Drought Tolerance of Geophytes

Ii, Kaori
Laboratory of Horticultural Science, Division Agricultural Botany, Department of Plant Resources, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

Huang, Kuang-Liang
Laboratory of Horticultural Science, Division Agricultural Botany, Department of Plant Resources, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

Inoue, Megumi
Laboratory of Horticultural Science, Department of Agronomy, Faculty of Agriculture, Kyushu University

Matsuda, Shikanori
Laboratory of Horticultural Science, Division of Agricuitural Botany, Department of Plant Resources, Faculty of Agriculture, Kyushu University

他

https://doi.org/10.5109/24356

出版情報：九州大学大学院農学研究院紀要. 45 (1), pp.49-55, 2000-11. Kyushu University
バージョン：
権利関係：

J. Fac. Agr., Kyushu Univ., **45** (1), 49–55 (2000)

Drought Tolerance of Geophytes[1]

Kaori Ii[2], Kuang–Liang Huang[2], Megumi Inoue[3], Shikanori Matsuda and Hiroshi Okubo[4]

Laboratory of Horticultural Science, Division of Agricultural Botany, Department of Plant Resources, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan
(Received July 31, 2000 and accepted August 18, 2000)

Drought tolerance was determined in 45 species/cultivars of 29 genera of seven families of geophytes. Salt water irrigation at concentrations of 0, 500, 1000, 5,000 mgl^{-1} was used. Fourteen species/cultivars with no salt treatment (control) either did not flower or flowered at very low rates. This was probably because no flowers were initiated or flower buds aborted at high temperatures of greenhouse. The remaining 29 species/cultivars were classified into eight categories using three flowering characteristics (flowering rate, plant height and days to flower) to the salt treatments. Flower characteristics were not affected in *Muscari armeniacum* with 5,000 mgl^{-1} salt treatment. Thus it was the most drought tolerant among the geophytes examined. In other geophytes, at least one characteristic was more or less affected by the treatment. Generally, spring–flowering geophytes tended to be more tolerant than summer–flowering geophytes. However, there were no clear relationships between families, classified categories and the types of storage organs (bulbs, corms, etc.). Salt (drought) tolerance in geophytes appears to be species/cultivar–specific.

INTRODUCTION

Geophytes have not been widely used for landscaping in Japan. Their potential use has been considered to be low, because they have a short flowering period and low tolerance to high temperatures and humidity. The use of geophytes in landscaping does have some advantages, they are; (1) they have some drought tolerance, (2) some can grow under shaded conditions, and (3) some flower in winter season when there are few outdoor flowers. In fact, geophytes are widely used in landscaping in Europe and North America. Studies on geophytes have focused on control of flowering for cut or potted flower production or on bulb production and their related physiology in Japan. Few studies have been carried out on growth behavior of geophytes left in soil for several years under outdoor climatic or soil conditions. Thus it is necessary to clarify the environmental adaptation of each species/cultivar and to establish the planting and management methods.

---

[1] This study is a part of "Fundamental studies on the utilization of geophytes in landscaping" (tentatively translated into English by H. O. from original Japanese title) supported by the Grant–in–aid for Scientific Research (B) No. 10306003 (Professor Hideo Imanishi, Osaka Prefecture University as a project head) from the Ministry of Education, Science, Sports and Culture, Japan.

[2] Laboratory of Horticultural Science, Division of Agricultural Botany, Department of Plant Resources, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

[3] Laboratory of Horticultural Science, Department of Agronomy, Faculty of Agriculture, Kyushu University

[4] Corresponding author. E–mail: hokubo@agr.kyushu–u.ac.jp

Salt tolerance, often considered to be the alternative of drought tolerance, has been studied in some ornamentals (Ishida, *et al.*, 1978, 1979a, b), but not in geophytes. The purpose of this study is to estimate the drought tolerance of various geophytes by means of salt water irrigation treatments to extend the marketing of geophytes. Screening of geophytes adaptable to dried areas may also be helpful not only for home gardening but also the development of an outdoor flower industry.

MATERIALS AND METHODS

Response of plants to salinity in soil resembles that of drought stress, however, salt tolerance may not absolutely reflect drought tolerance. It is difficult to maintain drought stress conditions at desired levels. Thus, salt treatments were adapted to estimate the tolerance of geophytes to drought conditions. They can be held constant throughout the experiment.

Plant materials were obtained from the Faculty of Agriculture, Osaka Prefecture University, Sakai, Osaka and some commercial growers in Japan in 1998. After arrival, they were kept at room temperatures (approx. 20–30 °C) until planting. All the plants were grown in a greenhouse to avoid the effect of rain that will dilute the salt concentration in the media. Five to 12 plants were used in each treatment. Flowering rate, plant height at flowering, and days to flowering from planting were recorded.

Experiments in 1998

Thirty–five genera/species/cultivars of geophytes of five families were used (Table 1). Bulbs of *Hippeastrum bifidum*, *Lycoris albiflora* and *Lycoris radiata* were planted on 31 August 1998. Other bulbs, corms or rhizomes were on 28 October 1998. Sea sand and plastic pots were used. The pot sizes varied due to the size of storage organs of each species/cultivar. The plants received four levels of salt water (0, 500, 1,000 or 5,000 mgl^{-1}) in combination with a 0.1% solution of compound fertilizer (OK–F–1, $N:P_2O_5:K_2O=15:8:17$, Otsuka Chemical Co., Tokyo). The salt water was applied until it came out the holes of the pots when the soil surface was dried. The electric conductivities of 0, 500, 1,000 and 5,000 mgl^{-1} salt water with fertilizer were 1.20, 2.10, 3.05 and 9.25 $mscm^{-1}$, respectively.

Experiments in 1999

Eleven genera/species/cultivars of summer flowering geophytes of six families were planted from 26 April – 12 May 1999 and grown in a greenhouse (Table 1). Salt treatments and other culture conditions were basically identical to the 1998 experiments.

RESULTS AND DISCUSSION

Of 45 species/cultivars examined, 14 did not flower or flowered at very low rate ($<$ 50% flowering) at 0 mgl^{-1} salt water irrigation (Table 1). Twelve species/cultivars of the remaining 31 produced 100% flowering and 17 had over 50% flowering at 5,000 mgl^{-1}. No species/cultivars grown in 1999 flowered at 5,000 mgl^{-1}. At 1,000 mgl^{-1}, 28 showed $>$50% flowering. A decrease in the flowering rate with an increase in salt concentrations was observed in *Crocus chrysanthus* 'Cream Beauty', *Crocus flavus* 'Mammoth Yellow',

Table 1. Effects of salt treatments on flowering (%).

Family	Genus, species, cultivar	Type[z]	Date of planting	No. of plants[y]	Salt concentration (mgl^{-1}) 0	500	1,000	5,000
Experiment in 1998								
Amaryllidaceae	*Galanthus elwesii*	B	28 October	8	12.5	0	25	25
	Hippeastrum bifidum	B	31 August	9	55.6	88.9	100	44.4
	Leucojium aestivum	B	28 October	10	10	0	0	10
	Lycoris albiflora	B	31 August	10	0	0	0	0
	Lycoris radiata	B	31 August	10	50	60	90	90
	Narcissus bulbocodium	B	28 October	5	40	80	60	20
	Narcissus tazetta var. *chinensis*	B	28 October	10	50	30	20	20
	Narcissus tazetta 'Galilee'	B	28 October	10	100	100	100	100
	Narcissus tazetta 'Grand Soleil d'Or'	B	28 October	10	80	90	100	100
	Sternbergia lutea	B	28 October	10	0	0	0	0
Compositae	*Liatris spicata* 'Syouki'	C	28 October	10	0	0	0	0
Iridaceae	*Babiana stricta*	C	28 October	10	100	100	90	100
	Crocus (winter flowering)	C	28 October	10	100	100	100	100
	Crocus chrysanthus 'Cream Beauty'	C	28 October	10	100	10	30	10
	Crocus flavus 'Mammoth Yellow'	C	28 October	10	100	80	20	10
	Freesia 'Elegance'	C	28 October	10	70	60	100	80
	Freesia 'Rijnveld's Golden Yellow'	C	28 October	10	100	100	100	100
	Gladiolus 'Comet'	C	28 October	10	100	90	70	40
	Gladiolus 'Rose Charm'	C	28 October	10	100	100	100	100
	Iris reticulata	B	28 October	10	90	80	70	60
	Ixia 'Rose Emperor'	C	28 October	8	25	12.5	0	0
Liliaceae	*Agapanthus africanus*	R	28 October	10	10	0	10	0
	Allium cowanii	B	28 October	8	100	100	100	100
	Allium chinense (small bulbs)	B	28 October	10	10	10	0	0
	Allium chinense (large bulbs)	B	28 October	10	0	0	0	0
	Allium unifolium	B	28 October	10	100	100	70	60
	Hyacinthoides hispanica	B	28 October	10	90	100	40	0
	Ipheion uniflorum 'Wisley Blue'	B	28 October	10	100	100	100	100
	Lilium 'Elite'	B	28 October	10	100	100	90	20
	Lilium 'White Angel'	B	28 October	10	100	40	0	0
	Muscari armeniacum	B	28 October	10	100	100	100	100
	Ornithogalum thyrsoides	B	28 October	10	100	90	80	60
Oxalidaceae	*Oxalis purpurea* 'Mixed'	B	28 October	12	100	100	100	100
	Oxalis purpurea 'Red'	B	28 October	8	100	100	100	100
	Oxalis purpurea 'Pink'	B	28 October	6	100	100	100	100
Experiment in 1999								
Amaryllidaceae	x *Amarcrinum howardii*	B	12 May	10	20	40	80	0
	Cyrtanthus mackenii	B	26 April	10	100	100	90	0
	Habranthus 'Cherry Pink'	B	5 May	10	100	100	100	0
	Zephyranthes candida	B	5 May	10	100	100	100	0
	Zephyranthes grandiflora	B	5 May	10	100	100	100	0
Cannaceae	*Canna* 'Butter Cup'	R	5 May	10	60	80	50	0
Compositae	*Dahlia* 'Hourai'	TR	12 May	9	66.7	44.4	66.7	0
Iridaceae	*Crocosmia* x *crocosmiiflora*	C	5 May	10	10	0	0	0
Liliaceae	*Allium tuberosum*	B	5 May	10	0	10	0	0
	Agapanthus africanus	R	28 April	10	0	0	0	0
Orchidaceae	*Bletilla striata*	R	26 April	10	0	0	0	0

[z] Type of storage organs, B; bulb, C; corm, R; rhizome, TR; tuberous root.
[y] No. of plants/treatment.

Gladiolus 'Comet', *Lilium* 'Elite' and *Lilium* 'White Angel'. Failures to flower at 0 mgl⁻¹ could be attributed to; (1) no flower bud initiation/development, (2) abortion at high temperature conditions in the greenhouse or (3) lack of required low temperature for flower initiation during cultivation. Those showed less than 50% flowering in the control and *Crocus chrysanthus* 'Cream Beauty' of which the flowering rates at other salt concentrations were too low to statistically analyze and were therefore excluded.

Treatment at 5,000 mgl^{-1} delayed flowering of winter flowering *Crocus* and *Allium unifolium* by 14 days and *Ipheion uniflorum* 'Wisley Blue' by 10 days when compared to the controls (Table 2). Flowering was delayed in other species/cultivars at 5,000 mgl^{-1}, but the differences from the controls were within six days. In contrast, there were 13 species/cultivars of which the days from planting to flowering were not significantly different from those of the control plants. Flowering was delayed in winter flowering

Table 2. Effects of salt treatments on days to flowering from planting.

Family	Genus, species, cultivar	Salt concentration (mgl^{-1})			
		0	500	1,000	5,000
Experiment in 1998					
Amaryllidaceae	*Hippeastrum bifidum*	20.4±1.2a[z]	19.5±0.9a	21.4±0.9a	25.0±0b
	Lycoris radiata	15.6±0.9a	17.0±0.4a	16.3±1.2a	18.8±1.4a
	Narcissus tazetta var. *chinensis*	57.2±0.7a	55.0±0.6a	53.0±2.0a	55.0±4.0a
	Narcissus tazetta 'Galilee'	46.7±0.5a	45.3±0.8a	45.3±0.8a	44.6±0.6a
	Narcissus tazetta 'Grand Soleil d'Or'	79.3±1.6bc	73.2±2.1a	76.1±1.9ab	84.5±1.9c
Iridaceae	*Babiana stricta*	140.4±1.0a	143.2±1.5ab	140.6±1.0a	146.5±2.0b
	Crocus (winter flowering)	94.4±0.9a	101.8±0.5b	102.4±0.4b	108.6±1.0c
	Crocus flavus 'Mammoth Yellow'	111.0±0.8a	112.9±0.8a	120.0±0b	-
	Freesia 'Elegance'	136.4±0.4a	135.5±0.5a	139.4±1.3b	139.8±0.8b
	Freesia 'Rijnveld's Golden Yellow'	126.8±1.8a	128.6±1.3a	128.3±1.2a	131.2±1.3a
	Gladiolus 'Comet'	117.5±1.5a	117.1±1.7a	113.6±1.0a	115.8±3.8a
	Gladiolus 'Rose Charm'	127.1±0.9a	129.0±0a	127.6±0.3a	133.3±1.0b
	Iris reticulata	128.7±1.9b	123.4±1.5a	122.6±2.0a	126.5±1.1ab
Liliaceae	*Allium cowanii*	119.4±1.2a	117.0±0.8a	118.3±1.2a	123.8±1.3b
	Allium unifolium	160.0±1.3a	161.0±3.1a	160.9±1.8a	174.0±2.5b
	Hyacinthoides hispanica	162.6±2.4a	164.9±3.1a	160.5±3.0a	-
	Ipheion uniflorum 'Wisley Blue'	96.5±2.0a	102.0±1.8ab	100.9±2.5ab	106.9±1.7b
	Lilium 'Elite'	194.9±1.3a	197.7±1.2a	196.1±3.2a	192.5±2.5a
	Muscari armeniacum	116.7±0.7a	118.6±0.9a	116.1±0.8a	118.7±1.0a
	Ornithogalum thyrsoides	169.2±2.1a	170.3±2.1a	170.1±2.4a	171.0±2.4a
Oxalidaceae	*Oxalis purpurea* 'Mixed'	93.2±4.2ab	92.6±4.4ab	83.9±2.7a	97.8±3.2b
	Oxalis purpurea 'Red'	90.5±4.2ab	83.3±3.8a	86.9±1.1a	98.6±2.3b
	Oxalis purpurea 'Pink'	84.0±2.9a	75.8±3.3a	83.0±2.8a	78.3±3.4a
Experiment in 1999					
Amaryllidaceae	*Cyrtanthus mackenii*	227.7±24.9a	245.5±9.6a	291.0±6.1a	-
	Habranthus 'Cherry Pink'	73.9±3.4a	78.7±1.8a	81.2±2.2a	-
	Zephyranthes candida	93.4±6.6a	88.2±5.9a	101.7±6.7a	-
	Zephyranthes grandiflora	89.2±10.0a	83.7±6.7a	79.5±5.6a	-
Cannaceae	*Canna* 'Butter Cup'	89.7±13.3a	93.9±7.5a	102.4±8.0a	-
Compositae	*Dahlia* 'Hourai'	73.7±6.7a	107.8±20.6a	102.7±11.2a	-

[z] Mean±S.E.
Mean separation within lines by Duncan's multiple range test, 5%

Crocus at 500 mgl^{-1}, and in *Crocus flavus* and *Freesia* 'Elegance' at 1,000 mgl^{-1}.

Four species/cultivars (winter flowering *Crocus*, *Ipheion uniflorum*, *Muscari armeniacum* and *Oxalis purpurea* 'Mixed') are small sized geophytes. They did not have a decreased height at flowering even at 5,000 mgl^{-1} (Table 3). In contrast, two *Gladiolus* cultivars and *Ornithogalum thyrsoides* were very sensitive to the salt treatment. Their plant height at 5,000 mgl^{-1} was about 60% of the control. *Hippeastrum bifidum*, *Gladiolus* 'Comet', *Babiana stricta*, *Gladiolus* 'Rose Charm' and *Lilium* 'Elite' had significantly decreased plant heights at flowering at 1,000 mgl^{-1}. The first two species/cultivars were also decreased at 500 mgl^{-1}.

Plant height in some species/cultivars in this experiment was less than their standard heights even at 0 mgl^{-1} salt treatment. It may be due to the lack of low temperatures in the greenhouse, since most spring flowering geophytes require low temperature for their

Table 3. Effects of salt treatments on plant height (cm) at flowering.

Family	Genus, species, cultivar	Salt concentration (mgl^{-1})			
		0	500	1,000	5,000
Experiment in 1998					
Amaryllidaceae	*Hippeastrum bifidum*	22.7±1.0b[z]	18.2±1.8a	20.0±0.6ab	17.4±1.2a
	Lycoris radiata	39.4±3.8b	36.4±2.2b	39.5±1.7b	29.6±2.0a
	Narcissus tazetta var. *chinensis*	29.5±2.1ab	35.0±3.5b	36.8±4.8b	23.5±1.5a
	Narcissus tazetta 'Galilee'	50.7±1.6b	50.1±1.4b	48.4±0.7b	44.9±0.9a
	Narcissus tazetta 'Grand Soleil d'Or'	19.5±0.8b	20.9±1.0b	19.0±0.9b	15.9±0.9a
Iridaceae	*Babiana stricta*	33.6±1.9b	32.1±2.1b	25.8±1.3a	21.2±2.6a
	Crocus (winter flowering)	5.9±0.3a	5.8±0.2a	5.3±0.3a	5.4±0.1a
	Crocus flavus 'Mammoth Yellow'	6.6±0.5a	6.6±0.4a	5.0±0a	–
	Freesia 'Elegance'	42.3±0.8b	38.2±2.2ab	38.2±1.6ab	34.8±2.0a
	Freesia 'Rijnveld's Golden Yellow'	37.0±2.1b	38.4±3.0b	37.3±1.8b	30.2±1.9a
	Gladiolus 'Comet'	115.8±5.7c	98.6±5.0b	104.4±3.8bc	71.1±5.2a
	Gladiolus 'Rose Charm'	97.6±2.7c	87.2±2.0bc	80.5±2.2b	68.9±3.9a
	Iris reticulata	11.7±0.5b	12.2±0.5b	11.9±0.5b	9.8±0.4a
Liliaceae	*Allium cowanii*	39.4±1.3b	39.4±2.4b	38.0±1.3b	29.6±2.0a
	Allium unifolium	35.2±1.9b	32.5±1.9b	30.9±1.9b	19.7±1.8a
	Hyacinthoides hispanica	12.6±1.4a	11.4±1.3a	7.8±2.4a	–
	Ipheion uniflorum 'Wisley Blue'	5.5±0.7a	6.4±0.6a	5.5±0.6a	7.3±0.8a
	Lilium 'Elite'	77.6±2.2c	74.5±2.1c	65.1±1.0b	27.3±3.8a
	Muscari armeniacum	5.0±0.7a	5.4±0.6a	4.4±0.3a	4.3±0.5a
	Ornithogalum thyrsoides	57.7±2.4c	52.1±2.7c	44.6±1.8b	32.1±0.7a
Oxalidaceae	*Oxalis purpurea* 'Mixed'	9.2±0.4a	8.9±0.5a	9.4±0.5a	7.9±0.5a
	Oxalis purpurea 'Red'	9.9±0.3b	9.5±0.5b	11.2±0.5c	8.0±0.4a
	Oxalis purpurea 'Pink'	6.5±0.3b	5.3±0.2a	4.9±0.5a	4.6±0.1a
Experiment in 1999					
Amaryllidaceae	*Cyrtanthus mackenii*	35.4±2.5a	33.8±1.0a	31.9±1.2a	–
	Habranthus 'Cherry Pink'	34.2±2.5a	34.9±3.6a	36.9±3.2a	–
	Zephyranthes candida	16.3±1.4a	21.5±3.3a	16.4±1.0a	–
	Zephyranthes grandiflora	23.0±1.9a	24.5±1.4a	26.9±1.5a	–
Cannaceae	*Canna* 'Butter Cup'	36.7±3.3a	43.8±4.4a	37.2±1.4a	–
Compositae	*Dahlia* 'Hourai'	82.3±5.7b	60.4±7.8a	67.3±3.6ab	–

[z] Mean±S.E.

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

growth and flowering. The use of plastic pots, which limits root growth, might be another reason.

Plant height decreased above 250 mgl^{-1} salt in *Chrysanthemum* (Ishida *et al.*, 1978) and carnation (Ishida *et al.*, 1979b). Flowering was markedly delayed above 2,000 mgl^{-1} in *Chrysanthemum* and above 500 mgl^{-1} in carnation. Salt injury occurred above 500–1,000 mgl^{-1} in rose plants (Ishida *et al.*, 1979a). These reports on salt effects in ornamental plants suggest that geophytes are more tolerant to drought conditions than ornamental plants having no storage organs.

Another experiment in which a high concentrations (10,000 and 15,000 mgl^{-1}) of salt water were used was conducted using *Lycoris albiflora*, *Narcissus tazetta* var. *chinensis*, *Babiana stricta*, *Crocus sativus*, *Freesia* 'Elegance', *Ipheion uniflorum*, *Muscari armeniacum* and *Ornithogalum thyrsoides* in 1999. Most did not flower at these concentrations (data not shown).

The classification of 29 geophytes into eight categories was carried out using three flowering characteristics; (1) flowering rate, (2) plant height at flowering, and (3) days to flowering affected by salt treatments (Table 4). All characteristics were affected in *Allium unifolium* and *Hippeastrum bifidum*, but not in *Muscari armeniacum*. Liliaceae species were placed in six of the eight categories and Amarylidaceae and Iridaceae five categories. Bulb species were included in seven categories and corm species in five categories. Thus, no clear relationship between families and classified

Table 4. Classification of geophytes into eight groups based on three flowering characteristics affected by salt treatments.

Group	Flowering rate[z]	Plant height[y]	Days to flowering from planting[x]	Genus, species, cultivars
1	–	–	–	*Muscari armeniacum*
2	+	–	–	*Canna* 'Butter Cup', *Cyrtanthus mackenii*, *Habranthus* 'Cherry Pink', *Hyacinthoides hispanica*, *Zephyranthes candida*, *Zephyranthes grandiflora*
3	–	+	–	*Freesia* 'Rijnveld's Golden Yellow', *Lycoris radiata*, *Narcissus tazetta* 'Galilee', *Oxalis purpurea* 'Pink'
4	–	–	+	*Crocus* (winter flowering), *Ipheion uniflorum*, *Oxalis purpurea* 'Mixed',
5	+	+	–	*Dahlia* 'Hourai', *Gladiolus* 'Comet', *Iris reticulata*, *Lilium* 'Elite', *Narcissus tazetta* var. *chinensis*, *Ornithogalum thyrsoides*
6	+	–	+	*Crocus flavus* 'Mammoth Yellow'
7	–	+	+	*Allium cowanii*, *Babiana stricta*, *Freesia* 'Elegance', *Gladiolus* 'Rose Charm', *Narcissus tazetta* 'Grand Soleil d'Or', *Oxalis purpurea* 'Red'
8	+	+	+	*Allium unifolium*, *Hippeastrum bifidum*

[z, y] +; Decreased, –; not affected

[x] +; Increased, –; not affected

categories and between the types of storage organs (bulbs, corms, etc.) and the categories were found. Neither hardiness, hardy or tender, nor their places of origin affected the tolerance. The three characteristics responding to salt treatment appear to be independent to each other. Thus, salt tolerance in geophytes is considered to be species– or cultivar–specific.

In a previous experiment with *Lilium longiflorum*, the bulbs were planted and grown in plastic pots in a plastic–film house on 24 October 1996 with nutrient water and the plants were treated with salt water from 18 February of the next year, the plants showed very dwarf but survived even at 15,000 mgl^{-1} (Okubo *et al.*, 1998). Thus, *Lilium longiflorum* might be another geophyte having tolerance to drought conditions. Salt water treatment was given just after planting of all the plant materials in the present study. When they are grown under sufficient water conditions until their full sprouting, and then received drought stress, some may show more tolerance than those did in the present study. There was no decrease in flowering rate at 5,000 mgl^{-1} in *Polianthes tuberosa*, a summer flowering geophyte. It was not used in the present study but was included in the experiments with *Lilium longiflorum* (Okubo *et al.*, 1997).

In conclusion, spring flowering geophytes are generally more tolerant to drought stress than summer flowering geophytes. However, plant height and days to flowering from planting of summer flowering geophytes are less affected with salt treatments. Among all the geophytes examined *Muscari armeniacum* has the greatest adaptability to be grown in drought conditions.

Reproductive ability is another important factor for the selection and use of geophytes in landscaping. This is excellent in *Muscari armeniacum*. The bulbs can be either lifted yearly or left for long years in soil even in Kyushu where the climate in summer is rather warm and humid with much rainfall. They sprout early in autumn and continue to develop leaves throughout winter season every year. This nature is also useful for keeping soil surface green in winter.

REFERENCES

Ishida, A., M. Masui, A. Nukaya and T. Ogura 1978 Salt tolerance of chrysanthemums. *J. Japan. Soc. Hort. Sci.*, **47**: 421–424

Ishida, A., M. Masui, A. Nukaya and T. Ogura 1979a Salt tolerance of roses in sand and soil cultures. *J. Japan. Soc. Hort. Sci.*, **47**: 517–523

Ishida, A., M. Masui, A. Nukaya and T. Ogura 1979b Salt tolerance of carnations in sand and soil cultures. *J. Japan. Soc. Hort. Sci.*, **48**: 322–326

Okubo, H., M. Ide and M. Toyama 1997 Effects of salt water irrigation on growth of spring–planting flower geophytes. *Annual Report 1996–97, Tottori University Arid Land Research Center*, pp. 28

Okubo, H., M. Ide and M. Toyama 1998 Effects of salt water irrigation on growth of Easter lily. *Annual Report 1997–98, Tottori University Arid Land Research Center*, pp. 39–40