Current Utilization of F_1 Hybrids for Vegetable Production in Japan

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The area devoted to vegetable crops is about 687,500 hectares, while the yield of the 29 principal products other than potatoes amounted to 14,570,000 (metric) tons in 1970 according to Japanese governmental statistics on the present vegetable production in Japan.

F_1 hybrids are used to a greater or lesser extent for 18 items among the vegetables cultivated in Japan and it is estimated that over 200,000 hectares are employed just for the production of those nine items of which F_1 hybrids constitute 80 per cent or more of the total output.

The present report is intended to describe the current use of those products for which F_1 hybrids are used in commercial vegetable-growing areas in Japan.

Moreover, the past history of the development of F_1 hybrids and their future outlook is discussed to help understand the present situation.

Progress in utilization of F_1 hybrids

1) Fruit vegetables

In 1923, Kakizaki reported the breeding of a F_1 hybrid of eggplant. This was the first fruit vegetable F_1 hybrid produced in Japan.

Thereafter through the 1930's, F_1 hybrids were produced at government agricultural experiment stations in the course of breeding in the areas under their respective jurisdictions and great benefits were obtained. Important examples are tomatoes from Kochi Prefecture, tomatoes and cucumbers from Osaka Prefecture, eggplants from Gumma Prefecture and elsewhere and watermelons from Nara Prefecture. Each was produced at its respective local agricultural experiment station. In the case of the watermelon, however, superior varieties appeared while fixing the hybrid and it was not until after the termination of World War II that the F_1 hybrid was standardized.

Although the war greatly hindered expansion of production, the basis for the eventual development of F_1 seed output was established through these prewar efforts.

Since 1948, when a seed company succeeded in the commercialization of F_1 hybrids of tomato and cucumber bred at its own station, the work of breeding F_1 vegetable hybrids has finally come under the realm of private enterprise.

The excellent results shown is the reason for the development of the current situation, so the contribution of the private seed companies has been significant in maintaining pure parent strains and in the large-scale production of F_1 seeds. Part of the impetus for this effort is due to the fact that the F_1 varieties held out the promise of being patentable.

2) F_1 hybrids of cruciferous vegetables

Many studies have been made in Japan on self-incompatibility in the Cruciferae since Kakizaki's work (1930) as well as several attempts to put it to a practical application.

In 1949, Takii & Co. succeeded in producing stable F_1 hybrids of cabbage and of Chinese cabbage which had self-incompatibility trait. Since then many F_1 hybrids have been commercialized and from about 1955, their breeding has become the overall main current in the seed industry and the species involved have expanded to include turnips, Brussels sprouts, cauliflower and broccoli.

Double cross-breeding of *Raphanus* was delayed somewhat beyond that of *Brassica* and was released by Takii & Co. in 1960. Since the latter half of the 1960's, all seed companies have been devoting their efforts to this area and much is expected of it, as is the case with turnips.

3) F_1 *hybrids by utilization of male sterility*

This area of work was initially begun in the United States. In Japan, Ito et al. (1953)

Table 1. Position occupied by F_1 hybrids in production of selected vegetables in designated vegetable-producing areas of Japan*

Vegetable	Harvesting period	No. of regions	Total area (ha)	Est. F_1 area** (ha)	F_1/Total (%)	No. of varieties	
						Total	F_1
Cucumber (31,500 ha)***							
Spring	Apr. ~June	44	2,039	2,039	100	19	19
Summer & Autumn	July ~Nov.	80	3,538	3,478	98	32	2
Winter	Dec. ~Mar.	10	420	420	100	2	2
Total		134	6,997	5,937	85		
Tomato (19,300 ha)							
Spring	Apr. ~June	42	1,451	1,431	99	13	
Summer & Autumn	July ~Nov.	47	1,805	1,775	98	18	
Winter	Dec. ~Mar.	5	114	103	90	4	
Total		94	3,370	3,309	98		
Cabbage (45,000 ha)							
Spring	Apr.	5	1,608	1,608	100	6	6
Early summer	May ~June	3	241	241	100	7	7
Summer & Autumn	July ~Oct.	18	3,142	3,110	99	21	20
Winter	Nov. ~Mar.	36	4,537	4,537	100	26	26
Total		62	9,528	9,496	99		
Chinese Cabbage (48,200 ha)							
Summer	Aug. ~Sept.	8	1,481	1,481	100	12	12
Autumn & Winter	Oct. ~Mar.	68	10,092	10,092	100	30	30
Total		76	11,573	11,573	100		
Radish (83,300 ha)							
Summer	July ~Sept.	10	1,369	1,000	71	12	4
Autumn & Winter	Oct. ~Mar.	39	4,899	700	14	30	10
Total		49	6,268	1,700	27		
Carrot (25,200 ha)							
Spring & Summer	Apr. ~July	15	1,236	40	3	14	1
Autumn	Aug. ~Oct.	17	2,339	160	7	12	1
Winter	Nov. ~Mar.	26	3,397	100	3	17	2
Total		58	6,972	300	4		

Notes: * Data other than F_1 area estimates were taken from Agricultural Statistics of 1970 (Tokyō Ministry of Agriculture and Forestry)

** F_1 production areas estimated from information for each region and from government reports

*** Bracketed figures show total production area for all Japan in 1970

and Kototani et al. (1957, 1958) studies F_1 hybrids by utilizing male sterility in onions. The first F_1 hybrids of onion were produced at the Hort. Exp. Sta. of Nagano (1960), Takii & Co. (1962) and the Agr. Exp. Sta. of Gifu (1963).

In the case of carrots, Coral Cross produced in 1965 represents the first F_1 hybrid. It will not be long before several varieties of hybrid carrots are put into practical use by the various seed companies.

Current utilization of F_1 hybrids

1) Extension of F_1 hybrids in vegetable production

In order to coordinate vegetable production, the Japanese Government has designated 13 items as the most important vegetables. Table 1 shows the position of F_1 hybrids in six of these designated items. It is difficult to establish the exact share of F_1 hybrids for all the items using the statistics of the Ministry of Agriculture and Forestry but for some items hybrids represent almost 100 per cent of the total acreage grown for the market. (Nishi 1966). It is expected that the proportion of F_1 hybrids in the designated items will increase rapidly in the future (Fig. 1).

2) Increase in commercial use of F_1 hybrids

Table 2 shows the increase in the number of commercialized F_1 hybrids from 10 years ago to date. This increase amounts to about 10 to

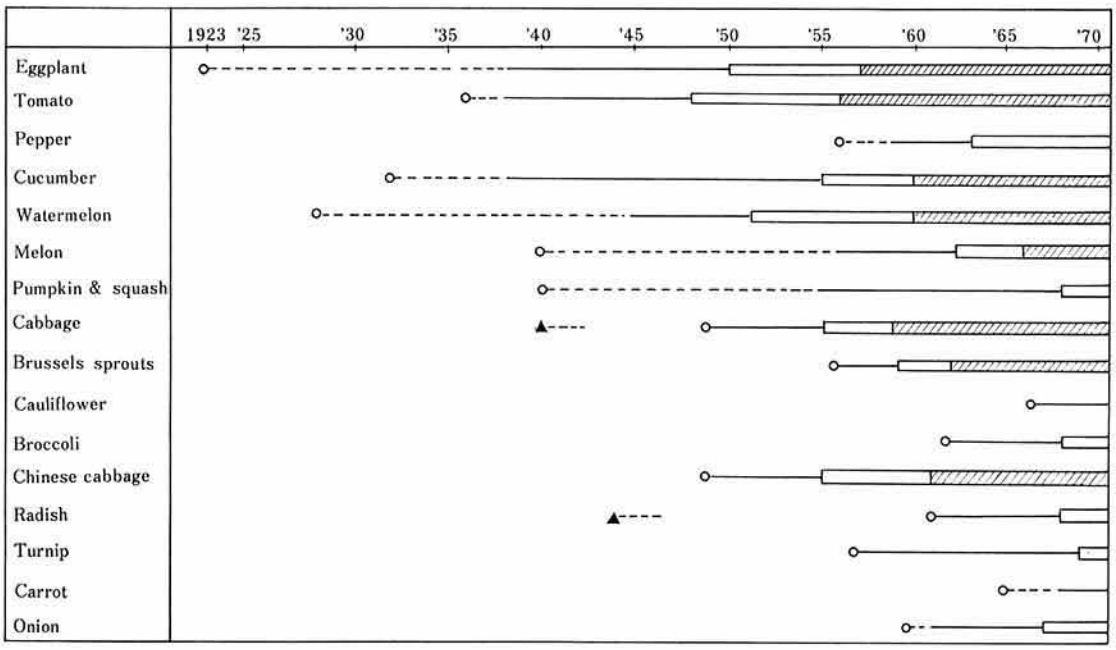

Fig. 1. Course of development of F_1 hybrid vegetables in Japan*
* Based on data from S. Nishi (1966), K. Kanagawa (1970) and information from vegetable producting areas (1971)

15 per cent. Exact figures on sales of seeds for F_1 hybrids are not available as the seed companies keep their records secret. It is, however, apparent that in recent years there have been few wholesalers who have not developed their own F_1 lines and it is thought that most wholesalers transact 80 to 90 per cent of their business in F_1 hybrids where these offer significant advantages over the common varieties.

Table 2. Proportion of F_1 hybrids to all commercial varieties listed in the catalogues of Japanese seed companies*

Vegetable	No. of commercial varieties*		% of F_1 hybrids	
	1959	1971	1958	1971
Eggplant	38	31	45	77
Tomato	43	41	56	87
Pepper	23	23	4	48
Cucumber	66	64	30	70
Watermelon	40	45	45	82
Melon	52	31	12	65
Pumpkin & squash	42	26	14	42
Cabbage	56	77	27	65
Brussels sprouts	6	3	17	67
Cauliflower	15	23	0	30
Broccoli	1	11	0	63
Chinese cabbage	62	96	35	67
Japanese radish	67	84	0	13
Turnip	20	38	5	24
Carrot	20	45	0	11
Onion	15	21	0	28

* Based on the retail catalogues of the five leading Japanese seed companies
Varieties bearing the same name are counted as one variety

The retail price of hybrid seeds is not excessively high—usually running about three times that of common variety seeds. Specialties run about 2 to 8 times higher. The greater utility of the hybrids has tended to offset their expense and has led to their generalized application.

3) Production and cultivation characteristics of F_1 hybrids

As shown in Table 4, comparison between the first F_1 O-S Cross of cabbage and common varieties show that the hybrid vigor and uniformity of the former result in high yields and easey cultivation. Successive new F_1 hybrids of cabbage have created new growing systems and made year-round cultivation possible all over the area.

A fine example of this is the N-S Cross which has cold resistance, less cracking of the head and is suitable for extensive cultivation. Other good examples are the K-K Cross and the K-Y Cross which maintain heat resistance and yield a good quality of harvest in summer.

Table 4. A comparison of the distributions by head weight of some common varieties of cabbage with the inbred lines and their F_1 hybrid, showing the higher yields to be expected. (From S. Ito, 1954 Res. Bull. 1. Takii Plant Breeding Exp. Sta.)

Generations	Inbred lines and varieties	Total No. Examined		Frequency distribution for head weight (%)													Relative weight	
		Lines or combinations	Plants	2	3	4	5	6	7	8	9	10	11	12	13	(×375g)	A (%)	B (%)
G9	O-X-9-9-17-5-2-7-5-2	5	50				40	52	8								97	53
G7	S-X-1-6-11-1-11-1	5	50				13	30	45	12							112	61
G9 × G7	O-S cross (O-X……7-5-2 × S-X……1-11-1)	5	30										17	37	46		183	100
G1	S-X_1	1	10						10	40	20	20	10				100	80
G0	Nozaki-early Summer	1	10				30	20	30	20								48
G0	Nozaki-mid Summer	1	10		10	40	30	10		10								36
G0	Masago-No. 3	1	10				30	20	20	10	10	10						52
G0	Hiro	1	10				20	30	40	10								51
G0	Senshu-Summer	1	10						20	20	50	10						71

Notes: A, B: Relative head weight in percent of common varieties, or F_1 hybrids

Table 3. New varieties of vegetables released in Japan after World War II and the percentage of F_1 hybrids*

	1946~1950** common var.	1946~1950** F_1	1951~1955	1951~1955 F_1	1956~1960	1956~1960 F_1	1961~1965	1961~1965 F_1	1966~1970	1966~1970 F_1	Total new var. (a)	Total F_1 (b)	(b)/(a) %
Eggplant	1	3	1	9	0	36	1	17	0	11	79	76	96
Tomato			3	14	8	50	2	40	0	25	142	129	91
Pepper	1	0	2	0	8	4	5	11	1	10	42	25	58
Cucumber	2	2	7	18	10	66	3	73	0	39	220	198	90
Watermelon	0	1	0	16	0	33	1	36	0	7	94	93	99
Melon			6	3	2	9	3	26	0	10	59	49	83
Pumpkin & squash	1	0	6	6	1	3	2	6	1	2	28	17	61
Other cucurbits					2	3	1	0			6	3	50
Strawberry			4	0	10	0	7	0	2	0	23	0	0
Beans & peas	1	0	1	0	9	0	6	0	9	0	26	0	0
Cabbage			20	8	9	46	1	65	0	36	185	155	84
Brussels sprouts			1	0	0	1	0	1	0	0	3	2	67
Cauliflower	2	0	2	0	3	0	8	0	0	4	19	4	21
Broccoli							1	3	0	1	5	4	80
Chinese cabbage	2	0	5	10	7	40	1	50	0	23	138	123	89
Other cruciferous vegetables			6	0	4	0	3	0			13	0	0
Spinach			4	0	3	4	1	10	0	4	26	18	69
Salad crops***			1	0	1	0	5	0			7	0	0
Japanese radish	1	0	11	0	21	0	9	5	1	9	57	14	23
Turnip			2	0	3	1	0	4	0	7	17	12	70
Carrot	4	0	4	0	5	0	6	1	4	0	24	1	4
Other root vegetables		0	3	0	2	0	1	0			8	0	0
Onion	2	0	0	0	7	0	8	7	2	0	26	7	27
Welsh onion	1	0	1	0	5	0	4	0	2	0	13	0	0
Other bulb crops					1	0	1	0			2	0	0
Total											1262		

* Based on data from T. Fujii, New Varieties of Vegetable Crops Vol. I ~ V, (Seibundo Shinkosha, Tokyō 1059~1971)

** Some varieties released before 1946 may be included

*** Celery, lettuce, parsley

Both the K-K Cross and the K-Y Cross are also popular in Southeast Asia because they give good results. There is a tendency, in the case of Chinese cabbage and the other cruciferous vegetables, to develop along the same course as cabbage.

In fruit vegetables, great progress has been made in extending the harvest period and the growing area due to the rapidly-developed techniques and the introduction of new apparatus and equipment. Thus, commercial varieties are fraught with beneficial characteristics and the hybrids are practically able to meet these new standards.

4) Current trends in F_1 *hybrid breeding*

It is only when the F_1 hybrids of vegetables show not only hybrid vigor, superiority and uniformity but also stability of the inherited characteristics that the hybrids can develop into commercial varieties.

Development of these commercial hybrids depends upon the quality of the parents and whether the maintenance of the parental lines and large-scale F_1 seed production are successful.

The majority of commercial hybrids have been bred by seed companies which have the capacity and organization to produce stock and F_1 hybrid seeds.

Further improvement of F_1 hybrids and the latest breeding methods may be summarized as follows:

1) Utilization of incompatibility

In cabbage and Chinese cabbage, whose hybrids represented 100 per cent of commercially grown varieties, breeding of disease-resistant varieties (Fusarium wilt, Black spot, Club root, etc.) represents the current trend. In vegetables such as the radish undergoing a rapid increase (see Fig. 1), F_1 hybrids, possessing characteristics superior to those of the common varieties and superseding them, have been produced. An example, Summer Cross No. 2, is resistant to heat and virus.

Due to the recent tendency toward a shortage of labor and its increasingly high cost, there have been many more double-cross hybrids not only the radish and turnip but also in other cruciferous vegetables. Such simplification of seed production will be important for the future.

2) Utilization of male sterility

In this section, the main crops are carrots and onion. F_1 hybrid onion, developed and released by a few seed growers, are providing varieties suitable for the various growing systems and are beginning to have an important impact on onion production.

New ecological types have been developed with excellent characteristics, such as the ability to bulb under more severe conditions and a resistance to phytophthora, botorytis and other diseases.

The breeding of F_1 hybrid carrots is still in its infant stage. Characteristics connected with breeding include heat tolerance, high summer quality, cold tolerance, early harvest, slow bolting and heavy yield in winter and spring.

Other notable F_1 hybrids based on male sterility include celery Welsh onion, tomato, pepper and squash. They are not all in practical use as yet and in the case of fruit vegetables and radish, a reduction in the cost of commercial seed production is anticipated.

3) Utilization of hand pollination

F_1 hybrid varieties of fruit vegetables are mostly based on hand pollinations and the characteristics mainly sought at present are resistance to Fusarium wilt, TMV, Cladosporium, Pseudomonas and other diseases. Since F_1 hybrids of fruit vegetables need a great variety of characteristics in order to be suitable for the numerous growing systems, their breeding has to date been directed mainly to that end. At present, breeding studies for disease resistance are insufficient.

4) F_1 hybrid varieties based on other methods

Although it is not common, Fuzieda et al. (1965) developed a new F_1 hybrid cucumber

by utilizing its gynoecius character. This may be important in the future for breeding F_1 hybrids of cucumber, melon and others.

Ten or more F_1 hybrid varieties of spinach which were developed by utilizing monoecius or dioecius plants have been put into production. There is considerable expectation of further improvement in the quality of these strains and lowering the cost of their commercial seed output.

Conclusion

Currently in Japan, F_1 hybrid varieties of important vegetables are generally used. The general trends in the breeding of F_1 hybrids point to the development of disease resistance and advantageous ecological characteristics. The introduction of new varieties and extensive maintenance of parental lines is expected to increase. With respect to commercial seed production of F_1 hybrids, cost reduction is important for the future. Novel methods such as embryo-culture, tissue culture and chemical control of sex differentiation and incompatibility should assume greater importance. The contribution made by national and other public research stations in Japan has been substantial.

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