Chapter 4. HEADING CHINESE CABBAGE: F_1-HYBRID SEED PRODUCTION

1. NATURE AND CHARACTERS OF CHINESE CABBAGE IN GENERAL

1.1 BRIEF HISTORY OF VARIETY DEVELOPMENT

Heading Chinese cabbage (*Brassica campestris, var. pekinensis*) is regarded as originated in nothern part of China and spread for the east through Korean Peninsual down to Japan, for the south through middle and south parts of Chinese Continent further to Taiwan and Hainan Islands, down to other South East Asian countries from Indo-Chinese Peninsula, Thailand, Malaysia to Singapore before World War II. According to C.W.L1 (1981)[1], a description of an original type of heading Chinese cabbage was found in a book in 10th Century stated "Ox-Stomach" cabbage at Young-Chou, a city at the jointed place of North and South Great Canals, supposedly present Tienchin, thereafter various types of head were developed step by step during later several Centuries upto Chin Era supposedly around in 1800. Heading Chinese cabbage had developed numerous local varieties adapted to their distributed localities in its various shapes, qualities and maturities as well as its flowering habits as explained hereafter. Those varieties originated in norhtern China had been refined into real commercial varieties (simple or basic varieties) in Japan in Pre-War Days and have been developed into F_1-hybrid varieties after World War II including recently the extra-early type taking in the tropical varieties.

In American and European countries Chinese cabbage had been cultivated in very limited areas for a long time supposedly because of its much more difficulty in producing good heads than common cabbage due to needing more intensive cultivation skills, adequate fertile soil and good moisture conditions in order to lead its rapid growth at a stretch up to its head maturity. Very recently perhaps since around in 1970, Chinese cabbage has been getting quiet boom in its cultivation and popularization in the market in West European countries as well as the United States, especially as a summer vegetable before the common cabbage comes on the market, mainly after Japanese excellent early F_1-hybrid varieties of non-bolting type have been introduced there.

In Japan Chinese cabbage had once become the top winter leaf vegetable in Pre-War Days owing to its importance for salted pickles and storage qualities for the winter diet, therefore, many heavy yielding late varieties had been developed and cultivated widely in the special mass production areas of its adaptable localities. After World War II, however, a big change happened on the situation of Chinese cabbage with faced at the general change in vegetable production such as in year round supply completed with most of leading vegetables, in diet and living customs of Japanese as well as changes in general agricultural structure and so forth. Chinese cabbage situation in Japan had been replaced by common cabbage and partially by

heading lettuce during 1960's, accordingly the acrage and consumption of Chinese cabbage have been getting gradual decrease during these 25 years, however, year round supply cultture has been developed and extended widely due to the development of ecological breeding on different seasons which shifted Chinese cabbage culture from one season of storing to all seasons supplying fresh products to the market. Accordingly, the breeding objective also changed not only from simple variety to F_1-hybrids but also from intending to heavy yield late varieties to intending to earlier type having tolerancies to various conditions such as tolerant to premature bolting for the spring sowing culture, to heat resistant for summer culture, fresh green coloured and so forth. Current Japanese Chinese cabbage varieties are therefore predominated in early to extra-early types.

1.2 CLASSIFICATION OF VARIETIES IN CHINA AND JAPAN

There are plenty of variations in the characters of heading Chinese cabbage with its head shapes, colours, qualities, tastes, maturities, growing adaptabilities, etc. as well as flowering habits and seeding capacities in accordance wtih the differences of environmental conditions and consumer's usages at every localities in the vast spread areas. Thus numerous varieties have been developed firstly as local varieties (basic types), secondly as bred simple varieties (basic varieties) and thirdly as F_1-hybrid varieties.

(1) In China

According to LI, Chia Wen (1981)[(1)], Chinese cabbage in China are classified into the following several basic types, as shown in Fig. 4-1.

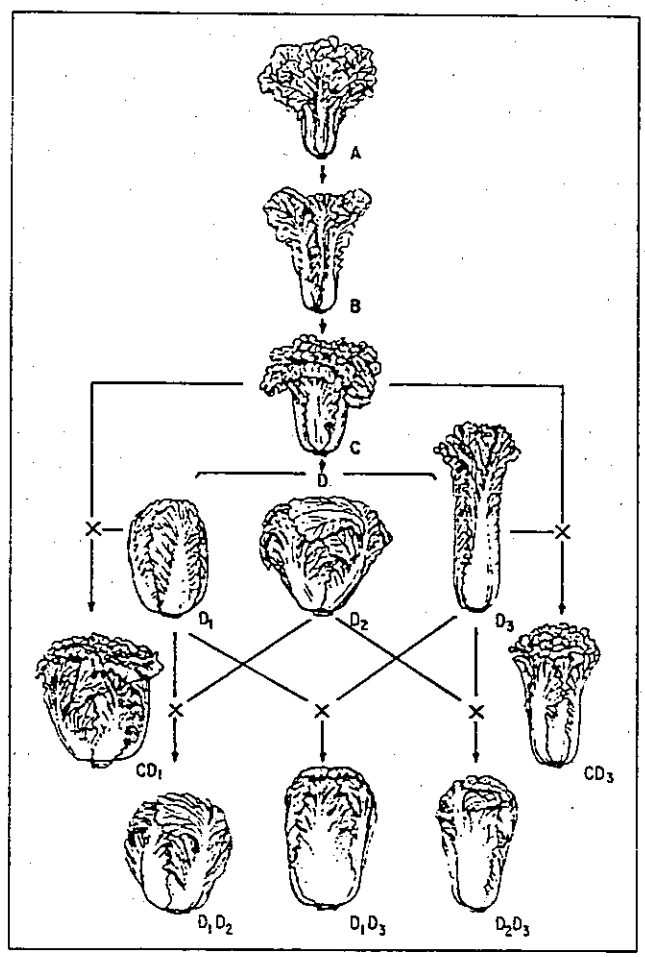
A. Type D_1 – Ovate type: Head shape ovate, leaf tips closing on the top but not overlapping, height/diameter index approximately 1.5. Originated in Shandong Peninsula, east part of China.

B. Type D_2 – Flat-topped type: Head invert conical, leaf tips overlapping deeply on head top, height/diameter index approximately 1.0. Originated in the costal part of Ho-Nan Province, south side of River Hwang Ho.

C. Type D_3 – Cylindrical type: Head long and cylindrical, leaf tips closing on the top but not overlapping, height/diameter index approximately 4.0. Originated in the eastern coast of Ho-Pei Province, northern part of River Hwang Ho. This type has spread widely almost all over Chinese Continent due to its wide adaptability.

D. Type D_1D_2 – Flat-topped ovate form: Head ovate with flat top, leaf tips overlapping on the top, more solid, better keeping quality and heavier yielder than D_1. Hybrid offsprings of D_1 and D_2 in the neibouring/overlapped area.

E. Type D_1D_3 – Stout cylindrical form: Head stout cylindirical, good shaped with height/diameter index of approximately 2.0. High yielding but late variety. Hybrid



The evolution of Chinese cabbage (*Brassica campestris* ssp *pekinesis*). A. var *dissoluta*, B. var *infarcta*, C. var *Zaxa*, D. var *cephalata*, D_1. f *ovata*, D_2. f *depressa*, D_3. f *cylindrica*, CD_1. var *Zaxa* x f *ovata*, CD_3. var *Zaxa* x f *cylindrica*, D_1D_2. f *ovata* x f *depressa*, D_1D_3. f *ovata* x f *cylindrica*, D_2D_3. f *depressa* x f *cylindrica*

Fig. 4-1. Classification of Basic Types of Chinese Cabbage
(LI, Chia Wen, 1981)

offsprings of D_1 and D_3.

F. Type D_2D_3 – Flat-topped cylindrical from: Head shape large flat top with slender lower section, H/D index more or less the same as D_1D_3. Only grown in a limited area.

G. Type C – Fluffy-topped heading type: Unclosing but certain extent solid yellowish white head, its heading leaves embracing up each other with fluffy tips top. Uncertain boundary from frame leaves to the head, in other words, inner frame leaves are also tender and eatable.

F. Type CD_1 – Fluffy-topped ovate head form. Head stout and solid with fluffy top, intermediate form between C and D_1 due to those hybrid offsprings. Supposedly originated in the east costal part of China. Adaptable to unfavorable climate because the head with some frame leaves are usable sufficiently if harvested at immature stage. Extensive growing conditions.

I. Type CD_3 – Fluffy-topped cylindrical form: Head cylindrical with fluffy top though not very solid. Hybrid offspring of C and D_3. Highly adaptable to unfavorable climate, so, extensive growing conditions.

Those three types of C, CD_1 and CD_3 have special quality for long keeping salted pickles like Korean KIMUCHI, although not storable in fresh.

Prof. LI described other two types of A and B as original types of evoluting into types of C and D but they are omitted here because of non-heading or semi-heading types. There are actually many intermediate forms among those described the above as continuous variations among them.

Most of those leading forms of Chinese cabbage had been introduced into Japan in those two decades holding between 1900 and step by step acclimatized domesticating into Japanese local varieties and bred up into refined varieties or basic varieties by 1930's as described in the next Section. C and DC_3 had been spread into Korea and acclimatized into special Korean local varieties particularly suited to make KIMUCHI, special long keeping solted pickles of Korea for favorable vegetable during long severe winter there, which is fermented with salted small fishes inserting between every heading leaves and very nutrious to keep health during long winter of vegetable lacking season.

C, D_2, D_3 and CD_3 had supposedly been spread into subtropical and tropical South East Asia and been acclimatized into tropical local varieties, selected into earliest maturing forms having a common habit of reporducible without certain low temperature, although they became rather small retrograde forms.

D_2 became rather small shaped but excellent leading heading varieties of the tropics in Taiwan and Hainan Islands which introduced into Japan during/after World War II calling

KENSHIN or HANAYOME-HAKUSAI as the earliest form and was utilized in the breeding resource of the earliest F_1-hybrids for summer culture and for tropical culture.

(2) In Japan

According to WATANABE, Eietsu (1981)[(2)], the basic varieties in Japan are classfied into 5 groups of CHIFU, KAGA, HOTOREN, AICHI and KENSHIN excluding Type C and its hybrids of Prof. LI.

A. CHIIFŪ Group

Head pointed cannon ball shape with closing tips;

Supposedly offsprings of D_1 came from Chefoo of Shantung Peninsula of east China but step by step developed into slightly overlapping tips of round top called MATSUSHIMA JUN-NIGO. This type cultivars are sometimes called Wongbok in English. This type had been extended almost all over Japan as a leading type due to its tolerancy to diseases and been developed into a lot of strains here and there. It can, however, roughly be divided into two groups of pointed top and roundish top, that is, one is typicla CHIIFŪ type which is medium late, heavy yielder spread in the mass production areas in Kantō and southern lowlands for late harvesting and storage marketings because the pointed head is more tolerant to frost damage and storing, and another is MATSUSHIMA type which is early, excellent quality and shape, and tolerant to long distant transportation, therefore, spread in the mass production areas in the highlands of central Japan and northern lowland areas of Tōhoku and Hokkaidō for early harvesting in summer and early autumn. This group is characterized with its much pubescencted dark green leaves.

B. HŌTŌREN Group

Head round topped beer barrel shape with deeply overlapping tips:

Supposedly offspring of D_2 or D_1D_2 originated in Shangdong Peninsula. This group has excellent taste with tender and white solid stout head and heavy yielder but spread only at limited areas being not widely due to its susceptible to diseases. Characterized with its less pubescented light green leaves.

C. KAGA Group

Head intermediate shape and general characters between CHIIFŪ and HŌTŌREN due to hybrid offsprings between them originated on the fertile alluvial soil of Kanazawa in Hokuriku. Heading leaf tips overlapping moderately. Performs the heaviest yield with large

excellent quality head but late maturing developed on the fertile alluvial soil of surrounded to heavy yielding paddy fields in Hokuriku and spread in central and south western districts having alike soils. Later on with the development of the earlier strains and become early medium type, this group expanded its growing area widely as heavy yielding cultivars. This type is also suited to long distant transportation.

D. AICHI Group

Head beer barrel shape of slender lower section with larger round top with very deeply overlapped tips:

Supposedly offspring of D_1D_2 or D_2D_3 and developed in suburban fields of Nagoya, central Japan. Because of its strong habit of head-formation with deeply overlapping leaf tips, this type had been selected on the heavy alluvial soil in the delta of Kiso River where CHIIFŪ type cannot easily perform good heads due to its habit of liable to last spreading of central leaves for a long time in case of under unfavorable condition. Almost no pubescented yellowish green leaves. Supposedly this phenomenon is the reason why hairly leaved cultivars are disliked and nonhairly leaved ones are preferred by the growers in South East Asian countries so far, that is, the former is the characteristics of CHIIFŪ type whereas the latter is that of AICHI or D_2 type cultivars, besides most of soils in Thailand, Malaysia and Philippines are heavy soil or alikes.

Accordingly AICHI group was spread mainly in westmore part of Nagoya where heavy soils are predominate in Japan. This type, however, did not spread to widely as other types in Japan owing to its susceptibility to many diseases and less transportation ability, spreading only in limited places at suburban vegetable production areas, while CHIIFŪ type became the leading varieties in the main shipping mass production areas developed on volcanic ash soil and other light soils distributing in the central to northern parts of Japan, where the said leaf spreading habit of CHIIFŪ and KAGA groups did not come to a big problem, in the other words, those light soils keeping moderate moisture and good aeration conditions are much more adapted to Chinese cabbage culture than on heavy soils.

E. Spring Sowing Group

Premature bolting tolerant type of AICHI group

AICHI group had firstly been refined into NOZAKI-WASE by Mr. NOZAKI, an ingenious farmer of west suburban of Nagoya, and later on developed into NOZAKI-HARUMAKI-WASE, a spring sowing type, by means of continuous selection of slow-bolting type so that this type can be grown by early spring sowing in hot nursery bed and setting in the field after frost gone, with its tolerance to premature bolting before World War II, which was the dawn of year

round culture of Chinese cabbage in Japan.

F. KENSHIN Group
Head small and inverted conical shape

As explained in the end of previous Section (1), this group is the tropical type originated from type D_2. This type cultivars were introduced into Japan mainly after World War II and utilized for the breeding materials aiming at the eraliest varieties for summer cropping in Japan, therefore, most of present Japanese earliest type F_1-hybrid varieties have more or less the blood of KENSHIN group. Needless to say, those F_1-hybrid varieties are now very much evaluated in South East Asian countries, with their strong ability of head-formation, excellent quality, and heavy yielder as well as non- or less-hairly leaves.

Although WATANABE, E. (1981) did not mentioned because of not typical heading types but there are a few other types as mentioned hereafter.

G. HANKEKKYŪ-SANTŌ Group

Head fluffy topped but fairly embracing up leaves form blanched solid head when it is completely matured. An acclimatized local variety of C or CD_3 called NISHIARAI-SANTŌ at Nishiarai north suburban of Tōkyō with rather heavy alluvial soil along Ara River where CHIIFŪ group is difficult to grow well. HANKEKKYŪ means semi-heading. This type can be harvested even at immature stage of semi-heading since its frame leaves are tender and eatable. The head has special flavour and taste being suited to long keeping salted pickles which is preferred by certain persons (EDOKKO) of Tōkyō with their nostalgia, although this type has decreased nowaday in cultivation and market due to the change of using custom of Chinese cabbage dominated with fresh use being not necessary to make long keeping pickles at every home.

H. KASHIN Group

More refined type of HANKEKKYŪ-SANTŌ forming more solid white head. Comparing with HANKEKKYŪ-SANTŌ, somewhat dwarfer in height, darker green frame leaves and yellowish coronal with white fluffy heart as if whole plant seems to be a flower which means KASHIN or flowering heart. This group deems to be an acclimatized variety of CD_1 developed at north suburban of Tōkyō too and spread widely all over Japan but limited for special growers on alike soils and social condition because KASHIN as well as NISHIARAI-SANTŌ are not suited to long distant shipping and storage therefore limited in suburban market production and home gardening.

I. TAKENOKO (bamboo shoot) Group

Introduced cultivars of D_3 which are called Chihili or Michili in English

Although introduced in Japan in the earlier time together with other various types, this type had not been preferred by Japanese consumers due to its fibrous and tough taste when pickled, since most of usage of Chinese cabbage in Pre-War days had been for salted pickles. Chinese people, however, prefer this type Chinese cabbage very much because of its long and wide ribs which are delicious when fried with meat in Chinese dishes, while they don't eat so much plain salted pickles like Japanese. Very recently perhaps since 1970's, Japanese breeders are looking up again this type for their breeding programme since Japanese diet custom of Chinese cabbage has been getting to change from salted pickle style into eating more fried dishes like Chinese as well as aiming at foreign countries in connection with the above mentioned Chinese people's preference of this type and also its easiness for cultivation tolerating to various unfavourable environmental conditions.

J. New Group

In addition to the above mentioned, there is a new group of artificially synthesized Chinese cabbage. That is a soft rot and mosaci virous tolerant variety of HIRATSUKA-ICHIGO. Its breeding process was to take the cytoplasmic gene and other genes of common cabbage (*B. oleracea*) into Chinese cabbage (*B. campestris*) by means of an inter-specific hybridization between the two, then three times of successive back crossings by the pollens of MATSUSHIMA Chinese cabbage were carried out so that the original cytoplasm of *B. oleracea* could exactly inherit to the offsprings but the chromosomal set was settled in the same genom as Chinese cabbage (recovered into *B. campestris* again). This complicated breeding programme was performed in National Horticultural Research Institute, Hiratsuka, since it was cleared in the foregone research work that among numerous collected cultivars tested for a few years, not only with Chinese cabbage but also with other campestris group cultivars, none showed any sign of resistancy to soft-rot but only the tolerancy was found out with *B. oleracea* in its epidermis.

Since HIRATSUKA-ICHIGO was excellent in its resistany to soft-rot but it was somewhat late in maturity, a number of F_1-hybrid varieties, e.g. "Olympia" etc., were developed utilizing HIRATSUKA-ICHIGO as their female parent line which should be said HIRATSUKA-ICHIGO group.

(3) Conclusion

At present most of the above mentioned basic varieties are disappeared from Japanese

seed market and they had been taken into the parental lines of current F_1-hybrid varieties, accordingly it is hard to classify present Japanese F_1-hybrid Chinese cabbage varieties clearly into the above mentioned groups. One thing can be said here is that all current Japanese varieties are completely refined ones got/getting effective tolerancies to various diseases and pests, to environmental stresses not only for climate, soil and other conditions but also for premature bolting in the cultures of spring sowing or of northern coutnries where Chinese cabbage is facing always at the low temperature which induces premature bolting. The breeding is generally intending to develop earlier varieties for fresh use rather than large later varieties for preservation, as the results, current Japanese varieties became generally much easier to cultivate than those original types.

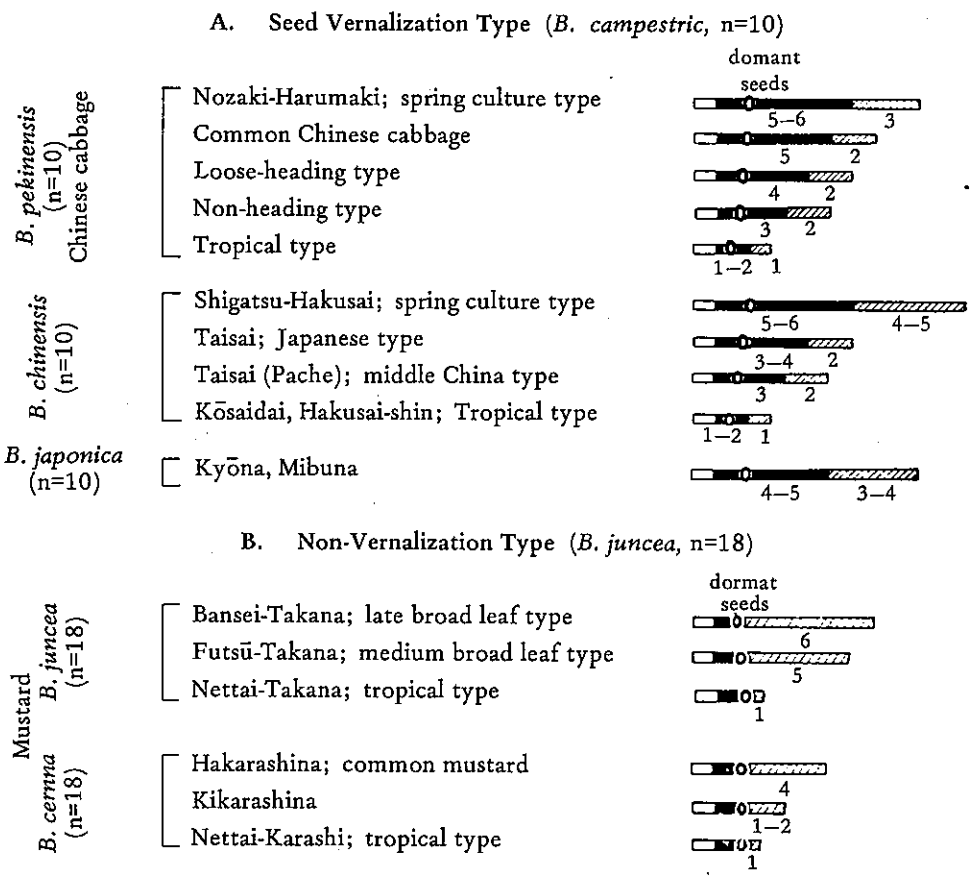


Fig. 4-2. Diagram of Varietal Difference of Reproductive Development of Chinese Cabbage, Petsai and Mustard as Viewed from Phasic Development as Seed Vernalization and Non-vernalization Types (SHINOHARA, S., 1959)

1.3 PHYSIOLOGY OF REPRODUCTIVE HABIT AND VARIETAL ECOLOGY

(1) General

As a Low-Temperature and Long-Day plant, Chinese cabbage fundamentally requires firstly to be exposed in certain low temperature condition (vernalization) for its flower induction (flower bud differentiation) and secondly to be exposed in certain extent of long-day or/and higher temperature conditions (photoperiodism) for flower bud development, seed stalk development and seed ripening to complete its reproduction. Accordingly almost all Chinese cabbage varieties except tropical type cannot produce their seeds in tropical and subtropical countries where the effective low temperature and long day conditions are not available. However, with Chinese cabbage originated in north China, around at 40°N, the long-day condition needed for its photoperiodism is actually not so sever as some of European varieties of common cabbage, radish and turnip which originated in northmore than 50°N, and most of Chinese cabbage varieties can flower and grow seeds under a little longer daylength than 12 hours, as seen in Fig. 4-2.

With the habit of Seed-Vernalization Type plant, most of Chinese cabbage varieties except tropical type are regarded as to be vernalized at seed-germinating stage around at 5°C for 30–40 days or more. In order to start their flower induction, therefore, it needs that the young plants should be grown under low temperature season for about two months so that the accumulated low temperature every night can be satisfied the above mentioned condition. It can be also satisfied theoretically by artificial vernalization or chilling of just germinating seeds with above mentioned condition, that is, theoretically the seed can be produced even in tropical areas if artificially vernalized, SHINOHARA, S. (1959).[3] This technique can be utilized only for the breeding programme, for example, in case to make hybrid between tropical cultivar and temperate zone cultivar in tropical and subtropical countries, but it can never be recommendable for commercial seed production time because the artificially vernalized seedlings are actually very susceptible to grow under hot humid or dry conditions so that large percentage of them are eventually killed in the process thereafter, moreover the capacity of seed production of them is very low, far smaller than normal seeding plants, due to their extraordinarily early stage of flower induction, therefore, it can never be economical since the seed production cost becomes eventually extraordinarily high.

(2) Special Types in Vernalization

The vernalization condition of spring sowing varieties is deeper than ordinary varities, the duration to complete vernalization may need more than 45 dyas. Moreover, for the maintenance of those slow-bolting basic lines, it needs ceaseless effort of selection of slow-

bolting individuals in the basic line, otherwise the line may recover ordinary premature-bolting habit very soon, since the heredity of slow-bolting habit is not simple and deemed to be multigenic recessive.

On the contrary, tropical type varieties can produce their seeds without so sever low temperature as temperature zone varieties require, that is, the vernalization can be completed by rather high temperature condition, e.g. at lower than around 20°C for a short period which could be supplemented by some extent of long day or increasing daylength condition, although precise condition about tropical varieties is not yet cleared since concerned research works are not yet available so far. At least what could be said now is that there is a certain varietal difference in the vernalization condition among tropical type varieties deviating deeper or shallower from the above mentioned rate though still vague. Even among tropical and subtropical places, their differences in low temperature and long day conditions are delicately affected on the flowering habits of local varieties (ecotypes) established at different places especially from 30°N to 10°N (those places in the zone less than 10°N or S have almost constant condition in temperature and daylength throughout a year), that is, local varieties established at the southmore places have the earlier flowering habit than local varieties at the northmore places which means liable to make premature bolting when sown in March and April at northern places, with vice versa trend, but those differences cannot be clearly identified in the pure temperate zone places, SHINOHARA, S. (1980).

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(Orginal writer: S. SHINOHARA)

2. ADAPTATION TO SEED PRODUCTION

2.1 GENERAL HABIT

(1) Climate Condition

Heading Chinese cabbage thrives under moderate cool climate and performs vigorous growth from September to early December in Japan. The optimum temperature in young stage is about 20°C, in head formation stage is around 15°C but its growth rate may be checked under lower than 10°C in daily mean temperature. It gets frost damage at the minimum temperature lower than –3°C in heading stage but in the case of commercial seed production, actual damage on the seed plants may happen only the temperature goes down lower than -8°C because they winter over usually in non-heading rosset leaves stage when the plants have fairly tolerance to freezing.

On the contrary, Chinese cabbage is rather susceptible to hot weather and in the case of spring sowing seed production, the seed plants are liable to suffer from physiological yield-decrease and disease damage by delayed flower time. Spring sowing seed production is usually carried out supplementary in case when ordinary autumn sowing culture has got damage during wintering over, besides in the cool places like Hokkaidō, the seed production in most case is managed by spring sowing culture.

(2) Adjustment of Flowering Times of Parent Lines

One of the biggest problems in F_1-hybrid seed production is how to coincide the flowering times of both parent lines adjusting the one to another as precisely explained in the chapter of brocooli. Since flowering period of Chinese cabbage is generally short and the combination of two parent lines in recent F_1-hybrids is rather complicated with using widely different types, for example, tropical origin/blooded variety with ordinary Japanese one or ordinary autumn sowing variety with spring sowing one, etc., the adjustment of flowering times is really one of the biggest knowhows in actual work. That is, sometimes adjusted by different sowing times in autumn but othertimes by combination of autumn sowing with spring sowing. In case sown in autumn, tropical origin/blooded cultivars are liable to flower in late autumn or even winter and the plants themselves are generally susceptible to freezing which result in no good performance of seed production, therefore, those cultivars are better to be sown in early spring under Japanese condition since they can produce seeds without normal vernalization condition and may be sufficient by exposure of lower temperature under 12°C for 7 nights. (This column was added by S. SHINOHARA.)

(3) Soil Condition

Since Chinese cabbage plant spreads its root system rather widely and deeply in case the soil has moderate moisture and good aeration conditions because the roots specially require plenty of oxigen, the optimum suited soil for the seed production is fertile deep cultivate soil owing to its long growing period, therefore, generally rather heavy alluvial soil or after-paddy field are preferred to be best in Kantō and northward areas which keep adequate moisture during long dry winter. Those heavy soil, however, is necessary to supply enough compost or other organic matters in order to improve the soil condition to be good aeration but if done such supply, the adaptability to seed production may be widen for various soil providing if sufficient moisture is kept during winter. In case over wintering in small plant stage, the development of ice needles on the volcanic ash soil in cooler places becomes a sever problem too.

Although the roots system develops well from the beginning, the roots of Chinese cabbage young seedlings are rather delicate and susceptible to the stresses of no-good conditions such as excess moisture, excess dryness, low soil temperature, etc. especially the dried up by floating up of surface soil with every night development of ice needles. Accordingly the management in young stage should be done very carefully.

The optimum pH for soil is around 6.5, therefore, on acid soil a lime application is necessary to neutralize it, usually dolomite is used.

2.2 ADAPTATION TO SEED PRODUCTION

(1) Climate Condition

Differed from marketing culture, since the fundamental vegetative growth period of seed production culture comes under low temperature period of winter, it is essential to improve the soil condition for better activities of micro-organism even during cold season especially in cooler areas like Tōhoku so that the root system can develop well and the fundamental growth be sound. Since Chinese cabbage seeds ripen early for the harvest, it can be grown in after-paddy field in Kantō and southward areas which have an ideal condition in the above respect. In this concern, such climate places can be said ideal as south-western warm areas of Japan where are mild weather and adequate rainfalls in autumn and no sever freezing cold in winter. But even in those warm areas, such coastal sandy soil areas as Pacific coasts are not always ideal because of being frequently suffered from unusual dryness during winter (winter of Pacific Ocean side of Japan is the dry season) and also southern part of Kyūshū has frequent early rainfalls of BAIU in the flowering and seed ripening period which

makes instable cropping situation.

Eventually Fukuoka Prefecture, northern part of Kyūshū, can be concluded as an ideal place of Chinese cabbage seed production as viewed from climatic condition where the situation is facing at Japanese Sea side having second rainy season in winter and rather less rains during the first rainly season of BAIU so that this palce became already the seed production center of various other cruciferous crops too. As seen in Table 4-1, the temperature condition of Fukuoka is ideal, having yearly average of approximately 15°C, being around 5°C in mean monthly average of January and February and 13°–8°C in November, December and March, April. Comparing with Fukuoka, the climate of Matsushima Islands, represented by Ishinomaki, where CHIIFŪ varieties have been refined and deemed to be the best seed production place in Japan in another meaning, is much cooler than Fukuoka and deemed to situate in the northern extremity of autumn sowing seed production of Chinese cabbage in Japan. Although Matsushima is the warmer place in the district of Tōhoku facing at Pacific Ocean, its mean monthly average temperature of January and February are -0.6° and -0.4°C which show the least acceptable condition for wintering over of the seeding plants.

Table 4-1. Comparison of Mean Monthly Average Temperatures of Fukuoka and Ishinomaki (Matushima) in Centigrade

	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Year
Fukuoka	22.4	16.3	11.6	7.2	4.8	5.2	8.2	13.0	17.4	15°C
Ishinomaki	20.0	13.8	8.2	2.2	-0.6	-0.4	2.8	8.4	13.1	11°C

(2) Natural Crossing Condition

Besides climate condition, there is another important factor of natural crossing condition in the seed production since Chinese cabbage has a sever habit of natural crossing owing to self-incompatibility especially in F_1-hybrid seed production. Although having ideal climate condition, Fukuoka cannot always be said the best place of seed production from this point. Since Fukuoka is a wide plane paddy field area and many seed production fields of various cruciferous vegetables are being concentrated throughout the area gathering the contract businesses of various seed growers from various places in Japan, the fields here are actually holding a big risk of natural crossing which makes to need tremendous taking care on the isolation distance from those other varieties fields.

Though having somewhat inferior point in the climate condition, Matsushima Islands

have a big merit in natural isolation condition for out pollination which was the reason why this place became the land of leading breeding and seed production center of chinese cabbage in Japan. Mr. Eiji WATANABE, the founder of WATANABE Seed Growing Co. and one of the leading pioneers of Chinese cabbage breeding in Japan, had put his biggest notice on the topography of this area and made up his mind to develop the breeding and seed production of Chinese cabbage, later on normal cabbage too, for his life work about 60 years ago. Matsushima is consisted of numerous islands scattered in Matsushima Bay and the fields in each should be the ideal places for cruciferous crops seed production being isolated completely from other island fields each other, that is, if utilized one variety per one isalnd, the circumstances for seed production are completely safety from natural hybridization by isolated with sea. So Mr. WATANABE materialized his idea and developed a big breeding enterprise which could be said the biggest and best origin of Chinese cabbage varieties in Japan in those days. (See colour plate at the front gravure pages.

One episode to prove complete isolation there is that due to the isolation his seed production fields at the beginning had been suffered from no good fertilizing of seeds, accordingly he brought honey bee hives to the fields to keep grazing bees in the fields and overcame the problem recovering normal yields of the seeds. It was really the first evidence to utilize pollination insects for practical seed production in Japan.

3. CONDITIONS ON THE REPRODUCTION AND GENERAL SYSTEM OF SEED PRODUCTION

3.1 CONDITION OF POLLEN FERTILIZATION

The flowering time of heading Chinese cabbage is generally 10–20 days earlier than normal cabbage and it starts blooming around on April 10 and its full blooming time may be at the beginning of May in Miyagi-Ken, northern part of Honshū. The flower consists of indeterminate inflorescence and cross polinative, besides it has a strong habit of inbreeding depression, therefore, in case inbreeding successively to improve its purity, the offsprings become dropping down their seed productivity which causes a serious trouble in the breeding and seed production.

The fertilizing ability of pistil lasts for approximately one week, but fluctuatable with temperature condition, being maximized at the bloomed date and lasting for both a few days before and after bloomed date. The pollens mature completely at the time of blooming and they have a high germination ability during the period from dehiscence to withering of anther under natural condition as seen in Table 4-2. However, it must not misunderstand it for the fact that in case when the inflorescence is kept in the bag for artificial pollination, the pollens are kept also looked like sound and abundance on the anthers for a few days but in such a case

Table 4-2. Germination Ability of Brassica Pollens at Their Different Ages (According to M. SHISA)

Age of flower	SEISAI	TAMBANA	AICHI HAKUSAI
Small bud	%	0 %	%
Large bud		0	
Half opened flower		0	
Opened, before anther dehiscence	0	23.6	34.4
Opened, begin. of anth. dehiscence	19.0	—	42.0
At opened date, flower A	25.5	34.7	68.4
At opened date, flower B	66.5	34.9	48.5
At opened date, flower C	86.0	45.4	31.9
Aged flower, anther discoloured A			31.0
Aged flower, anther discoloured B			31.1
Aged flower, petal dropped			1.6
Medium of germination test	Gelatin 4%	Agar 1%	Gelatin 4%

Remark: (1) Sucrose dilution of the media is 6/10 M, common to all.
(2) SEISAI belongs to *B. juncea,* TAMBANA and AICHI HAKUSAI belong to *B. campestris.*
(3) The above data are not always the same as actual germination figures on living stigma but showing the trend.

the pollens are actually almost lost their germination ability due to high temperature and humidity in the bag. Accordingly, in the case flowers open in the bag, be carefull to use exactly the fresh pollens of just opened date flowers and never use those of previous days.

Its long slender pod divides into two series of placentas which splits on maturity and usually contains about 20 seeds but may be reduced down less than 10 seeds when inbred. The seed ripening period is shorter than common cabbage and matures approximately 40 days after flowered. Seed plant is reaped about 30 days after the end of flowering. The seed is non-endospermic and 1,000 seeds weight is usually 2.5–3.0 g or 660–670 g per liter. The germination ability lasts for three years under ordinary room temperature in Japan and capable germination temperature is 10–35°C in general which range is wider than common cabbage, more-

over seed dormancy does not a matter with Chinese cabbage while it is sometimes a big problem in common cabbage.

3.2 NOTICE POINTS IN F_1-HYBRID SEED PRODUCTION SYSTEM

(1) On the Basic Seed Production

(i) In the case of F_1-hybrid seed production, generally basic seeds are used directly for the production of commercial seeds, which are usually produced by bud hand pollination in the net house in the case of single crossing method.

(ii) Both parent lines should be incompatible ones which cannot produce their seeds by selfing or mutual crossing among the same line at flowering time but set seeds when crossed with the partener parent line plants. The parent lines are bred by inbreeding purifying the incompatible gene.

(iii) Inasmuch as seeds cannot be produced in the line at flowering stage, the seeds of each parent line have to be produced at their bud stage by hand pollination which is called bud-pollination. Accordingly the basic seed production needs much labours for artificial pollination and cannot be managed in a big scale, therefore, F_1-hybrid seed production is generally managed in rather small scale limited in a few hectares.

(iv) More complicated and sophisticated methods have been designed as triple and double crossings by which F_1-hybrid seeds are utilized for one paent in triple crossing and for for both parents in double crossing.

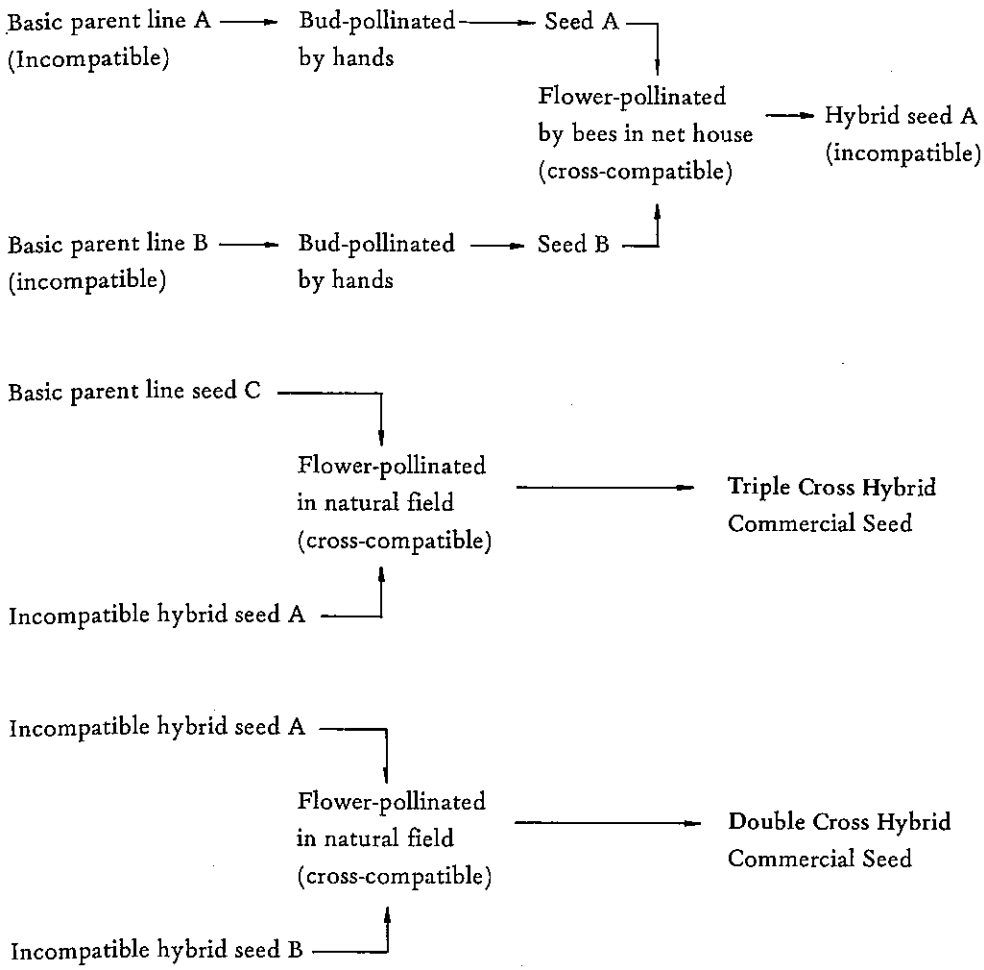
(v) As shown in Table 4-3, in these cases the F_1-hybrid lines (A and B) should be incompatible in the line but compatible with the partner line, although the two basic parent lines are compatible with each other, that is, hybridizable between two basic parent lines but incompatible in the resulted F_1-hybrid population. In this connection the detailed explanation of the genetics can be obtained in SHINOHARA (1981): "Principles of Vegetable Seed Production", Part III, and also refer to Chapter of turnip, 3.1.

(vi) Anyhow, in the cases of triple- or double-crossing hybrid methods, the basic seed/seeds of one/both parent lines can be produced at flowering time utilizing honey bees or other pollination insects in the net house by which the scale of basic seed production can be tremendously expanded. As the result the commercial F_1-hybrid seed production itself can be also expanded so large as 10 times or even 100 times of the scale of single crossing method. (This column is written by SHINOHARA, S.)

(2) On the Commercial Seed Production

Process and notice points of commercial seed production can be itemized as follows:

Table 4-3. Systems of Triple and Double Crossing Seed Production (SHINOHARA)



(i) Distribution of basic seeds for the commercial seed growing farmers.

(ii) Sowing of basic seeds – In seed beds (transplanting culture) or direct-sowing in the main field; autumn sowing or spring sowing.

(iii) Linearly mixed plantation of two parent line plants, usually 1 : 1.

(iv) Pollination honey bees grazing in the fields.

(v) Inspection – In order to avoid foreign pollens contamination (out-crossing) and on roguing of off-types if contaminated in the fields.

(vi) Dieseases and pests control.

(vii) Seed threshing, cleaning by winnow and handing over to the contractor.

4. SEED PRODUCTION METHOD WITH HEADED SEED PLANTS (HEAD TO SEED METHOD)

This method is adopted in the breeding process to develop parental lines and to determine the combination of hybrid when it needs to select the seed plants strictly examinating all the characters of the cultivars precisely. The plants are grown under the same cultivation method as normal marketing culture to form complete head in order to select the optimum type of plants adapted to the said cultivation type, early season, normal season, late season, etc., therefore, it cannot be expected to produce large amount of seeds.

4.1 CULTIVATION METHOD OF SEED MOTHER PLANT RAISING

Planning – Since the elite seed mother plants are strictly selected from the test field, the selection is done usually in the breeding line selection field in such manner as firstly promising a few lines are selected from whole test field and secondly a few or several elite plants are selected in the selected lines in which usually 40–50 plants are standing. In the case of simple mass selection, 20–50 times of number of candidate plants are usually grown to the necessary number of selected elite mother plants, that is, the rate of selection may be 2–5% of whole grown plants.

Slowing Time – Inasmuch as the cultivation method of seed mother plants is the same as marketing culture, the sowing time is from the end of August to the beginning of September according to the maturity of the said variety; the earlier varieties the later sowing, so that the head maturity become to the end of autumn when the elite mother plants are selected and transplanted.

Mother Plant Selection – Differed from common cabbage, the matured head of Chinese cabbage cannot be cut off from the stem for the examination because Chinese cabbage plant is so susceptible to soft rot and if the stem is cut, the plant is certainly killed by rotting. The examination of elite mother plants is done more or less the same as common cabbage, firstly on the characters of frame leaves and secondly on the head characters; shape, colour leaf wrinklage, pubescentage, etc. examinating also solidity of head by hand pushing, according to the standard characteristics of the said cultivar.

4.2 HANDLING OF SELECTED MOTHER PLANTS

Transplantation – Since headed Chinese cabbage plants are so susceptible to freezing, the selected mother plants are usually potted and carried into net house roofed with glass or plastic plate. That is, (i) Dig up the plants carefully holding the root system as complete as possible, (ii) remove the died/dying lower leaves carefully for only those removable easily so that never injure the stem, (iii) transplant them into the growing pots of 25–30 cm diameter then (iv) carry them into the net house.

Operation of the Head – The heads are cut and split as shown in Fig. 4-3. The notice points are: (i) Don't injure the heart or growing point, (ii) since completely matured head consists of white leaves part and yellow heart leaves part, and the formers never recover into active leaves whereas the latters will recover turning into green and grow up as normal rossete leaves later on, the cut head should be operated only on those white leaves part keeping those yellow leaves as complete as possible. Moreover, it is better also to keep the frame leaves because they are useful for the recovering of potted plants on their rooting and growing up of heart leaves for a while. Because headed Chinese cabbage is rather tolerant to transplantation with juicy leaves but susceptible to diseases starting from the bottom, sometimes the dug plants are exposed in in the sunshine of late autumn on their bottom laying on the ground for 1–2 hours so that the bottom part is dried and kill the pathogens some extent, sometimes putting lime dust on it too.

Management after Transplantation – Since the frame leaves and cut leaves are step by step withered and dropped down within 3–4 weeks but at the same time those dying leaves

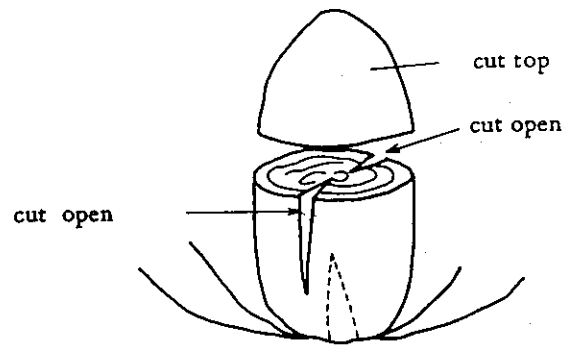


Fig. 4-3. Cut Open Operation of Head of Elite Mother Plant of Chinese Cabbage (SHINOHARA, 1977)

become also the source of sclerotinia and soft rots, those leaves should be taken off cleaning the bottom gradually with the following manner: About a week after the transplantation, from the lowest part of leaves, they become to be easily removed by hands with a touch gently shaking left and right due to the development of abscission layer at the base of leaves which protect the stem from pathogen invasion. Keeping this principle in the mind, the removal practice should be done step by step from the lowers to the uppers in 3–4 times for a few weeks until the white leaves are completely removed and the yellow heart leaves turn green and grow up. During this time if the heart leaves are tangling each other and disturbed their spreading, the outer cut white leaves have to be split deeply again in order to make easier growing up of the heart leaves but always very carefully. The heart leaves may start growing very soon turning into green and when they grow up to some 15 cm length and spread opened, then the grower can confirm the plants become already sound and safety, because before this time the plants are always facing at the big risk of freezing damage and rotting die but after this time the plants become so sound as if commercial seed plants in the next division.

4.3 CULTIVATION METHOD AFTER RECOVERY

After seed stalks develop, put 2–3 supporting sticks standed in every pot loosely binding the stalks in order to protect the fruiting branches from lodging. The methods of fertilizer supply, diseases and pests control are more or less the same as commercial seed production. In the case of mass selection plants of simple varieties, the pollination should be managed by means of grazing bees or other polliantion insect because it is in the net house and isolated from outside wild pollinaters.

Remark: Head to Seed method is not practiced usually for the basic seed production of F_1-hybrid parent lines since they are already purified genetically, therefore, do not need to select the head so strictly. (This column is written by SHINOHARA.)

5. SEED PRODUCTION METHOD WITH NON-HEADING SEED PLANTS (SEED TO SEED METHOD)

Usually commercial seed production adopts this method that the seeds are produced from non-heading seed plants which bolt and go to seed at pre-heading stage so that they can perform stablely a large amount of seed yield. Since a strict selection of seed plants cannot be applied by this method, the basic seed sown in this method should be purified beforehand genetically as uniform as possible by previous generation. Commercial seed production of F_1-hybrid is adopted always this method. Actual cultivation methods are divided into the following three ways.

5.1 TRANSPLANTING METHOD

Young plants are grown once in the nursery beds then transplant them in the main field. The merits of this method are: (i) to save the amount of basic seeds, in the other words, to maximize the production of seeds using the least amount of basic seeds, and (ii) to manage some extent of plant selection by means of examining general colour, shape and wrinklage of leaves. For the production of basic seeds of F_1-hybrid parent lines are usually adopted the intermediate between this method and head to seed method, that is, sowing seeds a little earlier than normal this method and select the seed plants at semi-heading stage. The demerits are: (i) labourous in the management and (ii) somewhat susceptible to freezing during wintering over.

5.2 DIRECT SOWING

Basic seeds are sown directly in the main fields. In case sufficient amount of basic seeds are available, since this method can be managed by less labour, it is suited for large scale seed production in the distant place from the contractor where an intensive inspection is difficult to manage. It is essential, however, to manage one or two times of roguing of off-types inspecting also the acrage of the production fields by the contractor.

This method is suited to a large scale seed production in after-paddy fields in warm areas or else to hilly upland areas where winter is rather severe since direct sowing makes to develop the roots deeply so that the plants become winter hardy.

5.3 SPRING SOWING METHOD

Basic seeds are sown directly in the fields in early spring when sufficient low temperature is still available for the vernalization of the said cultivar. This method is adopted usually for such parent lines as susceptible to sever cold due to belonging to tropical blooded/type cultivars being liable to go to flowering even in winter and sometimes adopted for the supplemental seed production when ordinary autumn sowing fields are got damage by accidental coldness. Anyway the seed yield of spring sowing culture is usually less than ordinary autumn sowing culture.

In Miyagi Prefecture of WATANABE SEED, we adopt thoroughly the transplanting method counting its merits mentioned in (i), although the natural condition here is more suited to direct-sowing because of rather severe winter. Accordingly, the cultivation method explained hereafter is based on transplanting method for commercial seed production.

6. RAISING SEEDLINGS

Differed from the warm areas like Kyūshū, the biggest point in cultivation in Tōhoku region is depended upon the wintering over condition, therefore, a prudent taking care is put on raising seedlings which sways over the performance of plants thereafter.

(1) Sowing Time

Counting back from the frost falling time, the sowing time should be scheduled 40–50 days prior to the frost fall, that is around in the middle of September which is somewhat earlier than the corresponding time of warm areas.

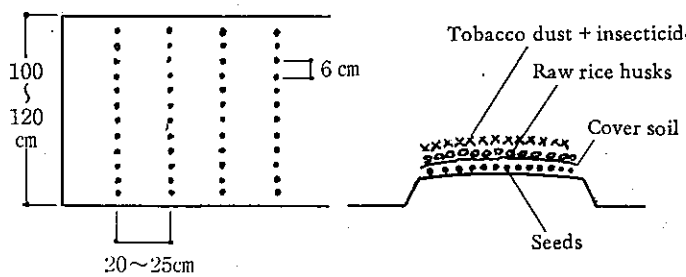


Fig. 4-4. Sowing Method in the Seed Bed

(2) Seed Bed

Location – Select such condition field as better sunny, drainage, fertile as well as convenient to water supply but also being not used to seed production for a few years. The last point is an essential caution to avoid spontaneous contamination of foreign varieties which sprout from the seeds of previous production, avoiding even the F_1-hybrid seeds of the same combination of parent lines.

Area – Necessary area of nursery beds is 40–50 m^2 per 10 a of main field.

Land Preparation – About 5–7 days prior to the sowing, firstly broadcast dolomite 300–500 g per 3.3 m^2 then plow up the land. Secondly a few days after the plowing, broadcast also a high-analysis compoumd fertilizer (e.g. 15-15-11) 200–300 g per 50 m^2 mixed with

soil of about 15 cm depth by hand tiller. Thirdly make flat beds of 100–120 cm width and 5–6 cm height, and wait the sowing.

(3) Sowing Method

As shown in Fig. 4-4, on the lines 20–25 cm apart, 1–2 seeds spot sowing about 5 cm apart in order to raise the maximized number of seedlings from the least amount of seeds with least practice of thinning since the basic seeds are so high valued as produced by hand bud-pollination. After cover the soil about 3 mm thickness, cover also rice-husks about 10 mm thickness in order to avoid from drying, dropping down of soil temperature and beating of heavy rain so that the germination and growing of sprouted seedlings be smoothly. After then, supply water on the coverings with watering can 10 ℓ per 3.3 m in which water disolving 12 g of Authocide or Daconyl for the control of damping-off, moreover, broad cast also tobacco dust mixed with some insecticide on the rice-husk mulching for the control of insects.

The two parent line seeds should be sown strictly separately.

(4) Management of Seed Bed after Sprouted

Thinning should be done at the spots of 2–3 seedlings sprouted in the cotyledone stage. Other managements are watering, hand weeding, hand cultivation of inter-lines, top dressing and spraying which are done according to the condition of plant growth. The point of raising seedlings is to grow up such seedlings having rather small roundish leaves but stout and also phosphorous responded seedlings having good root system in order to be tolerant to transplantation and thereafter coldness.

(5) Inspection of Seedlings

The inspection is done by the specialists in charge of seed production of the seed growing company, around the middle of October 30 days after sowing, when the seedlings grow up 7–8 true leaves stage. Such off-type seedlings should be discarded as extra-ordinary strong growth (mistaken hybrids), unusually shaped and coloured leaves or whole plants. The inspection should be done very precisely so that less roguing in the main field to avoid missing plants there.

7. CULTIVATION METHOD IN THE MAIN FIELD

(1) Setting Time

Especially in cool areas, healthiness of the transplants and time of the setting directly affect on the rate of their wintering over and thereby seed yield. Both excess early and excess late times result in no good performance. The early setting makes the plant growth too advanced which results in less winter hardiness of the plants making more missing plants in the case of early varieties having strong ability of head formation (most of those varieties are deemed to be subtropical origin and have less winter hardiness). Even in the case of ordinary medium and late varieties, if grown up too much big before winter, not only the plant growth are frequently sunk down in the next spring but also much infection of *Sclerotinia* disease which cause sure yield decrease.

On the contrary, in case of delayed setting, the plant root system cannot spread in the soil sufficiently deep so that the plants become less winter hardiness making much missing plants and even remained plants produce less yield. Accordingly, the setting should be done just in good time which is a short time especially in the cooler areas.

The setting time can be designed focused at about one month prior to the time of temperature goes down to 4–5°C under which plant growth stops. In Tōhoku area, it is late part of October deciding the actual time according to the topography.

(2) Spacing

For early varieties of small establishment – 75 cm of row to row, 30 cm of plant to plants and 4,400 plants per 10 a. For other varieties of larger establishment – 75 cm row to row, 40–45 cm plant to plant and 3,300 to 2,800 plants per 10 a.

(3) Fertilizer Application As shown in Table 4-4.

Nitrogen – Although regarded as nitrogen is effective on the seed yield when applied at the bolting time, nitrogen is really the most important element throughout the growing period. The basic and top dressing before wintering over (in warm areas) make good establishment of plants and better winter-hardiness. Nitrogen dressing at early spring makes much branching and encourages better flowering and seed ripening. As shown in table 4-5, as to the nitrogen difficiency, the earlier the defficiency happens, the bigger effect appears on the growth and reproduction of plants. Anyway, it suggests that it is better to take in of slow-release nitrogen fertilizer for basic and some top dressing of quick effective for supplementary.

Table 4-4. Standard Fertilizer Application per 10 a (per element)

Item	Basic	Top dressing at	
		Bolting time	Mid-flowering time
Nitrogen	7– 9 kg	3 kg	1.5 kg
Phosphorous	7–10	3	–
Potassium	6– 7	2	1
Boron	0.7– 1	Spray on the leaves according to the condition	

Table 4-5. Effect of Supplying Period of Nitrogen on the Growth, Flowering and Seed-Ripening of Chinese Cabbage Plants

Period of Nitrogen supply	Number of branches		Flowering		Harvest time	No. of pods	Amount of seeds	Seed germination
	Primary	2–3rd	Time of 1st fl.	Period				
+N for whole season	22.5	115.5	Mar. 13	54 days	Jun. 2	2,205	82.5 g	100%
-N from April 5	21.5	78.0	7	54	May 21	2,165	61.1	100
-N from March 5	18.5	54.5	11	49	14	1,307	27.1	100
-N from February 5	21.0	56.0	9	45	10	932	18.4	100
-N from January 5	18.0	39.0	7	44	7	772	16.8	100
-N from December 5	13.0	26.0	7	40	7	436	11.4	100
-N for Dec. 5–Jan. 5	20.5	91.5	Mar. 11	55 days	May 24	1,885	58.4 g	100%
-N for Feb. 5–Mar. 5	23.5	92.5	12	59	24	1,894	52.2	100
-N for Mar. 5–Apr. 5	22.5	61.5	9	56	24	2,187	48.1	100

Note: SUGIYAMA, T. (1952), by water culture in cold house in Tokyo

Table 4-6. Effect of Supplying Period of Phosphorous on the Yield and Fulfillment of Seed in Chinese Cabbage

Period of P-Supply	Seed yield	Weight of 1,000 seeds	P-Content per dry matter	Germination
+P for whole season	50.4 g	3.20 g	0.73%	99.8%
-P from Apr. 4	56.3	3.27	0.58	100.0
-P from Mar. 28	39.7	2.29	0.52	99.4
-P from Feb. 18	34.3	2.21	0.45	99.8
-P from Dec. 17	20.7	2.16	0.40	100.0
-P before Dec. 17	18.5	2.68	0.98	99.7
-P before Feb. 18	7.4	2.13	0.91	99.3

Note: SUGIYAMA, T. (1958), by water culture in Tokyo.
Apr. 26 is ripening stage, Mar. 28 at mid-flowering stage, Feb. 18 at the bolting, and Dec. 18 at the flower differentiation time.

Table 4-7. Effect of Supplying Period of Potassium on the Yield and Fulfillment of Seeds in Chinese Cabbage (1978)

Period of K-Supply	Seed yield	Weight of 1,000 seeds	K-Content per dry matter	Germination
+K for whole season	58.4 g	3.56 g	0.75%	99.8%
-K from Mar. 22	57.6	3.47	0.71	88.7
-K from Feb. 15	51.7	3.66	0.75	100.0
-K from Dec. 17	18.8	3.88	0.82	100.0
-K before Dec. 17	53.6	3.21	0.62	99.7
-K before Feb. 15	26.9	2.98	0.78	100.0

Note: Mar. 22 is at the flowering time, Feb. 15 is at the bolting time, Dec. 17 is at the flower differentiation time.

Phosphorous — Phosphorous is regarded at closely related with the flower formation, ripening and fulfillment of seeds, therefore, much P- and K-fertilizers are supplied in seed production. On acidity soils of the rainy places and on volcanic ash soils like Japan, phosphorous is an inevitable element for crops cultivation generally, therefore, soil neutralization by lime supply and much application of organic fertilizer are important practices for the improvement of cultivation soil. Effect of phosphorous appears specially from the early stage of plant growth and delayed application is less effective on the recovering of vegetative growth but also results in less numbers of branches and ripened pods, therefore, it should be applied as basic.

As seen in Table 4-6, in the case of seed production, phosphorous defficiency after the beginning of flowering makes also insufficient development of secondary and tertiary branches and less number of ripened pods as well as smaller seeds, therefore, some extent of top dressing of phosphorous is also necessary for the seed yield increase.

Potssium — Differed from phosphorous, potassium defficiency can be recovered quickly on the plant growth by top dressing, and if so done, the effect of some extent of K-defficiency does not affect so much on the plant growth at maturity and on the seed yield, as seen in Table 4-7. K-defficiency in the period from the flower differentiation up to the bolting time, however, is noticable because it affects later on the fulfillment of seeds to avoid broken seeds (seed coat breaking) and premature germination, therefore, as a conclusion, potassium application should be done from the basic to 1st and 2nd top dressings just as nitorgen.

Boron — Since seed-ripening trouble caused by boron defficiency is widely appearing in Japan, the effieciency of boron application is remarkable. In case of boron defficiency, the plants may be stunted their growth and killed in the severest case, even in light case, it causes light stunting, dropping down of buds and flowers, stopping of pod growth and no good fulfillment of seeds. General application method is that 1 kg per 10 a of borax is applied at the time of land preparation. Since boron deficiency appeares usually under dry soil condition, in case the soil is dry in early spring of bolting to flowering period especially in case of seed production of varieties having a trouble in seed fulfillment, it is recommended to spray 500 times dilution of wettable boron on the leaves and stems 2—3 times at the beginning, mid-season and the end of flowering period.

(4) Land Preparations

5—7 days period to the setting, the land is plowed deeply just after dolomite is broadcasted throughout the field. 3—5 days after then, broadcast firstly matured compost, secondly basic fertilizer (mainly compound fertilizer) and 6—9 kg per 10 a of soil insecticide, e.g. Karphos dust on the compost, and thirdly mix them in the soil about 15—20 cm depth by

hand tiller. An effective application of compost and basic fertilizers is really to apply them linealy in the rows, however, it is difficult to put them in every row of 75 cm apart with power tiller, therefore, making furrows 140—150 cm apart, spread the compost and basic fertilizers on the growing bed then mixed them with soil and set the transplants in double rows on the beds. In addition, in order to protect from freezing, it is better to make rows in north-south direction.

(5) Setting in the Field

In the middle and end of October (in cooler areas), 30—40 days after sown and at the time of 7—8 leaves stage, the transplants are set in the main field selecting a calm and warm day. Although in the market production, Chinese cabbage plant is regarded as susceptible to transplant because the purpose is aimed at head formation, but in the case of seed production in which head formation is not necessary, Chinese cabbage plant is rather tolerant to transplantation, or very easy to take roots, therefore, even if handle the transplants holding less roots and soil they can take roots rather easily, therefore, rather rough handling than cauliflower and broccoli can be done in this respect. However, in case of the varieties having less ability of rooting, in case of late setting or on poor soil, it is better to handle the transplants carefully to hold much roots and soil.

There are two manners in the setting. The one is alternative planting by beds or 2 by 2 rows method which is utilized for test seed production and in the case of harvest seeds separately in each parent line due to remarkable difference of shapes and colours in the two. The demerit of this method is somewhat decrease of seed yield due to it disturbs some extent the visit of pollination insects because of visiting habit of honey bees is making blind parts.

The other is separate planting on a couple of rows or 1 by 1 row method which is utilized for more generally. The merit is to increase the seed yield without disturbance of honey bee visits but the demerit is difficult to harvest seeds separately by parent lines. Anyway, set the first parent line completely then set the other in order to avoid mistaking of two parent line plants.

(6) Management before Wintering Over

Earthing Up — Although no severe problems in the over wintering in Kantō and southmore places, it is rather big notice in cooler areas like Tōhoku. Due to dry cold noth-west wind blow, the plants are liable to get cold and dry injury severely, therefore, an earthing up on the bottom of plants making ridges at the west sides of every rows and light cultivation also at the east side so that the heart of plants can be protect from both sides at the end of November or the beginning of December before the constant snow cover comes. Another earthing up

is done also in early spring at the time of first top dressing in order to make steady standing of branched plants.

Utilization of Herbicide – Recently utilization of herbicide became rather popular in Japan because the seed production places of cruciferous crops are usually located in hilly areas and midst of wide paddy field areas due to necessity of isolation distance where labour is shortened. Usage of herbicide is that for example in three times at just after every setting and earthing up times, spray such herbicide as 200–300 g per 10a of wettable powder of Planavin diluted in about 150 liters of water by hand sprayer on the soil. Planavin effects to kill weeds by absorving from the roots, therefore, almost no chemical injury happens even if touched on leaves of seed plants.

First Inspection – The plants grow up in remarkable size after 30–40 days from the setting. Then before severe cold weather comes, that is, before anthocyanin pigmentation and freezing injuries appear on the leaves, the first inspection should be done, that is, (i) to rogue the off-types remembering exactly the characters of both parental lines and (ii) examining the planted acreage and condition of plant growth, set up the first yield forecast.

(7) Management in Spring

Top Dressing and Earthening Up – The first top dressing is done at the beginning of bolting applying three elements of N-P-K as seen in Table 4-4. Excess nitrogen or delayed applications may cause severe appearance of sclerotinia rot or excess thriving of secondary and tertiary branches. The second top dressing is done examining the condition of plant growth when the growth is poor, which practice is not usual for Chinese cabbage in cool areas. The earthing up should be done before starts flowering for the protection of lodging.

Inspection for Out-Pollination and Pollination Condition – Out-pollination or contamination of foreign pollens is the biggest problem in seed production of cruciferous crops especially in F_1-hybrid seeds, because all the plants in the feild are completely self-sterile at the flowering stage. Fundamentally the seed production fields should completely be isolated from different variety fields by means of utilizing such topographics as isolated islands in the sea or isolated valleies in mountain sides, so doing as one variety or one combination of hybrids per one island or one valley. Other crossable varieties, however, always may exist flowering among the kitchen yards of other living farmers, remained plants or stumps in the marketing culture fields as well as sometimes wild type and escaped spontaneously growing plants may exist. Therefore, inspection for those foreign variety flowerings is an essential work for seed growers in early spring before the objective seeding plants blossom. The inspection is better to be done firstly by all the farmers of the members of local seed production association which contracted

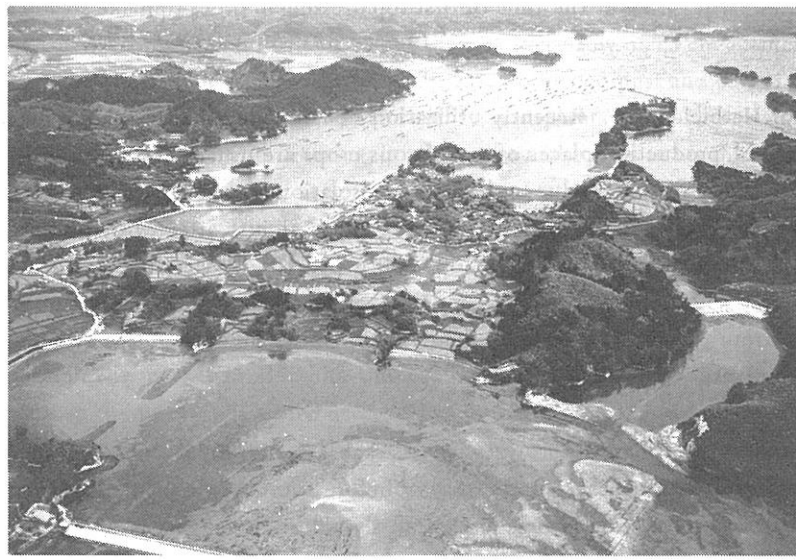


Fig. 4-5. Topography of Chinese Cabbage Seed Production Field in Matsushima Islands at Mid-Flowering Time

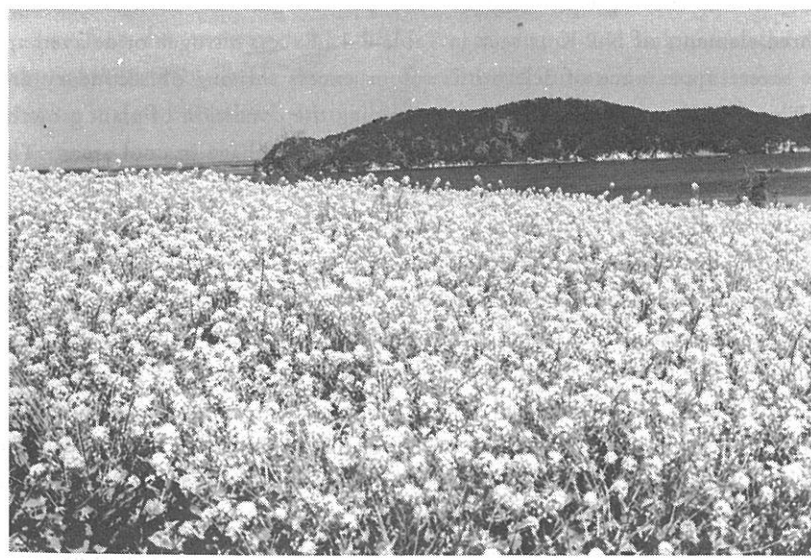


Fig. 4-6. Mid-Flowering View of Chinese Cabbage Seed Production Field with Simple Variety in 1950's in Matsushima Islands

with the seed growing company, and secondary by the specialists in charge of seed production business in the company by the change when they go around all the seed production fields to inspect final roguing of off-types and setting up of yield forecast. Since the special characters of seeding varieties clearly appear at the bolting time, the final roguing also is done at this oppotunity.

Another notice in the floweirng time is to improve the pollination condition of seed production fields themselves. This notice, grazing of honey bees, became rather essential recently in Japan because wild pollination insects become shortened in most of areas due to the change of environmental condition by extension of chemical sprayings and other change of agricultural structure itself etc. which disturb the existence of insects. Honey bee grazing is actually carried out by cooperation with bee-keeping business but in the other side cautious notice is also necessary in this case because firstly keeping bee box means to make more risk of foreign pollen contamination carried by the bees from distant places (bee moving area is normally regarded as a radius of 4,000 m), therefore, in case the plant population is not meetable to the keeping population of bees, the bees cannot help flying for distant fields to get their honey. The second notice is when bring the bee box newly, the bee box should be kept in the field of uncrossable crops like normal cabbage or radish flowering field in order to avoid the contamination of before time carried pollens of the bees. Accordingly the ratio of bee boxes per seed production field area is rather important notice, that is, one box per 30 a of Chinese cabbage seed production field is a standard but flexible by the actual condition of number of bee hive slides and the seeding plant growth which is a knowhow of Chinese cabbage seed growers.

8. HARVESTING AND THRESHING OF SEED

(1) Harvesting

At the time of 80% of seed pods turn the colour yellowish, the plants are reaped from the bottom, bundled in 2—3 plants then hanged on the sheaf drying pole for several days for afterripening and drying. It can not be recommendable to dry the cut plants laying on the ground because it may disturb the quality of seeds absorbing moisture from the ground, advance the disease infection, and in the worst case of rainfall, it makes seed germination in the pods.

(2) Threshing

About one week after plant reaping when all the pods are completely dried up if continue fine days, the seeds are threshed out on the sheet by foot-thresher or threshing handle, and the threshed seed are dried up for several days as explained in normal cabbage, then the

seeds are cleaned by winnower.

9. MAIN DISEASES AND PESTS

Downy Mildew (*Peronospora brassicae*) – Symptom: Yellowish brown irregular spots on the leaf surface and white powdery mildews on the back, appears mostly at the seedling stage and seed-ripening stage. Controlled by spraying at those times with 400–600 times dilution of Dithane wettable or 600–800 times dilution of Daconil wettable.

Sclerotinia Rot (*Sclerotinia sclerotiorum*) – As explained in normal cabbage, this disease originates from the frame leaves during winter, starts increasing on the flower petals, spreads on the branch leaves and stems by falling of infected petals then develop in the stem piths and makes sclerotium grains in the stems which contaminate in the threshed seeds, and if so, the seeds cannot be sold by quarrantine. The control method is as explained in cabbage, (i) good cultivation and earthing up so that the spores cannot emerge on the soil surface, (ii) not to be fertilizer deficiency but not excess introgen, (iii) spread lime on the soil surface for the same purpose of (i), and spraying of 1,000–2,000 times dilution of wettable Benlate at the time of bolting and beginning of flowering.

White Rust (*Albugo macrospora*) – Symptom: irregular shaped swollen pale white spots appear on the back of leaves, young stems and pedumcles, looked like attached insects. In the severe case, the top of flowering stems and peduncles fallen curving and petals and pistiles enlarged shaping deformity and greenish colour. This disease appears violently from flowering to seed ripening stages when wetty by much rains. Controlled by spray of 1,000 times dilution of wettable Benlate or 400 times dilution of Triazine wettable.

Striped Flea Beetle (*Phyllotreta striolata*) – Appearance: (i) much emergence and injure severely under continuous dry weather, (ii) emerge more in case radish is growing neighbouring, (iii) severely damaged in the seedling stage. Controlled by spraying powder insecticide of Karphos or Dipterex before or just after the seed sowing as explained in the seed bed.

Common Cabbage Worm (*Pieris rapae crucivora*), Cabbage Army worm (*Mamestra brassicae*) and other leaf worms – Effective chemicals are dusts of MPCP or Dipterex.

Aphids – Effective chemicals are application of granules of Ortran, Ekatin or Dizistone

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