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Effects of Short Term Flooding on Fruit Growth, Fruit Quality and Flowering of 'Miyauchi' iyo (*Citrus iyo* hort. ex Tanaka) Tangor Trees

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Summary

Effects of short term (one month from late July) flooding on fruit growth, fruit quality and flowering in 'Miyauchi' iyo (*Citrus iyo* hort. ex Tanaka) tangor were studied during July 2000 to May 2002. Fruit growth was significantly retarded by flooding. Fruit size and weight were smaller and Brix in the juice was lower in the flooding at harvest. More flower numbers were recorded in the following spring in the flooded plants but fruit set was two-fold higher in the control. The fruit growth in the second season was also retarded in the trees experienced with flooding so that the size and weight of harvested fruit were smaller, along with lower Brix and higher acid content. Each sugar component (fructose, glucose and sucrose) in the juice was lower in the flooding in both seasons. There was no flowering in flooded plants in the third season but in control it was normal as compared with the previous year. These data indicate that even a short period of flooding in one growing season affects a long term effect on fruit growth, fruit quality and flowering in 'Miyauchi' iyo tangor trees.

Introduction

Iyo tangor fruit is medium sized and has reddish rind color with glossy surface having a less than one ratio of length to width. Ehime Prefecture is called the kingdom of iyo tangor in Japan because its production accounts for 90% of the country's production (Kondo *et al.*, 2000). In some areas, iyo tangor trees were planted in low flat lands which had been used for rice paddies and changed to orchards according to the government policy for altering rice to other crops due to rice over-production.

Fruit trees are vulnerable to flooding, since poor drainage, even for a short period in one season, can have long term effects on productivity (Van't Woudt and Hagan, 1957). Morphological alternations such as formation of adventitious roots and aerenchyma have frequently been observed in flooded roots (Blom and Voesenek, 1996 ; Kludze *et al.*, 1994). The effect of waterlogging is more severe during the growing season than dormant season (Salesses *et al.*, 1970). Flooding causes hypoxia in the roots and can affect such whole plant activities as photosynthesis, transpiration and translocation. Waterlogging also influences nutrient uptake. Plants cannot con-

tinue their growth process without oxygen although different plant species have different capacities for flood tolerance. Citrus are classified as an intermediate group (Rowe and Beardsell, 1973).

Flowering and fruit set are important determinants of yield which also affect fruit size and quality (Guardiola, 1988). In some citrus cultivars the number of flowers per tree is more than sufficient to obtain a heavy crop but competition among growing organs and other factors greatly reduce fruit set so that a very low percentage of flowers develop into fruit (Agusti *et al.*, 1982).

The objective of this study was to examine the effects of short term flooding on fruit growth, fruit quality and flowering in 'Miyauchi' iyo tangor trees.

Materials and Methods

The experiment was conducted at the Ehime University Farm, Japan, from July 2000 to May 2002. In this experiment, three-year-old potted (30 cm in diameter) 'Miyauchi' iyo trees grafted on trifoliate orange rootstocks were flooded for a month from late July to late August in 2000. As flooding treatment, the pots were placed in plastic containers filled with tap water so that the soil media were completely waterlogged. The water level was corrected daily during the flooding period. Four replications were employed. Fruit growth was measured from July to December in 2000 and 2001. Flower numbers and fruit set were measured in mid April and early May, respectively in 2001 and 2002. Fruit were harvested in late December of 2000 and 2001 and fruit size, weight, Brix and acid content of the juice were analyzed.

Sugar composition (fructose, glucose and sucrose) in the juice was analyzed with a Shimadzu GC-8A gas chromatograph equipped with a flame ionization detector. Sugar analysis was done using the procedure outlined by Sweeley *et al.* (1963) with some modifications. Juice samples (2 μl) were transferred into vials and completely dried. Then 40 μl pyridine including 1,3,5-triphenylbenzene as an internal standard, 40 μl hexamethyldisilazane and 40 μl chlorotrimethylsilane were added and the vials capped. After heating at 60℃ for 30 minutes, 1 μl of the sample was injected into GC with a micro syringe.

Results and Discussion

In 2000, fruit growth was significantly reduced in the flooded trees during flooding from late July to late August (Fig. 1). The difference still continued after the cessation of flooding so that size and weight of harvested fruit were smaller in the flooded trees (Fig. 2). Brix content in the juice was slightly lower in the flooded trees (Fig. 3) but there was no significant difference in acid content between the flooded and control treatment (Fig. 4). In addition, each sugar component (fructose, glucose and sucrose) of fruit juice at harvest was lower in the flooded trees (Fig. 5).

In the following year(2001), the number of newly formed leaves was greater in the control (Fig. 6), whereas the flower numbers were significantly greater in flooded plants but fruit set

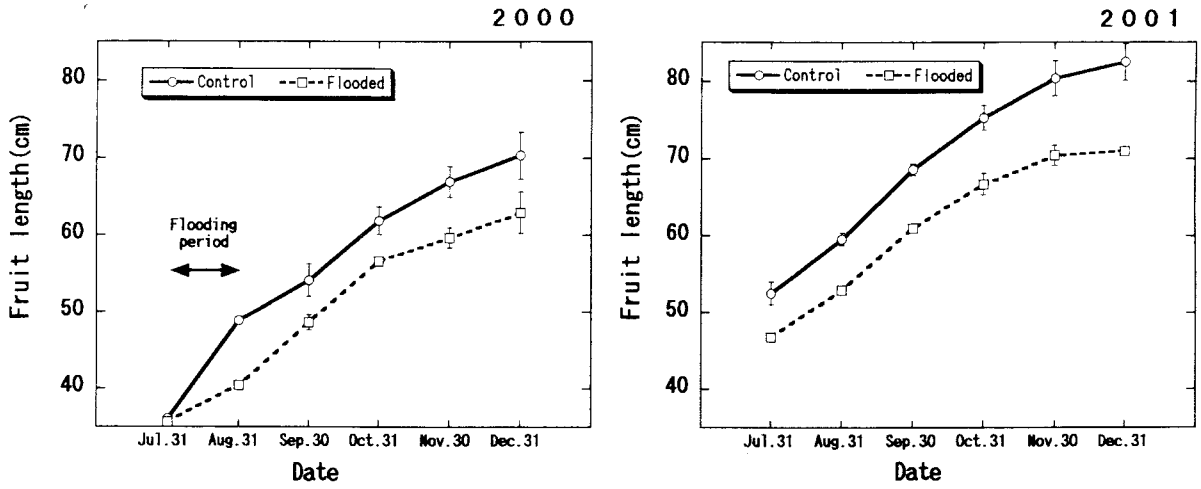

Fig. 1 Effects of short term flooding on fruit growth of 'Miyauchi' iyo tangor. Flooding was done for one month from late July to late August in 2000.

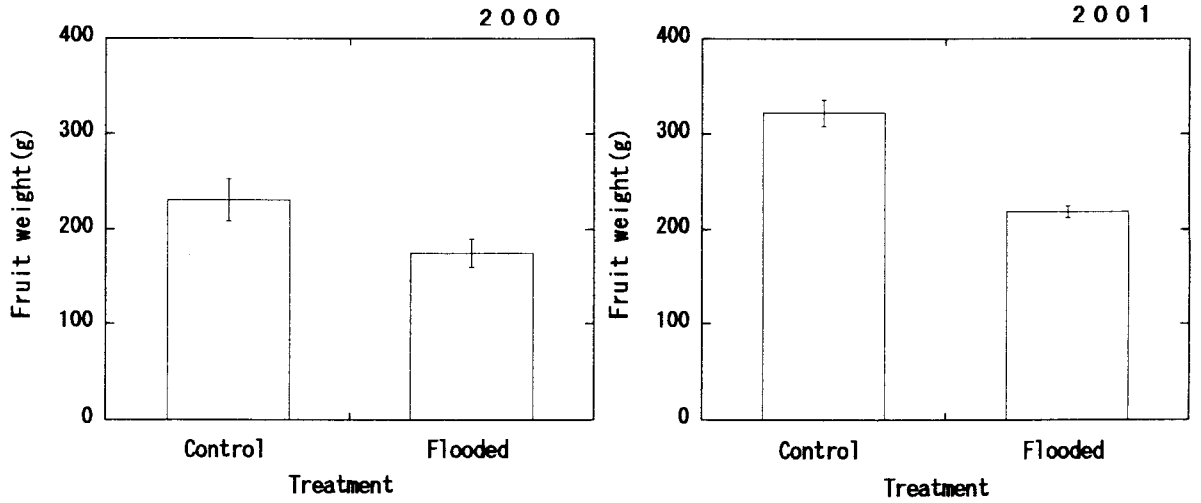

Fig. 2 Effects of short term flooding on fruit weight of 'Miyauchi' iyo tangor at harvest. (See the legend in Fig. 1 for details.)

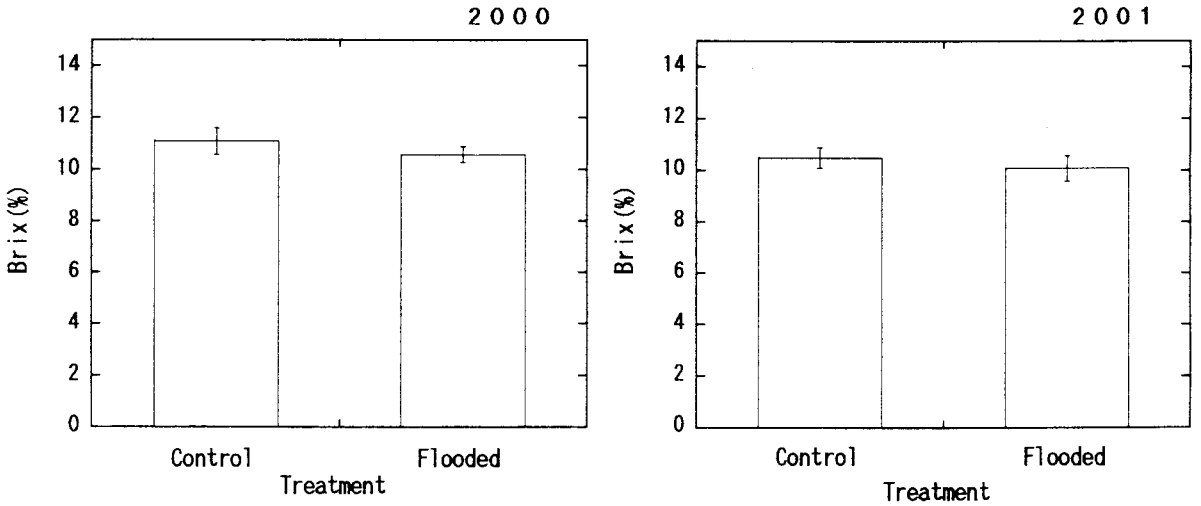

Fig. 3 Effects of short term flooding on Brix content in fruit juice of 'Miyauchi' iyo tangor at harvest. (See the legend in Fig. 1 for details.)

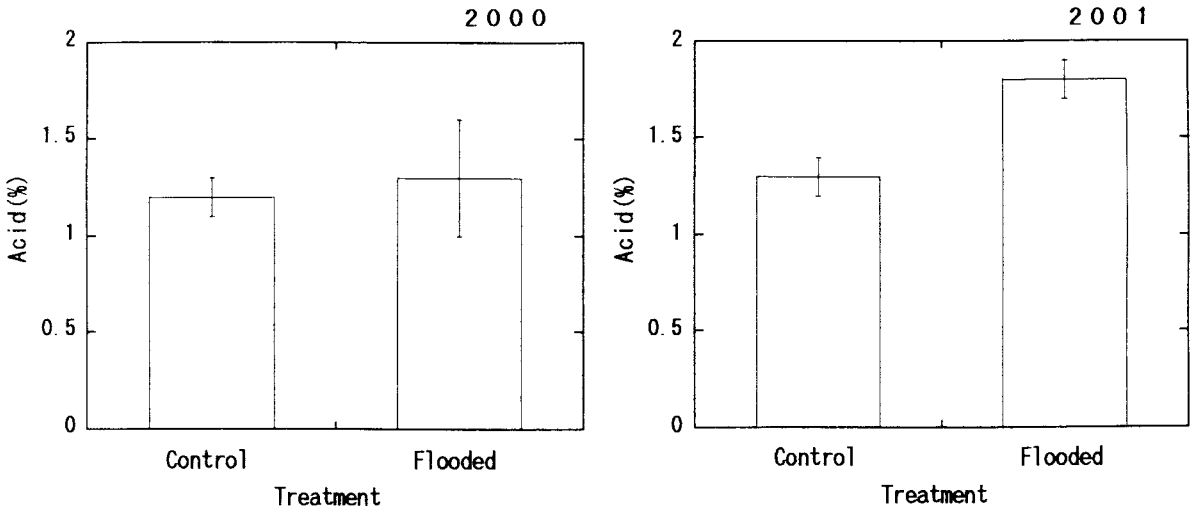

Fig. 4 Effects of short term flooding on acid content in fruit juice of 'Miyauchi' iyo tangor at harvest. (See the legend in Fig. 1 for details.)

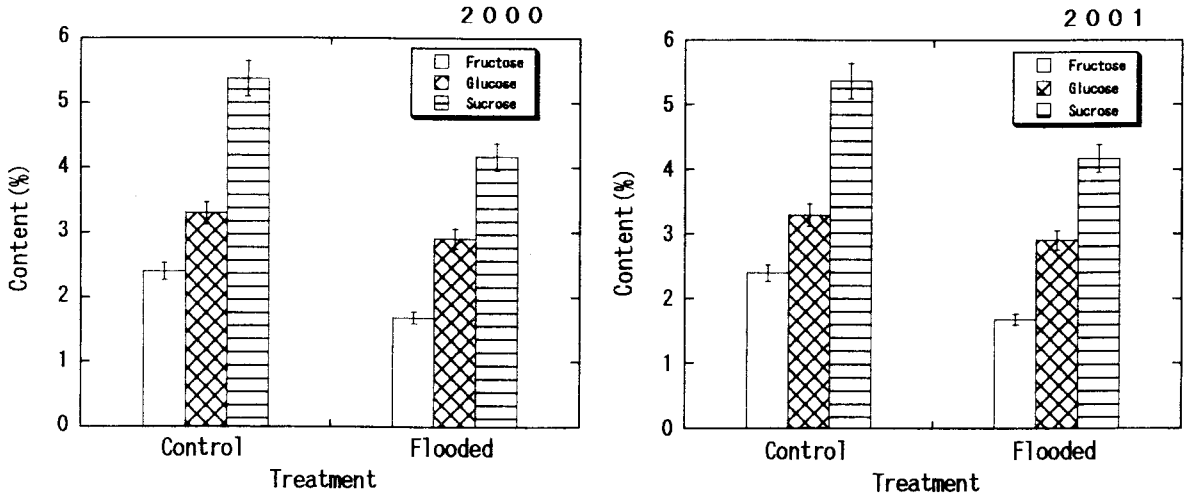

Fig. 5 Effects of short term flooding on sugar composition in fruit juice of 'Miyauchi' iyo tangor at harvest. (See the legend in Fig. 1 for details.)

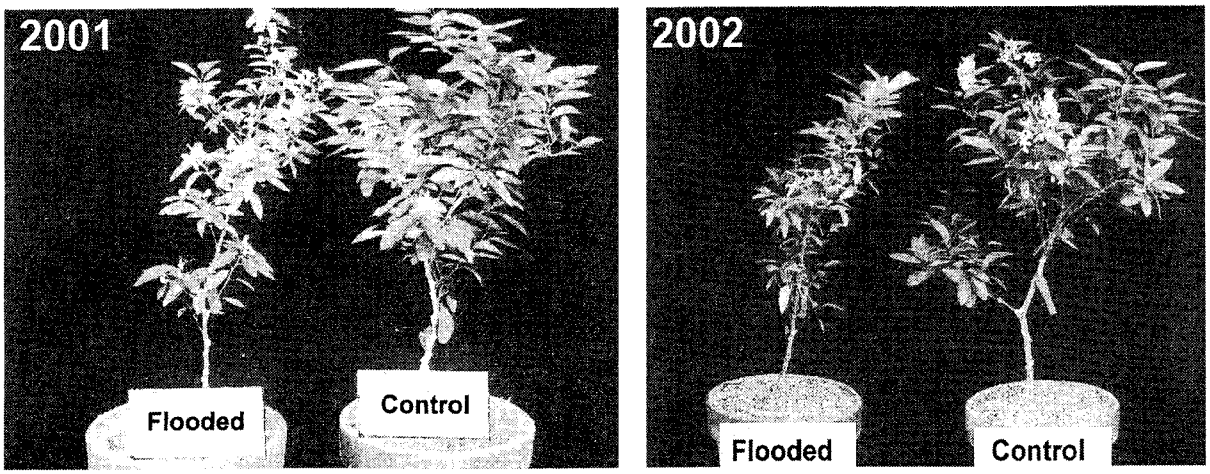

Fig. 6 Effects of short term flooding on 'Miyauchi' iyo tangor trees. Flooding was done for one month from late July to late August in 2000 and the photos were taken in April, 2001 and 2002.

Table 1 Effects of short term flooding on flowering and fruit set of 'Miyauchi' iyo tangor trees.

Treatment	No. of flowers/tree	fruit set (%)
2001		
Control	63.5 ± 10.5	25.6 ± 3.5
Flooded	139.7 ± 12.6	13.4 ± 2.4
2002		
Control	76.7 ± 8.2	29.6 ± 4.4
Flooded	0	0

was two-fold higher in control plants (Fig. 6 and Table 1). Flooding has been shown to increase ABA content in the leaves (Zhang and Davies, 1987; Jackson and Hall, 1987) and gibberellin is supposed to inhibit flower bud formation in fruit trees. Since ABA interacts antagonistically with gibberellin, the increase in the flower numbers may be due to the increase in ABA caused by flooding. The growth retardation of fruit was still noticed in the second season in the trees experienced with short term flooding in the previous year (Fig. 1). The final fruit size and weight were smaller in the flooded treatment (Fig. 2). Brix was slightly lower and acid content was higher in flooded trees (Figs. 3 and 4). Each sugar component in the fruit juice was also lower in the flooded trees (Fig. 5).

In 2002, there was no flowering in flooded plants, but in the control plants a little increase in flower numbers and fruit set relative to the previous year was observed (Fig. 6 and Table 1). Since new leaves were little formed in flooded plants in 2001 (Fig. 6), the ratio of leaves to fruit was smaller in flooded than control plants in the same season. The greater crop load seemed to cause the carbohydrate starvation in the roots of flooded plants leading no flowering in 2002.

Flooding adversely affects many tropical and subtropical fruit crops including citrus (Phung and Knipling, 1976). Prolonged flooding usually results in a cessation of root and shoot growth and wilting which decrease nutrient uptake, and eventually tree death (Schaffer *et al.*, 1991). We also found some hormonal imbalance in the roots of flooding intolerant citrus species (Bhusal *et al.*, 2002). Alternate bearing is a frequent phenomenon in many woody species and citrus species are no exception (Agusti *et al.*, 1992). In citrus, fruit can modify the hormonal balance through the synthesis of gibberellins, which inhibits flower formation the following spring in some cultivars (Moss, 1971). The reduction of carbohydrate and nitrogenous reserves in roots of trees with a heavy crop has also been put forward as a cause of reduced flowering and, therefore, directly linked to alternate bearing (Goldschmidt and Golomb, 1982).

In conclusion, our present results suggest that even a short term flooding during growing season has a long term effect on fruit growth, fruit quality and flowering in 'Miyauchi' iyo tangor trees.

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宮内イヨの果実生長、果実品質、開花に及ぼす短期間の湛水の効果

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摘　　要

短期間（2000年７月末から１ヶ月）の湛水処理が宮内イヨ樹の果実生長、果実品質、開花に及ぼす効果を2000年７月から2002年５月にわたって調査した。湛水処理によって当年の果実生長が抑制された。湛水処理によって収穫果の大きさ、重量は小さくなり、果汁の糖度はやや低くなった。湛水処理によって翌春の花数が多くなったが、着果率は対照区が湛水区の２倍であった。前年の湛水処理は２年目の果実生長をも抑制し、収穫果実の大きさ、重量は小さく、糖度は低く、酸度は高かった。収穫果の果汁の糖組成は両年とも、果糖、ブドウ糖、しょ糖いずれも湛水区の果汁で低い傾向が見られた。さらに、３年目の春には対照区は前年と同程度の花数、着果率が見られたものの、湛水区では全く花が着かなかった。これらの結果は生育期間のわずかな期間の湛水でも宮内イヨの果実生長や果実品質、開花に長期間にわたって影響が生じることを示していると思われる。