

Breeding of Asiatic hybrid lily cultivars to flower with increased number of flowers in one year from bulbils

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ABSTRACT

The objective of this research was to produce Asiatic lily (*Lilium ×elegans* Thunb.) hybrids in one year starting from small propagules with more than 3 flowers. Bulbils were harvested 30 days after flower (DAF) and treated with a sequential temperature treatment at 5°C for 2 weeks followed by 20°C for 2 weeks, and finally at 5°C for 2 weeks (5°C/2 W – 20°C/2 W – 5°C/2 W) and potted. Flowering was the earliest when 'Inferno' was used as a maternal parent; however, incidence to virus symptoms and a few flowers produced did not favor the use in breeding. Selected hybrid of 'Connecticut Lemon Glow' × 'Beni no Mai' produced 3.3 flowers and is considered suitable as a potted plant; however, flower morphologies should further be improved. Selected hybrid of 'Yellow Blazer' × 'Horner's Back Gold' produced more than 3.5 flowers on a short stem (28 – 31 cm) and considered as suitable for potted plants. Hybrid of 'Beni no Mai' × ('Yellow Blazer' × 'Horner's Back Gold') was considered as suitable for cut flower use, as 2.9 – 3.5 flowers were produced on a stem longer than 70 cm. To produce more than 3 flowers starting from bulbils, new hybrids should be bred based on the incidence of virus infection, early flowering, floral morphology, and plant height.

Keywords: *Lilium×elegans*, bulb harvest, pot plant, cut flower, forcing bulblets, virus susceptibility

INTRODUCTION

Two to three years are usually required to produce bulbs for commercial forcing in the greenhouse of the Easter lily (*Lilium longiflorum* Thunb.) (Blaney and Roberts, 1966) or at least two years are usually required to produce the Asiatic hybrid lily (*Lilium ×elegans* Thunb.) from scaling or bulbils that are naturally forming at the leaf axils using as a propagule (Roh, 1996). Therefore, bulbils that are naturally forming at the leaf axils in several Asiatic hybrid lilies should be used as a propagule for forcing. The Asiatic hybrid 'Beni no Mai' that produced bulbils in the leaf axils at flowering produced a minimum of two flowers in less than a year when mature bulbils were treated with a sequential temperature treatment of 14 to 20 days each at 5°C – 15°C – 20°C – 5°C (Roh, 1992; Suh *et al.*, 2013; Suh and Roh, 2014). Breeding of bulbil forming Asiatic hybrid lily was reported (Grassotti *et al.*, 1996); however, those hybrids were not evaluated for flowering starting from bulbils.

The growing period starting from bulbils to flower could be divided into two phases. The total growing period starting from bulbils to flower is about 300 to 330 days by-passing the bulb production period in the field that may be equivalent to the first phase from potting the treated bulbils to shoot emergence (about 200 to 230 days) and forcing phase from shoot emergence to flowering (about 100 days), (Roh, 1996, 2011; Suh and Roh, 2014; Yoo *et al.*, 2023). The first phase can be considered as bulb production phase in the field that last longer than a year or two. If bulb production phase is eliminated, dormancy and maturity and disease and insects' infestation could be eliminated. If bulbils are used to produce quality plants growing mother plants in the protected system, these problems can be eliminated.

However, regardless of various sequential temperature treatments applied to the mature bulbils, controlling the maturity of bulbils as influenced by flower bud removal and forcing temperatures, and different size of bulbils, forcing bulbils of 'Beni no Mai' Asiatic hybrid lily produced mostly one flower and rarely two flowers per mature bulbil weighing about 400 mg harvested 40 – 50 days after flowering (DAF) are treated with such as 5°C/2 W – 20°C/2 W – 5°C/2 W various low-high-low sequential temperature treatment (SEQ CD)(Roh, 1992; Suh and Roh, 2014; Yoo *et al.*, 2023) to break dormancy and induce maturity (Roh and Wilkins, 1977a, b; Roh, 1978).

Forcing bulblets of 'Beni no Mai' failed to produce more than two flowers per plant regardless of induction of maturity following manipulation of bulbil harvest dates and various bulbil treatments (Yoo *et al.*, 2023). Only one flower was produced from bulblets weighing 10 g obtained after field production (Suzuki, 1974) or two flowers forcing bulblets of Asiatic hybrid lily 'Rouge' weighing 4 g (Zhang *et al.*, 1990). Therefore, to produce more than two flowers per plants from bulbils, new hybrids should be bred and evaluated. The objectives of this research were (a) to breed new hybrids producing bulbils and (b) to force bulbils or bulblets to flower ensuring more than three flowers either for potted plant or cut flower production with desirable floral morphologies in less than a year.

MATERIALS AND METHODS

Plant material and general culture. These experiments were conducted following the general cultural practices described previously (Suh and Roh, 2014). Hybrids with bulbil forming characteristic were bred in 1987 as described (Table 1) and seeds were sown on 1, Oct. 1989. Large bulbs were grown in the greenhouse and at flowering between 27 Apr. and 23 May in 1991, one representative plant per each hybrid was selected, based on the floral morphology and bulbil forming characteristics (Table 1). Forcing experiment of new hybrids starting from bulbils were carried out, first comparing all hybrids under the same environment in the greenhouse (Table 2). Bulbils were harvested on 12 July and treated with sequential temperature treatment of 5°C/2 W – 20°C/2 W – 5°C/2 W (SEQ CD) and potted on 24 Aug. 1991.

Bulbils received SEQ CD treatments were grown in the greenhouse and bulblets as described in Table 3 were harvested after removing scaly leaves. Plants were grown in the growth chamber maintained at 21/19, 25/23, and 27/25°C (07:00 – 17:00, day/night) from 24 Aug. to 25 Oct. Irradiance during the day was 35 W·m⁻² (400–700 nm), provided by incandescent bulbs and cool white fluorescent tubes (Table 3). After these treatments, plants were moved to greenhouse and were grown at 21/15.5°C until 10 Dec. at 21/12.8°C until 27 Dec., at 10°C until 30 Jan. and finally at 21/15.5°C until flowering in the greenhouse.

Data analysis. All data were subjected to the analysis of variance using Microsoft Excel (Microsoft Corporation, 2019) and means were compared by Duncan's Multiple Range (DMR) test or Tukey's ω -procedure (highly significant difference; hsd) test, depending on

the number of means. At anthesis, the number of leaves and plant height measured from the growing medium surface to the bract were recorded (Suh and Roh, 2014). The number of flowers (x) were analyzed after square root transformation $(x + 0.5)^{1/2}$.

RESULTS AND DISCUSSIONS

Plants forced from bulbils of Asiatic hybrid lily 'Beni no Mai' produced mostly one flower with rarely a maximum of two flowers on a stem taller than 60 cm with more than 60 leaves, regardless of treatments given to bulbils after harvest (Roh, 1992; Suh *et al.*, 2013; Suh and Roh, 2014; Yoo *et al.*, 2023). To increase the number of flowers more than two, new hybrids forming bulbils with a potential to produce 3 - 4 flowers both for potted plant and cut flower use should be developed.

Overall characteristics of selected *Lilium ×elegans* hybrids describing the bulbil forming position on the stem and bulbil weights, flower bud orientation, and general morphological characteristics are presented (Table 1). Both up-facing for cut flower and pot plant production and side-facing hybrids for pot plant production were selected in all hybrids. The bulbils were generally formed in the middle and upper portion of stem in most of the hybrids, and flower bud orientation was up-facing when 'Inferno' was used as a female parent. However, difference in flower bud orientation was observed in 'Connecticut Lemon Glow' crossed with 'Beni no Mai' producing up-facing selection among for selections.

Although 'Connecticut Lemon glow' × 'Beni no Mai' selections A, C, and D produced more than two flowers, floral morphology of these selections is not considered ideal either as a potted plant or cut flower use as petals are easily separated from the receptacle due to one large lip-like petal (Frame B, Fig. 1). Further, selection of hybrids should be made free of floral abortion/blast (Frame A-1 and B-1, Fig. 1) which lowers the number of flowers reaching to anthesis even when plants were not exposed to high temperatures as reported by Roh (1990).

The weight of bulbils in 'Connecticut Lemon Glow' crossed with 'Beni no Mai' was either small (319 mg in selection D and 326 mg in selection A) or large (437 mg in selection B and 482 mg in selection B), (Table 2). Therefore, segregation of general morphological characters was noticed as both parents were propagated vegetatively, that required selection for forcing experiment. Since only a few plants from each hybrid were evaluated, it is not certain whether the weight of bulbils is related to the number of flowers. 'Connecticut Lemon Glow' × 'Beni no Mai' selection B produced 1.2 flowers when forced bulbils that weighted 437 mg, while selection D produced 2.2 flowers.

Hybrid selection 'Yellow Blazer' × 'Horner's Back Gold'-B was also promising the highest number of flowers (3.5) produced on a 28 cm tall plant height among all evaluated hybrids. With this selection, planting 2 bulbils per pot would produce finished pots with 7 flowers in 220 days starting from bulbils. For cut flower production, 'Beni no Mai' × ('Merry Jean' × 'Jolly Green Giant') is suitable as the plant height is 80 cm with 2.8 flowers (Frame A, Fig. 2). Hybrid, 'Beni no Mai' × ('Yellow Blazer' × 'Horner's Back Gold') can be used for cut flower production, while hybrid, 'Yellow Blazer' × 'Horner's Back Gold' selection B producing 3.5 flowers on a 45 cm plant height for potted plant production (Frame B, Fig. 2).

Flowering was the earliest in hybrids 'Inferno' × 'Beni no Mai' selection A and B in 210 and 219 days, respectively, using 'Inferno' as a female parent (Table 2) and this could be inherited from 'Inferno' which can flower without bulb vernalization treatment and classified as the early flowering cultivars (Lee *et al.*, 2007; Roh, 1990) even when hybridized with a late flowering 'Beni no Mai', due to a flower bud initiation that occurs after shoot emergence (Ohkawa *et al.*, 1990). However, both selections showed virus symptoms such as color breaking (Kim *et al.*, 1996), mainly in the flower petals (mild color

breaks) (Fig. 3), and this trait was inherited from 'Inferno' as this cultivar is susceptible to virus (Roh, unpublished data). As the number of flowers of these two selections was less than two, it is not desirable to use 'Inferno' as a female parent in breeding.



Fig. 1

Figure 1. 'Beni no Mai' × ('Merry Jean' × Jolly Green Giant) *L. ×elegans* hybrid lily, suitable for cut flower production (A) and Yellow Blazer' × 'Horner's Back Gold' B hybrid lily, suitable for potted plant production showing upright facing flowers and long basal leaves (B-1) and close-up images of inflorescence (B-1). Bar = 10 cm.



Fig. 2

Figure 2. Short stemmed *L. ×elegans* lily with a potential use as potted plant production; Yellow side facing flowers (A) and red side-pendent flowers (B) showing aborted flower bud as indicated by arrow (A-1 and B-1). Bar = 10 cm.



Figure 3. Virus symptom expression of *Lilium ×elegans* lily, 'Inferno' × 'Beni no Mai'; entire flower (A), single petal showing color break (dark streak) (B) and diagnostic by tissue blotting immunoassay showing infected (1) and clean (2) leaves (C).

Table 1. The position of bulbil formation, flower bud orientation, and general morphological characteristics of selected *Lilium ×elegans* hybrids

Parentage of hybrid			Position of bulbil formation ^y			Flower bud orientation	General characteristics
Female	Male	Se _z	Lo	Mi	Up		
'Beni no Mai'	'Merry Jean' × 'Jolly Green Giant'		Yes	Yes	Yes	up-facing	No characteristics were recorded
	'Yellow Blazer' × 'Horner's Back Gold'		No	No	Yes	side-facing	Medium size bulbils, and may not produce enough bulbils to harvest and did not produce bulbils in the middle and lower portion of the stem
'Connecticut Lemon Glow'	'Beni no Mai'	A	No	Yes	Yes	up-facing	Small bulbils. 22 bulbils are formed.
		B	Yes	Yes	Yes	side-facing	Large bulbils, and easily separated from the stem.
		C	Yes	Yes	Yes	side-facing	Large bulbils, and easily separated from the stem.
		D	yes	Yes	Yes	side-facing	Numerous small bulbils from each leaf axil. Floral morphology is not desirable due to a space between petals.
'Inferno'	'Beni no Mai'	A	Yes	Yes	Yes	up-facing	Small bulbils. Leaves showing virus symptom. Flower morphology like 'Inferno'.
		B	Yes	Yes	Yes	up-facing	Small bulbils. Desirable floral morphology with orange red petals.
'Yellow Blazer'	'Horner's Back Gold'	A	No	Yes	No	side-facing	Small bulbils. Leaves showing virus symptom. Flower morphology like 'Inferno'. 27 bulbils were formed.
		B	yes	Yes	yes	side-facing	Large bulbils formed mainly in the middle of stem. Easily separated from the stem.

^z Selection (Se);^y Low (Lo), middle (Mi), and upper (Up) of stem that formed bulbils.

Table 2. Evaluation of *Lilium ×elegans* hybrids forcing from bulbils

Parentage of hybrid		Se ^z	No. of			Plant height (cm)	No. of replication/ Bulbil weight (mg)
Female	Male		Days to flower	Flower	Leaves		
'Beni no Mai'	'Merry Jean' × 'Jolly Green Giant'		232 a	2.8 b	54 b	80 a	10/418
'Beni no Mai'	'Yellow Blazer' × 'Horner's Back Gold'		228 bc	2.4 bc	51 bc	54 b	5/381
'Connecticut Lemon Glow'	'Beni no Mai'		228 bc				
		A		2.2 bcd	49 bc	39 d	6/326
		B	228 bc	1.2 e	35 d	34 d	7/437
		C	218 d	2.2 bcd	37 cd	36 de	5/482
		D	226 c	2.0 cd	49 bc	49 bc	6/319
'Inferno'	'Beni no Mai'	A	210 e	2.0 cd	63 a	43 cd	5/285
'Inferno'	'Beni no Mai'	B	219 d	1.6 de	46 c	39 d	5/299
'Yellow Blazer'	'Horner's Back Gold'	B	236 a	1.6 de	52 b	28 f	13/328
'Yellow Blazer'	'Horner's Back Gold'	A	220 d	3.5 a	45 c	28 e	10/489

^z Selection (Se);^y Means with the same letter in a column is not significantly different by Duncan's multiple range test at $p \leq 0.01$

Selection criteria for hybrids are preferably set to the number of flowers and plant height for pot plant and cut flower use as time of flowering that differs 26 days among these hybrids can further be reduced by temperature treatment during development after potting treated bulbils (Roh and Wilkins, 1977a) and may not be reduced by photoperiod as floral initiation is completed upon shoot emergence (Lee *et al.*, 2010; Roh, 1985). Further hybridizations are suggested to produce as many bulbils observed in 'Yellow Blazer' × 'Horner's Back Gold' (10 to 13 bulbils evaluated) as possible to select that flower less than 200 days with more than 3.5 flowers.

When these hybrid selections were forced starting from bulblets, shoot emerged in less than 20 days in all hybrids (Table 3). When 'Inferno' was used in hybridization, virus symptom in petal is observed. Based on the floral morphology, 'Connecticut Lemon Glow' may not be used as one of parents, although 'Connecticut Lemon Glow' × 'Beni no Mai' produced higher than 3.3 flowers per plant and is considered suitable as a potted plant. 'Yellow Blazer', 'Horner's Back Gold', and 'Beni no Mai' is considered suitable to use as parental cultivars as 'Yellow Blazer' × 'Horner's Back Gold' produced more than 3.5 flowers on a short stem (28 – 31 cm) which is ideal for potted plant. 'Beni no Mai' × ('Yellow Blazer' × 'Horner's Back Gold') produced 2.9 – 3.5 flowers on a stem longer than 70 cm which is ideal for cut flower production. The relationship between the weight of bulblets and the number of flowers may not exist, although the heaviest bulblets (489 mg) produced the highest number of flowers (3.5 flowers) in 'Yellow Blazer' × 'Horner's Back Gold' hybrids.

Table 3. Effect of temperature treatments to bulblets from 24 Aug. to 25 Oct. on growth and flowering of *Lilium ×elegans* hybrids

Treatment Temp (°C)	No. of days to		No. of flowers	Plant height (cm)	No. of leaves
	Leaf emergence	Anthesis			
‘Beni no Mai’ × (‘Yellow Blazer’ × ‘Horner’s Back Gold’). N=15. 4.93 g, fresh weight					
21/19	16 b	229 a	2.9 b	70 c	46 b
25/23	18 ab	230 a	3.1 b	76 a	49 a
29/27	17 ab	230 a	3.5 a	73 b	48 a
‘Beni no Mai’ × (‘Merry Jean’ × ‘Jolly Green Giant’). N=20. 4.29 g, fresh weight					
21/19	19 a	225 c	2.9 a	44 a	41 b
25/23	18 a	229 b	2.9 a	43 a	46 ab
29/27	19 a	233 a	2.5 b	41 b	45 a
‘Connecticut Lemon Glow’ × ‘Beni no Mai’ - A. N=20.					
21/19	17 a	220 b	2.8 b	38 a	42 a
25/23	18 a	226 a	2.5 b	37 a	36 b
29/27	17 a	225 a	3.3 a	36 a	36 b
‘Yellow Blazer’ × ‘Horner’s Back Gold’ selection A. N=10. 4.67 g, fresh weight					
21/19	16 a ^z	223 b	2.0 a	52 a	37 a
25/23	17 a	224 b	2.0 a	50 a	36 a
29/27	16 a	226 a	1.9 a	47 b	34 a
‘Yellow Blazer’ × ‘Horner’s Back Gold’ selection B. N=10. 5.13 g, fresh weight					
21/19	17 a	213 a	3.5 a	31 a	41 a
25/23	16 ab	212 a	3.7 a	30 a	40 a
29/27	15 b	212 a	3.6 a	28 a	40 a

^z Means with the same letter in a column per cultivar is not significantly different by Duncan’s multiple range test at $p \leq 0.01$.

CONCLUSIONS

Generally, it is not possible to produce ‘Beni no Mai’ with two flowers per plant and this is the maximum potential, regardless of various temperature treatments given to bulbils or bulblets. Therefore, to produce more than three flowers starting from forcing bulbils, breeding of new hybrids for either potted plant or cut flower production becomes necessary. Selection of hybrids should be based on the incidence of virus symptom expression, the number of flowers, and floral morphology.

As the number of flowers are higher than three starting from bulbils on a 28 cm or forcing bulblets on a 28 to 31 cm short stem that were harvested a year later in ‘Yellow Blazer’ × ‘Horner’s Back Gold’, production of quality plants is proved possible starting from bulbils by-passing bulb (let) production phase that requires a year.

ACKNOWLEDGEMENTS

This research was conceived and carried out, and manuscript was completed to submit by M.S. Roh working with co-authors. Data were tabulated and analyzed by Y.K. Yoo and Y.S.

Roh who also assisted preparing the draft of the manuscript, reviewed references, and received English editing service.

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