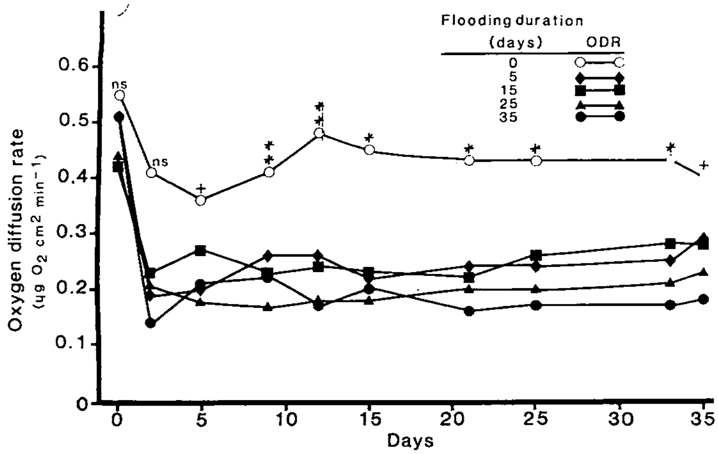

Fig. 1. Soil oxygen diffusion rate during summer, 1984. Each point is the mean of 3 replications taken at 15 and 30 cm soil depth. NS, nonsignificant, + significant at 10%, * significant at 5%, ** significant at 1%.

Table 1. Effect of flooding duration during spring and summer on leaf growth of 'Woodard' rabbiteye blueberries.

Flooding duration (days)	Spring		Summer	
	Total leaf area (cm²)^z	Indiv. leaf area (cm²)^{z,y}	Total leaf area (cm²)^z	Indiv. leaf area (cm²)^{z,y}
0	2500	4.0	1707	4.7
5	2402	4.0	1990	4.3
15	1974	3.7	1586	4.1
25	1965	3.8	1324	4.0
35	672	2.8	1292	5.5
SLR^x	*^{w}	+	+	NS

^{z}Mean of 3 plants/treatment.
^{y}90 leaves/treatment.
^{x}Simple linear regression.
^{w}NS, nonsignificant, + significant at 10%, * significant at 5%.

Table 2. Effect of flooding duration during spring or summer on shoot growth of 'Woodard' rabbiteye blueberries.

Flooding duration (days)	Spring	Summer
	Shoot growth (cm)^z	Shoot growth (cm)^z
0	130±80	114±22
5	186±37	133±78
15	82±30	137±15
25	147±108	65±6
35	52±20	44±21

^{z}Mean of 3 plants/treatment ± SD.

Table 3. Effect of spring flooding duration on flowering, fruit set and yield of 'Woodard' rabbiteye blueberries.

Flooding duration (days)	Flowers open (no.)^z	Fruit set (%)^z	Yield/plant (g)^z
0	189±41	50±10	170±69
5	199±15	48±16	342±74
15	181±47	56±11	312±121
25	167±16	35±8	246±100
35	184±34	30±13	130±111

^{z}Mean of 3 spring plants/treatment ± SD.

blueberry (5). Decreased shoot elongation may result from decreased nutrient and water uptake or from hormonal changes (8).

Flowering and fruiting. Number of flowers opening was not affected by spring (Mar.-Apr.) flooding duration; however, percent fruit set decreased by ca. 15% compared to controls after 25 days of flooding. Yields decreased dramatically after 35 days of spring flooding (Table 3). This may be due to increased leaf drop as flooding duration increased. Low yield in unflooded plots may be attributed to water stress as observed previously (5). Fruit shrivelling and abscission increased with flooding duration. Similarly, flooding stress has been reported to cause poor fruit set of apple (3) and abscission of avocado fruit (8).

Number of flower buds formed, as counted 11 Nov., decreased ca. 30% and 50% after 5 and 15 days of summer flooding, respectively (Table 4). This may have been due to a decrease in leaf area as flooding duration increased. In contrast, Childers (3) found a large increase in the number of flower clusters on a 'Staymen Winesap' apple tree after flooding of 5 weeks the previous spring.

Flooding symptoms. Rabbiteye blueberries show a progression of flooding stress symptoms. Early symptoms included wilting of immature stems and leaves, flower abscission, mature leaf curling (longitudinally) and browning, and growth cessation. Wilting of some immature stems and leaves occurred within 5 days of flooding. Flooding has been reported to cause rapid wilting in peach and apricot (11), tobacco (9), and tomato (8). Wilting may result from increased root resistance to water flow coupled with high transpiration (8). Fruit shrivelling and depressed fruit growth increased along with fruit drop as flooding duration increased. Later symptoms included leaf reddening or chlorosis, necrosis and abscission, decreased flower bud formation, stem desiccation and death. Flooding also caused leaf reddening, chlorosis, and abscission, and stem die-back in apple, peach, and some *Pyrus* species (1). Furthermore, the rate and severity of flooding symptoms often varies from plant to plant. Flooding symptoms appeared sooner in summer than spring. This may be due to increased plant metabolism as a result of higher air and soil temperatures in summer compared to spring.

Conclusions

Flooding duration of 35 days during the spring or summer decreased leaf areas of 'Woodard' rabbiteye blueber-

Table 4. Effect of summer flooding duration on flower bud development of 'Woodard' rabbiteye blueberries.

Flooding duration (days)	Flower buds formed (% of unflooded)^z
0	100
5	69
15	47
25	42
35	49
SLR^y	NS^w
LOG^x	+

^{z}Mean of 3 summer plants/treatment.
^{y}Simple linear regression.
^{x}Logarithm of number of buds regressed on flooding duration.
^{w}NS, nonsignificant, + significant at 10%.

ries under field conditions in 1984. Shoot growth of plants flooded in spring was variable, but decreased greatly after 35 days of flooding. In contrast, shoot growth of summer flooded plants decreased with flooding of 25 days or greater. Flooding durations greater than 25 days decreased percent fruit set and yields. Flower bud development was very sensitive to summer flooding, declining significantly with as little as 5 days of flooding.

Rabbiteye blueberries grown on Florida's flatwoods soils may become flooded if proper site selection and land preparation procedures (e.g. raised beds, tile drains) are not followed. Bushes growing on poorly drained sites have reduced vigor, growth and yields, and may die, particularly when soil and air temperatures are very high during flooding.

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EFFECTS OF HIGH TEMPERATURE, FERTILIZATION, AND IRRIGATION ON GROWTH AND LEAF ELEMENTAL CONTENTS OF NEWLY ESTABLISHED RABBITEYE BLUEBERRIES

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Abstract. **Subjecting 'Tifblue' rabbiteye blueberry (*Vaccinium ashei* Reade) bushes to high temperature; N, P, and K fertilization; and irrigation did not increase the leaf elemental contents. Roots retained significant levels of N, P, K, Fe, Mn, and Zn, most likely by a passive mechanism. However, translocation of these elements was impaired due to damage to the root systems from the high temperature.**

Interest in growing rabbiteye blueberries as a commercial crop has increased during the past 20 years. As fruit crops, rabbiteye blueberries are highly organized and dynamic systems with many physiological and biochemical processes which are completely dependent upon nutrients as well as moisture availability. Blueberry yield is greatly affected by nutrient and moisture levels in the soil (7, 16). Absorption and utilization of nutrients and moisture by plants are closely related to soil temperature. Cooling roots reduced the efficiency of the mechanisms which involve uptake and translocation in plants (3,11,12). Due to the fact that the native habitat of the blueberry ranges northward from Central Florida to Eastern North Carolina and westward to Eastern Texas and Southern Arkansas, the chilling requirements of rabbiteye blueberries differ significantly among different cultivars. Lowbush blueberry produced more flower buds, primordial meristems and anthacyanins in leaves at warmer than at cooler temperatures (14). Data relative to the influence of warmer temperature upon the growth and development of highbush blueberries are limited. This study was undertaken to evaluate the influence of high temperature on growth and leaf elemental contents of newly established rabbiteye blueberries.

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Materials and Methods

Thirty-six 2-year-old, uniform 'Tifblue' blueberry plants were grown under greenhouse conditions in a 1:1:1 (v:v) mixture of sandy loam soil, sphagnum peatmoss, and vermiculite, amended with agricultural sulfur to produce soil pH 4.8. The plants were randomly divided into 2 comparable groups. Soil temperature of the first group (high level) was maintained at 50 ± 2° C by means of propagation mats and heating coils attached to a electrical thermostat. Soil temperature in the second group (normal levels as control) was between 20 ± 2° C throughout the study. A drip irrigation system was installed and monitored to de-