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Cultural Experiment of Reddish–Purple Tuberose (*Polianthes*) under Different Climate Conditions in Taiwan

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The cultivation of reddish–purple tuberose ‘77A05’ in open fields was carried out at four different altitudes in Taiwan and the site selection for commercial production for cut flowers in colored tuberose was discussed.

Days to flowering from planting at Pingtung (altitude=25 m) and Tapan (1,200 m) were 80.3 and 89.5, respectively. The higher altitude, the longer the flower stalk. Floret size increased by increasing the altitude, but number of florets was not affected. Flowers cultivated at Chiayi (75 m) and Pingtung were pale purple but reddish–purple at Hsinshe (500 m) and Tapan. The anthocyanin content of the flowers at Hsinshe and Tapan was approximately two and three times higher than that at Pingtung, respectively.

The site selection for cultivation of colored tuberose when anthocyanin is the primary pigment must be carefully considered. High elevation areas in Taiwan seem to be suitable for the cultivation of anthocyanin–containing tuberoses.

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) is one of the most important cut flowers in Taiwan (Shen *et al.*, 1987). At present, there are only two white–flowered varieties ‘Single’ and ‘Double’ cultivated in Taiwan. We have bred many hybrid lines by the cross with *Polianthes howardii*. They have new flower colors such as pink, reddish–purple, purple, orange and yellow derived from reddish–purple flowers of *P. howardii* (Huang *et al.*, 1998).

In the previous report (Huang *et al.*, 2000), we observed that in one of the newly established reddish–purple tuberoses, ‘77A05’ a period from planting of the corms to anthesis was significantly shorter and the flowers were significantly larger at high temperature conditions than at low temperatures. However, the flower colors were almost white at 30 °C or at 25 °C with 45% shading of natural light. Accordingly, establishment of suitable cultivation conditions for anthocyanin–containing cultivars such as ‘77A05’ is necessary.

In the present investigation, the cultivation of ‘77A05’ in open fields was carried out at four different altitudes in Taiwan and the suitable site for commercial production for cut flowers in colored tuberose was discussed.

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MATERIALS AND METHODS

Plant materials and growing conditions

Cultivation of '77A05' in open fields was carried out at four locations in Taiwan; Pingtung (altitude=25m), Chiayi (75m), Hsinshe (500m) and Tapan (1,200m) (Fig. 1). Corms of '77A05' grown in the farm of National Chiayi University, Chiayi, Taiwan, Republic of China were harvested in the end of February 1999 and stored at room temperature. Fifty corms were planted in each experimental field on 1 April 1999. Average, minimum and maximum temperatures during cultivation and diurnal range of temperature in each experimental site are provided in Table 1 and Fig. 2, respectively.

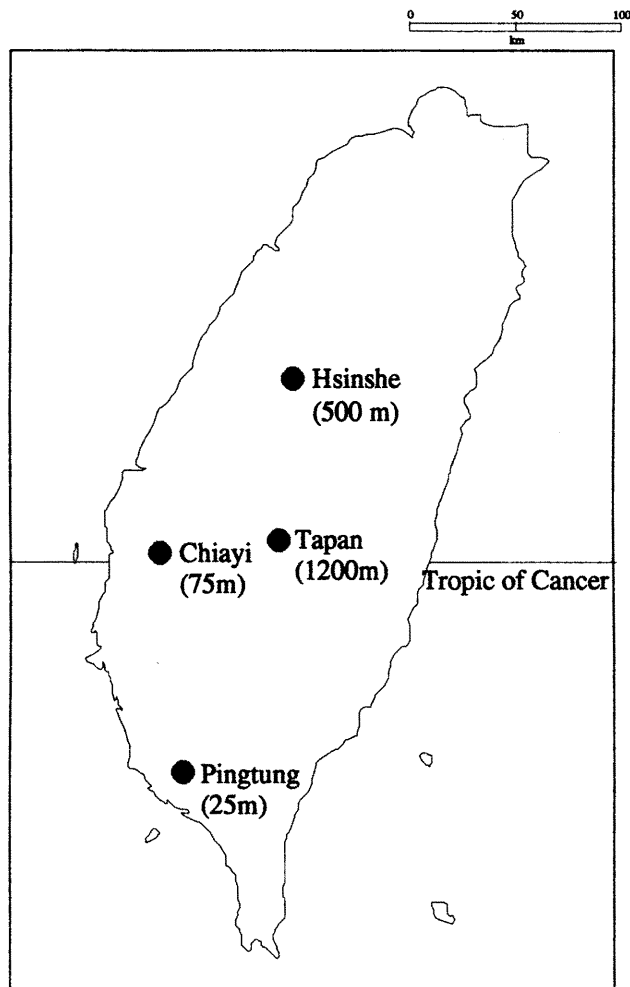
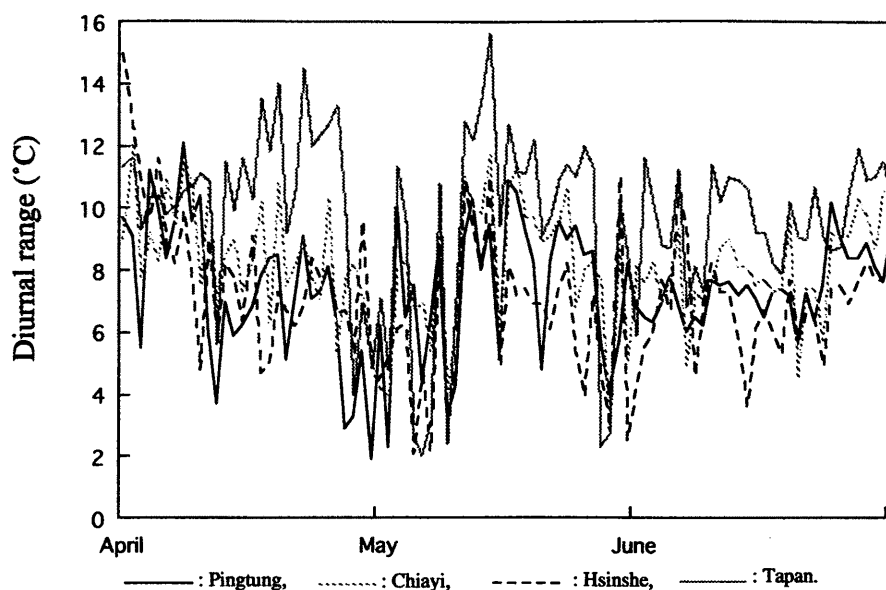


Fig. 1. Cultivation sites (altitude) of reddish-purple tuberose '77A05' in this study.

Table 1. Minimum, average and maximum temperatures during cultivation period of reddish-purple tuberose '77A05' at different altitudes in Taiwan.

Cultivated sites	Altitude (m)	Temperature (°C)		
		Min.	Ave.	Max.
Pingtung	25	23.2	26.5	30.6
Chiayi	75	21.8	25.6	30.0
Hsinshe	500	19.9	23.0	26.9
Tapan	1,200	15.9	20.6	25.6

**Fig. 2.** Diurnal range of temperature at four different cultural sites in Taiwan.

Measurement of growth, flower characteristics and flower colors

Days to sprouting and anthesis from planting and several morphological characteristics at anthesis were recorded. The petals were collected from the plants when the flowers were full-colored. The colors of the petals were measured by colorimeter (NR-3000, Nippon Denshoku Co., Japan).

Measurement of the amount of anthocyanins and analysis of the anthocyanidins

The dried and weighed petals (about 1 g) were soaked in 0.1% hydrochloric acid-methanol. The crude extracts were filtered and filled up to 50 ml and the absorbance were measured at 530 nm. The residue of the extracts were concentrated to a small amount and hydrolyzed with hydrochloric acid at 100 °C for 1 h. The hydrolysates

obtained were analyzed by high performance liquid chromatography (HPLC) for anthocyanidin constitutions. The details of HPLC analysis were described previously (Huang *et al.*, 2000).

RESULTS

A hundred percent flowering was observed at all sites (data not shown). Differences in the days to sprouting at four altitudes were 1.1 and those to flowering were 9.2 (Table 2). Flower stalk length was the longest at Tapan (1,200 m) and the shortest at Chiayi (75 m) (Table 3). The higher the altitude, the longer the flower stalk. There was, however, no significant difference in inflorescence length at any altitude. Floret size (diameter, petal width and thickness) increased by increasing the altitude, but number of florets was not affected by the altitude (Tables 3 and 4).

The values of brightness (L^*) of flowers were higher than 60 at Pingtung (25 m) and Chiayi (75 m), whereas they were below 60 at Hsinshe (500 m) and Tapan (1,200 m) (Fig. 3). The values of chroma (C^*) were between the range from 10 to 20 at Pingtung and Chiayi, but were from 20 to 37 at Hsinshe and Tapan. These indicate that '77A05' had pale purple flowers cultivated at Chiayi and Pingtung, whereas it was reddish-purple at Hsinshe and Tapan.

The anthocyanin content at Hsinshe and Tapan was approximately two and three times higher than that at Pingtung, respectively (Table 5). The higher the elevation of cultivation sites, the higher the anthocyanin content was. Delphinidin ratio to cyanidin increased with the increase of altitudes.

Table 2. Effects of altitudes on flowering of reddish-purple tuberose '77A05'.

Cultivated sites	Altitudes (m)	Days to sprouting	Days to flowering
Pingtung	25	14.7 ab ²	80.3 a
Chiayi	75	14.2 a	82.8 b
Hsinshe	500	15.0 ab	85.2 c
Tapan	1,200	15.3 b	89.5 d

² Mean separation within columns by Duncan's multiple range test, 5%

Table 3. Effects of altitudes on flowering performance of reddish-purple tuberose '77A05'.

Cultivated sites	Altitudes (m)	Flower stalk length (cm)	Inflorescence length (cm)	Flower stalk diameter (cm)	No. of florets
Pingtung	25	95.2 a ²	31.2 ab	0.62 a	40.7 ab
Chiayi	75	91.7 a	28.0 a	0.55 b	37.2 a
Hsinshe	500	105.2 b	27.0 a	0.55 b	45.6 b
Tapan	1,200	124.2 c	33.7 b	0.57 b	45.4 b

² Mean separation within columns by Duncan's multiple range test, 5%.

Table 4. Effects of altitudes on flower characteristics of reddish-purple tuberose '77A05'.

Cultivated sites	Altitudes (m)	Flower diameter (cm)	Petal thickness (mm)	Petal width (cm)
Pingtung	25	1.97 a ²	0.66 a	0.51 a
Chiayi	75	2.01 a	0.70 a	0.54 a
Hsinshe	500	2.33 b	0.84 b	0.54 a
Tapan	1,200	2.56 c	0.83 b	0.61 b

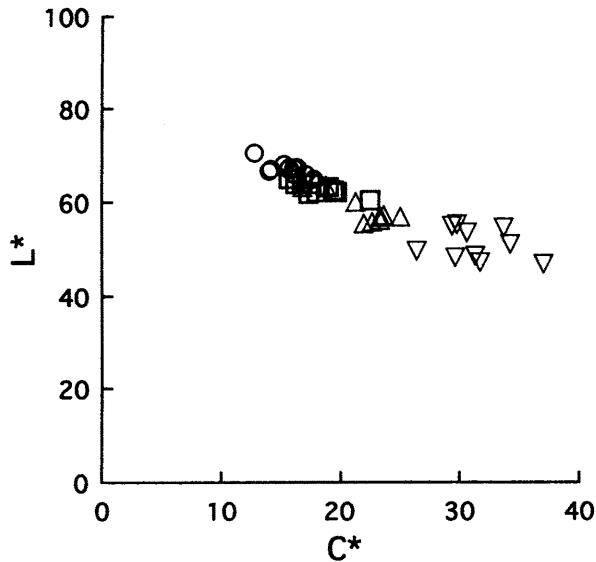
² Mean separation within columns by Duncan's multiple range test, 5%.

Table 5. Effects of altitudes on anthocyanin content and anthocyanidin constituents of reddish-purple tuberose '77A05'.

Cultivated sites	Altitudes (m)	Anthocyanin content ^z	Anthocyanidin constituents (%)	
			Cyanidin	Delphinidin
Pingtung	25	0.54 a ^y	76.2	23.8
Chiayi	75	0.72 b	75.7	24.3
Hsinshe	500	1.04 c	72.2	27.8
Tapan	1,200	1.40 d	71.3	28.7

^z Absorbance at 530 nm.

^y Mean separation within columns by Duncan's multiple range test, 5%.

**Fig. 3.** Effects of cultivated sites on the values of brightness (L*) and chroma (C*) of the flowers of reddish-purple tuberose '77A05'.

○; Pingtung, □; Chiayi, △; Hsinshe, ▽; Tapan.

DISCUSSION

The flowering performance and flower characteristics of '77A05' appear to be the best at Tapan because it had long flower stalk, many florets and reddish purple flowers. In contrast, the flowers at low altitude areas (Chiayi and Pingtung) showed pale purple with no commercial value.

Taiwan is an island and locates between 21 and 25 degrees north latitude. The central and east part of the country is mountainous and there are many mountains over 2,000 meters high. The climate of Taiwan is separated into three zones; subtropical climate in northern and central part, tropical climate in the most southern part and temperate climate in high elevation areas (Aiga, 1975). In this investigation, we selected four different cultivation sites. Pingtung (altitude=25 m) is in the tropical, Chiayi (75 m) and Hsinshe (500 m) are in the subtropical and Tapan (1,200 m) is in temperate zones. At present, white flowered tuberose 'Single' and 'Double' are cultivated mainly in Yunlin, Chiayi, Tainan and Pingtung of which the altitude are below 100 m in southern part of Taiwan (Anonymous, 1999). However, from the results of present investigation, these areas do not seem to be suitable for the cultivation for anthocyanin-containing tuberose.

A rise in temperature results in a lower concentration of anthocyanins and the decoloration occur under high temperature condition in rose flowers (Biran *et al.*, 1973). Tomana and Yamada (1988) investigated that the relationship between temperature and fruit quality of apple cultivars grown at different locations in Japan. They observed that the coloring of apple cv. Jonathan was superior at cool areas; Shinshu, Hirosaki, Hokkaido compared with that at temperate areas; Kyushu, Shizuoka, Ehime, Takatsuki, Kyoto, Hiroshima, Mie, and Tottori. Thus, it was concluded that anthocyanin content in the fruit skin of apple cv. Jonathan was negatively correlated with heat summation.

It is well known that the autumn redding of leaves such as *Acer* relates to diurnal range of temperatures between day and night (Hayashi, 1988), that is, it occurs by remarkable difference in diurnal range of temperatures.

The most remarkable diurnal range of temperature was observed in Tapan during the cultivation period of '77A05' where the flowers showed the most clear reddish-purple color. Since the anthocyanin content at high elevation areas (Tapan and Hsinshe) significantly higher and the flower colors were clearer than those at low altitude areas (Pingtung and Chiayi), the suitable cultivation area of anthocyanin-containing tuberose in Taiwan seems to be high elevation areas.

However, the temperature easily rise in greenhouses during a high temperature season even at the high altitude areas. Accordingly, the site and facility selection for cultivation of colored tuberose, for example, cooling system by fans or by spraying of fine mist for falling of temperature must be carefully considered when anthocyanin is the primary pigment.

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