

**[Short Report]**

# Effect of Calcium Concentration on the Shape of Sweet Potato (*Ipomoea batatas* Lam.) Tuberos Root

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Several environmental factors affect the sweet potato tuberous root shape. For example, water-logging increases the length/thickness, but extremely wet soil conditions increase the tuberous root thickness (Lowe and Wilson, 1974). Spence and Hamphries (1972) reported that short and round tuberous roots developed in high-temperature conditions. However, late planting increases the length/thickness ratio of tuberous roots and results in their decreased thickness (Anderson and Randolph, 1943). Several studies on the effects of major nutrients on the tuberous root shape have been reported. For example, under low potassium conditions, a long slender tuberous root is formed (Schermerhon, 1923). The application of high levels of phosphorus increases the length of tuberous roots (Zhao et al., 1995).

Several studies have been made on the effect of Ca on root elongation (Burstrom, 1986; Evans et al., 1990; Hasenstein and Evans, 1986). Takahasi et al., (1992) reported that Ca significantly stimulated root elongation of pea and corn. In our experiments using sweet potato plants cultured in river sand, the weight of vegetative tops, roots and tuberous roots decreased and slender tuberous roots were produced, but the carbohydrate content of tuberous roots increased as the Ca concentration increased (Sulaiman et al., 2003). However, there is little information about the effect of Ca on the development of tuberous roots of sweet potato. Therefore, in this study, we investigated the effects of Ca at various concentrations on the histology of tuberous roots to determine the effect of Ca concentrations on the shape of tuberous roots.

## Materials and Methods

### 1. Plant culture

Sweet potato, *Ipomoea batatas* Lam., variety Beniotome and Kokei No. 14 were used in this experiment. A vine (cut-sprouts) 25cm in length with 7 stem nodes was transplanted into a plastic tray with bottom (60 cm length × 50cm width × 10cm depth)

filled with 10 kg of wet river-sand containing about 17mg kg<sup>-1</sup> of exchangeable Ca and 2mg kg<sup>-1</sup> of water-soluble Ca. The trays were placed above ground at a slope of 15° and covered with sliver sheets for mulching. One plant was planted on each tray. Each plant was supplied weekly with 500ml of nutrient solution containing the following elements (/L); 1.43g NH<sub>4</sub>NO<sub>3</sub>, 1.51g KNO<sub>3</sub>, 3.0g MgSO<sub>4</sub>, 0.95g KH<sub>2</sub>PO<sub>4</sub>, 0.6g Fe-EDTA, 0.07g H<sub>3</sub>BO<sub>3</sub>, 0.006g ZnSO<sub>4</sub> · 7H<sub>2</sub>O, 0.002 g CuSO<sub>4</sub> · 5H<sub>2</sub>O, 0.01g MnCl<sub>2</sub> · 4H<sub>2</sub>O and 0.0009g (NH<sub>4</sub>)<sub>6</sub>Mo<sub>7</sub>O<sub>24</sub> · 4H<sub>2</sub>O and 0 mg (low concentration), 4mg (moderate concentration) and 28mg Ca (high concentration) as CaCl<sub>2</sub>. The optimum pH range of the nutrient solution was 6.0-7.0. Ten trays -were prepared for each treatment. The present study was carried out on the experimental farm of Kagoshima University during the cropping season from June to October in 2000 and 2001. The results in the 2000 cropping season were similar to those in 2001; therefore, only the data of the 2001 cropping season are presented in this report.

### 2. Experimental procedures

Five plants from each treatment were sampled at 90 and 120 days after transplanting (90 and 120 DAP). Lengths (from the base 1cm in diameter and to the tip 1 cm in diameter), thickness (maximum thickness), and fresh weights of the tuberous roots were measured (Fig. 1). Pieces (1cm<sup>2</sup>) of tuberous root including the

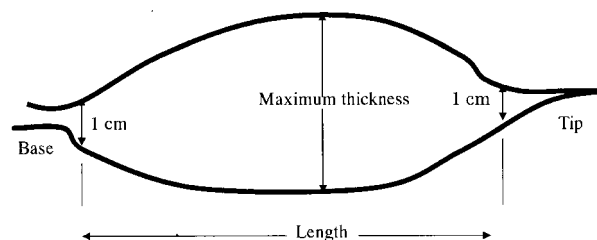


Fig. 1. Diagram of a sweet potato tuberous root in which length and thickness are measured.

Table 1. Effect of Ca concentration on top weight and the weight, number, length and thickness of tuberous roots in two sweet potato varieties at 90 and 120 days after transplanting (DAP). <sup>a</sup>Ca concentration; Low : 0 mg Ca L<sup>-1</sup>, Moderate : 4 mg Ca L<sup>-1</sup> and High : 28 mg Ca L<sup>-1</sup>. <sup>b</sup>DW; dry weight (g plant<sup>-1</sup>), <sup>c</sup>FW; fresh weight (g plant<sup>-1</sup>), <sup>e</sup>Number; per plant, <sup>d</sup>Length and <sup>d</sup>Thickness; cm per tuberous root.

Variety	DAP	<sup>a</sup> Ca concentration	Vegetative tops		Tuberous roots							
			<sup>b</sup> DW	%	<sup>b</sup> FW	%	<sup>c</sup> Number	%	<sup>d</sup> Length	%	<sup>d</sup> Thickness	%
Beniotome	90	Low	42.01a	(100)	90.4a	(100)	3a	(100)	9.3a	(100)	2.31a	(100)
		Moderate	36.14a	(86)	72.6b	(80)	3a	(100)	11.0a	(118)	1.90b	(82)
		High	30.32b	(72)	63.5b	(70)	4a	(133)	13.5b	(145)	1.83b	(79)
	120	Low	36.35a	(100)	133.8a	(100)	3a	(100)	9.7a	(100)	3.85a	(100)
		Moderate	29.45a	(81)	128.8a	(96)	4a	(133)	11.5a	(119)	3.42b	(89)
		High	26.47b	(72)	89.8b	(67)	3a	(100)	14.4b	(148)	3.18b	(83)
Kokei No. 14	90	Low	45.14a	(100)	147.3a	(100)	2a	(100)	9.2a	(100)	3.51b	(100)
		Moderate	41.05a	(90)	122.1b	(83)	3a	(150)	8.3b	(90)	2.81b	(80)
		High	36.10b	(80)	65.4c	(44)	2a	(100)	8.0b	(87)	2.30c	(66)
	120	Low	40.61a	(100)	202.1a	(100)	3a	(100)	10.3a	(100)	4.83a	(100)
		Moderate	36.57a	(90)	174.9b	(87)	3a	(100)	8.8b	(85)	4.73a	(98)
		High	30.49b	(75)	109.8c	(54)	4a	(133)	8.5b	(83)	4.22a	(87)

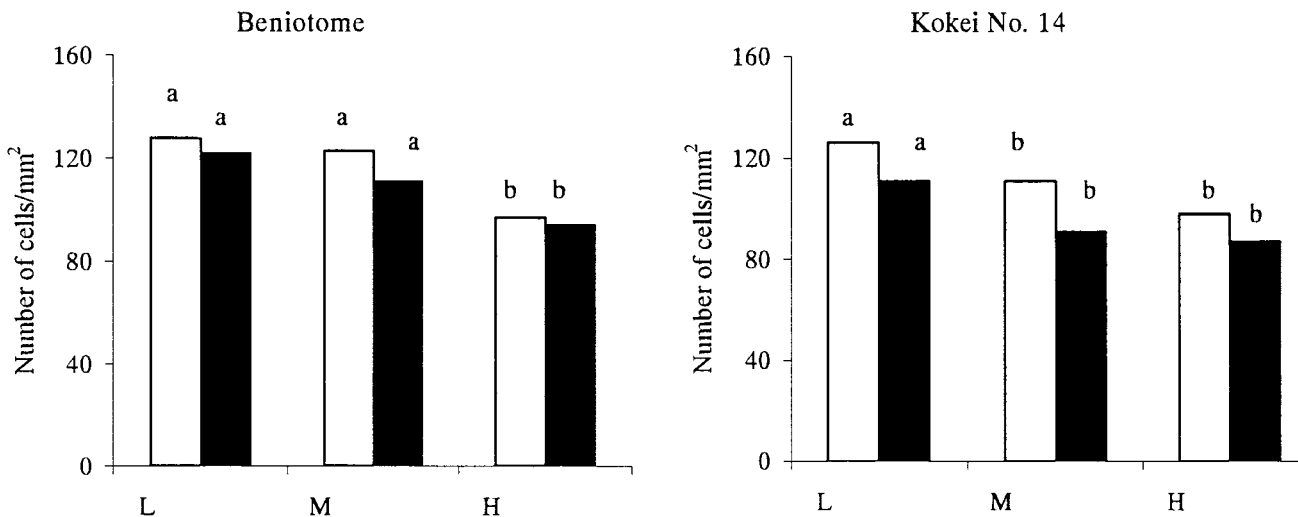


Fig. 2. Effect of Ca concentration on cell numbers per mm<sup>2</sup> in the secondary xylem parenchyma of sweet potato tuberous roots. Ca concentration; L : low, M : medium, H : high, □ : 90 DAP, ■ : 120 DAP, DAP : days after transplanting. Values with different letters are significantly different at 5% level according to Tukey's multiple range test at each harvesting time. Data are expressed as the means value of 15 tuberous roots.

secondary xylem parenchyma were fixed in formalin-glacial acetic acid (FAA) 80% ethanol solution (Johansen, 1940). The secondary xylem parenchyma was selected because it occupied a major part of the tuberous root tissues (Kokubu, 1973).

The materials fixed in FAA were dehydrated in an ethanol series, embedded in paraffin and sectioned transversely at a 15 μm thickness with a rotary or

sliding microtome. The sections were stained with safranin and aniline blue, and mounted in Canada balsam after dehydration with ethanol and clearing with xylene (Johansen, 1940). Cell sizes and numbers were observed under an optical microscope.

### Results and Discussion

The effects of the Ca concentration on the dry

weight (DW) of tops, yields and shape of tuberous root are shown in Table 1. The DW of tops and tuberous roots in both varieties at 90 and 120 DAP were lighter at the high Ca concentration than at the low Ca concentration. However, there were no significant differences in the number of tuberous roots with the concentration. Furthermore, the thickness of tuberous roots of both varieties at 90 DAP decreased as the Ca concentration increased. The H/L thickness ratio (the ratio of thickness of tuberous roots at the high Ca concentration to that at the low Ca concentration) in Beniotome and Kokei No. 14 were 0.79 and 0.66, respectively. The H/L length ratio (the ratio of length of tuberous roots at the high Ca concentration to that at the low Ca concentration) in Beniotome and Kokei No. 14 were 1.4 and 0.87, respectively. A similar tendency was observed at 120 DAP. These results suggest that the lower fresh weight of tuberous roots at the high Ca concentration is because the tuberous roots are slender in addition to the restrained growth of the vegetative tops.

The effect of Ca on root elongation has been reported as either inhibitory or stimulatory depending on the method of Ca application (Evans et al., 1990; Hasenstein and Evans, 1988). In the present study, the effects of Ca concentrations on the tuberous root length at 90 and 120 DAP differed between the two varieties. The tuberous root of Beniotome was longer at the high Ca concentration than at the low Ca concentration, while that of Kokei No. 14 was shorter at the high Ca concentration, than at the low Ca concentration. Differences in the responses of tuberous roots to the Ca concentration suggested that the sensitivity to Ca differed between the two varieties. The longitudinal growth rate of tuberous roots (from 90 to 120 DAP) in Beniotome was 4.3% at the low Ca concentration and 6.7% at the high Ca concentration. However, the transversal growth rate of tuberous roots during this period in Beniotome was 66.7% and 73.8% at the low and high Ca concentrations, respectively. A similar tendency was observed in Kokei No. 14. These results indicate that the rate of tuberous root elongation during the 30-day period was very low as compared with that of thickening. Togari (1950) reported that in the tuberous roots at 40 DAP cells in the outside of the basal and apical parts of tuberous roots were almost lignified, and had no ability to divide and enlarge. Lowe and Wilson (1974) found that the tuberous root virtually completed elongation within in 16 weeks after planting but continued thickening after the 16th week in the six cultivars examined. Somda et al. (1991) also reported that the tuberous root length reached a maximum within a certain period (i.e. 8 wk) after planting, but the diameter increased throughout the growing season. These results showed that the length of tuberous roots might be decided in an early growth stage.

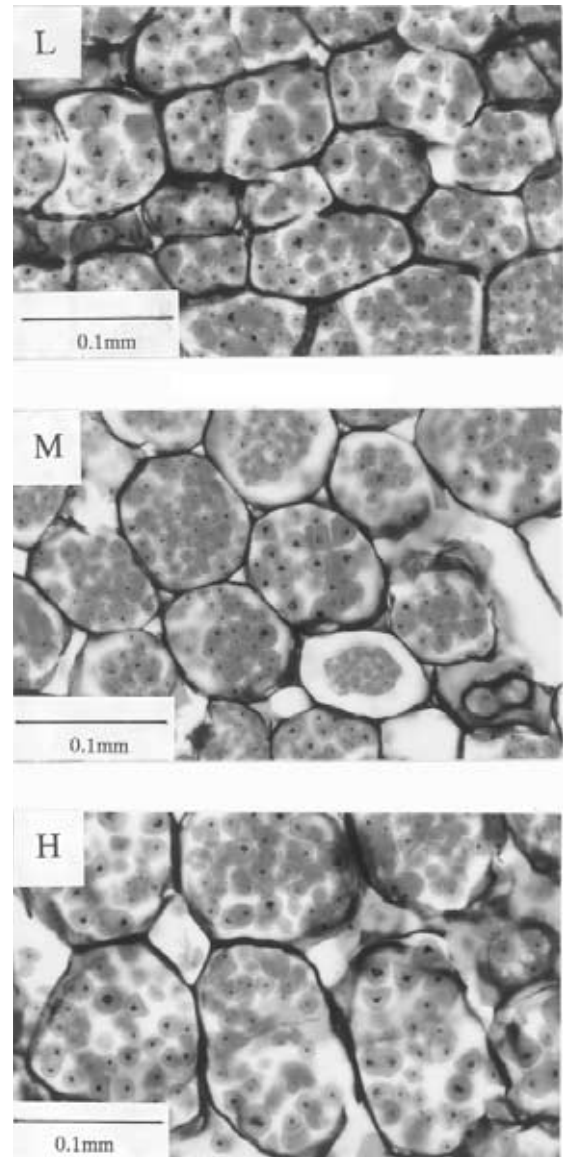


Fig. 3. Transverse sections of the tuberous root variety Beniotome showing the cell size in secondary xylem parenchyma at 120 days. Transverse sections of tuberous roots at L) low, M) moderate and H) high Ca concentrations.

Fig. 2 shows the cell density (number/mm<sup>2</sup>) in the transversal section of a tuberous root. The cell densities in both varieties at 90 and 120 DAP decreased with the increase of Ca concentration, especially in Kokei No. 14. In each Ca concentration, the cell density in Beniotome was higher than that in Kokei No. 14. On the other hand, the cell size in the secondary xylem parenchyma of the tuberous root in Beniotome was larger at the high Ca concentration than low Ca concentration (Fig. 3). The same result was observed in Kokei No. 14. Generally, the size of the tuberous root is determined by the relationship between the rates of cell multiplication and enlargement. In this experiment, the thickness of the tuberous roots was

reduced, but the cell size was increased at the high Ca concentration suggesting that a high Ca concentration reduced the cell multiplication rate. In higher plants, Ca plays a key role in many cellular processes including cell division and cell enlargement (Hepler and Wayne, 1985; Kaus, 1987). Burstrom (1952) observed that Ca promotes cell enlargement rather than cell division in the root of wheat plant. In narrow tuberous root under a high Ca concentration, cell division activity may be low compared with cell elongation. Burstrom (1968) also pointed out that Ca binds with pectin materials in the primary cell wall, permitting cell wall extension as a result of the increased plasticity. In our experiment also, a high Ca concentration might promote cell elongation by the same mechanism.

In conclusion, the growth of tops, yield and thickness of tuberous roots decreased as Ca concentration increased. The effect of Ca concentration on the length of tuberous root were different between the two varieties, which might be due to a difference in sensitivity to Ca. A high Ca concentration might restrain cell multiplication. A slender tuberous root in high Ca concentration might be due to the increased cell elongation rather than decreased cell multiplication. Sweet potato tuberous root grown at a high Ca concentration contained larger amounts of total sugar and crude starch (Sulaiman et al., 2003). This may be due to the depression of starch synthesis by lower absorption of

potassium. However, the mechanism is unclear. The effects of Ca as well as other nutrients on tuberous roots development need to be examined further.

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\* In Japanese with English summary.