

***Lilium*: Breeding History of the Modern Cultivar Assortment**

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Abstract

During the last 50 years the lily has become worldwide one of the most important flower bulbs and cut flowers. They are mainly cultivated in The Netherlands with bulb production acreage of more than 5000 ha. The assortment of lilies consists of thousands of cultivars which can be classified in different hybrid groups. Due to innovative new hybrid breeding strategies that have been developed and implemented over these last 50 years, the assortment of lilies has changed dramatically. The development of the assortment and the important steps herein from the first diploid Asiatic hybrids to the wide variety of intersectional polyploid hybrids that are available now or within the near future is described. The characteristics of the most widely grown cultivars will be presented.

INTRODUCTION

The genus *Lilium* consist of about 80 species ($2n=2x=24$) which can be classified in 7 sections. Based on Comber's classification (1949), the genus *Lilium* consists of the sections *Martagon*, *Pseudolirium*, *Liriotypus*, *Archelirion*, *Sinomartagon*, *Leucolirion* and *Dauroilirion*. De Jong (1974) revised this classification and defined the seven sections as follows: *Martagon*, *Pseudolirium*, *Lilium*, *Archelirion*, *Sinomartagon*, *Leucolirion* and *Oxypetala* (Fig. 1). Nishikawa (1999, 2007) performed some phylogenetic studies in the genus *Lilium* using sequences of the internal transcribed spacer region of nuclear ribosomal DNA. The position of the species in the section *Sinomartagon* was improved. In our interspecific crossing studies (Van Tuyl et al., 2002; Lim et al., 2008) these findings in general could be confirmed.

EARLY AND CLASSICAL BREEDING

Compared with tulip the breeding history of lily is rather short. In the first decennia of the 20th century in Japan and the US the first crosses within the section *Sinomartagon* were produced. The species involved were *Lilium maculatum*, *L. davidii*, *L. dauricum*, *L. bulbiferum* and *L. tigrinum*. A number of hybrid groups were developed, like the Preston hybrids, the Mid-Century hybrids, the Patterson hybrids, the Harlequin hybrids and so on (De Graaff, 1970; Rockwell et al., 1961; McRae, 1998). A breakthrough was the Mid-Century Hybrid 'Enchantment' bred by Jan de Graaff in 1944, of which more than 700 hectares were grown in The Netherlands in 1977. In this group the first polyploid (triploid and tetraploid) lilies were introduced. Nowadays most of them are polyploid (Table 1).

After World War II Dutch companies started breeding activities, but it was not until after 1970 that lily became an important crop. As can be seen from Figure 2, the Asiatic hybrids were the main product for more than 30 years (1970-2000). Meanwhile, the Oriental hybrids, originating from crosses of mainly *L. auratum* and *L. speciosum* from the *Archelirion* section, were developed. These lilies, with large, exotic, mainly pink and white flowers became the most important hybrid group during the 1990s. 'Star Gazer', the first upfacing Oriental hybrid, was bred by Leslie Woodriff (introduced in 1975), and was for more than 25 years the most important cultivar in this group. In the eighties and nineties, Oriental hybrids became more and have been the most important group of lilies today (Fig. 2).

INTERSECTIONAL HYBRIDISATION

Due to the development of pollination- and embryo rescue- and polyploidization methods (Asano, 1978, 1980; Asano and Myodo, 1977a,b; Barba-Gonzalez, 2005; Barba-Gonzalez et al., 2004, 2005, 2006; Lim, 2000; Lim and Van Tuyl, 2004, 2006; Lim et al., 2001, 2004, 2007; Van Tuyl and Boon, 1997; Van Tuyl et al., 1989, 1991, 1992, 2002, 2003), a range of intersectional hybrids were developed. The first group of intersectional hybrids, the *Longiflorum* × Asiatic hybrids or LA hybrids, was developed two decades after the Oriental hybrids, by interspecific hybridization between hybrids of different sections, the *Longiflorum* and the Asiatic group. The ploidy level of these lilies is triploid, since they are backcrosses from a chromosome doubled F₁ LA hybrid with an Asiatic hybrid (Fig. 2). During the last ten years this group became more important than the Asiatic hybrid group and have in large part essentially replaced them in the industry.

Similarly, other intersectional crosses, mostly triploid hybrids (which possess a superior growth vigour and plant habit) have been bred, such as the LO (*Longiflorum* × Oriental), OT (Oriental × Trumpet) and OA (Oriental × Asiatic) hybrids. Like the LA-hybrids have mainly replaced the Asiatic hybrids and the LO-hybrids the Longiflorums, it can be expected that in the future the Orientals will (partly) be replaced by the OTs. Besides, the development of the seven main hybrid groups (O, A, L, T, LA, LO and OT) a number of other species have been bred successfully as can be seen in Figure 1.

Species which are bred successfully but not yet included in the commercial assortment are *L. candidum* (section *Lilium*) crosses with *L. henryi* and with *L. longiflorum*. Many successful crosses were made with *Longiflorum* as mother and *L. auratum*, *L. bakerianum*, *L. canadense*, *L. concolor*, *L. dauricum*, *L. henryi*, *L. kelloggii*, *L. lankongense*, *L. lophophorum*, *L. monadelphum*, *L. martagon*, *L. hansonii*, *L. nepalense*, *L. pardalinum*, *L. pumilum* and *L. sempervivoideum* as father. With Oriental as mother, crosses were made with *L. dauricum*, *L. nepalense* and *L. pardalinum*. For the future some of these new combinations can be expected in the assortment.

TOP 25 LILY ASSORTMENT 2010

The top 25 most widely grown lily hybrids are listed (Table 1), according to the bulb acreage grown in the Netherlands in 2010 and in 1994 as published by the Dutch Flower Bulb Inspection Service (BKD). Given is the type of hybrid (A=Asiatic, O=Oriental, L=*longiflorum*, LA, OT), the ploidy level, the breeder and the year of introduction. The situation when the first *Lilium* symposium was held in 1994 is compared with the situation in 2010, it is clear that a complete change of the assortment has taken place. Only five Oriental cultivars are in both lists. In 1994 of ‘Star Gazer’, which was the most important lily grown for more than 25 years, 437 ha were grown. This cultivar is with 7,300 ha grown between 1980 and 2010 the top grown cultivar ever. On a second place ‘Enchantment’ comes with 6,700 ha. It is not likely that this ranking will ever change.

In 1994 only 20 ha of the intersectional hybrids (LA, OT, LO) were grown while in 2010 this has increased to 1,290 ha. Except for ‘Star Gazer’, all the cultivars in the list are still protected by Breeder’s Rights. Using tissue culture propagation, new lily cultivars can be placed in the market in a short time. The most important lily breeders nowadays are all located in The Netherlands: they include Vletter and Den Haan (recently joined with Marklily), Mak Breeding, Royal van Zanten, World Breeding and De Jong Lilies.

FUTURE DEVELOPMENTS

As can be concluded from Figure 2 breeding plays an important role in the development of the assortment. Due to advanced breeding techniques, the assortment has changed dramatically in the last 15 years. Whereas Asiatic hybrids have been replaced by LA-hybrids (in 2010 for 75%), a similar process is visible with the OT-hybrids which will probably replace the Orientals (in 2010 for 15%) and with the LO-hybrids which will likely replace the Longiflorums (in 2010 for 50%) (Table 2). All these new hybrids are triploid intersectional hybrids.

Finally for the future, besides the development of the seven main hybrid groups (O, A, L, T, LA, LO and OT), a number of other species have been used successfully. Species which were crossed successfully with a high potential to be used in new hybrid groups are: *L. candidum* and *L. monadelphum* (section *Lilium*), *L. pardalinum* and *L. canadense* (section *Pseudolirium*), *L. martagon* and *L. hansonii* (section *Martagon*), *L. nepalense* and *L. bakerianum* and *L. henryi*. Techniques which are being used to enhance the introgression of characters from wild species to the assortment are molecular cytogenetics (Lim, 2000; Barba-Gonzalez, 2005; Zhou, 2007; Khan, 2009) and molecular assisted breeding (Shahin et al., 2009).

Recently, comprehensive genetic maps of 2 lily populations including 6 QTLs for *Fusarium*-resistance were published (Shahin et al., 2010). While genetic transformation is a technique investigated in lily for more than 25 years (Cohen, 2011), it is used in genetic studies but until now transformation has played no role in the development of new cultivars. In the near future, knowledge of DNA-sequences linked to horticultural traits will play a key role in bridging the genomes of lily. This will enable combinations of favourable complex traits from the wide genetic variation available to breeders.

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rubellum and *L. auratum* × *L. henryi*. Yb. North Amer. Lily Soc. 55:17-22, 70-72.
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Tables

Table 1. Top 25 most widely grown lily cultivars in The Netherlands in 2010. Given is the hybrid group (A=Asiatic, O=Oriental, L=*longiflorum*, LA, LO and OT), the ploidy level (2=diploid, 3=triploid, 4=tetraploid), the bulb production area (in ha) grown in The Netherlands in 2010 and 1994, the Breeder (VH=Vletter and Den Haan BV, (recently joined with Marklily), M=Makbreeding, IM=Imanse, RVZ=Royal van Zanten, WB=World Breeding) and the year of introduction (Intro).

Cultivar	Group	Ploidy	Production area (ha)		Breeder	Intro.
			2010	1994		
Sorbonne	O	2	200		VH	1994
Siberia	O	2	193	6	Mak	1992
Robina	OT	3	84		Marklily	2004
Tiber	O	2	71		VH	1994
Conca d'ór	OT	3	67		VH	2002
Brindisi	LA	3	67		VH	2002
Rialto	O	2	63		VH	2002
Santander	O	2	61		VH	2007
Litouwen	LA	3	59		VH	2005
Tresor	A	4	56		VH	1997
Casa Blanca	O	2	53	48	VH	1977
Pavia	LA	3	50		VH	2003
Yelloween	OT	3	50		WB	2005
Original Love	LA	3	41		Mak	2006
Dazzle	LA	3	40		Mak	1997
Nova Zembla	O	2	33		Mak	2001
White Heaven	L	2	38		WB	1999
Crystal Blanca	O	2	38		WB	1999
Star Gazer	O	2	37	437	Woodriff	1977
Merostar	O	2	37	18	IM	1991
Navona	A	3	34		VH	1994
Belladonna	OT	3	33		VH	2003
Corvara	O	2	32		Sande	2003
Acapulco	O	2	30	48	VH	1990
Triumphator	LO	3	30		RVZ	2003

Table 2. Bulb production acreage of the main lily groups grown in the Netherlands in 1994 and 2010.

Hybrid group	1994	2010
Asiatic	1627	436
Oriental	1155	1799
<i>Longiflorum</i>	137	46
<i>Longiflorum</i> × Asiatic	21	886
<i>Longiflorum</i> × Oriental		53
Oriental × Trumpets		349
Total	3020	3624

Figures

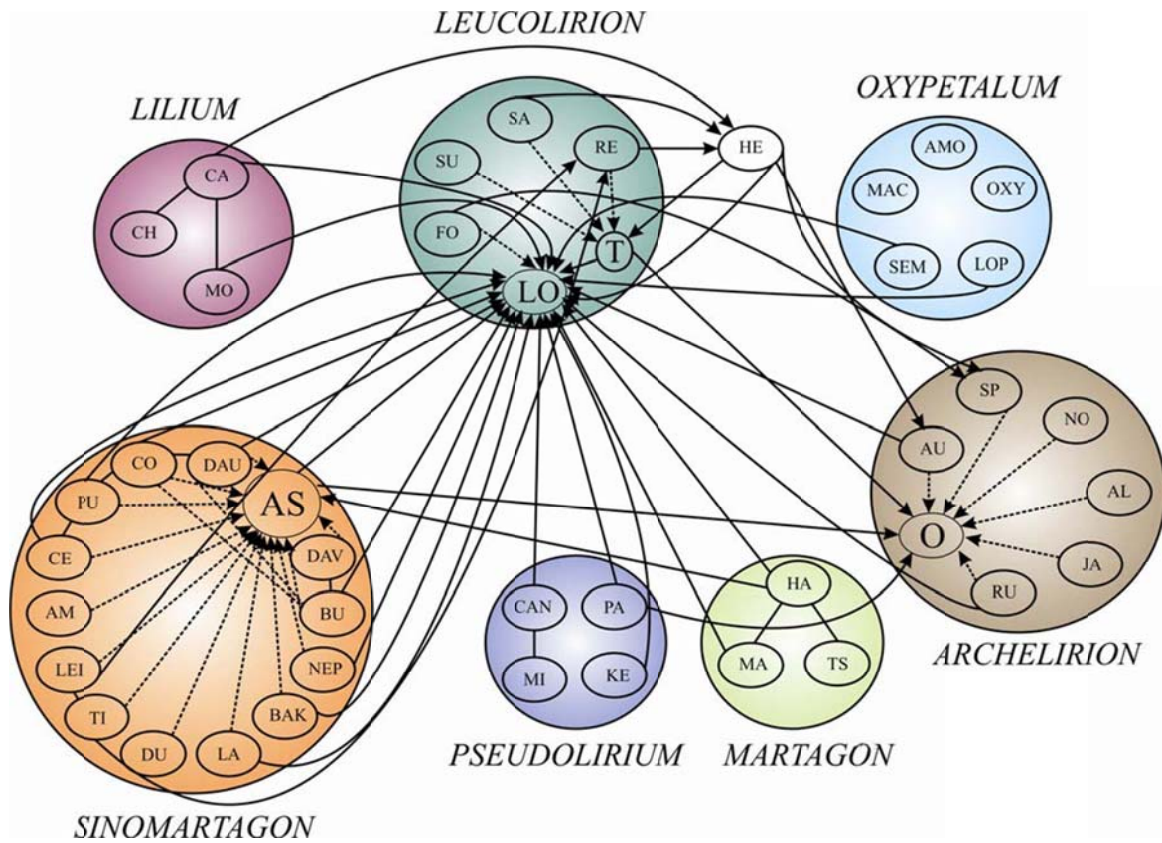


Fig. 1. Crossing polygon of the genus *Lilium* including all the successful crosses of species between different sections of the genus *Lilium*. In this figure, the connection between the Asiatic (AS), Trumpet (T), *Longiflorum* (LO) and Oriental (O) hybrid groups are shown by dotted lines. In successful crosses between species (small ellipses) of different sections (large circles) the arrows point towards the female parent. Abbreviations: AL: *L. alexandrae*; AM: *L. amabile*; AMO: *L. amoenum*; AS: Asiatic hybrids; AU: *L. auratum*; BAK: *L. bakerianum*; BU: *L. bulbiferum*; CA: *L. candidum*; CAN: *L. canadense*; CE: *L. cernuum*; CH: *L. chalcedonicum*; CO: *L. concolor*; DAU: *L. dauricum*; DAV: *L. davidii*; DU: *L. duchartrei*; FO: *L. formosanum*; HA: *L. hansonii*; HE: *L. henryi*; JA: *L. japonicum*; KE: *L. kelloggii*; LA: *L. lankongense*; LEI: *L. leichtlinii*; LO: *L. longiflorum*; LOP: *L. lophophorum*; MA: *L. martagon*; MAC: *L. macklinae*; MI: *L. michiganense*; MO: *L. monadelphum*; NEP: *L. nepalense*; NO: *L. nobilissimum*; OXY: *L. oxypetalum*; O: Oriental hybrids; PA: *L. pardalinum*; PU: *L. pumilum*; RE: *L. regale*; RU: *L. rubellum*; SA: *L. sargentiae*; SEM: *L. sempervivoideum*; SP: *L. speciosum*; SU: *L. sulphureum*; T: trumpet hybrids; TI: *L. tigrinum*; TS: *L. tsingtauense*.

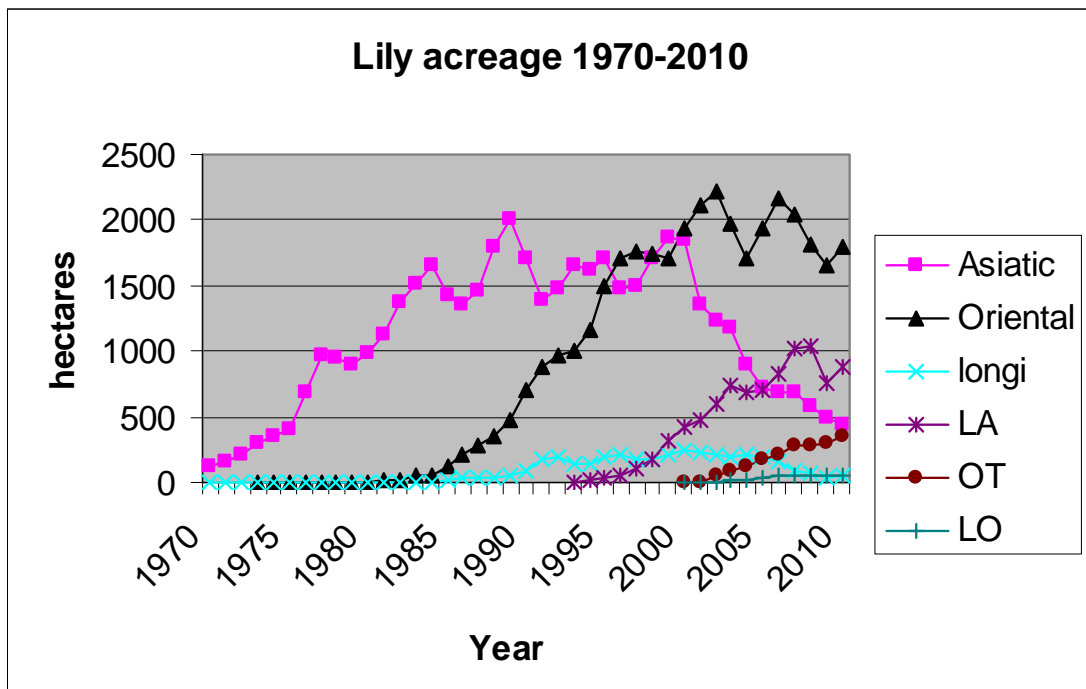


Fig. 2. Change in bulb production area (in hectares) of lily hybrids (Asiatic hybrids, Oriental hybrids, *Lilium longiflorum*, LA-hybrids, OT and LO-hybrids) in the Netherlands from 1970-2010 based on statistics published by the BKD (Dutch Flower Bulb Inspection service).