Effects of light intensity, soil acidity, and nitrogen concentration on the vegetative growth of pitaya seedlings©

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INTRODUCTION

Pitaya (*Hylocereus undatus*) is a little-known tropical fruit in Japan. Pitaya fruit contains important nutrients to enhance human health, including dietary fiber, vitamins, minerals, and polyphenols (Mahattanatawee et al., 2006). The fruit also contains oligosaccharides known to improve the intestinal environment (Wichienchot, 2010). Red pitaya fruit contains betalains, pigments with antioxidant activity that are used as natural dyes and to remove active oxygen species (Wu et al., 2006; Tenore et al., 2012).

The pitaya flower opens at night and wilts the next morning. It resembles the queen of the night flower (*Epiphyllum oxypetalum*), which is approximately 25-30 cm in length. The queen of the night flower usually blooms 3-4 times a year, whereas the pitaya flower blooms 5-6 times a year, from spring to autumn.

Pitaya plants tolerate temperatures as low as -4°C; thus, they could grow during the winter season in the warmer regions of western Japan (Fumuro et al., 2013). Pitaya requires relatively simple management practices and is expected to increase in popularity.

Comparisons of pitaya cutting propagation techniques have identified an auxin that promotes rooting (Fumuro, 2011). Fumuro (2015) measured the effects of growth regulators on pitaya growth and reported that gibberellin promoted cladode growth. Alternatively, spraying cladodes with ethephon and applying 1-naphthaleneacetic acid (NAA) inhibited cladode growth (Fumuro, 2015).

Pitaya is a type of epiphytic cactus native to tropical forests. Pitaya growth is weak in the presence of strong solar radiation and requires cheesecloth to provide shade. The optimal light intensity varies by species (Le Bellec et al., 2006). The optimal light intensity in Japan, which is at higher latitude than the location where pitaya is normally found, has not been determined.

Pitaya is grown in a wide range of climates, from arid to high-rainfall areas (Le Bellec et al., 2006). Although slightly acidic soil is common in Japan, there is a difference from most strongly acidic to alkaline soils. Pitaya is adapted to a wide range of soil types, and is minimally affected by soil acidity. However, the relationship between seedling growth and soil acidity is unclear. In addition, the optimal method of fertilization for pitaya cuttings has not been established.

This study was conducted to measure the effects of light intensity, soil acidity, and nitrogen concentration on pitaya growth to improve the efficiency of pitaya cutting production.

MATERIALS AND METHODS

All experiments were performed in 2006 and 2007 using rooted cladodes growing in pots (13.5 cm diameter, 11 cm height) in a greenhouse (6.3 m width, 9.6 m length; about 60 m^2) at the experimental farm of Kinki University. Cladode cuttings were collected from 4- and 5-year-old trees grown in the greenhouse (6.5 m wide, 20.8 m length; about 135 m^2). Each cutting was trimmed to 11-12 cm, sprayed with a solution of 500 ppm of benomyl and 150 ppm of streptomycin, and placed in a shaded, well-ventilated location for 48 h to allow the wounds to heal. The cuttings were dipped into a 2,000 ppm solution of NAA (Wako Pure Chemical Industries, Osaka, Japan) for 10 s to promote rooting. Each cutting was planted at a depth of 4 cm in a container (22 cm wide, 65 cm long, 18 cm deep) filled with a soil mixture

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(mountain soil, peat moss, and vermiculite mix (2:1:1, by vol.), and grown in a greenhouse under 50% shade. Cladode cuttings were rooted about 1 month after preparation. Using the cuttings propagated as described above, the following experiments were conducted.

Experiment 1. the effect of light intensity

In 2007, the 3- to 4-month-old rooted cuttings with one new cladode, approximately 10 cm long, were used. Ten rooted cuttings were shaded with three types of cheesecloth to create variations in light intensity; 10 untreated cuttings were used as controls.

The light intensity prior to shading was measured on 14 April, inside and outside the greenhouse, using a solar radiation meter. The light penetration rate (LPR) of the controls (non-shaded) was 86% outside the greenhouse. Light penetration through the three types of cheesecloth was 10, 45, and 71% outside the greenhouse. If a new cladode started to sprout from the old cladode it was removed immediately. The average lengths of the old rooted cladodes for the three types of cheesecloth and the control were as follows: 10%, 12.1±0.7 cm (mean±standard deviation); 45%, 12.6±1.2 cm; 71%, 12.3±2.1; and 86% (controls), 11.8±1.2 cm.

The plants were watered once daily, and 5 g of delayed release fertilizer (10 N:10 P_2O_5:10 K) was applied to each pot at the start of the experiment. The greenhouse was ventilated by a fan when the internal air temperature reached 30°C to maintain the temperature below 35°C. Both the side windows and skylights remained open from April to November.

The degree of sunburn occurrence was rated using five levels based on the percentage of new cladode death: 0 (0%), 1 (10%), 2 (20%), 3 (30%), 4 (40%), and 5 (more than 50%). The lengths of all new cladodes were measured 30 (14 April), 60 (14 May), 90 (13 July), and 120 days (12 August) after shading. The plants were separated into new cladodes, old cladodes, and roots on the last day of measurement. Fresh weights were recorded before drying to a constant dry weight in an oven at 80°C The weights were recorded after drying, and the dry matter percentage of each organ was calculated.

Experiment 2: the effect of soil acidity

In 2007, 3- to 4-month-old rooted cuttings with one new cladode, approximately 10 cm long, were used in this experiment. Soil pH adjustment was performed by adding hydrated lime to mountain soil, which was strongly acidic (around pH 4.5). Acidic soil with a pH of 5.5, neutral soil with a pH of 7, and alkaline soil with a pH of 8 were prepared.

On 14 May, the plants were transplanted to larger pots (18 cm diameter, 15 cm height) using the adjusted and unadjusted soils as described above. Similarly, on 26 July the soil was replaced with recently adjusted soil or unadjusted soil to correct for any changes in soil acidity. Ten rooted cuttings were used for each soil acidity level.

To prevent sunburn, the seedlings were covered with cheesecloth to provide 50% shade. The seedlings were watered once daily, and liquid fertilizer (N:P_2O_5:K = 6:10:5), diluted 500-fold, was applied at 200 ml per pot on 22 May and 9August. On 22 October, the new and old cladode lengths were recorded and separated into new cladodes, old cladodes, and roots. Their fresh and dry weights were measured as described above. The average lengths of the old cladodes were as follows: strongly acidic soil, 12.1±2.2 cm; acidic soil, 12.5±1.0 cm; neutral soil, 12.5±1.2 cm; and alkaline soil, 11.9±1.8 cm.

Experiment 3: the effect of nitrogen concentration

In 2006, 2-month-old rooted cuttings without new cladodes were used in this experiment. The mountain soil did not contain inorganic or organic components, and the electrical conductivity was almost 0. The nitrogen concentration was adjusted to 25, 50, and 100 ppm, applying 150 ml of ammonium nitrate solution per pot once a week from 6 July to 31 January of the following year. As a control (N = 0 ppm), tap water was applied. With respect to phosphorous and potassium, liquid fertilizer (0 N:6 P_2O_5:4 K) lacking nitrogen was applied biweekly by diluting it 500-fold (120 ppm P_2O_5 and 80 ppm K) under 50% shade. Fifteen plants were used for each nitrogen concentration.

The lengths and rate of new cladode occurrence were measured once a month until 7 February. They were separated into new cladodes, old cladodes, and roots on the last day of measurement. Their fresh and dry weights were measured as described above. The average lengths of the old cladodes of the seedlings were as follows: 0 ppm, 11.2±0.5 cm; 25 ppm, 11.6±0.5 cm; 50 ppm, 11.3±0.4 cm; and 100 ppm, 10.9±0.7 cm.

RESULTS AND DISCUSSION

Experiment 1: the effect of light intensity

The extent of sunburn occurrence for 86 and 71% LPR was 1.4±0.7 and 0.1±0.3, respectively. Sunburn did not occur at 10 or 45% LPR. The new cladodes were the longest for both 71 and 45% LPR, followed by 86 and 10% LPR (Figure 1). The fresh weight of new cladodes was the highest for 71% LPR, followed by 45 and 86% LPR, and the lowest for 10% LPR (Table 1). The root fresh weight was the highest at 71% LPR, and there were no significant differences between other LPRs. The total fresh weight was the highest for 71% LPR, followed by 45 and 86% LPR, and lowest for 10% LPR. As for flesh weight, the dry weight of the new cladodes was the highest for 71% LPR, followed by 45 and 86% LPR, and the lowest for 10% LPR. The root dry weight was also the highest for 71% LPR, and there were no significant differences between other LPRs. The dry weight percentages of old cladodes were higher for 71 and 86% LPR than that of 10% LPR. The new cladode dry weight percentages were the highest for 71% LPR, followed by 45 and 86% LPR, and the lowest for 10% LPR (Table 2).

Table 1. The effect of light intensity on the flesh and dry weights of each organ in pitaya seedlings.

Light penetration rate (%)	Flesh weight (g)[1]				Dry weight (g)[1]			
	Old cladode	New cladode	Root	Total	Old cladode	New cladode	Root	Total
10	64.2 a[2]	60.3 c	4.5 b	129.0 c	5.0 a	4.1 c	0.8 b	9.9 c
45	63.7 a	158.1 b	4.7 b	226.5 b	5.5 a	13.8 b	0.9 b	20.2 b
71	56.6 a	188.3 a	6.8 a	251.7 a	5.5 a	19.4 a	1.4 a	26.3 a
86	51.8 a	58.3 b	4.5 b	214.6 b	4.9 a	14.2 b	1.0 b	20.1 b

[1]Measured after 4 months of the treatment.

[2]Values in a column followed by the same letter are not significantly different (P<0.05) by Tukey-Kramer's multiple range test.

Table 2. The effect of light intensity on the dry weight percentage of each organ in pitaya seedlings.

Light penetration rate (%)	Old cladode (%)	New cladode (%)	Root (%)
10	7.8 c[1]	6.9 c	19.6 c
45	8.6 b	8.7 b	19.9 b
71	9.8 a	10.3 a	20.1 b
86	9.4 ab	9.0 b	20.9 a

[1]Values in a column followed by the same letter are not significantly different (*P*<0.05) by Tukey-Kramer's multiple range test.

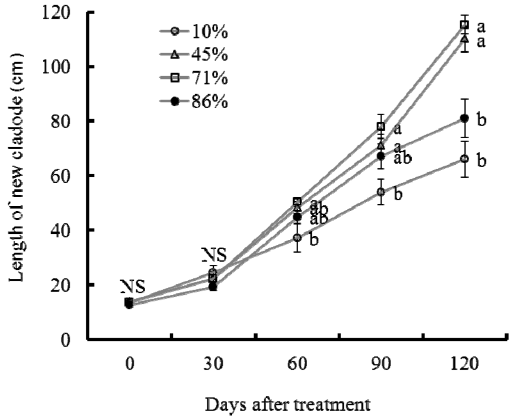

Figure 1. The effect of light penetration rate on the elongation of new cladodes in pitaya seedlings. Vertical bars represent ± SE. NS and values followed by the same letter are not significantly different (P<0.05; Tukey-Kramer multiple range test).

Pitaya, which is native to tropical forests, does not tolerate strong solar radiation. Pitaya also does not require a high photosynthetic photon flux density for photosynthesis (Nobel and Barrera, 2004). Raveh et al. (1998) reported that the most favorable conditions for growth and fruit production were 30% shade for *H. polyrhizus*, while, for *Selenicereus megalanthus*, 60% shade was optimal. This study showed that 30% shade is best for *H. undatus*, as reported by Raveh et al. (1998) for *H. polyrhizus*.

Experiment 2: the effect of soil acidity

There were no significant differences in new cladode length, or in the flesh and dry weights of each organ (Figure 2, Table 3). Cladode growth was not affected by soil acidity at a pH range of 4.5 to 8.

"Kanuma-tsuchi" and "Akadama-tsuchi" gardening soils are popular in Japan and are frequently used to grow horticultural crops. The former is strongly acidic (pH = 4-5), and the latter is slightly acidic (pH = 6-7). Soils mixed with vermiculite, peat moss, or compost are also commercially available. They are often adjusted to a pH that is slightly acidic to neutral. However, the cost of plant production is high because these soils are expensive. Since there is little influence of soil acidity on plant growth, field soil could be used to reduce the production cost.

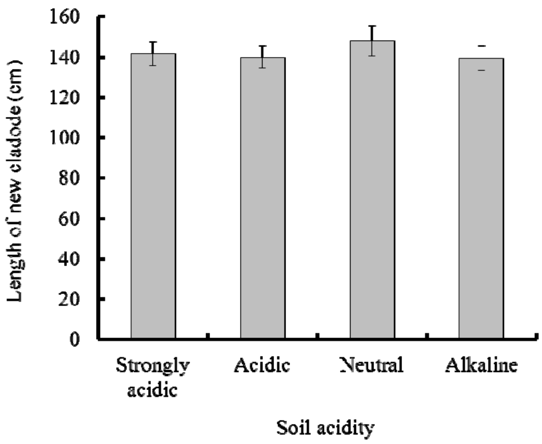

Figure 2. The effect of soil acidity on the elongation of new cladodes in pitaya seedlings. Vertical bars represent ± SE.

Table 3. The effect of soil acidity on the flesh and dry weights of each organ in pitaya seedlings.

Soil acidity	pH	Flesh weight (g)[1]				Dry weight (g)[1]			
		Old cladode	New cladode	Root	Total	Old cladode	New cladode	Root	Total
Strongly acidic	4.5	57.0	193.0	8.6	258.6	5.8	21.6	1.7	29.1
Acidic	5.5	57.9	212.8	9.6	280.3	5.6	22.9	1.9	30.4
Neutral	7.0	59.7	218.1	9.3	287.1	6.2	23.7	1.9	31.8
Alkaline	8.0	55.2	206.6	7.9	269.7	5.8	23.2	1.6	30.6
Significance[2]		NS	NS	NS	NS	NS	NS	NS	NS

[1]Measured after 5 months of the treatment.

[2]NS: non-significant at P=0.05.

Experiment 3: the effect of nitrogen concentration

The rates of new cladode occurrence after 1 month of treatment were approximately 60-90%. The rate increased as the nitrogen concentration increased (Figure 3). New cladodes were observed at all nitrogen concentrations after 2 months of treatment. The new cladodes were longer as the nitrogen concentration increased (Figure 4). The growth of new cladodes in 0 ppm nitrogen stopped after 2 months of treatment, and growth in 25 ppm nitrogen remained low after 2 months of treatment. As the nitrogen concentration increased, the fresh and dry weights of the total plant, new cladodes, and roots increased (Table 4).

Several reports have been published regarding the effect of chemical fertilizer application on pitaya growth. The application of chemical fertilizers, including nitrogen, improves tree growth and the fruit yield and quality of pitaya (Muchjajib and Muchjajib, 2012; Chakma et al., 2014). However, research focusing on a suitable nitrogen concentration for potted seedlings has not been reported. The results of this study indicate that the nitrogen concentration for seedling production was sufficient at 50-100 ppm.

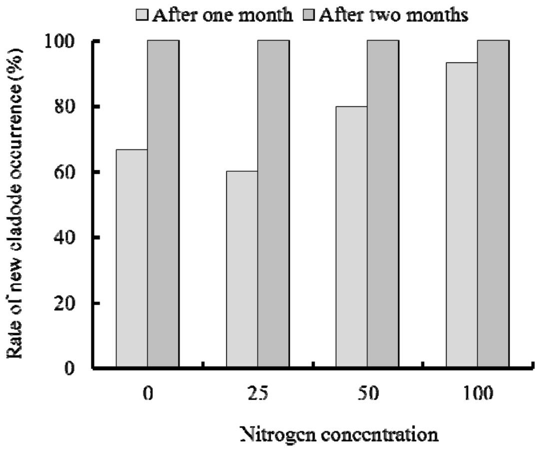

Figure 3. The effect of nitrogen concentration on the rate of new cladode occurrence in pitaya seedlings.

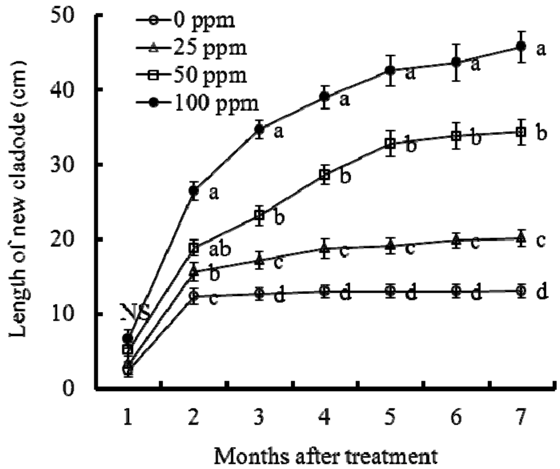

Figure 4. The effect of nitrogen concentration on the elongation of new cladodes in pitaya seedlings. Vertical bars represent ± SE. NS and values followed by the same letter are not significantly different (*P*<0.05; Tukey-Kramer multiple range test).

Table 4. The effect of nitrogen concentration on the flesh and dry weights of each organ in pitaya seedlings.

Nitrogen concentration (ppm)	Flesh weight (g)[1]				Dry weight (g)[1]			
	Old cladode	New cladode	Root	Total	Old cladode	New cladode	Root	Total
0	53.3a[2]	23.3d	1.1c	77.7d	6.0a	2.5d	0.2c	8.7d
25	56.8a	42.2c	1.9b	100.9c	6.3a	4.6c	0.4b	11.3c
50	59.0a	65.6b	2.5b	127.1b	6.6a	7.1b	0.5b	14.2b
100	56.0a	82.6a	3.2a	141.8a	6.4a	9.1a	0.7a	16.2a

[1]Measured after 5 months of the treatment.

[2]Values in a column followed by the same letter are not significantly different (P<0.05) by Tukey-Kramer's multiple range test.

CONCLUSIONS

The results of this study indicate that a suitable light intensity for the growth of pitaya seedlings is about 70%. Seedling growth was unaffected by soil acidity, and 50–100 ppm was found to be a suitable nitrogen concentration.

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