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Cabbage seed production in the subtropics[1]

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Abstract : Low temperatures are essential for cabbage flower induction. Most cabbage varieties cannot bloom and produce seeds in the tropics because of insufficiently low temperatures. Some shallow bolting types may flower completely in the highlands but fail to produce seed during the subsequent rainy season. According to the phasic development of cruciferous crops, plants were instead planted in the highlands for first phase (Thermo-phase) development, and then transplanted to the lowlands for second phase development.

The materials used were tropical Yehsen cabbage which requires only shallow low temperatures, and the northern K-Y cross Chu-Chiou cabbage which requires a deeper degree of low temperatures. The results show that flowering and seed ripening were accelerated by warmer and dryer (or longer day) conditions after complete vernalization. Seed production is thus possible by using different altitudes in the tropics corresponding to the phasic requirements of cabbage.

Seed production of cabbage in the tropics and subtropics is difficult because of insufficient winter chilling to promote flower development. Most cabbage varieties in Taiwan remain in the vegetative stage throughout the winter season. The local cv. Yehsen cabbage (shallow bolting type) does not require as low a temperature as other cabbage varieties to induce flowering and therefore can produce seed in the lowland subtropics. Insufficient low temperatures, however, induce only incomplete flowering, and thus seed yields differ from year to year and are much lower than those obtained in temperate regions. At high elevations, the winter chilling is sufficient to attain complete flowering, but the cabbage grows much slower and therefore flowers into the rainy season. Heavy rains prevent flower pollination, and the cabbage then rots [11].

Most seed-vernalizing and green-plant vernalizing cruciferae require long days and warm temperatures for bolting and flowering after vernalization [3,17,19]. Seed maturation also requires dry conditions. The southern and southwestern coastal areas of Taiwan have warm temperatures and a low relative humidity in the winter season. These conditions can be favorable for bolting and ripening seeds of cabbage after vernalization. The

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purposes of this experiment were to determine the optimal planting time for Yehsen cabbage seed production at Taiwan Seed Sevice (500m above sea level), and for completely vernalized plants transplanted in the southern and southwestern coastal areas. Timing for seed production of those varieties requiring lower temperatures and longer periods was also evaluated with crops planted first in highland areas and then transplanted to lowland areas. The results may provide some guidelines for cabbage seed production in the tropics and subtropics.

Materials and Methods

a. Yehsen cabbage sown at different times

Seeds were sown in seedling flats at Taiwan Seed Service (500m above sea level) on September 24, October 13 and November 1, 1975. One-month-old seedlings were transplanted to the field. Plants were observed for day-to-first-flower, and the number of leaves and stem diameter at flowering. If the plants did not bolt, after wintering, their heads were intersected to let them bolt. Seed yield, 1000-seed weight, seed number per milliliter, and seed germination rate were investigated after seed harvest.

b. Transplanting Yehsen cabbage to southern and southwestern coastal areas after vernalization.

Seeds were sown in seedling flats on September 28, and then transplanted on October 24, 1975 at TSS. After heading, the heads were cut on January 21, 1976 and then transferred to An-nan in Tainan city, Yen-shui of Tainan county, Hu-wei of Yun-lin county, and the experimental farm of TSS (Taichung county) to evaluate the potential for seed production in these areas. Days-to-harvesting and seed quality were observed.

c. Seed production methods for K-Y cross Chu-Chiou cabbage after vernalization

Seeds were sown at the Wu-lin Farm (1,700m above sea level) and at the lowland Fengshan Tropical Horticultural Experiment Station (FTHES) on June 15 and September 15, 1976 respectively. Plants at the Wu-lin farm were vernalized for a certain period and then transplanted to FTHES on November 18, 1976. Both treatments were observed for flowering and seed production efficiency.

d. Transplant timing for K-Y cross Chu-Chiouc abbage

Cabbage seeds were sown at Wu-lin Farm on June 20, 1977. Headed plants were harvested in the middle of October and then left in the field for natural vernalization. The stems were then transplanted to the FTHES experimental farm on November 1 and December 8, 1977, and January 12. 1978 for flowering and seed production. To compare the seed-to-seed and headed plant-to-seed methods of seed production, seeds were sown on September 22, 1977 at the FTHES experimental farm. One-month-old seedlings were transplanted to the Wu-lin Farm on November 3 for vernalization, and those plants which did not form heads were returned to FTHES on December 20 for evaluation on flowering and seed production.

Results and Discussion

A. Seed production of Yehsen cabbage sown at different times

Plants sown on September 24, 1975 headed completely, whereas plants sown on the plater dates headed only partially. Leaf number and stem size at flowering are shown in Table 1. The average leaf number and stem size of the first planting were greater than

Table 1. Flowering behavior of Yehsen cabbage under different sowing dates

Sowing date	Date of flowering[a]	Days from sowing to flowering	No. of leaves at flowering	Size of stem at flowering (cm)
9/24	2/26	182	51.75	2.98
10/13	2/28	151	36.00	2.63
11/1	3/20	140	32.00	2.19

a. Date on which half of the plants had flowered.

those of the later planting dates. Plants of the first and second plantings flowered respectively on February 26 and 28, 1976, and the third planting flowered on March 20, 1976. Plants of the second sowing had the highest seed yield, bearing large-sized seeds and plants of the third sowing had the lowest seed yield (Table 2). Both 1000-seed weight and seed germination rates followed the same pattern as seed yield.

Table 2. Sowing time and quantity and quality of Yehsen cabbage seed

Sowing date	Seed yield[a] (g/plant)	1000-seed weight (g)	No. of seed/ml	Germination rate (%)
9/24	21.4	4.05	162.3	87.8
10/13	29.03	4.50	159.0	88.5
11/1	14.03	3.20	210.5	83.2

a. Average of 20 plants

Commercial cabbage seed production in the temperate regions usually does not progress through head formation, whereas in the tropics and subtropics, plants remain vegetative because of insufficiently low temperatures. Even plants planted at TSS in the low temperatures of average 14.8°C late winter or early pring had to head to seed normally. Therefore, seed to seed methods cannot be employed as in the temperate regions. However, cabbage heads were cut and used for seed production. Axillary buds were used to prevent pest infestation. Plants of the first sowing were larger and had a greater soft-rot infestation rate at the time of cutting than the other two sowings. Average seed production was thus lower. Plants of the third sowing did not flower until March 20, and as a result of gradually increasing temperatures and the approaching rainy season, seed production was the lowest among the three treatments.

B. Yehsen cabbage seed production at different southern and southwestern coastal locations after vernalization

Plants transplanted at An-nan, Yen-shui and Hu-wei began flowering in February

and were comparable with those plants remaining at TSS. During the flowering period, the average temperature and relative humidity at An-nan were 19.5°C, 72% ; Yen-shui 18.6°C, 78% ; Hu-wei 17.9°C, 72%, Taiwan Seed Service 16.9°C, 81.1%, respectively (Table 3, Fig. 1, 2).

Table 3. Climate data from different seed production areas

Areas and locations	Weather variable[a]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Taiwan													
Seed	M. T. (°C)	14.2	15.3	18.5	21.9	25.3	25.4	26.5	25.2	25.2	22.7	19.6	16.6
Service	T. P. (mm)	23.8	81.4	98.4	109	222	430	299	295	237	42.8	24.3	20.9
(Taichung county)	T. S. (hr)	92.5	93.4	102	100	103	96.0	94.2	86.4	93.6	100	138	116
Hu-wei	M. T. (°C)	15.5	16.3	19.4	22.4	24.9	26.8	28.0	27.2	26.4	23.5	19.9	17.6
(Yun-lin	T. P. (mm)	35.9	23.3	50.0	44.7	198	214	190	311	45.2	11.4	17.3	12.7
county)	T. S. (hr)	158	132	133	139	133	174	216	135	167	184	138	177
Yen-shui	M. T. (°C)	16.1	16.8	20.3	23.8	25.3	27.8	29.3	28.9	28.8	25.1	21.6	18.1
(Tainan county)	T. P. (mm)	34.6	12.2	34.3	43.6	153	242	266	331	32.3	10.1	8.3	5.7
An-nan	M. T. (°C)	16.9	17.9	21.0	23.7	25.4	27.5	27.9	27.3	26.9	24.7	20.9	18.9
(Tainan	T. P. (mm)	20.7	10.9	22.4	52.6	177	442	340	348	74.2	17.5	21.9	3.9
city)	T. S. (hr)	155	148	164	154	137	166	177	150	159	183	151	154
Fengshan	M. T. (°C)	18.3	19.3	21.6	24.8	27.4	28.3	28.9	28.6	28.1	26.4	23.5	20.3
(Kaohsiung	T. P. (mm)	21.9	16.7	35.1	44.6	154	394	308	337	190	60.8	9.1	9.8
county)	T. S. (hr)	170	155	165	193	178	379	200	159	155	172	142	171
Lishan	M. T. (°C)	7.55	9.13	12.3	14.9	17	18.8	19.6	18.7	17.2	14.3	11.6	9.3
	T. P. (mm)	79.9	86.2	138	108	240	181	96.5	397	102	124	54.7	56.9

a. M. T. : mean temperature, T. P. : total precipitation, T. S. : total sunshine.

Seeds were harvested at the end of April for those plants transplanted in southern and southwestern coastal areas. Plants transplanted at Hu-wei, Yen-shui and An-nan of coastal areas had higher seed yields, 1,000-seed weights and large-sized seeds compared with those plants remaining at TSS (Table 4).

The 1,000-seed weight and number of seeds/ml of the seed harvested from the coastal areas compare with that of imported seed. The results indicate that relatively dry weather has a great influence on seed quality.

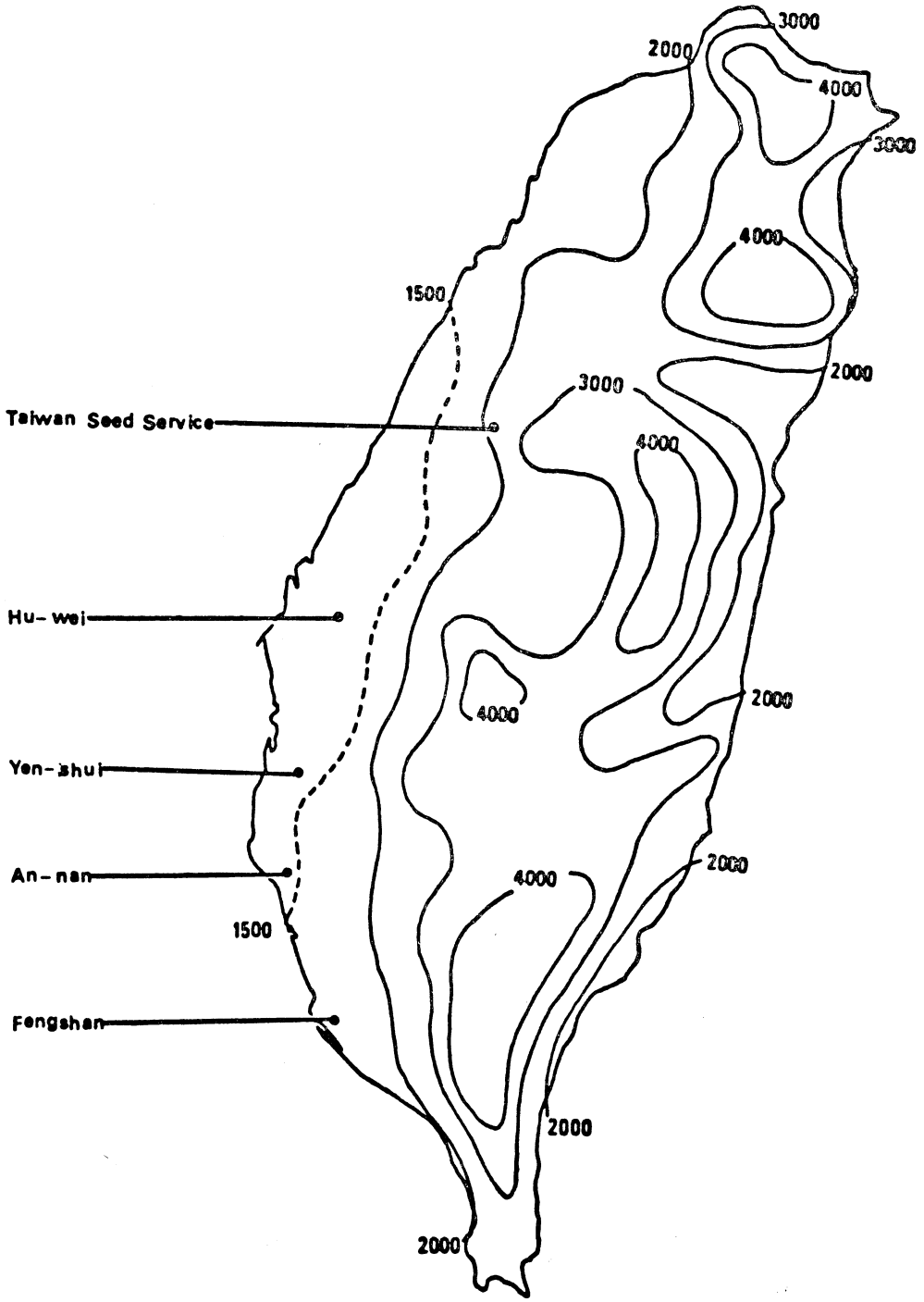

Fig. 1. Annual total precipitation (mm) in different of Taiwan

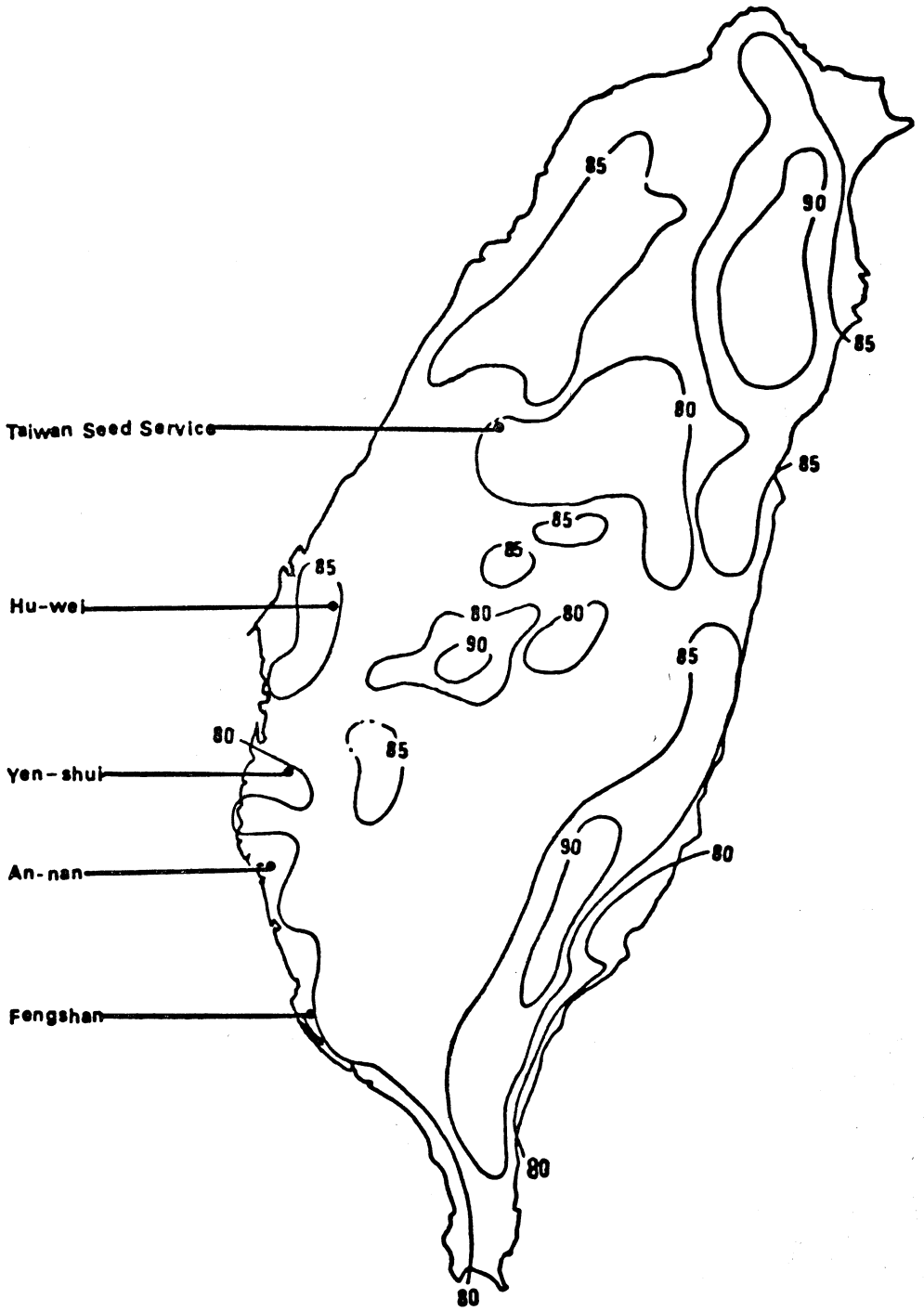

Fig. 2. Annual mean relative humidity (%) in different areas of Taiwan

Table 4. Quantity and quality of Yehsen cabbage seed produced in different areas

Production area	Date of seed harvest	1000-seed weight (g)	No. of seed/ml	Germination rate (%)
An-nan	4/26	4.29	160.5	95.2
Yen-shui	5/1	4.23	155.6	95.0
Hu-wei	4/30	4.43	158.8	94.2
Taiwan Seed Service	4/25	2.85	234.0	89.3

C. Seed production methods for K-Y cross Chu-Chiou cabbage after vernalization

K-Y cross Chu-Chiou cabbage does not flower when planted in southern Taiwan. In this experiment, plants sown in the middle of September at FTHES and cut out the head on December 24 still did not flower until the following March. On the other hand, plants grown in the highlands, heads harvested in October, and transplanted at FTHES in November, began flowering on December 18 and completed flowering on January 28. Seeds were harvested on March 15(Table 5). Seed qualities such as 1,000-seed weight and seed number per milliliter did not differ from those of imported seed.

Table 5. Seed production method and the quantity and quality of K-Y cross Chu-Chiou cabbage seed.

Seed Production method	Date[a] of flowering	Date of seed harvest	1000-seed weight (g)	No. of seed/ml	Seed[b] yield (g/plant)
Transplanted to lowland after vernalization in highland	12/18	3/15	5.45	112.5	18.8
Planted in lowland	—	—	—	—	—

a. Data on which half of the plant had flowered

b. Average of 20 plants

After plants were transplanted to the lowlands, warm and dry condition of the southern parts of Taiwan were favorable for accelerating flowering and seed ripening after vernalization. Average temperatures in December, January and February were 20.3, 18.3 and 19.3°C respectively, mean relative humidity was less than 80% and daylengths were long. Seeds were harvested before the rainy season. Seed harvesting for Yehsen cabbage planted at TSS is done normally at the end of April. By vernalizing headed plants in the highlands and then transplanting to the lowlands for seed production, seeds can be harvested up to one and one half months earlier than is possible using traditional production methods.

D. Transplant timing for K-Y cross Chu-Chiou cabbage

Different transplanting dates significantly influenced flowering time. Plants which vernalized perfectly demonstrated earlier or quicker flowering. Headed vernalized plants of the first transplanting (November 1) flowered after 30 days. Plants of the second (December 8) and third (January 12) transplantings flowered after 12 and 8 days respectively (Table 6). It appears that perfect vernalization accelerated bolting and flowering. Imperfectly vernalized plants from the first transplanting showed imperfect bolting and flowering. 1,000-seed weight and seed yield per plant from the first transplanting were the lowest among the four treatments. Plants from the second transplanting flowered perfectly, bearing large-sized seeds and producing high seed yields. Although plants from the third transplanting flowered perfectly, their longer bracts sustained more injuries during transport, resulting in small seed size and low seed yields. The non-heading, vernalized plants also had low 1,000-seed weight, low seed yield per plant and small-size seed. The results, however, indicate that complete vernalization in the highlands may lead to normal flowering and seed production when plants are transplanted to the lowlands. Early to mid-December appeared to be the optimal time for transplanting.

Table 6. Date of lowland transplanting and the quantity of cabbage seed after high altitude vernalization.

Date of transplanting from highland to lowland	Date[a] of flowering	Date of seed harvest	1000-seed weight (g)	No. of seed/ml	Seed[b] yield (g/plant)	Remarks
11/1	11/30	3/3	3.71	169.5	7.50	headed plant
12/8	12/20	3/15	5.56	106.4	17.00	to seed
1/12	1/20	3/27	4.65	129.7	8.56	
12/20	1/20	4/25	4.21	147.1	7.50	seed to seed

a. Date on which half of the plants had flowered

b. Average of 20 plants

Bowswell [2] and Miller [15] found that cabbage flowered when it over-wintered at the seedling stage in which the stem diameter was greater than 6mm. They also found that flowering was accelerated by high temperature conditions after vernalization. Watanabe [21] pointed out that there were varietal differences in the sensitivity of seedlings to low temperature treatments. Sugiyama [19], Eguchi and Koide [3] and Shinohara [17] evaluated Chinese cabbage and radish under different sowing times and concluded that the later the sowing time which still allowed for complete vernalization, the fewer the number of days to bolting. Their experiments showed that bolting and flowering after vernalization were accelerated by long day and high temperature conditions.

Based on Lysenko-Whyte's phasic development theory, Shinohara [17] illustrated the phasic development of several cruciferous crops. Cabbage is a green plant vernalization type, The lengths of the first phase(thermophase) and second phase (photophase) were shown

to vary with different cabbage varieties. In this experiment, different cabbage varieties were vernalized at different altitudes in order to complete perfectly the development of the first phase. After satisfactory exposure to low temperatures for vernalization, the plants were transplanted to the warmer and longer day conditions of the lowlands to accelerate the second phase development. From December to February, mean temperatures range from 18° C to 20°C and relative humidity is the lowest of the year (less than 80%) in southern Taiwan. These are good conditions for bolting and seed production. The method of transferring plants to favorable environmental conditions to adjust the development of the first and second phases, with its resulting smooth vernalization and flowering , appears ideal for cabbage seed production in the tropics and subtropics.

Perfect vernalization not only accelerated bolting and flowering, but also promoted complete seed setting [17,21]. The problems of cabbage seed production in the tropics and subtropics were insufficiently low temperaturer in the first phase and rain in the second phase. Thus, considering the varied conditions required for vernalization, flowering and seed ripening the date when plants are transplanted from the highlands to the lowlands is crucial to the success of seed production. The experimental results present several different modes of cabbage seed production in the subtropics (Fig. 3). Modes I and II are produced in the lowland. Insufficiently low temperatures were problems for both

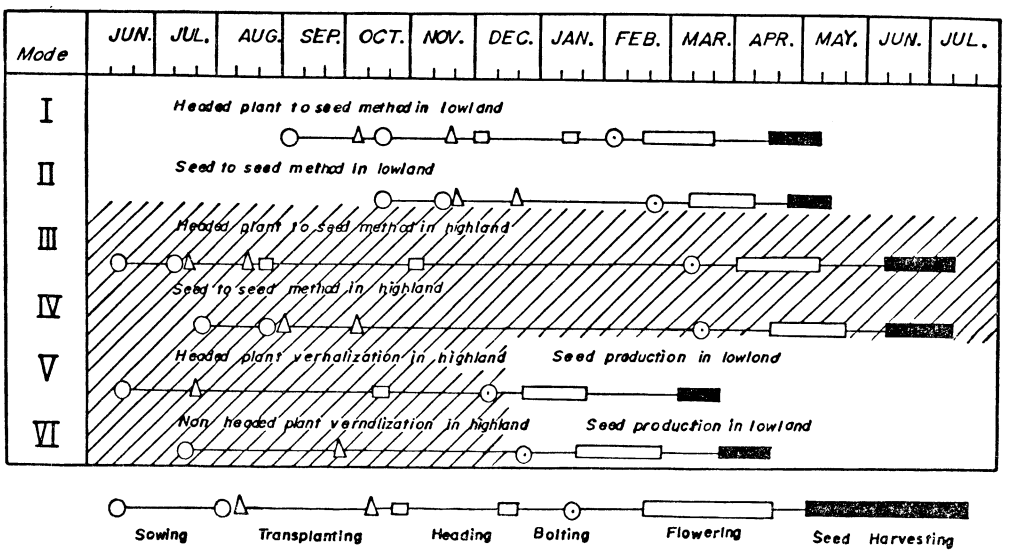

Fig. 3. Modes of cabbage seed produceion in the subtropics

the headed plant-to-seed and seed-to-seed methods and resulted in unstable seed yields. Furthermore, in the lowland, the choice of variety for seed production was limited to shallow bolting types such as cv. Yehsen. Both headed-plant-to-seed and seed-to-seed plants in modes III and IV were flowering during the rainy season. The low temperature conditions were sufficient for the first phase to develope completely, but flowering during the rainy season increased problems with pollination, soft-rot and sclerotinia

rot resulting in failed seed production[11]. The first phase of Modes V and VI developed under low temperatures and the second phase was completed under warmer and dryer conditions. Although the results from mode VI were not as good compared with those of mode V, further study on the exact seedling stage, duration of vernalization and transplanting time for the seed-to-seed method is required.

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亞熱帶地區之甘藍種子生產

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摘 要

甘藍之開花需有足够的低溫，在熱帶地區大部份甘藍品種因低溫不足而不能開花採種。一些低溫要求較淺的品種雖可在高海拔地區開花， 但花期逢雨季，致結種子困難。依十字花科蔬菜開花之相的發育 (phasic development)，可在較高海拔地使其完成第一相 (感溫相) 之發育，然後移植於平地行第二相 (感光相) 之發育。

以低溫要求較淺之熱帶型葉深甘藍和低溫要求較深之北方型初秋甘藍爲材料。於高冷地春化後再移植於平地，利用其溫暖乾燥的條件促進開花和種子的成熟。因此，依甘藍開花相的發育需要，在熱帶地區可利用不同之海拔行採種。

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