Production and Breeding of Cacti for Grafting in Korea

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Grafted cacti are now regarded as one of the most admired ornamental indoor plants worldwide. Approximately 15 million grafted cacti are being traded in the international market, and 10 million of these has been developed and produced in Korea. Ninety new cultivars many with brilliant colors and unusual forms have been developed by the National Horticultural Research Institute (NHRI), Rural Development Administration (RDA), and Goyang Cactus Experiment Station, Gyeongggi Province. The grafted cactus industry in Korea has been stabilized but is expected to expand with the introduction of new cultivars and advanced grafting technology (Lee and Oda, 2003).

☐ Present State of Production

Approximately 2,500 species of cacti are distributed in the subtropical zone of the arid regions in the North and South America. Grafted cacti were introduced in Korea by private collectors in the mid 1940s and commercial cultivation was launched in the late 1970s. The cultivation area was 3.5 ha in 1985, increased to 61.6 ha in 1995, and reached 64.2 ha in 2002, with a production of 48 million plants in that year (Table 1). Rapid increase in cacti production was due to grafting, which now accounts for 60% of the total cactus cultivated area and 64% percent of total production in 2002.

Table 1. Cultivation area and production of total cacti in Korea.

Year	Cultivation area (ha)	Production (1,000 plants)	Value (US $1,000)
1985	3.5	368	235
1990	38.3	10,819	2,799
1995	61.6	28,747	8,621
2000	50.2	29,160	7,935
2001	58.4	36,267	8,851
2002	64.2	48,970	8,837

Fig. 1. Production of stock plants of *Hylocereus trigonus* for grafting.

Fig. 2. Production of grafted cacti of *Gymnocalycium mihanovichii*.

In Korea, grafted cacti are commonly cultivated in greenhouses using soil beds or benches (Figs. 1 and 2). Cutting down the grafting labor cost for mass production has been the major concern for profitable growing because grafted cacti are a labor-intensive crop. They require 17,000 hours of labor per hectare and grafting operation accounts for 30 to 40% of all labor required. Recently, new implements for grafting have been developed to reduce grafting labor by more than 40% in comparison with the traditional method that use threads (Fig. 3) (Lee and Oda, 2003). Optimized curing of the grafted cacti is critical for the production of uniform, high-quality cacti (Fig. 4).

Fig. 3. Cactus grafting using a rubber-band attached grafting plate.

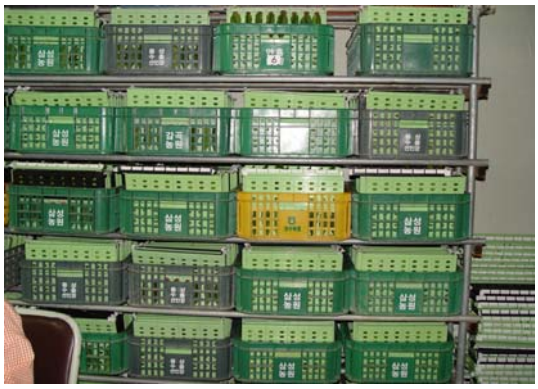

Fig. 4. Curing grafted cacti in a temperature and humidity controlled room for one week after grafting.

New technological improvements have been developed for producing high quality cactus; clarification of the quality and quantity of light, establishment of the irrigation practices, nutrient solution culture technique, and off-season growing technology through controlling root-zone temperature. Advances in these techniques have resulted in more stabilized production of grafted cacti year-round.

The sizes of grafted cacti are determined by the size of the stock used for grafting. The cacti for grafting are classified into three categories; large, medium, and small. The days required for production depends on the size of stock and the kind of plant (Table 2).

Table 2. Cacti size and duration required for the production of different cactus species.

Species	Product size	Stock length (cm)	Desirable size for sale (cm)	Periods required for production (month)
Gymnocalycium mihanovichii	Large	12~14	Globe diam. 4.5	8~9
	Medium	9	3.0	5~6
	Small	6	2.5	2~3
Chamaecereus silvestrii	Large	12~14	Length 5~6	5~6
	Medium	9	3~4	4~5
Gymnocalycium denudatum	Medium	9	Globe diam. 3~4	4~5
Notocactus scopa	Medium	9	Globe diam. 3~4	4~5
G. badianum	Medium	9	Globe diam. 3~4	4~5
Eriocactus leninghausii	Medium	9	Globe diam. 3~4	4~5

The standardized grafted cacti are sent to export companies with the roots removed. Export company groups classify the cacti according to their size and quality upon arrival and then brush away the soil and dust attached to body before exporting them. Cacti are packaged in boxes and exported by air or ship (Fig. 5).

Fig. 5. Packing grafted cacti for export.

☐ Present Status of Export

Grafted cacti have been cultivated since the 1940s in Japan. Thus, Japan had been the major exporting country until the early 1980s. Korea began to export cacti for the first time in 1978 and bulk export was begun in 1984. Exports were valued at 2.47 million cacti worth US $2.47 million in 1993 and US $ 2.26 million in 2002, averaging in excess of US $ 2 million annually over the last 10 years (Table 3).

Korea now exports grafted cacti to more than 20 countries including the Netherlands, USA, China, and Canada; the Netherlands and USA are the major importing countries. Among the various cacti, *G. mihanovichii* accounts for 70%, *C. silvestrii* for 20%, and *N. copa*, *E. leninghausii* and *G. baldianum* for 10% of the export (see Table 2). *G. mihanovichii* consisted of 50% red color, 15% yellow, 15% orange, 15% pink and other colors 5% (Fig. 6). Recently, attractive cultivars having various colors have been developed and color availability is now extensive. Grafted plants are replanted in a small pot or planted in a medium to large pot with other succulents for distribution or local sale.

Table 3. Changes in the quantity and amount of grafted cacti trade according to countries and year.

Country	1998		2000		2002	
	Quantity (ton)	Value (US $000)	Quantity (ton)	Value (US $000)	Quantity (ton)	Value (US $000)
The Netherlands	272	707	187	686	223	921
USA	56	451	54	588	54	453
China	23	80	223	466	16	204
Hong Kong	91	321	329	391	-	2
Canada	36	281	35	304	54	381
Others	50	424	38	302	55	458
Total	528	2,266	866	2,737	402	2,419

Fig. 6. Korean grafted cacti being conditioned in the glasshouse of Edel Cactus Co. in the Netherlands until retail sale.

☐ Breeding of New Cultivars

Korea now ranks first in the production and export of grafted cacti in the world. In the past, however, the rating of cacti grown in Korea was low in the international market due to low quality with color limited to red until the early 1990s. To promote the breeding and development of cacti cultivars and produces, the NHRI-RDA made an assessment of the international markets of main importing countries like the Netherlands, USA, and Japan. This assessment led to the resolution of breeding cacti for international standards. NHRI was then able to collect more than 400 species of *Gymnocalycium* and *Lobivia*. Researchers evaluated the characters and used these as basic germplasm. In addition, Random Amplified Polymorphic DNA (RAPD) technique was applied to elucidate relationships between major cacti species. Other technologies such as controlling flowering period, pollen storage, in vitro culture and selection methods, cross-compatibility between species, and inheritance analysis of color and quality were thoroughly investigated.

By utilizing elaborate in vitro culture techniques, we have been able to increase the percentage of successful selection of new pigmented, chlorophyll-deficient cultivars. Korean cactus breeding has been based on inbreeding, maintenance of germplasm for cross breeding, and well-executed selection techniques. These breeding efforts have raised about 10 outstanding cultivars each year and total of 90 cultivars have been released since 1994, including 42 of *G. mihanovichii* cultivars, 11 of *C. silvestrii*, and 1 of *G. denudatum* (Table 4). This year, NHRI plans to release 5 new cultivars of *G. mihanovichii* and 2 of C. *silvestrii*. The diversified color of the new cultivars extends the marketability of the grafted cacti and provides for the preference of different importing countries. The 10 different colors released include yellow, red-yellow, scarlet, pink, black-pink, greenish-yellow, and deep red. Separate breeding work at the Cactus Experiment Station of the Gyeonggi Agricultural Research and Extension Services (GARES) (http://nongup.gyeonggi.go.kr) of Gyeonggi Province also made significant contribution to various areas of cactus production, marketing, export, and breeding. Thirty outstanding cultivars were developed from this station (Table 5).

Table 4. Cacti cultivars bred and released by NHRI (also see Fig. 7).

Species	Years	No.	Cultivar
G .mihanovichii	1994	4	Hongil, Hongwoo, Honghwa, Hongjo
	1997	3	Myeongweol, Seonhong, Hongkwang
	1998	5	Hongsil, Cheongsil, Yeongji, Konji, Hongweol
	1999	10	Seolhong, Jinhong, Manhong, Hongsu, Yeonmin Hukwang, Ojak, Saekdong, Sinseong, Binghwa
	2000	9	Baekya, Mihong, Hongsung, Yeonhwa, Keumhong Keumhwang, Hwangweol, Danhong, Bihong
	2001	5	Damdam, Yeonhwang, Yeonhong, Hoohwang, Damhong
	2002	6	Heukhong, Suhwang, Gamhong, Seohong, Seohwang, Noksim Hwihwang, Hwisung, Heukseong, Suhong, Geoseong
	2003	5	
C. silvestrii	1999	5	Mangwool, Sumji, Bosong, Doran, Somsom
	2000	3	Duri, Mongsil, Woori
	2001	2	Hongwoon, Tosil
	2002	1	Chongchong
	2003	1	Doldol
G. denudatum	2000	1	Hwangkeum
Total	-	60	-

Table 5. Cacti cultivars bred and released by the Cactus Experiment Station of the GARES, Gyeonggi Province, Korea (see Fig. 8).

Species	Years	No.	Cultivar
G. mihanovichii	1998	4	Achi #1, Achi #2, Achi #3, Manchu #1
	1999	5	Achi #4, Achi #5, Achi #6, Rainbow 1, Black Pearl 1
	2000	5	Heorum, Hedoji, Hemin, Jinsol, Noul
	2002	5	Saebyul, Ruby, Fire, Gumbich, Gold
	2003	3	Red Jewelry, Sun Rise, Star Fish
C. silvestrii	2002	3	Light, Champion, Chungsol
	2003	2	Blossom, Aram
Lobivia Spp.	2003	2	Shinbi, Geumhyang
Notocactus scopa	2002	1	Soonjung
Total	-	30	-

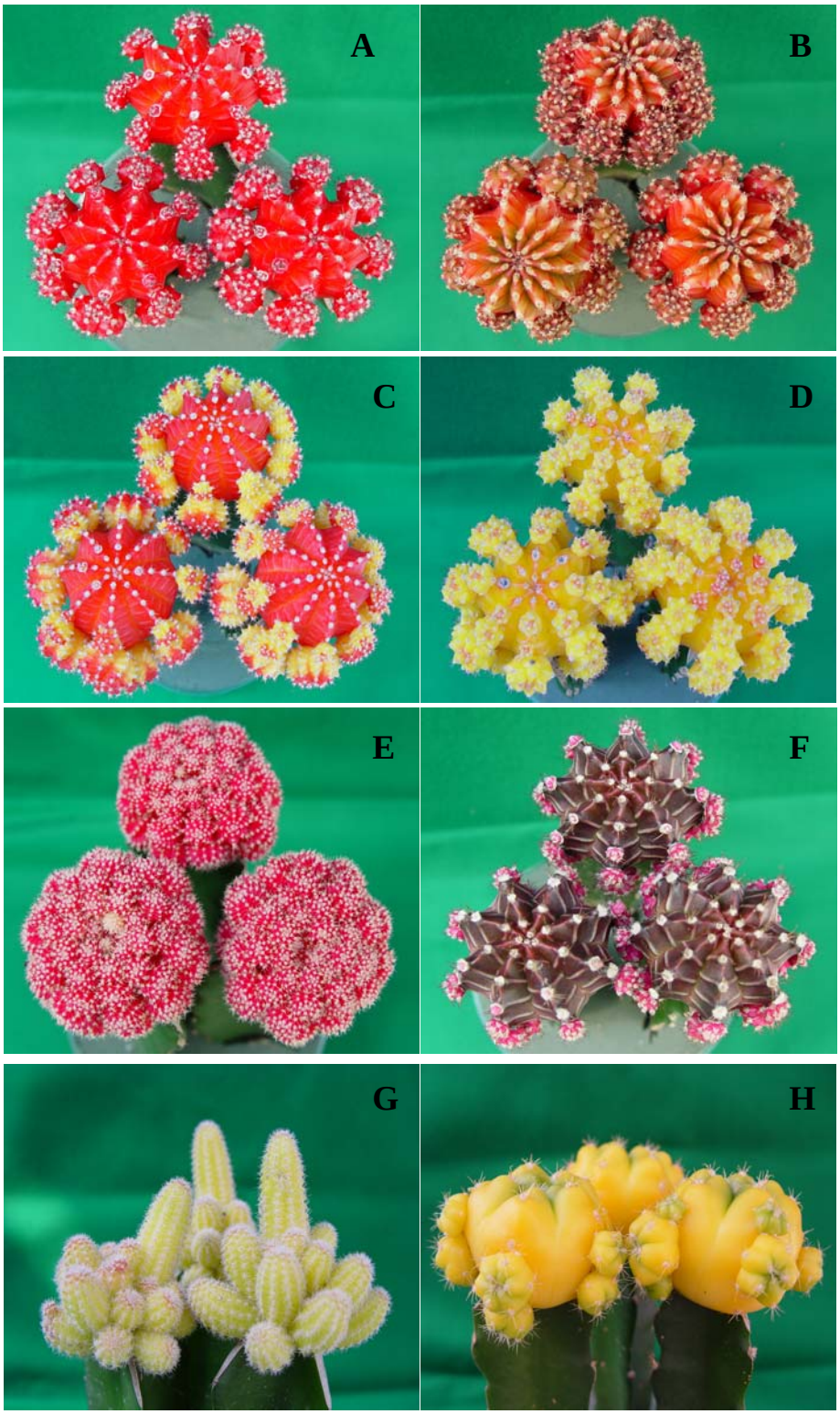

Fig. 7. New grafted cacti cultivars bred at NHRI, RDA, Korea. A: *G. mihanovichii* cv. Seolhong, B: cv. Damdan, C: cv. Saekdong, D: cv. Hwangweol, E: cv. Binghwa, F: cv. Ojak, G: *C. silvestrii* cv. Hongwoon, and H: *G. denudatum* cv. Hwangkeum.

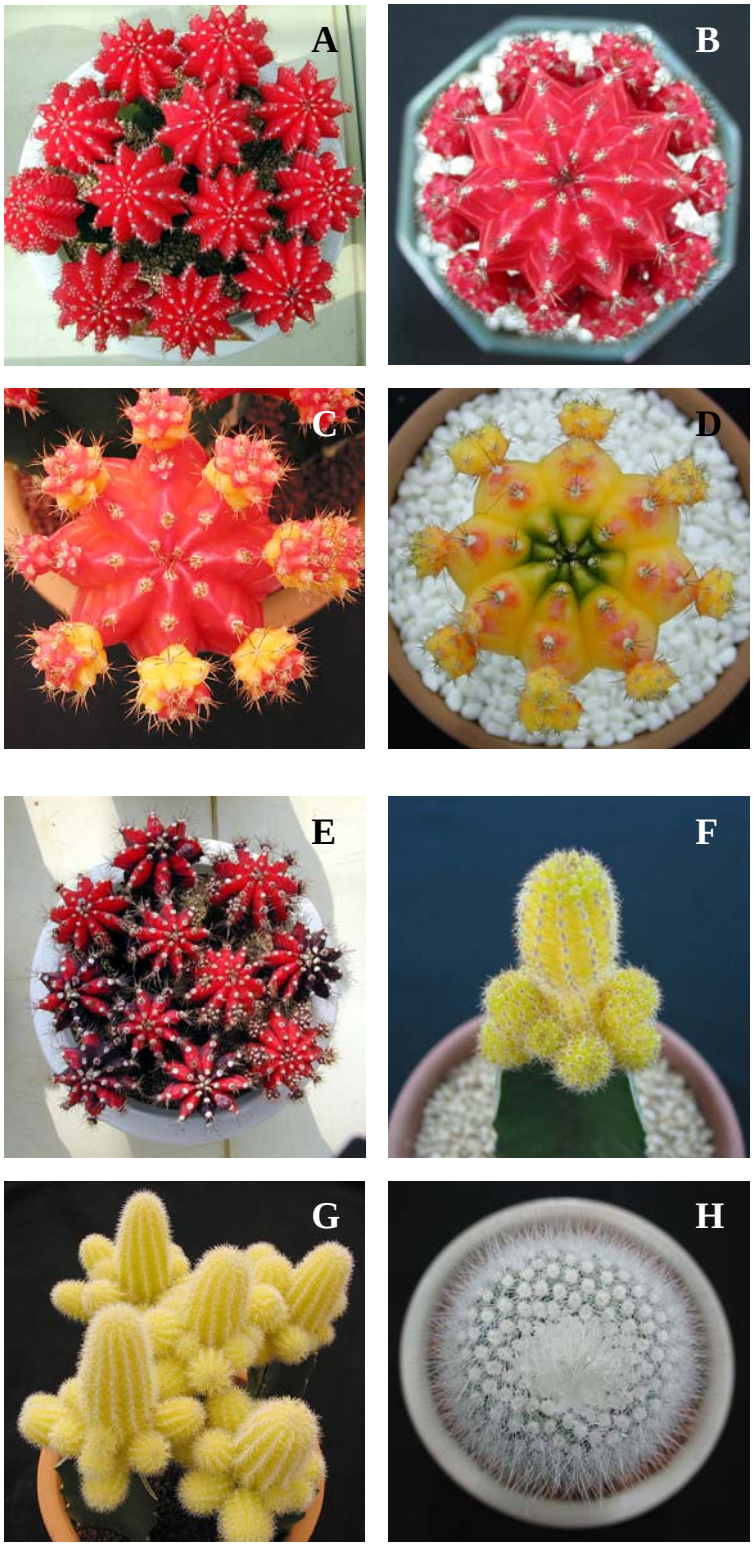

Fig. 8. New grafted cacti cultivars bred by Cactus Experiment Station, GARES, Gyeonggi Province, Korea. . From top left to right A: *G. mihanovichii* cv. Achi 1, B: cv. Fire, C: cv. Star Fish, D: cv. Gold, E: cv. Mujigae 1, F: *C. silvestrii* cv. Light, G: cv. Blossom, and H: *Notocactus scopa* cv. Soonjung.

☐ Future Prospects

The majority of potted cacti traded in the international market are green. The colorful, but chlorophyll deficient, cacti are mainly produced in Asia and South America. Grafted cacti account for less than 10% of all potted cacti in the world market. However, the demand for grafted cacti has been increasing sharply as a result of the new cultivars developed. The creation of a vibrant, ornamental cactus industry in Korea is an example of the progress that can be made with advances in horticultural sciences. Efforts are now being focused to breeding virus-resistant cultivars. In 2004, new, large-canopy cultivars will be released from interspecific crosses. Efforts are also exerted on the improvement of storage technique to reduce handling and transportation expenses.

Fig. 8. Grafted cacti arrangement with succulent plants.

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Photographs of authors (From left: MI Jeong, CH Cho and JM Lee)