

S18331
-15
C.2

APR. 29. 1981

CHINESE CABBAGE

PROCEEDINGS OF THE FIRST INTERNATIONAL SYMPOSIUM

Edited by

N. S. Talekar

*Associate Entomologist
and
Chinese Cabbage Research Coordinator*

T. D. Griggs

*Associate Information Officer
and
Head, Office of Information Services*

Asian Vegetable Research and Development Center

1981



Asian Vegetable Research and Development Center
Shanhua, Tainan, Taiwan, China

10044

Layout

L. S. Cheng and Fred Tsai

Typing

Mei Hong Chen

Art work and Cover design

L. S. Cheng

AVRDC Publication No. 81-138

Printed by

Hong Wen Printing Works, Tainan

The Origin, Evolution, Taxonomy and Hybridization of Chinese Cabbage

CHIA WEN LI

Department of Horticulture, Shandong Agricultural College, Tai-an, Shandong, China

(Chinese cabbage (*Brassica campestris* L ssp *pekinensis* (Lour) Olsson) is a vegetable crop originating from China. However, its wild form has not been found there. Its primary cultivated form (A), a loose-leaf variety (var *dissoluta* Li) was first recorded in Chinese literature in the 5th century, and was probably produced by natural crossing between pak-choi (ssp *chinensis* (L) Makino) and turnip (ssp *rapifera* (Metzky)). By developing the head forming habit, it evolved successively to (B), a semi-heading variety (var *infarcta* Li), (C), a fluffy-topped heading variety (var *laxa* Tsen et Lee) and then (D), a heading variety (var *cephalata* Tsen et Lee). There are three morphotypes of the last, which have developed in different climatic areas, each adapting to different ecological conditions and having different head shape.) These are: (D₁) oval form (f *ovata* Li); (D₂) flat-topped form (f *depressa* Li); and (D₃) cylindrical form (f *cylindrica* Li). (By crossing these varieties and forms, five hybrid forms were developed in the past.) These are fluffy-topped oval (C×D₁), fluffy-topped cylindrical (C×D₃), flat-topped oval (D₁×D₂), stout-cylindrical (D₁×D₃) and flat-topped cylindrical (D₂×D₃). (In 198 cross combinations the average heterosis percentages on the basis of yield were significantly different in combinations differing in parental interrelationships; crosses within the same variety or form -10.16±2.47%; those between different varieties or forms -20.44±2.19%; those between variety form and hybrid form -26.24±3.22%; and those between different hybrid forms -44.22±8.42%. (Therefore, crossing different varieties or forms, especially different hybrid forms, is promising for obtaining heterosis of yield.)

Chinese cabbage (*Brassica campestris* L ssp *pekinensis* (Lour) Olsson) is the most important vegetable crop grown in China, and its production has increased tremendously during the last 30 years. In the northern provinces, it now comprises 25% of the total amount of vegetables consumed year round, and 80% in winter and spring, when other vegetables are in short supply. In the southern provinces, its production is also increasing year by year, though pak-choi (*B. campestris* L ssp *chinensis* (Rupr) Olsson) is the traditional major vegetable crop there. In the arid areas, such as Inner Mongolia and Sikiang Uighur, as well as on the plateaus of Chianghai Province and Tibet, where Chinese cabbage was never grown in the past, it is also grown fairly extensively now.

Research into Chinese cabbage has proliferated during recent years. New cultivars have been bred and cultural practices improved, physiological studies have been made, and a nationwide survey of local cultivars undertaken.

ORIGIN

Though Chinese cabbage is known to be a vegetable crop that originated in China, its wild form has not been found there so far, and its cultivated forms appear fairly late in ancient Chinese literary records. In Shin-Jing (The Classics of Poems) edited in the 5th century BC, in which many kinds of plants grown in North China were recorded, the only *Brassica* crops mentioned were turnip (*B. campestris* ssp *rapifera*) and mustard (*B. juncea*). From then to the 7th century, turnip was grown in north China only, while pak-choi was grown in south China only. In the 10th century, it was written in a medical book, Ben-Cao-Tou-Jing (The Classics of Illustrated Medical Herbs), that at Young-Chou, at city at the junction of the northern and southern sections of the Great Canal connecting north China and south China, there was a kind of vegetable called "ox-stomach cabbage". This differed from pak-choi by having wrinkled, hairy leaves as large as fans and not so fibrous as pak-choi in texture. The characteristics so described are much like those of the loose-leaved Chinese cabbage, the primary form of this crop. This record gave the author a hint that Chinese cabbage might have originated from hybridization between turnip from north China and pak-choi from South China when they were grown together in Young Chou. From 1960 to 1962 different forms of turnip and pak-choi were collected from the north and south respectively and artificial crosses were made between them. The hybrids obtained all showed typical morphological characteristics of Chinese cabbage, having large thin, hairy leaves with fairly clear wings along their petioles and also fairly thick hypocotyls. This morphological evidence may be supported by a cytological study by Richharia (1937). He reported that the chromosomal formula of both ssp *chinensis* and ssp *pekinensis* was ABCDDEEFF, and that of ssp *rapifera* was ABCDDEEFF, while the E and F chromosomes of ssp *pekinensis* were morphologically alike with those two of ssp *rapifera*. However, more detailed cytological, biochemical and serological studies are necessary for further proof of the possible hybrid origin of this crop.

TAXONOMY

Since 1952, a nationwide survey of local cultivars has been under way in China. As the individual farming system had survived about 2,000 years of Chinese history, cultivars of crops were all narrowly localized. As for Chinese cabbage, there were usually two or three cultivars in every district - an early one, a late one, and sometimes one for mid-season. Thus there are thousands of local cultivars of this crop in China.

Bearing in mind the morphological, ecological and economical characteristics of this large scale survey of local cultivars, the author tried to classify Chinese cabbage into the following four varieties:

(A) Loose-leaved variety (var *dissoluta* Li): Terminal bud underdeveloped, forming no leaf-head; rosette leaves oblanceolate, spreading or erect; usually grown in spring and summer and used as greens in all parts of China.

(B) Semi-heading variety (var *infarcata* Li): Terminal bud with its outer layers of leaves fairly well developed, forming a head with hollow center; plants large and tall; rosette leaves oblanceolate and erect; semi-developed heads together with rosette leaves are consumed; usually grown in autumn and stored over winter in cold and arid areas where the growing season is too short for heading varieties.

(C) Fluffy-topped heading variety (var *laxa* Tsen et Lee): Terminal bud well developed, forming a rather solid head with its leaf-tips curling upward and forming a fluffy top; plants small, rosette leaves obovate and spreading; usually grown in late summer and early autumn as an early crop in many localities; keeping quality bad, cannot be stored over winter; sometimes grown in spring season.

(D) Heading variety (var *cephalata* Tsen et Lee): Terminal bud well developed, forming a solid head with leaf-tips close to overlapping on the top; either as an early crop for autumn or a late crop for winter. This variety is further classified into three types differing in their morphological and ecological characteristics, and also differing in their localities of distribution.

(D₁) Ovate type (f *ovata* Li): Head ovate, height/diameter index approximately 1.5, veneration of bud leaves plicate, leaf-tips closing on the top, but not overlapping; rosette leaves obovate, spreading; center of origin in Shandong Peninsula, maritime climatic ecotype, adaptable to temperate and fairly humid climates.

(D₂) Flat-topped type (f *depressa* Li): Head invert conical, height/diameter index approximately 1.0, veneration of terminal bud leaves conduplicate, leaf-tips overlapping on head top; rosette leaves broad obovate, spreading; center of origin in central part of Ho-nan Province, continental climate ecotype, adaptable to inland areas with fluctuating daily temperature, low relative humidity and with many sunny days.

(D₃) Cylindrical type (f *cylindrica* Li): Head long and cylindrical, height/diameter index more than 4.0, veneration of terminal bud leaves convolute, leaf-tips closing on the top, but not overlapping; rosette leaves oblanceolate, erect; center of origin on the eastern coast of Ho-bei Province with Pu-hai Gulf at its south and the Inner Mongolian Plateau at its north, thus making a maritime and continental crossing climate. This type of Chinese cabbage is thus widely adaptable to almost all parts of China.

These six varieties including the three heading types mentioned previously, make the six basic forms of Chinese cabbage. However, hybrid forms were produced in the past. Though the possible number of hybrid forms which might be produced from six basic forms should be 35, only the following five valuable ones (Figure 1) were found to be used in production.

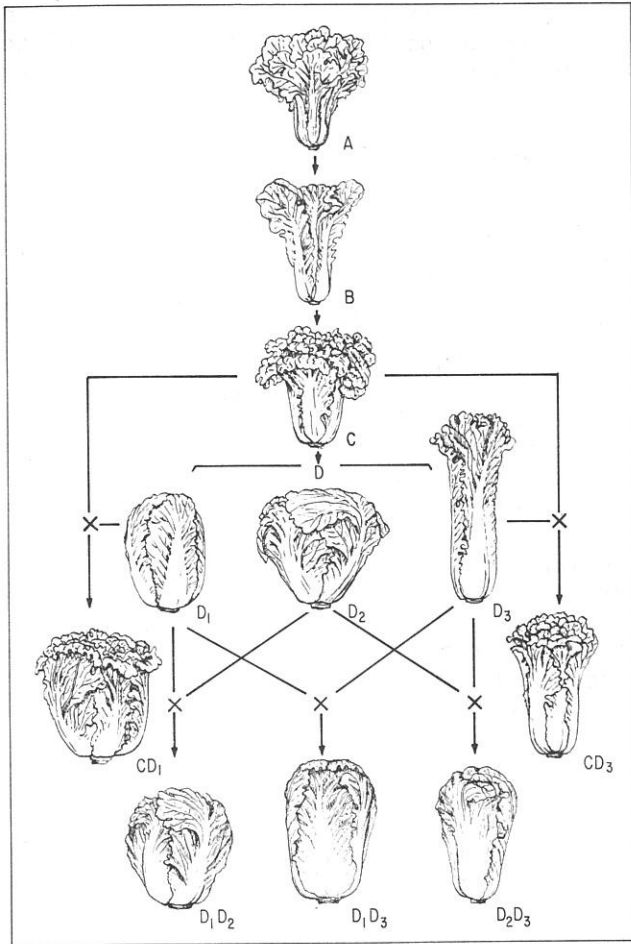


Figure 1. The evolution of Chinese cabbage (*Brassica campestris* ssp *pekinensis*). A. var *dissoluta*, B. var *infarcta*, C. var *laxa*, D. var *cephalata*, D₁. f *ovata*, D₂. f *depressa*, D₃. f *cylindrica*, CD₁. var *laxa* × f *ovata*, CD₃. var *laxa* × f *cylindrica*, D₁D₂. f *ovata* × f *depressa*, D₁D₃. f *ovata* × f *cylindrica*, D₂D₃. f *depressa* × f *cylindrica*

(CD₁) Fluffy-topped ovate form: Hybrid form produced from var *laxa* × f *ovata*, head stout, solid, with fluffy top; adaptable to unfavorable climate and extensive growing conditions.

(CD₃) Fluffy-topped cylindrical form: Hybrid from var *laxa* × f *cylindrica*, head cylindrical with fluffy top, though not very solid; highly adaptable to unfavorable climate and extensive growing conditions.

(D₁D₂) Flat-topped ovate form: Hybrid form from f *ovata* × f *depressa*, head ovate with flat top, more solid and better keeping quality than f *ovata*.

(D₁D₃) Stout-cylindrical form: Hybrid form from *f ovata* × *f cylindrica*, forming good shaped head with a height/diameter index approximately 2.0, a high yielding gross feeder requiring long growing season.

(D₂D₃) Flat-topped cylindrical form: Hybrid form from *f depressa* × *f cylindrica*, head having a large flat top and a slender lower section, only grown in a limited area.

EVOLUTION

The evolution of Chinese cabbage, like that of other cultivated crops, is evidently a course of development from primitive forms to advanced ones effected through the improvement of growing conditions by aimed selection. As indicated above, the primary form of Chinese cabbage, var *dissoluta*, was first produced in a city between north and south China, possibly by hybridization. In the south, this form has remained in its original state. The heading forms grown there were introduced from the north not earlier than the 19th century. The reason for this is mainly that the temperate autumn season in the south is not long enough and not sunny enough for the plant to reach full growth and form a head as a storage organ. On the contrary, the climate in the north is preferable for growing cool season crops like *Brassicacae*. In the Yellow River region, the temperate and sunny autumn lasts 90 to 120 days. Such a growing season is not only enough for full growth of the rosette itself, but also permits development of a storage organ. In Chinese cabbage, excess photosynthetic product is first stored in the petiole. Therefore, the primary form introduced to the north first developed thick petioled cultivars, as recorded in the literature of the 12th century. By further improvement of growing conditions, mainly by better mineral nutrition and water supply, more excess photosynthetic products were stored in the outer layers of leaves of the terminal bud. Thus the semi-heading *f infareta* appeared. As a result of gardeners improving their cultural practices further and paying attention to selecting more solid heads when they grew *f infareta*, *f laxa* appeared. This form was recorded in a horticultural book in the 14th century named Shue-Pu Tsa-Su (Miscellanea on Gardening). Form *laxa* produces quite solid heads, but the head tops remain loose and fluffy. By further improvement effected through the same continuous efforts by gardeners, *f laxa* was further improved to *f cephalata*. The first record of the last form was found in a Chin Dynastic geographic book entitled Shiun-Tian-Fu-Tse (Local Records of Shiun-Tian-Fu) in the 17th century. Of course, a new form must be in existence many years before it is recorded in literature.

The fact that the centers of origin of the three types of *f cephalata* are all located in the north is evidence of the northern origin of this advanced variety. However, why these three types which originated in different localities not only differ in their climatic requirements but also differ in their morphological characteristics is not quite clear. Perhaps the role played by temperature on the shape of leaves is important. In Ho-nan Province, the average daily temperature in the growing season of Chinese cabbage is relatively high. As a higher temperature usually causes the leaves of plant species to grow wider,

the type of Chinese cabbage developed in Ho-nan should form broad leaves. Just as, in the case of common cabbage (*B. oleracea* var *capitata*), cultivars with broad leaves always form heads in conduplicate vernation, the f *depressa* plants with obovate leaves also form their heads in the same vernation and thus are flat-topped. In the Shandong Peninsula, where the daily temperature is lower, the f *ovata* developed there forms broad leaves with plicate vernation, while on the eastern coast of Ho-bei Province where the daily temperature is much lower the f *cylindrica* developed there forms long oblanceolate leaves with convolute vernation. It is also evident that the three types of var *cephalata* were developed in different centers independently under the pressure of different ecological conditions and selection for different shapes of heads.

The hybrid forms were developed by natural crossing when different varieties or types were grown together for seed on certain individual farms; and when the hybrid plants were better than their parents, they would become stabilized by long term mass selections carried on by the gardeners aiming to obtain a new strain with the same characteristics as the F₁ plants. Such stabilized hybrid forms are often found in localities between areas growing different varieties or types.

It is evident that in Chinese cabbage, the characteristics of primitive forms are often, though not always, dominant over those of the advanced ones. When var *dissoluta* is crossed with the other varieties, not all F₁ hybrids will form heads. When var *infarcta* is crossed with var *laxa* and var *cephalata*, all F₁ hybrids will form inferior hollow heads. Therefore, all of the above hybrids that happened to be produced in the past were discarded and cannot be found in production. When var *laxa* is crossed with f *ovata* and f *cylindrica*, the F₁ hybrids will form solid heads and will be more widely adaptable. Thus, these hybrid forms were used in production, though they have fluffy topped heads elsewhere. It was found that when var *laxa* is crossed with f *depressa*, the conduplicate habit is always dominant over the fluffy-top habit and thus the hybrid plants have flat-topped heads like f *depressa*. Therefore, this hybrid form cannot be found in production. As a rule, crosses between the three types of f *cephalata* all produce hybrid forms with solid heads and wider adaptability. As the conduplicate vernation is dominant over plicate and convolute, and plicate is dominant over convolute, the vernation and shape of heads of the hybrids between the three types within var *cephalata* can be predicted.

HYBRIDIZATION

Since 1954 hybrid breeding for heterosis on Chinese cabbage has been carried on in many agricultural research institutes and colleges. At first, local cultivars were used directly as parental materials. As all the local cultivars in China have been isolated in different areas for many generations, and thus their inheritance, especially for the major characteristics, is relatively pure, heterosis was obtained from many of the crosses between them. Of course, inbred lines have later been used as parents. The author has analyzed the percentage of heterosis on the basis of middle value on yield of both parents of

198 different crosses made by various institutes, including 45 crosses made by him and his co-workers, and then found that the taxonomic inter-relationship between the parents crossed plays an important role in the heterosis of their F_1 hybrids, as summarized here:

1. Crosses between cultivars or inbred lines within the same basic form, as $C \times C$, $D_1 \times D_1$, $D_2 \times D_2$, $D_3 \times D_3$: The average heterosis of 49 crosses is $10.16 \pm 2.47\%$.

2. Crosses between cultivars or inbred lines of different basic forms, as $C \times D_1$, $C \times D_3$, $D_1 \times D_2$, $D_1 \times D_3$, $D_2 \times D_3$: The average heterosis of 82 crosses is $20.44 \pm 2.19\%$.

3. Crosses between cultivars or inbred lines of a basic form with those of a hybrid form, as $D_1 \times CD_1$, $D_1 \times CD_3$, $D_1 \times D_1D_2$, $D_1 \times D_1D_3$, $D_1 \times D_2D_3$, $D_2 \times CD_1$, $D_2 \times CD_3$, $D_2 \times D_1D_2$, $D_2 \times D_2D_3$, $D_3 \times CD_1$, $D_3 \times CD_3$, $D_3 \times D_1D_2$, $D_3 \times D_1D_3$, $D_3 \times D_2D_3$: The average heterosis of 85 crosses is $26.24 \pm 3.22\%$.

4. Crosses between cultivars or inbred lines of different hybrid forms, as $CD_1 \times CD_3$, $CD_1 \times D_1D_2$, $CD_1 \times D_1D_3$, $CD_1 \times D_2D_3$, $CD_3 \times D_1D_2$, $CD_3 \times D_1D_3$, $CD_3 \times D_2D_3$, $D_1D_2 \times D_1D_3$, $D_1D_2 \times D_2D_3$, $D_1D_3 \times D_2D_3$: The average heterosis of 14 crosses is $44.22 \pm 8.42\%$.

The differences in heterosis percentage of yield produced by the above four kinds of cross combinations are statistically significant, $p < 0.01$. It is suggested that crossing cultivars or inbred lines of different varieties or morphotypes, especially in stabilized hybrid forms, is much preferable for obtaining heterosis in yield. However, it was found that high heterosis was produced by crossing some inbred lines of the same morphotype. Furthermore, other economical characteristics besides yield must also be considered.

LITERATURE CITED

MODERN

- Li, C. W. 1954. Chinese cabbage. (In Chinese). Biol. Mag. No. 5.
 Li, C. W. 1962. Problems on the origin and evolution of Chinese cabbage. (In Chinese). Hort. Mag. 1: No. 3-4.
 Richhardia, R. H. 1937. Cytological investigations of 10-chromosome species of *Brassica* and their hybrids. J. Genet. 37:45-55.
 Yarnell, S. H. 1956. Cytogenetics of vegetable crops. II. Crucifera. Bot. Rev. 22:81-116.

CLASSICAL (in Chinese)

- Chao-Mo-Dian in Gu-Jin-Tu-Shu-Zin-Chen (Classics of Herbs and Woods in Encyclopedia of Ancient and Present Books). Chin Cynastic Scholastic Bureau. 17th century
 Shi-Jing (Classics of Poems). 5th century BC.
 Shian-Tian-Fu-Tse (Local Records of Shian-Tian-Fu). 17th century.
 Su Sung: Ben-Chao-Tu-Jing (Classics of Illustrated Medical Herbs). 10th century.
 Wang Shi-Mu: Shue-Pu-Tsa-Su (Miscellanea on Gardening). 14th century.

DISCUSSION

Dr. FRITZ: Did you find, in your collection, any material resistant to clubroot? Do you have any hope that it will be possible to find resistance in the future?

C. W. Li: We did not find any cultivar immune to clubroot, virus, downy mildew and softrot. But cultivars do differ in resistance. The dark colored cultivars are usually more resistant to diseases. Trying to cross dark colored cultivars with the light colored for developing resistant light colored cultivars was not successful.

C. Y. LIN: What are the most important diseases of Chinese cabbage in China? How do you control them? Are there any softrot resistant cultivars?

C. W. LI: There are three important diseases of Chinese cabbage:

1. TuMV: Control of aphid vectors is the most effective way to control this disease.
2. Downy mildew: Systemic fungicide spray is effective.
3. Softrot: Leveling plots well to ensure even irrigation helps to reduce softrot incidence.

The most effective way of avoiding these diseases is to grow Chinese cabbage in cereal production areas, not in areas previously given over to vegetables.