Cultivation and conservation of *Lilium philippinense* (Liliaceae), the Philippine endemic Benguet Lily

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ABSTRACT. *Lilium philippinense*, endemic to the Cordillera Administrative Region (CCR) of the Philippines, grows on steep mountain slopes of Benguet and the southwestern part of the Mountain province. The flowers, fragrant and used as wedding decorations, occur from late May to July. Recent observations indicate declining populations of this species, which is said to be difficult to grow. Under greenhouse conditions, seed and bulb germination show only 27.63% and 16.67% success, respectively. The apparently acute sensitivity of this species to environmental factors such as soil pH, light, humidity, air and soil temperature, and possibilities for *ex situ* cultivation, are discussed.

Keywords. Benguet lily, conservation, Cordillera Administrative Region, cultivation, endemic, *Lilium*, Philippines

Introduction

Lilium philippinense Baker (Liliaceae) is endemic to the Philippines (Elwes 1880) and occurs in the southern part of the Cordillera Central Range (CCR). Its fragrant, white, trumpet-shaped flowers sometimes have a reddish tinge at the corolla base, and annual mass flowering events are spectacular. The species grows among grasses such as *Themeda triandra, Miscanthus sinensis* and *Imperata cylindrica.* Each plant bears one or two flowers per stem, rarely three or four. The fruit is a capsule with numerous small seeds. At the end of the short flowering season, the floral parts wither and the capsule matures and eventually releases its seeds. Following the end of the growing season, only the subterranean bulbs remain.

This lily is known by local names such as *kanyon* or *luplupak* (Ilocano)*, us-usdong* (Mt. Province Kankanai), *putputak* (Benguet Kankanai), *tuktukpao* (Kayan, Tadian), *swasoy* (Ibaloi), and *suyosoy* (Ikalahan). Each local name illustrates a unique characteristic of the plant. For instance, *suyosoy* means "flower of the mountain"; *us-usdong* means "to bow" referring to the pendulous flowers; and *kanyon* means "a bomb", illustrating the somewhat explosive expulsion of seeds when mature fruits dehisce. Descriptions of *L. philippinense* are provided by Chittenden (1956), Bailey (1960), Steiner (1960) and Madulid (2001). *Lilium philippinense* is morphologically similar to *L. formosanum* and *L. longiflorum*, which are endemic to Taiwan and Japan, respectively, and which grow well in the CCR. Often, horticulturists regard these three lilies as the same species and sometimes refer to them interchangeably. In the Benguet and Mountain provinces, this lily is often a favorite adornment for wedding ceremonies and special occasions because of its delicate white flowers and fragrance.

There is scanty research on *L. philippinense*. A monograph of the genus *Lilium* is the only published account that gives some basic information of this species (Elwes 1880). In the Philippines, of two undergraduate reports on *L. philippinense*, one describes shoot and root initiation of bulb scales using low temperature stratification and a rooting hormone. That study showed that root formation can be enhanced by treating bulbs at 3°C for 60 days; and more and longer roots are initiated by soaking the bulbs in Hormex, a rooting hormone, prior to planting (Alipio & Ladilad 2005). In vitro propagation of *L. philippinense* was demonstrated by Ampaguey et al. (2002), who showed that callus formation was enhanced with three different media used; unfortunately, field evaluation of calli was not tried. There have been no previous studies of seed germination in this species.

Recently, *L. philippinense* populations were reported to have declined due to human activities such as over-collection (Madulid 2001) and destruction of habitat including landuse conversion and road widening (Balangcod 2009). From a conservation perspective, it is important to understand the reproductive behaviour of a species. This includes seed and bulb germination in this case. As pointed out by Schemste et al. (1994), detailed information on the different stages in the reproductive cycle of a species may contribute basic information helpful to conservation management decisions. The aim of the present study was to determine the germination and survival capacity of seeds and bulbs of this species, taking into account factors such as relative humidity, light, air and soil temperature in the greenhouse, as well as elevation and geographic location of the original material. Specifically, this study was conducted to (1) evaluate the percentage germination of *L. philippinense* using seeds and bulbs; (2) determine which of the two propagules, the seed or bulb, has a better performance for *ex-situ* cultivation; and (3) compare the percentage germination of seeds and bulbs from different *L. philippinense* populations.

Materials and methods

Seeds and bulbs of *L. philippinense* were collected from 28 populations from the southern part of the CCR (Fig. 1). Elevation was determined using a Geographic Positioning System (GPS). The collection sites ranged from 873 to 2091 m elevation,

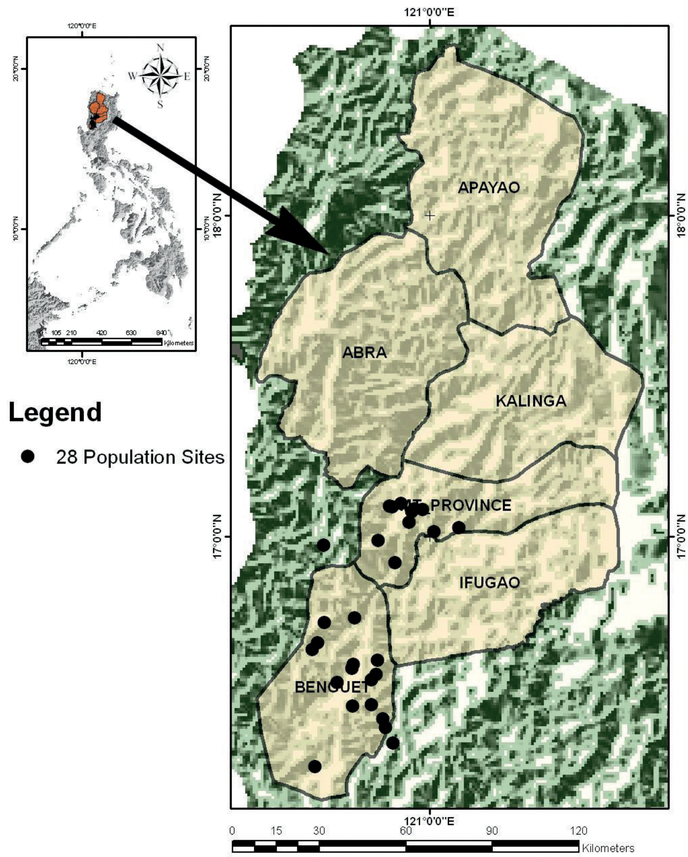

Fig. 1. Location of the 28 *Lilium philippinense* collection sites.

extending from 16°28’44” to 17°10’45”N and from 120°63’55” to 121°83’23”E. Collection of bulbs and seeds were made in August and September 2007 when mature seeds were available. Experiments were performed to investigate the germination capacity of seeds and bulbs and seedling survival of *L. philippinense* under greenhouse conditions that simulated the natural environment of this species. The environmental requirements of *L. philippinense* were noted in a separate study.

Seeds and bulbs were planted simultaneously after collection in standard plastic pots (11.43 × 10.16 cm) and maintained in a greenhouse. The germination capacity of the two propagules was evaluated 150 days from sowing. Observation was continued until the flowering phase to assess seedling survival over a 1-year period for bulb-originated plants, and over a 3-year period for seed-originated plants. Greenhouse parameters such as relative humidity, light, air and soil temperature were recorded and monitored. The daily average readings of different environmental factors were calculated and used for the monthly average within the first year.

The soil used in the experiment was collected from one of the population sites to conform to the soil requirements of *L. philippinense.* Soil parameters such as soil pH, organic matter content and phosphorus were analysed once before planting.

Descriptive, Correlation, and Principal Component analyses using Statistical Package for the Social Sciences (SPSS) were used to analyse the data. Graphs were generated using Microsoft Excel.

Results

The greenhouse condition

The air and soil temperature measured in the greenhouse for the duration of the experiment ranged from 22.57°C to 28.56°C and 19.07°C to 23.49°C, respectively. The relative humidity showed a minimum of 61.61% and a maximum 80.72% while light ranged from 581.53 footcandles (fc) to 1364.89 fc (Table 1). The Coefficients of Variation indicate that relative humidity, air and soil temperature did not vary significantly during the year, but that light varied slightly.

Relatively high air and soil temperatures were recorded from March to August and falls slightly in the succeeding months (Fig. 2). Light peaked in June with a mean value of 1363 fc. This corresponds with the time when *L. philippinense* starts to bloom in its natural habitat. Relative humidity oscillated uniformly throughout the year.

Of the four parameters measured in the greenhouse, correlation analysis shows that air temperature is highly and positively correlated with soil temperature ($r = 0.867$, $p = 0.000$) and negatively correlated with relative humidity with a correlation value of $r = -0.657$, $p = 0.020$ (Table 2). This suggests that there is positive relationship between air and soil temperatures. On the other hand, there is a negative relationship of air temperature and relative humidity.

The soil used in the experiment has a pH of 6.5, which is slightly acidic, a high organic matter content of 4.68 per gram of soil and available phosphorus of 9.04 ppm. The last is moderately low (PCARRD 1982). These quantities fall within the ranges of parameters recorded in a previous study (Balangcod 2009). The ecological parameters measured in the greenhouse were comparable with data obtained in the natural habitat (Balangcod 2009).

Table 1. Environmental factors measured in the greenhouse, October 2007 to November 2008.

	Relative Humidity (%)	Air temperature (°C)	Soil temperature (°C)	Light (foot-candles)
Minimum	61.61	22.57	19.07	581.53
Maximum	80.72	28.56	23.49	1364.89
Mean	70.50	25.71	21.25	921.54
Standard Deviation	6.92	2.43	1.42	232.18
Coefficient of Variation	9.82	9.45	6.58	25.19

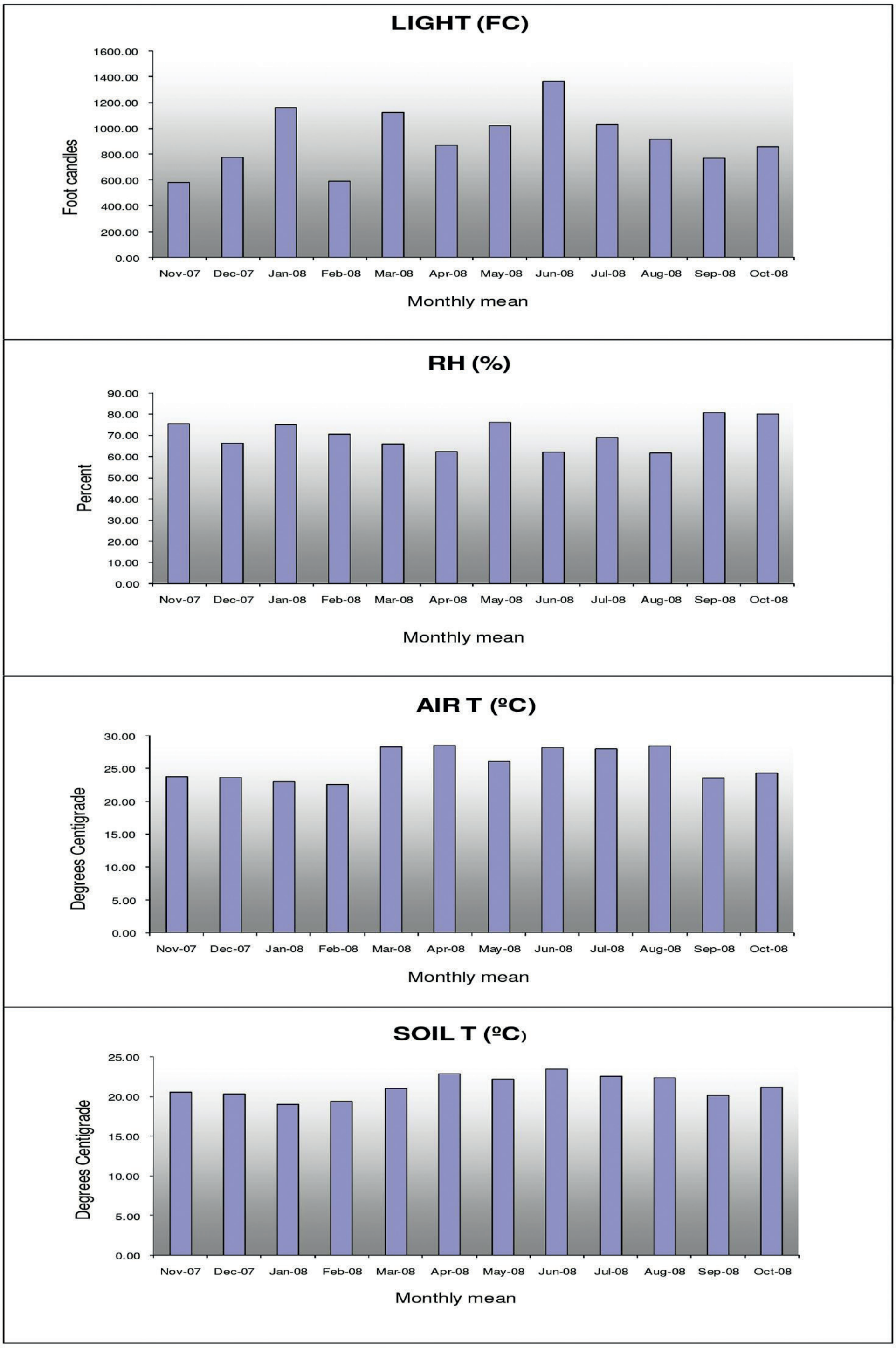

Fig. 2. Monthly means of environmental factors (from top: light, relative humidity, air temperature, soil temperature) measured in the greenhouse.

Table 2. Correlation analysis of environmental factors measured in the greenhouse. RH = Relative Humidity, temp = temperature.

			RH	Air temp	Soil temp	Light
Spearman's rho	RH	Correlation Coefficient	1.000			
		Sig. (2-tailed)	–			
		N	12			
	Air temp	Correlation Coefficient	-0.657*	1.000		
		Sig. (2-tailed)	0.020	–		
		N	12	12		
	Soil temp	Correlation Coefficient	-0.538	0.867**	1.000	
		Sig. (2-tailed)	0.071	0.000	–	
		N	12	12	12	
	Light	Correlation Coefficient	-0.434	0.434	0.420	1.000
		Sig. (2-tailed)	0.159	0.159	0.175	–
		N	12	12	12	12

Germination from bulbs

Of the total 252 bulbs collected from the 28 population sites, only 16.67% germinated. From the 16.67% that germinated, 57.14% seedlings developed till the flowering stage (Table 3).

The number of bulbs collected from each population differed because of availability. However, to solve the problem of sample size, the collection sites were pooled by performing hierarchical cluster analysis in SPSS (Fig. 3). Consequently, there were four clusters formed based on variables used, such as geographic location, elevation, number of bulbs and seeds, and percentage germination of both propagules. Characteristically, cluster 1 has an elevation range from 873 to 1103 m, cluster 2 has an elevation range of 1232 to 1354 m, cluster 3 has an elevation range between 1481 and 1794 m and cluster 4 has an elevation range from 1959 to 2091 m.

To determine if there were differences of variation in the number of bulbs collected and the germination capacity of the bulbs from different population sites within and among the clusters, one way ANOVA showed that all the values obtained were not significantly different, except for elevation (Table 4). This demonstrated that the population sites and the number of bulbs have no significant differences in their ability to germinate.

Table 3. Percentage germination of *Lilium philippinense* bulbs and seeds from the different collection sites.

Population Sites	Latitude	Longitude	Elevation	Bulbs planted	Germinated bulbs surviving to flower (A)	Germinated bulbs not surviving to flower (B)	Total bulbs germinated (A+B)	% bulb germination (after 150 days)	No. of seeds sown	Germinated seeds	% seed germination (after 150 days)
Ambuklao, Inidian	16.4728	120.7622	1042	6.00	2.00	0.00	2.00	33.33	210	81	38.57
Atok, Balangabang	16.5893	120.7586	1959	18.00	0.00	0.00	0.00	0.00	150	47	31.33
Atok, Topdak	16.5447	120.7132	1792	4.00	1.00	1.00	2.00	50.00	180	44	24.44
Atok, Halsema Rd.	16.6017	120.7640	2091	2.00	0.00	0.00	0.00	0.00	150	82	54.67
Bakun, Bagtangan	16.7476	120.7682	2058	9.00	0.00	0.00	0.00	0.00	90	34	37.78
Bauko, Lower Buga	17.0277	121.0922	2074	7.00	0.00	0.00	0.00	0.00	150	23	15.33
Bessang Pass	16.9728	120.6713	1292	29.00	6.00	0.00	6.00	20.69	300	130	43.33
Bokod, Bila	16.5531	120.8214	1481	7.00	0.00	0.00	0.00	0.00	270	101	37.41
Bokod, Bobok, Sawmill	16.4332	120.8551	1514	6.00	0.00	1.00	1.00	16.67	60	37	61.67
Bokod, Moatong	16.4755	120.8196	873	12.00	0.00	1.00	1.00	8.33	240	41	17.08
Bokod, Pito	16.4060	120.8649	1321	6.00	0.00	0.00	0.00	0.00	150	3	2.00
Bontoc, Bayyo	17.0158	121.0157	1276	10.00	2.00	1.00	3.00	30.00	30	0	0.00
Bontoc, Dantay	17.0777	120.9459	922	4.00	0.00	1.00	1.00	25.00	180	42	23.33
Bontoc, Gonogon	17.0459	120.9371	951	1.00	0.00	0.00	0.00	0.00	180	32	17.78
Bontoc, Km 388 Bon-Ban Rd.	17.0874	120.9544	911	10.00	3.00	3.00	6.00	60.00	210	10	4.76
Itogon, Ampucao	16.2844	120.6449	1353	14.00	1.00	4.00	5.00	35.71	120	86	71.67
Kabayan, Caleng, Bashoy	16.5712	120.8360	1085	1.00	0.00	0.00	0.00	0.00	60	6	10.00
Kabayan, Duacan	16.6140	120.8390	1232	12.00	0.00	3.00	3.00	25.00	150	16	10.67
Kapangan, Amunget	16.6489	120.6355	1066	13.00	0.00	3.00	3.00	23.08	30	21	70.00
Kayapa, Nueva Vizcaya	16.3576	120.8880	1103	2.00	0.00	0.00	0.00	0.00	150	24	16.00
Kibungan, Leseb, Sagpat	16.6695	120.6526	1324	2.00	0.00	0.00	0.00	0.00	60	35	58.33
Kibungan, Napsung	16.7332	120.6728	1291	13.00	0.00	1.00	1.00	7.69	30	0	0.00
Sabangan	16.9202	120.8928	1794	10.00	0.00	0.00	0.00	0.00	150	9	6.00
Sagada, Danom	17.0941	120.8856	1728	3.00	0.00	1.00	1.00	33.33	90	50	55.56
Sagada, after Danom	17.0950	120.8773	1685	5.00	1.00	2.00	3.00	60.00	90	7	7.78
Sagada, Madongo	17.1045	120.9130	1556	11.00	0.00	1.00	1.00	9.09	120	52	43.33
Samoki, Km 380 Bon-Ban Rd.	17.0849	120.9807	899	21.00	1.00	0.00	1.00	4.76	150	28	18.67
Tadian	16.9874	120.8417	1354	14.00	1.00	1.00	2.00	14.29	210	53	25.24
			Total	252.00	18.00	24.00	42.00	16.67	3960.00	1094.00	27.63

Table 4. One way analysis of variance (ANOVA) of the different variables.

		Sum of Squares	df	Mean Square	F	Signi-ficance
latitude	Between Groups	.047	3	.016	.191	.901
	Within Groups	1.956	24	.082		
	Total	2.003	27			
longitude	Between Groups	.037	3	0.012	.886	.462
	Within Groups	.336	24	0.014		
	Total	.373	27			
elevation	Between Groups	3735577	3	1245192.337	156.681	.000
	Within Groups	190735.1	24	7947.296		
	Total	3926312	27			
number of bulbs	Between Groups	152.730	3	50.910	1.233	.320
	Within Groups	991.270	24	41.303		
	Total	1144.000	27			
bulb germination	Between Groups	1502.604	3	500.868	1.491	.242
	Within Groups	8063.130	24	335.964		
	Total	9565.734	27			
number of seeds	Between Groups	3212.500	3	1070.833	.193	.900
	Within Groups	133330.4	24	5555.432		
	Total	136542.9	27			
seed germination	Between Groups	564.793	3	188.264	.366	.778
	Within Groups	12353.843	24	514.743		
	Total	12918.636	27			

Germination from seeds

Seed germination was observed and recorded after 150 days from sowing. Of the total 3960 seeds collected from the 28 population sites that were sown under greenhouse conditions, total seed germination was 27.63%. Of the seeds collected from the 28 population sites, the highest percentage seed germination was observed from Ampucao, Itogon with 71.67% germination. This is followed by seeds collected from Amunget, Kapangan, which showed a germination of 70%. In contrast, seeds collected from Bayyo, Bontoc and Napsung, Kibungan did not show signs of germination even after 150 days. Comparatively, the percentage seed germination in all the 28 populations showed variable percentages, from a minimum of 0% to a maximum germination of 71.67% (Table 3, Fig. 4). Nevertheless, despite the variable seed germination percentages, one way ANOVA showed that the number of seeds and the capacity to geminate did not significantly differ in the different population sites (Table 4).

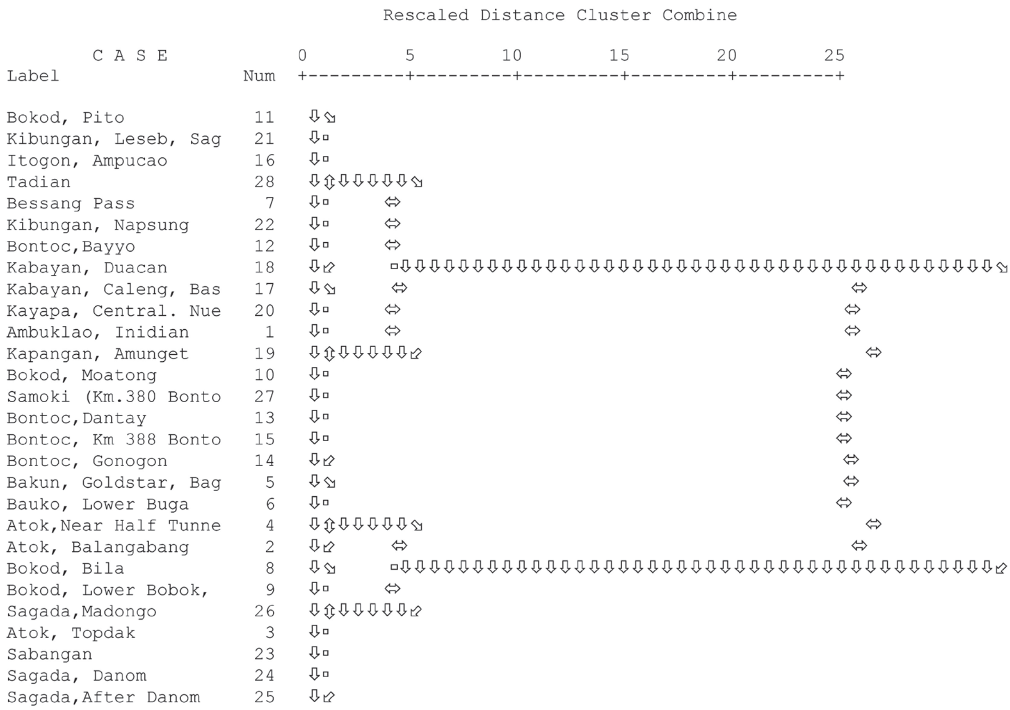

Fig. 3. Dendrogram of the population sites using hierarchical cluster analysis.

Generally, seed germination had a higher value of 27.63% relative to bulbs, which only showed a germination percentage of 16.67%. Across the 28 populations, seed germination was higher than bulb germination with few exceptions (Fig. 4). Additionally, in terms of seedling survival, despite the higher germination capacity from seeds, the plants remained as seedlings up to the third year. These seedlings did not reach maturity, unlike the sprouts from bulbs where 57.14% of the 16.67% that germinated survived until the flowering and fruiting stage.

To determine if there is a relationship among the percentage germination of seeds and bulbs across the 28 populations with respect to elevation and geographic origin, principal component analysis (PCA) was performed. Results showed that the 28 population sites had high loadings on the principal axis (Factor 1) with an *eigen* value of 99.89%. Furthermore, one way ANOVA shows that there were no significant differences among the number of seeds, percentage germination and collection sites. This demonstrates that elevation and geographic location of *L. philippinense* populations did not show significant variation in terms of their germinating capacity, both for the seeds and the bulbs.

Survival of plants from bulb and seed origin

The survival of plants originating from bulbs was observed over one year. Results showed that 57.14% of the 16.67% plants that germinated from bulbs were able to reach flowering stage. Almost half the seedlings from bulbs did not survive up to the

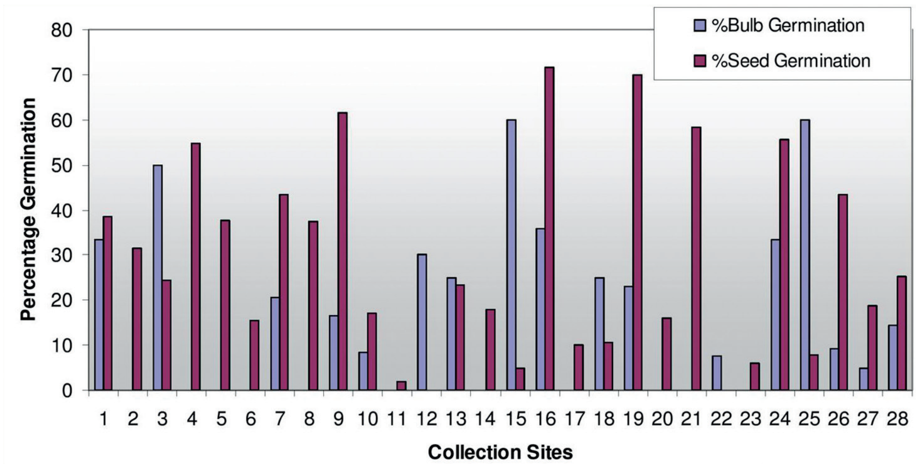

Fig. 4. Germination performance of *Lilium philippinense* bulbs and seeds from different collection sites. Collection sites: 1 Ambuklao, Inidian; 2 Atok, Balangabang; 3 Atok, Topdak; 4 Atok, Halsema Rd.; 5 Bakun, Bagtangan; 6 Bauko, Lower Buga; 7 Bessang Pass; 8 Bokod, Bila; 9 Bokod, Bobok, Sawmill; 10 Bokod, Moatong; 11 Bokod, Pito; 12 Bontoc, Bayyo; 13 Bontoc, Dantay; 14 Bontoc, Gonogon; 15 Bontoc, Km 388 Bon-Ban Rd.; 16 Itogon, Ampucao; 17 Kabayan, Caleng, Bashoy; 18 Kabayan, Duacan; 19 Kapangan, Amunget; 20 Kayapa, Nueva Vizcaya; 21 Kibungan, Leseb, Sagpat; 22 Kibungan, Napsung; 23 Sabangan; 24 Sagada, Danom; 25 Sagada, after Danom; 26 Sagada, Madongo; 27 Samoki , Km 380 Bon-Ban Rd.; 28 Tadian.

reproductive stage. This could perhaps be attributed to the presence of white aphids on the bulb-originated material during the observation period.

The plants that germinated from seeds demonstrated a peculiar characteristic. During the first year, these seedlings remained in their 2–4-leaf stage and wilted after eight months, leaving tiny bulbs that became dormant in the soil. In the second year, new sprouts developed from these tiny bulbs from the first year but these also remained vegetative, after which they again wilted without reaching reproductive stage, surviving once more as dormant bulbs in the soil. In the third year, sprouts again grew from 2-year-old bulbs, but also remained in a vegetative stage. Even at this particular stage, the bulbs had not reached their mature size (about 30–40 mm diameter).

Discussion

One of the most basic ways of propagating plants is through seed. For plants that develop both seed and bulbs such as lilies, seed germination has some advantages. First, it allows growers to propagate lilies that are difficult to obtain as bulbs. Second, seeds are usually disease and virus-free, even if they come from infected plants. Third, using seeds for propagation allows genetic variation in the succeeding population.

Germination from seeds is influenced by different factors such as dormancy, seed size, exposure to environmental factors and other factors that are inherent in the plant. Lily seeds have different types of germination depending on the species. *Lilium philippinense* exhibits an epigeal type of germination. In this study, seeds and bulbs of *L. philippinense* were exposed to a uniform set of environmental conditions in a greenhouse. There was low germination percentage for both seeds and bulbs. Lilies display a unique characteristic in terms of germination capacity. According to Elwes (1880), this is inherent to temperate species where germination from seeds in *Lilium* would show alternating dormancy and seedling initiation for three or more years. This period allows the bulblets to attain a functional size before it can finally grow into a reproductively active plant. Inherent dormancy was also demonstrated by Silvertown in 1999. He observed that Liliaceae species exhibit double seed dormancy. Two cold seasons are required for the seeds to fully germinate; the first cold stratification releases the radicle and the second releases the shoot so that the seeds require two years for germination. Related to this, some plant species have inherently low germination capacity even when exposed to suitable environmental conditions for germination. This observation was described by Lanta et al. (2003) for *Amaranthus cruentus* and *A. retroflexus*, which exhibit poor seed germination.

Studies of some species have shown that seed size often have significant effects on final germination percentage, seedling survival or seedling growth (Gross 1984, Navarro & Guitian 2003). Harper (1977) proposes that the poor performance of smaller seeds is due to their lower endosperm content. Seed germination in *L. philippinense* is possible to an extent of 27.63%; however, reproductive plants cannot directly grow from seeds. The plants that germinated from seeds wilted before reaching maturity but remained as tiny bulbs in the soil. This was also demonstrated in other studies (Schaal 1980, Dolan 1984, Marshall 1987, Naylor 1993). The size of the bulbs is an essential consideration owing to its capacity to store enough food materials to supply the seedlings the needed food during its development. Accordingly, the size of the bulb for commercial production of some lilies should range from 20 to 14 cm. In addition, plants grown from bulbs that are below 10 cm bears small and fewer flowers (Hermano 2000). In Benguet lilies, the size of the bulbs should reach an average of 30 to 40 mm.

In this study, bulb propagation in *L. philippinense* showed 16.67 % germination. This low germination percentage seems rather normal for some temperate species, even if the propagules were reared under optimal flowering conditions (Elwes 1880). In the present case, out of this percentage, only 57.14% developed until the flowering stage. Almost half of the germinated seedlings from bulbs died before reaching the reproductive stage, but it is not possible to know if the observed presence of aphids was a cause.

One important factor that determines the distribution and survival of a species is its ability to exist in harsh environments. In the case of *L. philippinense*, the 28 populations are part of a narrow distribution in the southern part of the CCR. This suggests that there is a suitable but restricted environmental condition for this species in this part of the CCR. The observation of horticulturists in the region that this species is difficult to cultivate outside of its natural habitat can be attributed to its specific and limited range of environmental requirements.

Conclusions

The fact that germination from seeds and bulbs can be obtained despite its limited extent demonstrates that it is possible to propagate *L. philippinense* using bulbs and seeds outside of their natural environment, provided that optimal environmental conditions will be met.

However, in conservation terms, germination from bulbs and seeds are just two techniques for propagating material. Other faster means of propagation, like tissue culture, have yet to be explored for *L. philippinense*. With declining populations of this species, it is essential and interesting that proper and efficient ways of rapid multiplication of material should be considered in future studies.

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