CHINESE CABBAGE

PROCEEDINGS OF
THE FIRST INTERNATIONAL SYMPOSIUM

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1981

Asian Vegetable Research and Development Center
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Avrard Publication No. 81-138

Printed by
Hong Wen Printing Works, Tainan
The Origin, Evolution, Taxonomy and Hybridization of Chinese Cabbage

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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 (N), 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 (Netzey)). By developing the heading 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) ovate 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 ovate (C×D1), fluffy-topped cylindrical (C×D1), flat-topped ovate (D1×D2), stout-cylindrical (D1×D3) and flat-topped cylindrical (D2×D3). In 198 crosses 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 Brassicaceae 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 ABCDEF, and that of ssp rapifera was ABCDEEFF, 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 underway 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:
1. LI ORIGIN OF CHINESE CABBAGE

(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. infarcta 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) Oval type (f. ovata Li): Head ovate, height/diameter index approximately 1.5, vernation 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, vernation 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, vernation of terminal bud leaves convolute, leaf-tips closing on the top, but not overlapping; rosette leaves ovolanceolate, 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 3⁶, only the following five valuable ones (Figure 1) were found to be used in production.
(D_1D_1) 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.

(CD_1) 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.

(D_1D_2) 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 Brassica. 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 netioed 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 infravagata appeared. As a results of gardeners improving their cultural practices further and paying attention to selecting more solid heads when they grew f infravagata, 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 Shiu-Tian-Fu-Tse (Local Records of Shiu-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-man 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 (S. 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 oblong-ellate leaves with convolute
vernation. It is also evident that the three types of var ophalata
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 loca-
Figures between areas growing different varieties or types.

It is evident that in Chinese cabbage, the characteristics of primiti-
ve forms are often, though not always, dominant over those of the
advanced ones. When var dissolata is crossed with the other varieties,
not all F₁ hybrids will form heads. When var infarata is crossed with
var laxa and var ophalata, 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 con-
duplicate 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 be-
tween the three types of f ophalata 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 ophalata 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
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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 F1 hybrids, as summarized here:

1. Crosses between cultivars or inbred lines within the same basic 
form, as C × C, D1 × D1, D2 × D2, D3 × D3: The average heterosis of 49 
crosses is 10.16±2.47%.

2. Crosses between cultivars or inbred lines of different basic 
forms, as C × D1, C × D3, D1 × D2, D1 × D3, D2 × D3: The average hetero-

s of 82 crosses is 20.44±2.19%.

3. Crosses between cultivars or inbred lines of a basic form with 
those of a hybrid form, as D1 × CD1, D1 × CD3, D1 × D1D2, D1 × D1D3, 
D1 × D2D3, D2 × CD1, D2 × CD3, D2 × D1D2, D2 × D2D3, D3 × CD1, D3 × CD3, 
D3 × D1D2, D3 × D1D3, D3 × D2D3: The average heterosis of 85 crosses is 26.24±3.22%.

4. Crosses between cultivars or inbred lines of different hybrid 
forms, as CD1 × CD3, CD1 × D1D2, CD1 × D1D3, CD1 × D2D3, CD3 × D1D2, 
CD3 × D1D3, CD3 × D2D3, D1D2 × D1D3, D1D2 × D2D3, D1D3 × D2D3: The aver-
age heterosis of 14 crosses is 44.22±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 charac-
teristics besides yield must also be considered.

LITERATURE CITED

MODERN


Richardia, R. H. 1937. Cytological investigations of 10-chromosome 


CLASSICAL (in Chinese)

Chao-Mi-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.