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Recent Advances of Carnation Production in Japan

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Abstract
The present status of technological improvements and problems in carnation production in Japan is reviewed. One of the urgent issues in breeding program in Japan is to find out cultivars resistant to a soil-borne bacterial wilt disease, which is difficult to control in cultural practices. Some wilt-free and very resistant species are identified in dianthus species. They are presently utilized in a breeding program. High temperature generally causes carnation plants to accelerate respiration and reduce photosynthesis. With the purpose of making full use of solar radiation, a mulching technique with aluminized reflective film was developed. It is now widely adopted in Japan because of its effectiveness in obtaining high yields of cut flowers. Stems of cut flowers grown under a high temperature easily droop and their market values are lost. A foliar spray treatment with a plant growth regulator, called ethychlozate, immediately before the first blooming stage was effective in improving carnation stem quality. It was confirmed that use of silver thio-sulfate was recommendable. This treatment is widely employed in Japan. Other two methods art reviewed: one is a technique of transplanting at a high density followed by thinning to an ordinary density at the first blooming stage, and the other is a bud cut technique, thereby the flowers harvested at the stage of tight green buds are stored under a low temperature and flowered artificially by soaking the base of cut flowers in an opening solution.

Discipline: Horticulture
Additional key words: ethychlozate, mulching, reflective film, STS

Increasing production of carnation

Carnation production in Japan has made steady progress during the past 25 years. In 1988, the annual production of cut flowers was estimated at about ¥25 billion in value, which ranked second next to chrysanthemum in the country. Total number of carnation cut flowers for marketing, planted area and number of growers were 690 million, 561 ha and 4490, respectively (Fig. 1). Such an increasing trend of carnation production is expected to continue for many years to come.

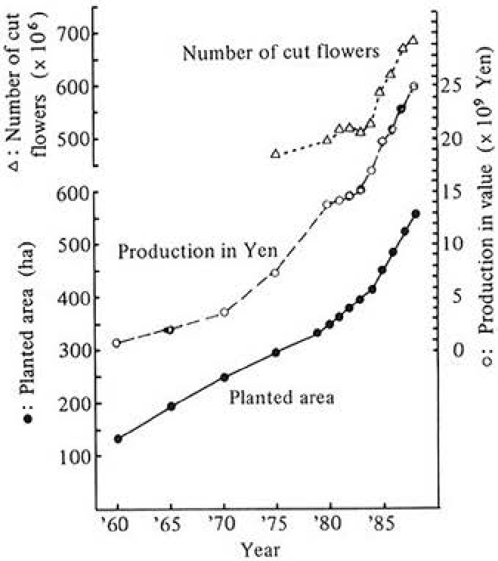

Fig. 1. Development of carnation production in Japan

Producing areas and their temperature relations

Producing areas spread over the country, ranging from Hokkaido to Okinawa, with main centers in Honshu, Shikoku and Kyushu districts. Among the various factors affecting carnation production, meteorological factors in general, air temperature in

Table 1. Monthly changes of temperature in some carnation growing areas

Country	Place	Average temperature (°C)												
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Japan	Aichi	3.6	4.3	7.5	13.5	18.0	21.7	25.6	26.8	22.8	16.9	11.4	6.2	14.9
	Nagano	−1.2	−0.4	3.1	10.2	15.5	19.4	23.6	24.5	19.9	13.3	7.2	1.9	11.4
U. K.	London	4.2	4.4	6.6	9.3	12.4	15.8	15.9	16.2	14.7	11.9	8.9	7.2	10.8
Holland	De Bilt	1.7	2.2	5.0	8.5	12.4	15.5	17.3	16.8	13.6	9.1	4.9	1.8	8.6
Colombia	Bogota	14.2	14.7	14.7	15.0	14.7	14.5	13.9	14.2	14.2	14.5	14.5	14.2	14.5
U. S. A.	San Francisco	9.2	10.5	11.8	13.2	14.6	16.2	17.1	17.1	17.7	15.8	12.7	10.1	13.8

Table 2. Growing areas of carnation in Nagano Prefecture, Japan, by altitude

Year	Percentage of cultivated areas by altitude (%)								
	<300	~400	~500	~600	~700	~800	~900	~1000	1001< (m)
1945	4.7	29.4	9.9	35.5	20.5	-	-	-	-
1984	4.3	24.5	8.3	29.7	23.2	1.9	1.2	6.9	-
1987	-	15.4	6.5	22.6	26.2	18.3	2.9	8.0	0.1

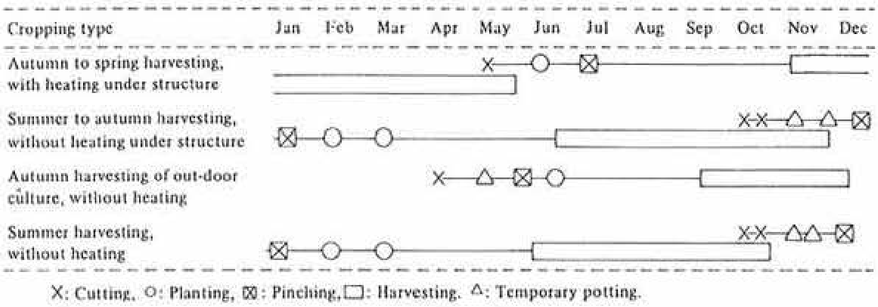

Fig. 2. Main cropping types in Japanese carnation production

particular, are closely relevant to diversification of producing areas and cropping patterns as well.

The highest quality of cut carnation flowers can be produced under the environmental conditions where average day temperatures range from 18 to 20°C, with a temperature of 12°C at night. For the growth of young plants, a slightly higher level, i.e. approximately 3°C, than those temperatures is more suitable. When the day temperature goes up above 25°C, the growth and the quality of carnation are both hampered. The districts where the day temperature goes beyond 30°C are really not suited.

Major producing centers in Japan are situated in lowland plains as well as in cool highlands. Aichi Prefecture is an example of the former case, with an annual average temperature of 15°C, whereas Nagano Prefecture represents the latter case with an average temperature of 11°C.

Colombia presently ranks the world's largest producer of this flower replacing the United States. This status might be partly associated with the environmental conditions of Colombia, where the annual average temperature is 14.5°C without a great variation through the year. There is therefore no need for artificial control of air temperature (Table 1). In addition, Colombia has another advantage; i.e. the wage rate of laborers in this country is lower than that in the United States and other developed countries.

In Japan, there is a great seasonal variation in temperature, which necessitates a long heating mainly in winter for growing carnation. For this reason, carnation has the highest ratio in utilizing greenhouses and plastic houses in this country. An adoption of heating in glasshouses is also economically viable for producing carnation. However, cooling during the hot season is not viable. Even in Nagano Prefecture which is generally located in highlands, new farms of growing carnation are established at higher areas, i.e. 800 to 1,000 m above sea level (Table 2)[5]. For furtherance of carnation production, improved technologies to overcome these heat damages or high temperature injuries are urgently required.

Cropping types for carnation production in Japan

Seasonal changes of air temperature lead to the diversification of cropping types of carnation in Japan, as indicated in Fig. 2. The most popular type in lowland plains is characterized by the harvesting of flowers from November to mid May. In cool highland areas, the harvesting of flowers generally takes place during the period June to November. Thus, the year-round supply of carnation in Japan is primarily achieved by these two cropping types. Farmers in lowland plains presently attempt to introduce another cropping pattern in order to save heating costs and to harvest long-stemmed flowers. Those flowers, being cut off at the base of stems, are harvested within the year of planting. The plants are grown without heating, but with a simple protective measure only during the flowering period. In cool highlands, cultivation without heating is also introduced by some growers. In this case, the young plants are grown in pots and subjected to pinch in winter so that they are harvested for a prolonged period in summer.

Trends in carnation cultivars

Flower colors and sizes in the market have presented considerable changes over the decades. During the postwar period, a limited number of cultivars were grown in Japan: predominant were Coral, Peter Fisher and some other medium flowers-sized cultivars. In the following period, Sim cultivars with large-sized flowers were added in the market: Nora, Scania and Lena were among these newcomers. In the last several years, a large quantity of Mediterranean cultivars with a standard type characterized by "one flower per stem" have been introduced, while a spray type with "multi-flowers per stem" has been increasing in market shares. The recent trend in flower color is inclined to light- or pale-tint. As a consequence, the cultivars of carnation in Japan's market have been greatly diversified.

Noticeable outcome of the recent breeding efforts includes resistance to fusarium wilt, resistance to calyx splitting, high productivity, great variations in plant types and flower colors and prolonged vase-life. These new cultivars, however, differ from the Sim cultivars since they originate from interspecific hybridizations among carnation cultivars and various wild species, while the Sim varieties are derived from mainly flower color mutants. As a result, these new cultivars have great differences among them in their growth habits and other characteristics. It is therefore important for growers to be acquainted with appropriate practices for growing each of those cultivars. A more or less the same type of cultivation method is available for growing Sim cultivars. However, the growers are requested to adopt suitable techniques, which may vary for each of the new

Table 3. Classification of wild species in *Dianthus* according to their resistance to bacterial wilt (*Pseudomonas caryophylli*)

Grade of resistance	Species
No symptom	*D. capitatus, D. gallicus, D. gratinopolitanus, D. henteri*
Wilted ratio: 1–20% (Very strong)	*D. acicularis, D. anatolicus, D. arenarius, D. ferrugineus* ssp. *liburnicus, D. fragrans, D. gratinopolitanus, D. monospessulanus* spp. *sternbergii, D. pavonicus, D. plumarius* var. *albiflorus, D. plumarius* ssp. *praecox, D. ponderae, D. regis, D. viscidus*

Tested with a cut root soaking method: Inoculum concentration; 2.5×10^7 CFU, Testing duration; 80 days, Soil temperature; 20 to 39°C.

cultivars. Even the cultivars resistant to fusarium wilt may require hygienic control, since the related pathogen, *Fusarium oxsporum* f.s. *dianthi*, has generally physiological differentiation. Careful attention should be given to those races. Distribution of the races is one of the urgent issues to be identified.

In spite of those remarkable outcomes of breeding, there still exist serious problems. One related to bacterial wilt (*Pseudomonas caryophylli*) disease. It outbreaks widely in the warmer districts of Japan, despite a strong recommendation of the use of pathogen-free seedlings as well as of the careful soil disinfection. A study was undertaken to test differences in bacterial wilt resistance of *Dianthus* wild species[1,6]. The differences were identified by using a cut-root soaking method with an inoculum concentration of 10^7 colony-forming unit. As a result, the *Dianthus* species was classified as shown in Table 3. Introduction of resistance genes into carnation cultivars and a study on their genetic behaviors are presently under way.

Another problem relates to heat intolerance. Almost all cultivars do not grow well and their stems easily droop or break at nodes when they are grown under a high temperature and a high humidty. It is therefore urgently needed to develop heat-tolerant cultivars and to improve cultural practices as well. In order to promote further demand for carnation, efforts are required to release new types of cultivars that are highly suited to Japanese climate, easy to grow at low costs of long vase-life and of high productivity.

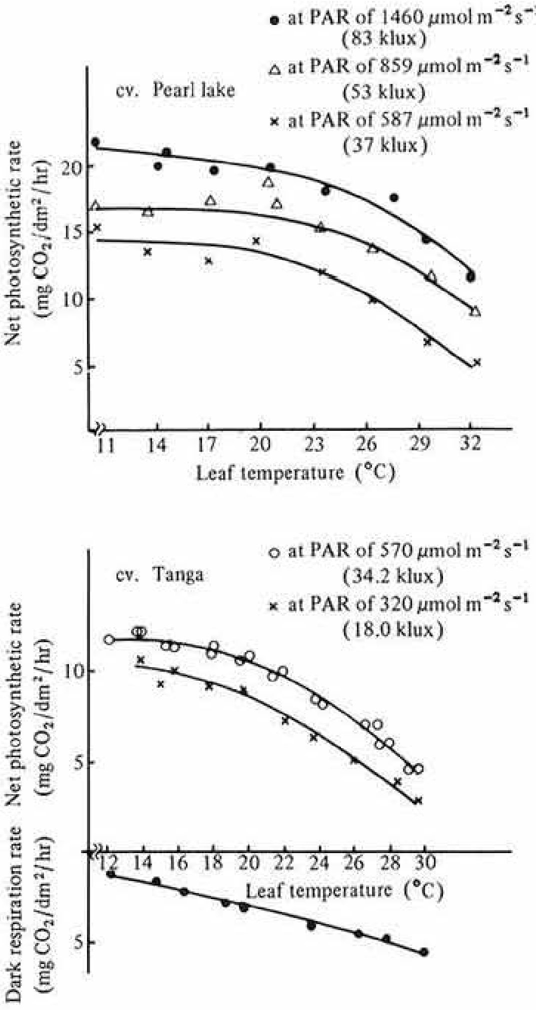

Fig. 3. Temperature response of net photosynthetic and dark respiration rates in carnation

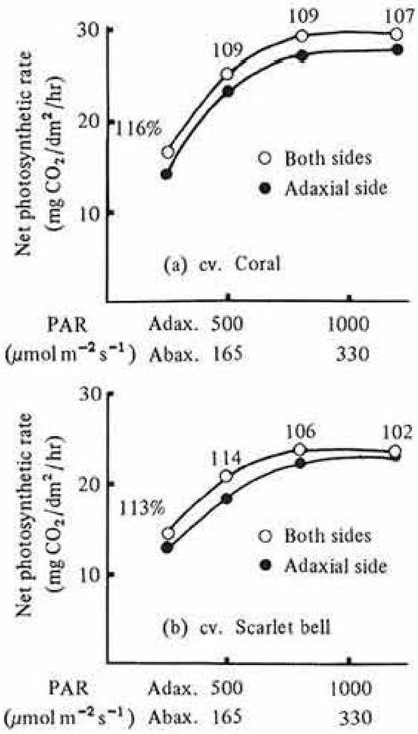

Fig. 4. Comparison of net photosynthetic rates illuminated on adaxial side and both sides (supplementally illuminated also on abaxial side) of single leaves

Table 4. Effect of mulching with reflective film (MRF) and shading with cheese cloth (SC) on photosynthetically active radiation on a fine day in autumn

Height (cm)	Outdoor MRF[b]	Non-treated[a]	Glasshouse MRF[b]	SC 84%[c]	SC 66%[d]
	Photosynthetically active radiation (μmol m^{-2} s^{-1}) over canopy				
100	1292	939	1104	826	726
	Reflectivity (%) of PAR in canopy				
100	26.6	5.8	9.3	6.0	6.4
90	31.7	5.3	9.4	5.9	5.8
80	38.3	4.6	8.8	5.4	4.8
70	44.1	4.0	9.7	4.9	3.3
60	49.7	3.2	9.0	3.6	2.9
50	54.3	2.1	9.7	3.1	1.7
40	62.2	1.6	11.4	2.0	1.3
30	70.8	1.6	19.4	1.2	0.7
20	75.6	1.4	30.1	1.0	0.5
15	87.8	1.3	18.4	0.9	0.4

a): Control plot, b): Mulching with reflective film, c): Shading with 84% light transmissible cheese cloth, d): Same with 66% cheese cloth.

Table 5. Influence of mulching with reflective film on net photosynthetic rate of carnation (cv. Pearl lake) plants

Treatment[a]	Net photosynthetic rate (mg CO_2 dm^{-2} hr^{-1})	Reflective flux (μmol m^{-2} s^{-1})	Reflectivity (%)
No mulching	16.1 (100%)	14	3
MRF (A)	21.2 (132%)	158	32
MRF (B)	19.0 (119%)	94	19

a): (A); Polyshine cloth, (B); Silver polyto, Leaf temperature; 21.5°C.
Under the PAR of 495 μmol m^{-2} s^{-1} at 10 cm above the top of leaves.

Recent improvements in growing methods

1) Mulching technique with reflective film[4,5,8,9]

Carnation plants give a good harvest of flowers when they are grown under ample irradiation. High temperature, however, causes the plants to accelerate respiration and reduce photosynthesis (Fig. 3). Under the climate in Japan, the cooling of glasshouses needs high costs. It is therefore very important to make full use of solar radiation, which is of the lowest cost and the cleanest energy, in inducing stimulated photosynthesis. The National Research Institute of Vegetables, Ornamental Plants and Tea has developed a mulching technique with reflective films of aluminized polyethylene (mulching with reflective film, MRF)[4,5,8,9]. Under this method, about 90% of the photosynthetically active radiation (PAR) is reflected at 15 cm above the outdoor MRF level. In the case of the plants 18 weeks after transplanting, 30% of PAR is reflected at 20 cm above the MRF (Table 4). This reflective PAR is mainly applied to the undersurface (abaxial) of leaves, giving greater effects on the lower leaves than the upper ones. And those effects are larger under weak light in the lower part of the plant mass than under strong light at the upper part (Table 5 and Fig. 4). Since it is confirmed that the photosynthate of lower leaves are more translocated into roots, the PAR on those leaves may also play a key role in maintaining the vigor of the root growth. In addition, the aluminized films restrain evaporation from the soil surface, resulting in saving 35 to 40% of irrigation water in the mid summer season.

It was also found that the MRF technique had effects of increasing number of long and thick branches and raising an annual yield of cut flowers by 30 to 40% (Table 6).

Table 6. Effect of mulching with reflective film and shading with cheese cloth

(1) On the growth of secondary branch[a)]

Cultivar	Treatment[b)]	No. of branches	Ratio (%) grouped by length			Total length of branch (cm)	Diameter of 3rd node (mm)
			6 cm<	11 cm<	16 cm<		
Scania	Control	6.33	34	17	42	84.2	6.7
	MRF	7.93	15	17	63	152.3	7.5
	SC 84%	6.33	36	23	32	79.2	6.3
	SC 66%	5.33	31	28	29	62.7	5.7
Lena	Control	7.60	44	28	23	88.5	5.9
	MRF	9.33	19	19	60	153.2	7.2
	SC 84%	6.67	42	22	29	79.1	6.3
	SC 66%	7.07	47	30	17	78.6	5.6

(2) On the number, length and drooping grade of cut flower[c)]

Cultivar	Treatment[b)]	Total no. of cut flowers per m^2	Number of cut flower classified by					
			Length (cm)			Drooping grade (°)		
			36–50	51–65	66<	10	11–20	21<
Scania	Control	271	3	88	180	78	65	128
	MRF	382	10	184	188	93	100	189
	SC 84%	217	0	58	159	63	55	99
	SC 66%	205	5	64	136	55	26	124
Lena	Control	272	0	226	46	136	76	60
	MRF	353	5	224	124	126	126	101
	SC 84%	249	5	181	63	121	80	48
	SC 66%	222	0	156	66	124	35	63

a): Measured in 11 weeks after planting. b): Refer to Table 4.
c): Measurements were carried out during one cropping season.

Table 7. Effect of foliage spray with ethychlozate solution on the drooping grade of cut flowers in carnation

Treatment	Drooping grade degree (°) of cut flowers					Breaking strength[a)] (g)
	Late Nov.	Early Dec.	Mid Dec.	Late Dec.	Mean	
Control	20.6	21.6	20.4	18.6	19.9	644
GA (100 ppm)	26.3	16.9	19.1	16.6	18.7	704
E10 (ppm)	20.6	17.0	15.0	12.9	15.7	673
E50 (ppm)	20.7	17.4	12.3	12.5	14.1	723
E100 (ppm)	18.8	11.5	11.4	9.1	11.6	753
GA + E10	26.5	17.7	21.5	18.5	20.7	662
GA + E50	16.5	13.7	15.0	10.0	12.9	707
GA + E100	16.3	12.2	14.1	10.9	12.7	727

Treated on Nov. 21, 1989 at the first blooming stage.
a): Breaking strength (g) was measured at the center of 5 cm fulcrums in each 8th internode downward from flower. The figures above indicate mean strength during the period late Nov. to late Dec.

2) A countermeasure to protect cut flowers from drooping in hot season[7,11]

As earlier described, stems of cut flowers grown under high temperature and high humidity easily droop and their values in the markets are seriously lost. Drooping of cut flowers takes place quite often during the harvest time of the main cropping type, i.e. from autumn to early winter. This is particularly true with carnation plants in the lowland plains, where those cut flowers grow and elongate under such an unfavorable hot condition.

With the purpose of improving the stem quality, several chemicals, including NAA, were tested regarding their effectiveness[7]. NAA thickened plant stems and could prevent them from drooping. However, it showed chemical injuries such as accelerated malformation and depressed elongation of stems when treated in the young stage. It is identified that ethychlozate accelerating lignification of vascular bundle has an effect in reducing the drooping and increasing the strength of stems. The strength of each stem is measured by maximum weight (g) for breaking it at its center of 5 cm fulcrums in each internode (Table 7). Recommendable concentration of ethychlozate for treatment is 50 to 100 ppm of its own, or its mixture with GA 100 ppm. A foliar spray at the first blooming stage is recommended[11].

3) Post-harvest physiology and preservation[10]

The floral organ of carnation plants produces ethylene, a gaseous phytohormone, to which the plants are highly sensitive. The phenomenon of non-flowering and wilting of this flower under the presence of ethylene has been well known, called "Sleepiness". It is presumed that the endogenous ethylene is synthesized in the following process: methionine → S-adenoxyl methionine (SAM) → 1-aminocyclopropane-1-carboxylic acid (ACC) → ethylene. Silver thio-sulfate (STS) blocks the receptor site for ethylene and inhibits its critical increase. Base application of STS helps prolong the vase-life of carnation flower by about two times. This treatment is widely adopted by carnation growers in Japan. In future, there would be a great need for developing new preservatives without use of any heavy metal. It would also be important to seek for effective gene sources for breeding new cultivars of long vase-life.

4) High planting density and bud cut technique

Some improvements in growing methods have been achieved in Japan in the past decade. One of them is to plant carnations primarily with a high density in nurseries. Namely eight plants are planted in each row and two central plants are thinned out at their first blooming time; only inner two plants are harvested at their stem base for marketing. This procedure lessens the detrimental effects of high planting density and compensated yields are secured[3]. Another method has also been developed: the flowers are cut at the developmental stage of tight green buds and the bases of those cut flowers are soaked in an opening solution to stimulate flowering. This method enables the growers to obtain a high yield of cut flowers. A modified method is also available: the flowers are cut during the stage of buds, stored under a low temperature for long-term preservation after pretreatment and bloomed in an opening solution under a suitable condition. This modified method enables the growers to ship the plants according to their marketing plans. However, since special skills are required for long-term preservation to be followed by artificial flowering, this method should be employed with a great care[2].

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