BREEDING OF CUCUMBER, SWEET PEPPER AND CHINESE CABBAGE FOR ADAPTABILITY TO SUMMER CROPPING IN CHINA

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ABSTRACT

To develop vegetable varieties adapted to summer cropping in Shanghai and Guangdong, performance of accessions and crosses among them in earlier and later croppings, and possibility of convenient screening techniques for the adaptability were examined. Cucumber : In Shanghai, the yield of the North Chinese accessions was less reduced in summer than that of the Japanese accessions. In Guanzhou, the Japanese accessions and crosses between Japanese and South Chinese F_1s performed well. Difference in yield reduction in summer among varieties and locations was related to the difference in virus disease severity and reduction of vegetative growth. The difference in heat tolerance between summer and spring cucumber varieties could be estimated by analysis of electrolyte leakage or chlorophyll reduction rate of detached and heated leaves. Pepper : Chinese semi-hot peppers gave a high yield. Medium bell accessions were generally productive among the sweet pepper varieties. In the large bell accessions with fewer fruits, both the number and size of fruits were markedly reduced in summer. The reduction was related to virus disease severity and the reduction of vegetative growth. Crosses among Japanese or Chinese accessions and Japanese CMV resistant selections gave higher yield mainly through hybrid vigor in vegetative growth. Chinese cabbage : Productivity in summer cropping was largely determined by the heading ability and soft rot resistance. The former was observed only among accessions of the tropical type. Introductions from AVRDC performed best. The larger the number of distinctive characteristics of the tropical type in the accessions, the higher the heading rate. The heading ability could be estimated based on the morphological and physiological characteristics of the outer leaf. The highest resistance to soft rot was found among the autumn varieties. The size of the individuals in the crosses among varieties became larger but the heading rate was not enhanced.

Introduction

The five year joint research project between Japan (Tropical Agriculture Research Center) and China (Shanghai and Guangdong Academies of Agricultural Sciences) on the improvement of vegetable production in the tropics was initiated in 1986. The activities of the breeding groups are as follows :

1) Yearly evaluation of domestic and foreign accessions of cucumber, sweet pepper and Chinese cabbage to identify elite varieties for production or breeding materials in

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each location. Also the factors controlling a higher summer production are being analysed.

2) Breeding varieties for summer cropping. Crosses among accessions are made and evaluated as materials for further breeding or as new F_1 varieties for short term breeding.

3) Development of screening techniques for heat tolerance. The achievements of the breeding group in 1988 will be presented in this report.

Cucumber

Variety trials in Shanghai

North Chinese and Japanese summer-autumn cucumber varieties, and some other foreign accessions were evaluated in the early summer (May 20-August 1) and late summer (July 26-September 28) croppings (abbreviated as EC and LC, respectively). The former had long massive fruits with a rough or smooth surface while the latter had medium slender fruits with a smooth surface. All of them had white spines with or without protrusions.

In the EC, yield as a whole was not much different between the two varietal types. In the LC, while the yield was reduced in general compared with the EC, the reduction rate of yield was remarkably greater in the Japanese accessions (Fig. 1). Varietal differences in the yield and the yield reduction were determined much more by the fruit number than by the fruit weight. While the North Chinese accessions to some extent compensated for the decrease in fruit number by maintaining the fruit weight, both the fruit number and weight remarkably decreased in the LC in the case of the Japanese accessions.

High-yielding North Chinese accessions were less affected by virus diseases caused by CMV, ZYMV and WMV (Fujisawa *et al.*, 1989), and downy mildew than the Japanese

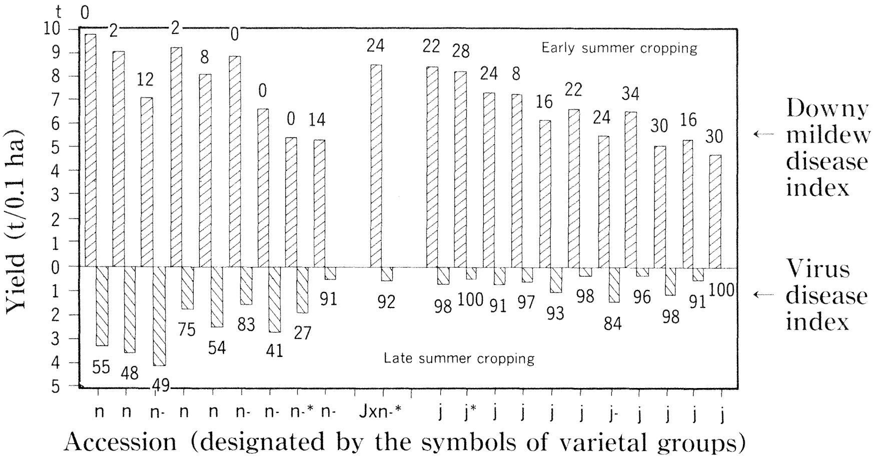

Fig. 1 Yield and disease incidence of Japanese and Chinese cucumber varieties in the early and the late summer croppings in Shanghai

Varieties are arranged in the order of total yield of the two croppings and represented by the combinations of the following symbols. 1) origin 'j' : Japanese, 'n' : North Chinese 2) type '—' : pure bred, 'x' : hybrid between two varieties designated by '*'. Varieties without '—' or 'x' are commercial F_1 varieties.

accessions. The latter and American CMV resistant introductions were severely damaged. The yield reduction was predominantly affected by the virus disease severity (Fig. 1). Reduction rate of plant height of apparently or nearly healthy plants was partly correlated with that of yield, while the plant height itself showed no relation to the yield. Highest-yielding accessions were of the concentrated fruiting type, but such fruiting type was not always associated with high yields.

Breeding in Guangzhou

A set of breeding materials involving 'Xiaqing 2', a standard South Chinese cucumber variety in Guangzhou, and three Japanese F_1 varieties selected as promising in the preceding trials, their F_2s (selfed F_1) and crosses between 'Xiaqing 2' and Japanese F_1s were grown in the spring (March 19-June 16) and summer (July 19-September 7) croppings (abb. SPC and SUC, respectively) together with several Chinese and Japanese summer-autumn varieties.

Though yields were generally higher in the SPC, varietal differences in yield were not as remarkably affected by the growing season as in Shanghai. The set of breeding materials including Japanese materials generally performed equally or better than the other North or South Chinese F_1s and local varieties (Fig. 2). The crosses between the F_1s were mostly more productive than their parental F_1s or F_2s. Their advantage was greater in the SPC. The crosses between F_1s produced more fruits and gave a higher yield when 'Xiaqing 2' was used as a female parent. As the Japanese counterparts, 'Tubasa' and 'Kofu yokusei 3' were best in the SPC and in the SUC, respectively. There was practically

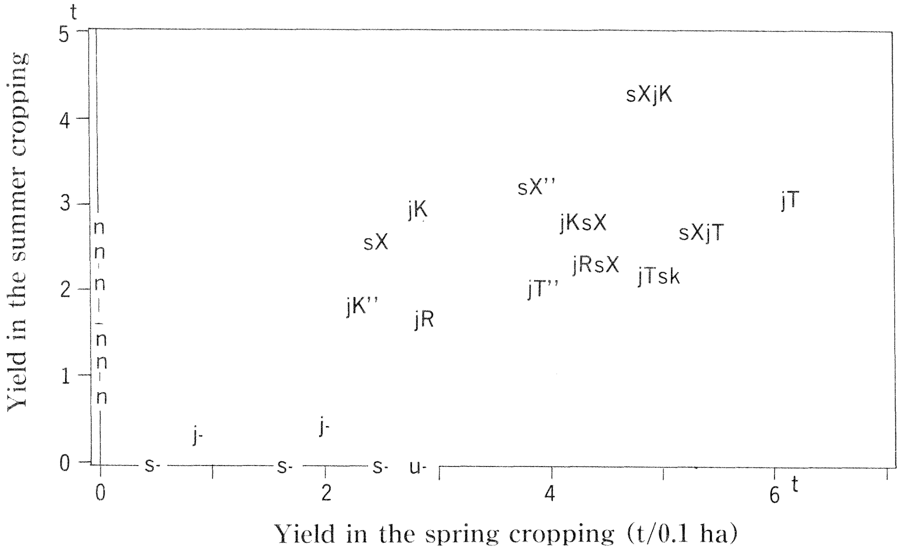

Fig. 2 Yields of Chinese and Japanese cucumber varieties and their hybrids in the spring and the summer cropping in Guangzhou

Varieties and hybrids are represented by the combinations of the following symbols. 1) origin 'j' : Japanese, 'n' : North Chinese, 's' : South Chinese varieties 2) type '—' : pure bred, '"' : selfed commercial F_1 varieties (F_2), without '—' or '"' : commercial F_1 varieties 3) variety name 'X' : Xiaqing 2, 'T' : Tsubasa, 'K' : Kofu Yokusei 3, 'R' : Rensei. Combinations involving two symbols of variety indicate the hybrid between them. Varieties on the X- or Y- axis were tested in either the spring or the summer cropping only.

no noticeable difference in the fruit uniformity in the set of breeding materials involving F_1 varieties, their F_2s and crosses between F_1s. The uniformity was apparently affected more by the original fruit shape and plant vigor than by the generations of the materials. Long and slender fruits of the North Chinese varieties displayed more often irregular curvatures than the short and thicker fruits of the South Chinese varieties. Though the crosses matured early, they maintained a high plant vigor throughout the growing season.

The same virus diseases as those in Shanghai were prevalent in the SUC but they were not as severe. The highest resistance was found among the North Chinese varieties. Yield difference among the set of the breeding materials, including the difference between the reciprocals of the crosses, mostly corresponded to the severity of the virus diseases.

Screening techniques

Chlorophyll content of the detached leaves of the Chinese and Japanese spring and summer cucumber varieties before and two days (in the dark) after heat treatment was measured using the SPAD-501 greenmeter (Yadava, 1986) and the reduction rate was calculated. Electrolyte leakage by heating (Lester, 1985) was also measured as widely used heat injury index. The chlorophyll reduction and the electrolyte leakage rate of the spring varieties were as a whole greater than those of the summer varieties in either the Chinese or the Japanese varieties. The rate was generally higher and the varietal difference was greater in the Chinese varieties (Table 1).

Discussion on cucumber trials

In both Shanghai and Guangzhou, the yield of the LC was lower than that of the EC. The reduction rate of yield in the LC was closely related to virus disease severity. Japanese F_1 varieties performed better in Guangzhou than in Shanghai in the LC. The difference in the varietal performance between the two locations was also related to the

Table 1 Heat tolerance of detached leaves of Japanese and Chinese summer and spring cucumber varieties expressed by the rapidity of yellowing and electrolyte leakage

Variety	type[b]	Reduction rate of chlorophyll content				Electrolyte leakage
		9/26[a]	10/08[a]	10/12[a]	mean	9/26[a] 10/08[a] mean
		%	%	%	%	%
(Japanese varieties)						
Natsu Sango	Nwa	17	8	5	10	12
Shimoshirazu Jibai	Swa	22	14	10	15	13
Sagami Hanjiro	Sbs	20	14	8	14	13
Ochiai Aonaga	Sbs	23	20	15	19	14
(Chinese varieties)						
Xiezuo 17	Nwa	23	16	12	17	13
Jinyan 4	Nwa	20	19	13	18	14
Luchun 32	Nwas	22	19	14	18	14
Changchun Micu	Nws	28	23	18	23	19
Yanghang	Sbs	30	30	19	26	18
LSD (5%)					3	5

a) Seedlings were sown on September 3 and grown in a closed glasshouse. Leaves were sampled on each date, divided into two parts and used for each test.
b) N-North Chinese type, S-South Chinese type,
w-white-spined, b-black-spined,
a-summer-autumn variety, s-spring variety.

difference in the virus disease incidence. Since in Guangzhou virus diseases are usually more prevalent than this year, virus disease resistance is regarded as one of the main factors controlling the adaptability to summer cropping in these locations. Yield reduction mainly resulted from the decrease in the fruit number, which was presumably associated with virus disease damage. Among the viruses identified in the area (Fujisawa *et al.*, 1989), ZYMV and WMV are probably more important, since a large number of white-spined summer cucumbers are known to be resistant to CMV (Igarashi *et al.*, 1986).

Since the reduction rate of the height of the plants with few disease symptoms was related to that of yield, it is suggested that some kind of stress tolerance of vegetative organ other than disease resistance affected the yield, though the influence of disease could not be completely eliminated from the analysis. The present physiological tests indicated that the heat tolerance of the leaf tissues of the summer varieties was higher than that of the spring varieties. The productive crosses between the South Chinese and Japanese varieties tested in Guangzhou were more tolerant to water stress than the Japanese varieties (Hanada, personal communication). The contribution of such physiological adaptability to the productivity in summer should be further examined.

Since the growing period of summer cucumber is usually very short in China, concentrated fruiting habit is advantageous. Actually the highest-yielding accessions belonged to this type. But this characteristic alone played a less important role in yield in summer than disease or other stress tolerances. Without a sufficient plant vigor, concentrated fruiting can only increase the incidence of deformed fruits by increasing the fruit load on the plant (Kanahama, 1989).

The screening techniques for heat tolerance, i. e. chlorophyll reduction and electrolyte leakage rate of leaves gave similar results. The varietal differences obtained were, on the varietal type basis, similar to those in heat tolerance (Aoki *et al.*, 1988) and chilling sensitivity (Aoki *et al.*, 1987) measured by chlorophyll fluorescence. The results do not agree with the summer field performance of the varieties in that the high-yielding North Chinese varieties did not give a better score than the Japanese varieties. The apparent discrepancy can be attributed to the difference in the disease resistance of the two groups. The chlorophyll reduction rate which reflects the rapidity at which yellowing occurs is an indicator of aging. As the dark condition primarily promotes yellowing and heating apparently only accelerates the process, it may not be a direct expression of heat tolerance. The measurement is quite easy and the results were satisfactory for the small samples tested, but further investigations are required.

Summer-autumn cucumber varieties belong to the North Chinese type in Shanghai and mainly South Chinese type in Guangzhou. In both areas, the Japanese varieties have a higher local preference than the North Chinese type for fruit shape and than the South Chinese type for taste or texture, respectively. Though the Japanese varieties cannot contribute to disease resistance, they can be superior materials for improving the quality. Actually some of the Japanese F_1 varieties tested could be used in commercial production in spring or early summer when the disease incidence is not as critical as in summer. While the selection will be continued starting from the crosses between the Chinese and Japanese F_1s, the crosses themselves will be tested in several areas in Guangzhou for certification.

Sweet pepper

Variety trials in Shanghai

Chinese, Japanese, American and Taiwanese sweet pepper and several Chinese semi-hot pepper accessions were tested in the earlier (February 25- August 3) and later (March 25- September 1) croppings (abb. EC and the LC, respectively).

Chinese semi-hot peppers recorded the highest yield in the EC (Table 2). These and the Japanese medium bell (abb. MB) F_1 varieties were relatively productive both in the EC and LC. Many of the Japanese bell accessions had smaller fruits than the Chinese bells. Either Japanese or Chinese MBs had more fruits and gave higher yields in both the EC and LC than the large bells (abb. LB). The yield of the LB accessions was especially low in the LC, except for a Taiwanese variety. Japanese finger varieties (sweet, thin-walled) produced the largest number of fruits, though the yield was not high. Japanese F_1s of the intermediate type between the bell and the finger varieties showed a medium productivity, which decreased considerably in the LC. American accessions gave low yields and the yield reduction in the LC was highest regardless of the fruit size and shape.

Among the accessions of the bell type, the fruit number contributed more to the yield than the fruit weight. The contribution of the fruit number was larger in the LC. Reduction rate of the fruit number in the LC was smaller in accessions with many fruits in the EC while that of fruit weight was larger in those with large fruits. The Chinese accessions had more compact canopies than the Japanese or the American accessions. The majority of the LB and some of the small-fruited accessions had large leaves. Those with large leaves showed a higher rate of yield reduction. Japanese MB F_1s were generally less affected by virus diseases including TMV-P and CVMV (Fujisawa *et al.*, 1989) than the Chinese accessions except for hot peppers. The reduction rate of the yield was related

Table 2 Yield, virus disease incidence and earliness of flowering of pepper accessions in Shanghai and Guangzhou

(Shanghai) Variety	Type[a]	Yield (/0.1 ha) E. C.[b]	L. C.[c]	Virus D. I.[d]	(Guangzhou) Variety	Type	Yield[e] (/0.1 ha)	1st[f] Flower
		t	t				t	July-
Chigusa	JF b	1.4+[g]	1.5++	24++	Zaofeng 1	CF sbh	0.9	4
Zaofeng #	CF sbh	1.6++	1.2++	19++	T. 8312	CF b	0.8	4
Ace	JF b		1.2++	34+	Tienjianjiao 1	C L	0.8	6
Sujiao 2	CF 1 h	1.8++	0.9+	40+	Bell Homare	JF b	0.6	5
New Ace	JF b	1.5++			Akino	JF sb	0.5	8
Bell Homare	JF b	1.4+	1.0+	32+	Chihaya	JF b	0.5	5
Akino	JF sb	1.2+	1.2++	37+	CPO 1	J b	0.4	7
Baixing	T B	0.0	0.9+	59	Ryokuo	JF b	0.4	6
Suigyoku 2	JF b	1.2	0.9+	30++	Suisan	JF s	0.3	11
Jiapei 3	CF b	1.0	0.9+	55	Ryuo	JF b	0.3	13
King	J B	1.3+	0.5	60	Shanghai Q.	C b	0.3	9
Suiko	JF s	1.1			Zhongjiao 2	CF b	0.2	16
Bayan T.	C b	1.1	0.6	60	Shuryoku	J b	0.2	6
Shuryoku	J b	0.7	0.7+	48+	Saitama	J B	0.2	20
Jiangqiao Q.	C B	1.2+	0.3	74	Erzhuju	C b	0.1	16
Hunjiao 1	C B	0.8	0.6	57	Miyoshi Kyoho	J B	0.1	15
Kyonami	JF b	1.0	0.3	49	King	J b	0.1	17
Guanghua T.	C B	1.0	0.3	40+	Myojo	J B	0.1	18
Yolo Wonder	E B	0.9	0.2	80	World Crown	E B	0.1	21
Suizan	JF s	0.8			Seiyo W. Oama	J B	0.1	17
Keystone R. Giant	E B	0.7	0.1	76	Eiko	J B	0.1	16
					Australian P.	E B	0.0	20
					Giant Bell	E B	0.0	18
					Hodaka W. Ogata	J B	0.0	17
					Nigerian P.	E B	0.0	21

abbreviation of variety names :
T.-Tianjiao, Q.-Qiemen, W.-Wase,
R.-resistant

Accessions were arranged in the order of yield (Guangzhou) or the sum of yield (Shanghai).

a : J-Japanese, C-Chinese, T-Taiwanese, E-other origin, F-F1 varieties, L-long, l-small long, s-'Shishito' (thin-walled finger type), sb-slender bell, b-medium bell, B-large bell (optimum fruit weight>50 g), h-semi-hot.

b : Earlier cropping (February 25-August 3).

c : Later cropping (March 25-September 1).

d : Disease index (0-100)   g : ++ 1st and + 2nd quartile.

e : May 25-October 25   f : 1st flowering date.

to that of the canopy size of plants with few disease symptoms and the increase of virus disease severity (Table 3). The contribution of the former and the latter to the yield reduction was mainly through the effect on the fruit number and weight, respectively.

Variety trials in Guangzhou

Chinese, Japanese and some other sweet pepper and a Chinese semi-hot pepper accessions were tested in the summer cropping (May 25-October 25). Highest yield was achieved by three Chinese accessions including a semi-hot accession (a popular hybrid variety between a local hot pepper variety and a sweet bell, 'Qiemen'), a newly developed F_1 sweet pepper variety, and a long-fruited one developed from an African introduction (Table 2). In addition, several Japanese F_1 MB peppers and a true bred of the same type which is assumed to be partly parthenocarpic performed well. Except for the latter, true bred accessions gave low yields. LB accessions were less productive regardless of their origin, though the Japanese ones generally gave a higher yield than the Western introductions. There was no correlation between the fruit number and weight among the accessions, and the former determined the yield except for a small finger variety. Virus diseases, bacterial leaf spot and stem blight diseases (unidentified) caused severe damage in the later growing period. The highest-yielding Chinese accessions were less affected by these diseases. Vegetative growth of the Western accessions was markedly restricted. Among the others, no relation was found between the canopy size and yield. High-yielding accessions had a smaller number of nodes up to the 1st flower. When the number was equal, they flowered earlier. The opposite was the case in the LB accessions.

Breeding in Guangzhou

From the crosses between several CMV and Phytophthora blight-resistant materials given by Dr. E. Pochard and the Japanese varieties, 'Ccm' lines screened for CMV resistance and 'CM' lines screened for fruit characters were selected at NIVOT. These selections, local varieties in Guangzhou and Japanese F_1s were grown in an unheated greenhouse in winter. Several crosses were made among these materials and grown with the accessions of the variety trials in summer.

Table 3 Correlation between the reduction rate of yield and growth parameters and the increase of virus disease severity in the later cropping

Reduction rate of[a]		Correlation coefficients				
		Yield	FN	FW	CW	LL
Fruit number	FN	0.89**[c]				
Fruit weight	FW	0.48*	0.05			
Canopy width	CW	0.65**	0.54**	0.26		
Leaf length	LL	0.32	0.14	0.38	0.42	
Virus dis. index[b]	VI	−0.58**	−0.42	−0.51*	−0.54*	−0.24

Reduction rate of[a]		Partial correlation coefficients[d]		
		CW	VI[b]	CWxVI
Yield		0.49	−0.36	−0.26
Fruit number	FW	0.41	−0.18	−0.41
Fruit weight	FW	−0.01	−0.44	−0.43

a) Reduction rate of the parameters (except for virus disease index) of the later cropping to those of the earlier cropping.
b) Increase of virus disease index from the earlier to the later cropping.
c) **, *-Significant at 1% and 5% level, respectively.
d) Figures on each row were calculated for each set of four variables including those on the left column. CW (canopy width), VI (virus disease index), and the interaction term of CW and VI.

In winter, the Guangzhou local varieties bore smaller bell fruits, matured late and were much less productive than the Japanese F_1 MB varieties. Fruit size and numbers of 'Ccm' and 'CM' lines were different between Guangzhou local varieties and Japanese F_1s. In the summer cropping, the difference in yield among the parental materials was not as large as that in the winter cultivation. Many of the crosses recorded a higher yield than their parents, and some of the best crosses were comparable to the best accessions in the variety trial. The majority of the fruits was small to medium in size and crosses with larger fruits gave a higher yield. The Guangzhou local varieties and the crosses involving 'Ccm' lines were more resistant to virus diseases. The crosses with the Guangzhou local varieties were more resistant to leaf spot and stem blight diseases than the others. As a whole, the crosses survived longer than the majority of the accessions in the variety trials.

Discussion on pepper trials

In Shanghai, two-hot F_1 varieties and several Japanese MB F_1s recorded a high yield. In Guangzhou, a semi-hot F_1, a Chinese MB F_1 and a long-fruited true bred derived from an African introduction ranked high, followed by Japanese MB F_1s. Since hot peppers are known to be generally more tolerant to a summer environment than sweet peppers in China and have been often grown in areas where sweet peppers could not be produced in summer as Guangzhou, highest adaptability is likely to be found among hot peppers. Actually, the semi-hot accessions involved in the present trials performed well in both locations. The trials, however, also suggested that the improvement of the adaptability of sweet peppers is still possible using sweet pepper materials.

Accessions with high yield were less affected by diseases. The increase of virus disease severity partly determined the yield reduction in the LC. The majority of the Chinese accessions was more affected. Virus infection may involve seed transmission of TMVs (Nishiyama, 1962) under roughly controlled seed harvesting and handling methods. The high-yielding Japanese F_1s were not resistant to TMV-P (Nagai, 1989), but the most prevalent viruses were reported to be TMV-P and CVMV (Fujisawa *et al*., 1989). Investigation on the kind of virus diseases affecting yield is still required. The increase of virus damage and the reduction of vegetative growth in the LC apparently affected more the reduction of the fruit weight and number, respectively. Some other stress tolerances of vegetative organs than disease resistance seemed to have played a role in the varietal performance, though the same problems as those in the case of cucumber trials affected the analysis.

MB varieties with good fruit-setting were more productive throughout the trials. Though thick-walled large fruits are favored by the people, the varieties with such fruits gave a lower yield especially in summer and branches are more often broken especially in the case of the California wonder type. More important was the later maturity, which prevents them from setting a number of harvestable fruits before they were exposed to a most adverse environment.

Since a partly parthenocarpic line with ordinary characteristics of Japanese MB peppers performed well, it is suggested that parthenocarpy genetically controlled (Shifriss and Eidelman, 1986) may enable to achieve higher yield with larger fruits especially in summer production. Though most of the LB accessions were less adapted to the summer environment, better ones like a Taiwanese accession with some of the characteristics may be utilized for the breeding.

The beneficial effect of hybrid vigor on yield was clearly seen in the majority of the crosses tested in the summer cropping in Guangzhou. Though virus disease resistance was not appreciably improved by the crossing except for the combinations where 'Ccm' lines were involved, both the fruit number and weight of the crosses exceeded those of their mid-parents possibly due to their higher vegetative growth. 'Ccm' lines keep the characteristics of original wild materials and may harbour another kind of resistance than CMV resistance.

Guangzhou local varieties are primitive, less productive varieties, but the crosses with them performed relatively well in the summer cropping. Under severe environmental conditions where high yield cannot be expected, while early maturity enables to overcome most of the unfavorable growing conditions, the maintenance of vigorous vegetative growth for a longer period of time by avoiding concentrated fruiting may be another option to secure total yield.

Chinese cabbage

Variety trials in Shanghai

Japanese, Chinese and Taiwanese (given by AVRDC as heat-tolerant) accessions of heading Chinese cabbage of varying maturity were grown in the summer (July 28-October 8) and autumn (September 10-November 25) croppings (abbreviated as SC and AC, respectively). In addition to the routine items of examination, several morphological and physiological traits were analysed as parameters of the heat tolerance.

All the accessions headed normally in the AC. In the SC, only the Taiwanese and Japanese accessions of the tropical type (abb. TT) were able to form head in early autumn. Within a few weeks later some of the Chinese and Japanese autumn varieties (abb. AT) with early to medium-early maturity formed heads as the temperature decreased, though their heading rate was mostly lower than that of the former. None of the late maturing AT accessions could form a head well even after the temperature became cool. A Chinese michihli variety was most resistant to soft rot disease, though it did not form heads. In general, only the accessions heading tightly in the AC could form heads in the SC.

TT accessions were characterized by an early maturity and overall small size, smaller number of outer and inner leaves with relatively thick petiole, round leaves and head, larger proportion of inner stem and root weight in total weight. The more the accessions harboured these traits, the higher was their heading rate in the SC. Leaf index was well correlated with the heading rate (Table 4). While the round leaf shape apparently facilitated heading regardless of varietal maturity, TT varieties showed a higher heading rate than AT varieties for the same level of leaf index.

Higher dry matter percentage (abb. DM) of outer leaf, higher electric conductivity (abb. EC) and brix value of outer leaf sap were apparently associated with better head-forming (Table 4). None of the accessions with low values of all these three factors could form head well in the SC. High EC may be an attribute common to TT or early maturing varieties, since they have generally a high EC value regardless of their heading rate in the SC. Among the early varieties, the majority of those with a low brix value showed a lower heading rate, while a high brix value was recorded among the autumn varieties with low heat tolerance. DM was correlated with the heading rate among the tropical varieties but not among the autumn varieties.

Variety trials in Guangzhou

Partly different accessions of the same varietal groups as in Shanghai were tested in the SC (July 1-September 21). Since high temperature lasted longer and rainfall was heavier than in Shanghai, yield was more affected by the survival rate determined by soft rot incidence, and the heading rate among the plants which survived was more strictly controlled by the earliness of maturity. The accessions could be grouped based on the two parameters (Fig. 3).

Taiwanese accessions with the earliest maturity and Japanese TT F_1s recorded the highest heading rate among the plants which survived. The yield of the latter was lower due to the lower survival rate. While the heading rate of the Taiwanese accessions varied widely depending on their maturity, they were less affected by soft rot regardless of their heading rates. The Chinese TT variety most popular in Guangdong showed a lower

Table 4 Relation between head formation of Chinese cabbage accessions in summer and autumn croppings and several characteristics of outer leaves in autumn cropping in Shanghai

Criterion variables	Summer cropping Heading rate (%)[a)]			Autumn cropping Heading date		Autumn cropping Head weight	
Independent variables in autumn cropping ↓	r[b)]	b[c)]	b[c)]	r[b)]	b[c)]	r[b)]	b[c)]
Calculated for all accessions in the trial							
Heading date	−.55	−.29					
Head weight	−.43			.64			
Leaf shape index[e]	−.67	−.60	−.66	.18		.15	
Leaf weight	−.48	−.26	−.33	.62	.24	.88	.85
Leaf dry matter (%)	.51			−.53	−.34	−.60	−.47
EC of leaf sap	.32		.23	−.67	−.51	−.43	
Brix of leaf sap	.13			.11		−.19	
R *[d]		.82	.82		.82		.91
Calculated for accessions with head weight below 1.5 kg							
Heading date	−.42	−.30					
Head weight	−.19			.45			
Leaf shape index[e]	−.86	−.77	−.78	.18		. 3	
Leaf weight	−. 1			.34	.29	.78	.79
Leaf dry matter (%)	.52		.28	−.51	−.40	−.43	
EC of leaf sap	.15		.15	−.48	−.51	−.10	−.31
Brix of leaf sap	.30	.17		.11		−.20	−.24
R *[d]		.92	.92		.74		.84

a) Percentage of headed plants among those which survived until September 19.
b) Correlation coefficients.
c) Partial regression coefficients, variables were selected by stepwise regression analysis.
d) Multiple correlation coefficient (adjusted by the degree of freedom).
e) Leaf length/width. All the measurements of the leaf characteristics were made on the largest outer leaves before heading.

heading ability and soft rot resistance than any of the Taiwanese accessions.

Japanese F_1s of the intermediate type between the TT and AT varieties, whose maturity was a little later than that of the above two groups, showed a higher survival rate but lower head formation ability. The majority of them continued to spread rossette leaves. None of the common AT varieties could form head at all while their soft rot incidence varied widely. Highest soft rot resistance was shown by a Japanese michihli variety as was the case in Shanghai.

Breeding in Guangzhou

Crosses among varieties (including F_1s) differing in their origin and maturity were grown in the early AC (August 11-October 25) to select parental materials for F_1 breeding. Hybrid vigor was revealed in size factors such as head weight in most of the combinations. Heading rate was as a whole not enhanced by crossing. In some crosses it was reduced possibly due to their later maturity. Crosses among early TT varieties with compact heading always produced compact heads. Crosses with a medium early AT variety always resulted in looser heading than their parents. Yield increase by crossing was specific to combinations. Best crosses were among those between a Taiwanese heat-tolerant accession with early maturity and a Japanese or a Chinese variety with medium early maturity.

Discussion on Chinese cabbage trials

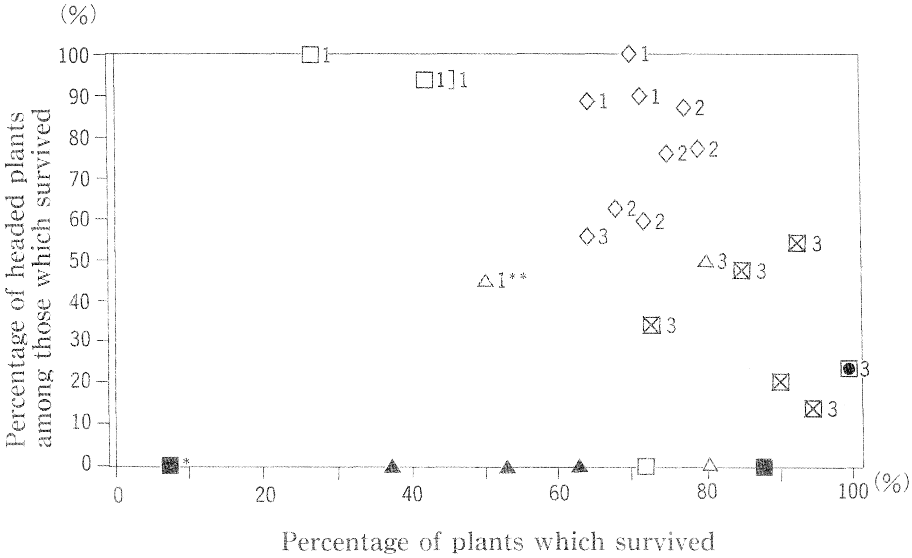

Fig. 3 Survival and heading rate of Chinese cabbage varieties in summer cropping in Guangzhou

Origin of seeds : □-Japanese, △-Chinese, ◇-Taiwanese, type : (inside of the symbols) □ (blank)-tropical variety, ⊠ : intermediate type between tropical and autumn variety, ■-autumn variety, ▣-michihli, *-soft rot susceptible check variety, **-standard variety in Guangdong.

The numbers (1 to 3) beside the marks indicate the relative earliness of heading. 1 : early (head formation before September 7) -3 : late (later than September 12).

Only some of the TT accessions could perform well in the SC. The yield in the SCs was largely controlled by the heading rate and soft rot disease incidence. Japanese TT accessions showed the heading ability in the SC but were not resistant to soft rot disease. Chinese local TT accessions did not display either characteristics. Only the Taiwanese TT had accessions showing both attributes. Highest soft rot resistance was found among the AT accessions, though they could not form a head in the SC. Original head firmness was an absolute requirement for heading in the SC.

As reported by several authors (Kuo and Tsay, 1981, Opena and Lo, 1981, Yoon and Lee, 1981), heat-tolerant TT accessions were characterized by earliness of maturity, small heads and several distinctive morphological and physiological traits. Among them, earliness of maturity decreases the risk of the incidence of diseases and other disorders. Many of the distinctive shape factors which minimize the plant surface/volume ratio and high osmotic pressure in plant sap with high EC or brix enable to retain plant water, while leaf turgidity is a prerequisite for heading (Kuo and Tsai, 1981).

Since maturity, head shape and size, and heading ability in the SC were correlated with several characteristics of the outer leaves, those characteristics were expected to be predictable to some extent before transplanting. Though none of the single traits could well account for the varietal differences, some combination of key traits such as those listed in Table 4 may be utilized for early screening. Such prediction could be especially useful when selecting heat-tolerant stock plants in the AC. It is difficult to harvest seeds from selected plants in the SC due to the high rate of disease incidence.

Early maturity leads to small head and lower yield. Small head and those water-saving characteristics will not be appreciated by the local markets and consumers. As they are relevant to heat-tolerant varieties, it is difficult to combine all the desired characteristics. The current project aims at the development of relatively high-yielding varieties with acceptable levels of heat tolerance which can be harvested earlier than the commercial varieties.

As heat tolerance of heading Chinese cabbage is basically controlled by a single recessive factor (Opena and Lo, 1979), it was not strictly evaluated in the present crosses. The heading rate was in general about average of that of their parents. When crosses are observed for the trait, it should be taken into consideration that hybrid vigor may increase head size and retard maturity, which could adversely affect the heading rate.

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Discussion

Saxena, M. C. (ICARDA) : Could you briefly describe the procedures used for the determination of heat tolerance using the chlorophyll reduction and electrolyte leakage methods. Also please indicate the number of samples for treatment that are necessary to be examined to obtain reproducible results.

Answer : The procedure of the chlorophyll reduction method is as follows : 1. Measure the chlorophyll content of detached leaf using the SPAD-501 greenmeter. 2. Keep the materials in a moist chamber and heat at 45°C for 1hr. 3. Leave the materials in the dark at room temperature for 2 days. 4. Measure the chlorophyll content again. 5. Calculate the reduction rate of chlorophyll content. A total of 9 spots×5 leaves×2 replications were measured at one time. The procedure of the electrolyte leakage method is as follows : 1. Leaf disks 1 cm in diameter are floated on distilled water. 2. After shaking for a few minutes the EC (A) is measured. 3. Leaves are heated at 48°C for 5 minutes, shaken and the EC (B) is measured. 4. The leaves are boiled and the total EC (C) is determined. The electrolyte leakage by heating is calculated as (B-A)/(C-A). The same number of samples from the same leaves was taken and treated as in the case of the chlorophyll reduction test. The difference between the Chinese summer and spring varieties listed in Table 1 was reproducible when the plants were grown at a higher temperature.

Aoki, S. (Japan) : In the screening method of chorophyll reduction, if the leaf disks are kept in darkness, senescence may occur. Can you differentiate the chlorophyll reduction induced by senescence from the heat-induced chlorophyll reduction ?

Answer : We have not studied this aspect. We obtained constant results only in four Chinese varieties. They are typical summer and spring varieties of North and South China origin, empirically known to be quite different in their performance in summer. As the genetic distance between them is much larger than that between Japanese commercial varieties, the method may not be applicable to the latter and should be further examined for other genotypes.