STUDIES ON SOYBEAN BREEDING IN TAIWAN

1. Growing Seasons and Adaptabilities of Introduced Varieties

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Before 1948, soybean culture in Taiwan was quite limited except for growing them for green manure. Later, a few varieties introduced from the U. S. A. and Japan were extended to certain areas of the island. At present, soybean production is growing year after year, arriving at 55,563 hectares and 61,897 tons in 1965. In retrospect, at the beginning of this study, the writers wanted to know why no soybeans had been grown in Taiwan, though this valuable legume of Asian origin was cultivated in all countries or areas surrounding the island. We then learned that this was due to lack of adaptive varieties.

We have obtained seeds of a number of varieties from the U. S. A., Japan and other Asian countries, and have conducted experiments on their adaptability to the climatological conditions at Taichung. Then, we devoted ourselves to hybridization and breeding studies. Similar efforts were also made by Prof. W. T. Tang of the National Taiwan University and coworkers. The results of our experiments have been partly published in Chinese language (Lu 1953, 1954, 1956, 1959 and 1961; Lu and Tsai 1956, 1964, etc.). However, as our data seem to suggest considerations of certain fundamental aspects of adaptation in crop plants, some of them, seemingly of general interest, are reported in this series of papers. The present paper deals mainly with the varietal responses to day-length and temperature and with the growing seasons to which they are adapted. The writers are indebted to Dr. J. Fukui (National Institute of Agricultural Science, Japan) and Dr. T. Nagata (Hyogo University, Sasayama, Japan) for their kind review of the manuscript.

Materials and Methods

Seeds of about 160 varieties, obtained through the kindnesses of various

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agricultural institutions of the U. S. A., Japan, Thailand, Philippines and Taiwan were used for the experiments. They were repeatedly grown in the experimental field of Chung-Hsing University, Taichung (24°N), seeded monthly throughout the year. Such growing-season experiments were made three times, from September 1952 to August 1953, July 1955 to December 1956, and July 1960 to August 1961. A part of the varieties were used in all these experiments, and the rest in one or two only. The data from 1955–6 and 1960–1 experiments are presented in this paper.

The growing scheme we adopted, which was determined after a series of planting-method experiments, was as follows: A field plot was cultivated and furrowed at 50 cm intervals, and a basic dressing of fertilizers was applied at the rate of N 15, P_2O_5 45 and K_2O 80 kg/ha. Three seeds per hole were sown by hand at 20 cm spacing on the ridge, and after germination thinning was made so that one plant per hole remained. Usually, a variety was grown in a single row of 25 plants (5 meters long). Weeding was made about three weeks after seeding with a hoe, so as to mould the ridge a few centimeters higher. Irrigation was made once in 10 days when it did not rain. Insecticides were applied two or three times during the growing period.

Records on individual plant basis were taken regarding the following traits: 1) number of days to flowering (from the next day of seeding to the opening of the first flower), 2) number of days to maturity (from the first flower opening to maturity of the plant), 3) number of branches per plant (branches with pods), 4) number of pods per plant, 5) number of good beans per plant, 6) fertility (percentage of good beans), 7) plant height, 8) plant weight (of a dried plant including roots), 9) bean yield (weight of dried grains per plant), 10) weight of 100 grains, and 11) color and other seed characters.

Results

1. Varietal responses to day-length and temperature.

In many varieties, it was generally found that seeding in March and in September shortened the growth period in comparison with seeding made in other months, as shown in Fig. 1. When seeded in November to December, flowering was delayed, the time to flowering exceeding 100 days. In most varieties, April-May seeding gave also a prolonged growth. This indicates that flowering is retarded by the long days of May-July (exceeding 14 hours) as well as by the low temperatures in winter months (15° to 20°C in monthly average).

The number of days from flowering to maturity also varied in a similar manner according to the seeding time. In most varieties, the variation was correlated with that of the days to flowering. It may be inferred that flower

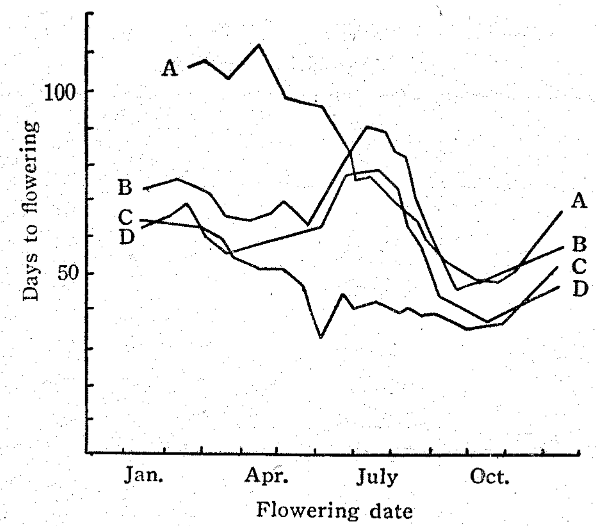

Fig. 1. Number of days to flowering related to flowering date.
A: U-tou (a green-manure variety native to Taiwan)
B: Otootan (U. S.)
C: Hsinying-tatou (from Northern China)
D: Hanashirozaki-1 (Japan)

initiation, development of flower organs and seed ripening are controlled by a common factor, as postulated by Nagata (1960) as well as by Fukui and Matsumoto (1961).

In each variety, the mean number of days to flowering from different seeding dates and that from flowering to maturity were computed. They showed a positive intervarietal correlation ($r=0.596$, $n=109$). Comparing the growth periods (seeding to maturity) of U. S. A. varieties with Morse and Cartter's (1949) classification of maturity groups, the growth periods at Taichung were found to be highly correlated with those in the U. S. A.

With eight arbitrarily selected varieties, day-length experiments (9–14 hours) were conducted in summer and winter, with plants seeded on July 25 and November 19, respectively. The results are given in Table 1. The table shows that the difference in the days to flowering between long-day and short-day treatment is generally larger in winter than in summer. It seems that the flowering-promoting effect of short days becomes high when flowering is retarded by low temperatures (15°–20°C). Late varieties show this tendency more strongly than the early ones. It is well known that both short days and high temperatures promote flowering and maturation at different rates according to varieties. As will be discussed later, however, the varietal responses to combined effects of day-length and temperature seem to be too complicated to interpret them by a simple rule.

Table 1. *Days to flowering under different day-lengths in winter and in summer.*

Variety	Season	Day-lengths (hour)						
		9	10	11	12	13	14	Natural
Mamotan 6680	Summer	25	26	26	30	35	33	33
	Winter	56	61	63	62	77	105	59
Mikuni	Summer	27	28	27	28	31	30	37
	Winter	56	62	64	63	117	135	62
Chichibusyakin-nashi	Summer	26	27	27	27	28	31	30
	Winter	62	63	66	62	72	79	65
Seminole	Summer	28	28	29	29	32	35	36
	Winter	58	67	66	57	82	106	60
Manchu	Summer	27	27	28	29	31	36	37
	Winter	58	55	66	61	84	88	63
Avoyelles	Summer	30	32	34	32	34	41	40
	Winter	60	55	65	65	113	125	62
Ping-tong-ching-pi-tou	Summer	34	34	37	35	44	47	49
	Winter	72	72	100	102	128	130	108
U-tou	Summer	37	37	38	37	48	53	53
	Winter	69	85	110	125	141	146	118

Average temperature: Summer 27.8°C, Winter 16.1°C.

In the growing-season experiments, the gradual shortening of the period to flowering in June to September seedings may be attributed to the shortening of day-length after the summer solstice, as the temperatures in this period are uniformly high (26°–28°C). For estimating day-length sensitivities of individual varieties, the "tangent-day-minute" method used by Oka (1954, 1958) for rice varieties was employed, by which the rate of acceleration of flower initiation (in day) in response to one minute shortening of day-length at the time of flower initiation is shown by an angle. According to Kato *et al.* (1951), flower initiation may be assumed to take place 25 days before flowering. Accordingly, the initiation date was taken to be 25 days before flowering, and the day-length (including twilight) at that date was related to the days to flowering. The "T. D. M. degree" thus obtained may be regarded as representing the requirement for a certain short-day of a plant to initiate flower primordia. The day-length sensitivity estimated by this method showed positive intervarietal correlations with the mean number of days to flowering and that from flowering to maturity (Table 3).

It may be inferred from Fig. 1 that excluding the delay of flowering due to long days after April-June seedings, the seasonal variation in the days to flowering would be largely due to temperatures. An overall estimate of tempe-

Table 2. *Comparison of day-length sensitivity and other characters between spring and summer type varieties.*

Type	Day-length sensitivity (T. D. M.)								No. of var. s
	0°	5°	10°	15°	20°	25°	30°	35°	
Spring	1	15	11	1	3	1	1		33
Summer		2	3	3	10	3		2	23
	Temperature response (b, %)								
	1	2	3	4	5	6	7	8	
Spring					8	20	4	2	34
Summer	1	2	4	4	4	10	5	1	31
	Mean no. of days to flowering								
	40	45	50	55	60	65	70	70	
Spring	2	16	9	5	2				34
Summer		2	5	5	3	8	6	2	31
	Mean no. of days of seed maturation								
	50	55	60	65	70	75	80	85	
Spring	1	4	13	9	4	3			34
Summer		3	10	5	5	2	4	2	31

rature responses of the varieties may then be obtained by the regression of the days to flowering on the average temperatures of corresponding growth periods. The regression coefficient in per cent of the mean number of days to flowering was computed for each variety. It showed a high intervarietal correlation ($r=0.853$, $n=66$) with the difference in the number of days between January and August seedings. It may then be considered to show the magnitude of variation in the days to flowering due to temperatures. As shown in Table 3, this index of temperature response was found to be negatively correlated with day-length sensitivity, mean number of days to flowering and that from flowering to maturity. In general, early varieties appeared to be less sensitive to day-length, but more sensitive to temperature, than late varieties.

2. *Adaptive growing seasons in Taiwan.*

The data of growing-season experiments showed that the bean yield of a variety markedly differed according to the seeding date, as shown in Fig. 2. Basing on the seasonal variation in yield, the tested varieties could be divided into three groups, *i.e.*, 1) varieties producing a considerable yield (1.5 ton/ha or more) from Febrary or March seeding (spring type), 2) those producing

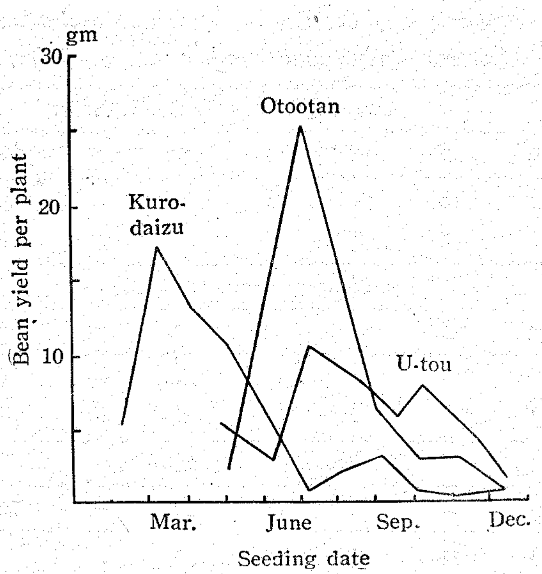

Fig. 2. Examples of seasonal change in bean yield.

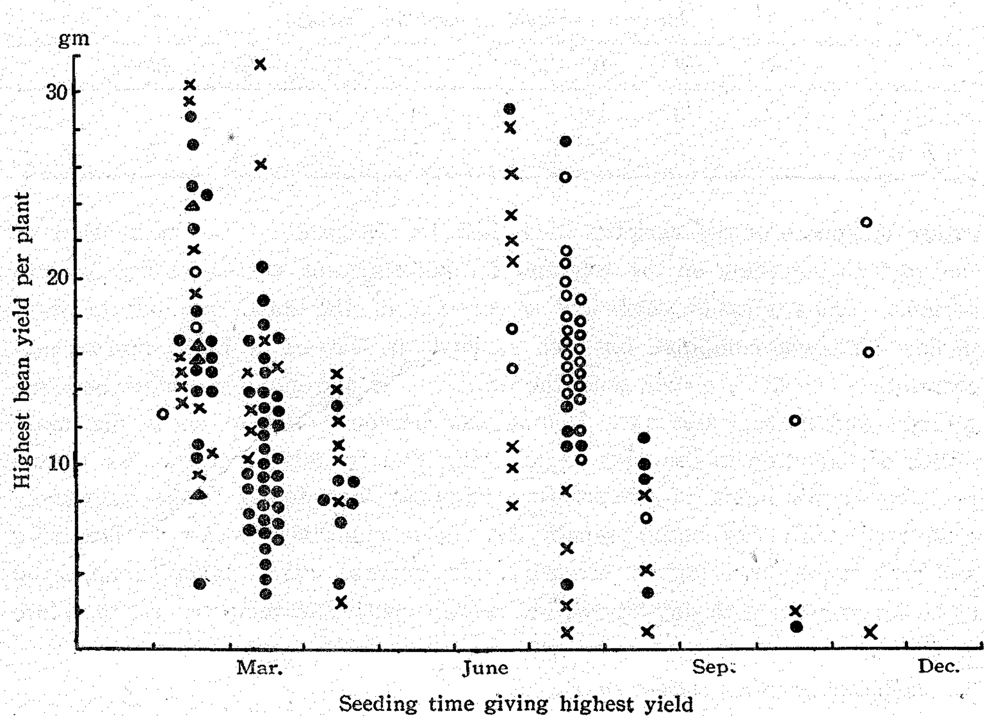

Fig. 3. Highest bean yields of varieties related to seeding dates giving the highest yield.

such a yield from June or July seeding (summer type), and 3) those showing a low yield at any seeding time (inadaptive varieties). The number of varieties belonging to these three groups were, throughout the experiments repeated three times, 34 (spring type), 31 (summer type) and 97 (inadaptive), respectively. In addition, the experiment in 1955-6 proved that three selections from green-manure varieties native to Taiwan gave their maximum yield when seeded in October or in November, though they then had a long growth period (180 days or more, maturation in May).

In Fig. 3, the maximum bean yields of various varieties are related to the seeding dates giving the maximum yield. The figure clearly shows that the adaptive seasons of soybean culture at Taichung are represented by February-March and June-July seedings. No variety appeared to be adaptive to both spring and summer crop-seasons. Taking the highest yield of a variety in a season (that exceeding 1.0 ton/ha) to be 100, its second high yield in the other season was at the best 68, but was in most varieties only 10 to 20.

Varieties of spring and summer types were compared regarding the mean number of days to flowering, from flowering to maturity, day-length sensitivity, and temperature index. The results are in Table 2. The table shows that varieties of spring type generally have a smaller number of days to flowering and to maturity, lower day-length sensitivity and higher temperature response than those of summer type. It seems that the adaptabilities to spring and summer crop-seasons are at least partly determined by varietal responses to day-length and temperature.

Intervarietal correlations between the above four values and bean yields in spring (February seeding) and summer (July seeding) crops are given in Table 3. For this computation, 63 varieties with complete data were used, among which 20 were spring types, 13 were summer types, and the remaining 30 were inadaptive. The table shows that bean yield in the spring season is

Table 3. *Intervarietal correlations between bean yields in spring and snmmer crops and other characters.*

Character	B	C	D	E	F
A) Days to flowering	.201	.599**	-.106	-.262*	.331**
B) Days of seed maturation		.371**	-.314*	.120	.263*
C) Photo-senitivity (T. D. M.)			-.404**	-.342**	.513**
D) Temperature response (b, %)				.296*	-.119
E) Yield in spring					-.168
F) Yield in summer					

** Significant at 1% level, * at 5% level (n=63) negatively correlated with the days to flowering and day-length sensitivity, and positivly correlated with temperature response, while yield in the summer season is positively correlated with the days to flowering, from flowering to maturity and day-length sensitivity. Roughly saying, early varieties with a low photoperiodic sensitivity can be spring types, and late varieties with a high photo-sensitivity can be summer types.

To look into this relation in more detail, the mean number of days to flowering (A), from flowering to maturity (B), day-length sensitivity (C) and temperature response index (D) were combined so as to maximize the correlation of the combined value with bean yield in the spring crop and with that in the summer crop, by using the method of selection-index computation. The results (standardized) were as follows:

$X_1 = -0.407A + B - 0.814C + 0.824D$, r_{X_1}: Spring yield $= 0.502$;

$X_2 = 0.031A + 0.213B + C + 0.240D$, r_{X_2}: Summer yield $= 0.531$.

It was found that linear combinations of these four values gave correlation coefficients approximating 0.5 with spring as well as summer yield. All these four characters seem to take part in spring yield, but for summer yield photoperiodic sensitivity seems to be particularly important. In other words, varieties flowering early, with a long period for seed ripening, not sensitive to photoperiod and highly responsive to temperature, may produce a high yield in the spring season, and varieties sensitive to photoperiod may be adapted to the summer season.

The correlation coefficient, 0.5, however shows that only one fourth of the yield variance could be explained by the four characters. Yield might be conditioned by many other physiological factors than those four. In this relation, variannces of yield obtained from a varietal trial continued for three years may be examined.

Nine varieties were tested for yield in the spring and summer crop-seasons from 1957 to 1959, each variety being planted in three rows and the plots were randomized with three replications. Variance analysis of the data showed that, as given in Table 4, the components of variance due to variety×season and to variety×year were considerably large, but that due to varietal genotype was almost nil. Similar results were also reported by Johnson *et al.* (1955) and other workers (Bartley and Weber 19652; Horie *et al.* 1965). Since in our experiment the varieties used were adaptive either to spring or to summer crop, the variety×season variance may be regarded as representing varietal variation. Then, the sum of σ^2_s and σ^2_{vs} amounts to about one half of the total of variance components. The yield of a variety in a crop season thus seems to fluctuate in a wide range, possibly in response to various environmental conditions.

Table 4. *Variance analysis of yield data from a variety trial* (*Unit: kg/a*).

Variance due to:	d. f.	Mean square	Expectation
Year	2	178.86**	${\sigma^2}_e + 2{\sigma^2}_{vy} + 9{\sigma^2}_{ys} + 18{\sigma^2}_y$
Season	1	535.00**	${\sigma^2}_e + 3{\sigma^2}_{vs} + 9{\sigma^2}_{ys} + 27{\sigma^2}_s$
Year × Season	2	82.97**	${\sigma^2}_e + 9{\sigma^2}_{ys}$
Variety	8	73.89**	${\sigma^2}_e + 2{\sigma^2}_{vy} + 3{\sigma^2}_{vs} + 6{\sigma^2}_v$
Variety × Year	16	32.42**	${\sigma^2}_e + 2^2\sigma_{vy}$
Variety × Season	8	64.90**	${\sigma^2}_e + 3{\sigma^2}_{vs}$
Variety × Year × Season	16	9.93	${\sigma^2}_e$
Error due to replication	108	11.72	

9 varieties, spring and summer crops, 1957, 58 and 59, 3 replications.
** Significant at 1% level.

$${\sigma^2}_e = 9.93 \qquad {\sigma^2}_{ys} = 8.12$$
$${\sigma^2}_{vs} = 18.32 \qquad {\sigma^2}_s = 14.71$$
$${\sigma^2}_{vy} = 11.25 \qquad {\sigma^2}_y = 4.08$$
$${\sigma^2}_v = 0$$

In our growing-season experiments, since a variety was represented by a row and no replication was made, the error variance might be larger than the above estimation. It may then be inferred that excepting the fluctuating variation due to "minor environments", the varietal variation in yield could be for a considerable part explained by the combination of growth periods and indices of responses to day-length and temperature.

3. *Correlation of characters due to seasonal variation.*

Together with the seasonal changes in growth period, yield as well as other characters change resulting in within-varietal seasonal correlations. The seasonal correlations were computed for six varieties of spring type and three of summer type, respectively. They showed on the whole similar patterns of correlations. The within-varietal correlations were then averaged for spring and summer types, after being transformed into z values. The results are in Table 5.

The table shows that due to seasonal variation, bean yield is negatively correlatd with the days to flowering and the days from flowering to maturity, and positively correlated with plant height and other vegetative characters, which are generally positively inter-correlated. A comparison between spring and summer types shows a major difference in that the days from flowering to maturity are in spring types negatively, but in summer types positively correlated with vegetative characters. It is also found that seed fertility is in spring types positively correlated with the days to flowering, but shows no correlation in summer types. In both types, bean yield is strongly correlated

Table 5. *Within-varietal correlations of characters due to seasonal variation (18 seeding dates).*

Character	a	b	c	d	e	f	g	h	i
a) Days to flowering		.025	-.136	.056	-.152	-.108	-.060	-.349*	-.017
b) Days of maturation	.315**		.312*	.197	.249	-.503**	-.240	.551**	-.207
c) Plant height	-.342**	-.347**		.816**	.908**	-.318*	.792**	.843**	.717**
d) Branch number	-.414**	-.631**	.612**		.782**	-.134	.809**	.796**	.767**
e) Pod number	-.350**	-.520**	.638**	.840**		-.393**	.749**	.877**	.623**
f) Fertility	.280**	-.370**	-.218**	-.090	-.158		.258	-.374**	.384**
g) Bean number	-.204*	-.512**	.372**	.728**	.843**	.249*		.785**	.972**
h) Plant weight	-.109	-.373**	.608**	.746**	.904**	.115	.692**		.676**
i) Bean yield	-.133	-.478**	.441**	.645**	.869**	.259*	.919**	.873**	

Above the diagonal: Average for 3 varieties of summer type (Ping-tong-ching-pi-tou, Otootan & Pl-181698)

Below the diagonal: Average for 6 varieties of spring type (Fuchien-tatou, Hsinying-tatou, Chinmen-tatou, Nung-yuan 1, Misao-daizu, & Kuro-daizu)

** Significant at 1% level, * at 5% level.

with the number of beans per plant, suggesting that single grain weight does not change much with the season.

With the view to finding out common factors underlying seasonal variations of characters, the technique of principal component analysis (cf. Kendall 1961) was employed to the correlation matrices in Table 5, excluding bean yield and two characters apparently closely correlated with it, bean number and plant weight. The first and second component vectors extracted from the correlation matrices for spring and summer types are in Table 6. The two components made a more than 70% contribution to the total variance. They may be considered as showing latent phases of character association independent of each other.

The six characters under observation are in Fig. 4 scattered in the plane defined by the first and second component axes. The figure shows that three characters showing vegetative growth (plant height, branch number and pod number) can be distinguished from the other three characters supposedly indicative of reproductive growth, the number of days to flowering, that from flowering to maturity and seed fertility. For demonstrating this classification of characters more clearly, the component axes were rotated to hypothetical ones, X and Y, by using the method of rotation to "simple structure". The rotated vectors are also shown in Table 6. The X vector has in both spring and summer types positive loadings on vegetative characters and negative or

Table 6. *Component vectors extracted from within-varietal correlations due to seasonal variations in characters.*

Character	Spring type				Summer type			
	Component		Rotated		Component		Rotated	
	I	II	X	Y	I	II	X	Y
a) Days to flowering	-.64	.39	-.70	.25	-.08	.71	-.40	.58
b) Days of seed maturation	-.76	-.77	-.61	-.88	.50	.92	0	1.06
c) Plant height	.85	-.25	.88	-.09	1.00	-.29	1.01	.21
d) Branch number	1.00	.10	.96	.26	.89	-.39	.96	.07
e) Pod number	.98	-.02	.96	.13	.99	-.28	.98	.21
f) Fertility	-.16	1.00	-.36	.94	-.54	-1.00	0	-1.13
% variance	50.9	20.9			49.5	21.8		

zero loadings on the other characters, indicating that when flowering and maturation are promoted, the vegetative characters may develop. Varieties of spring type have this tendency more strongly than those of summer type. The Y vector indicates another phase of correlation at which fertility becomes high when maturation is promoted. It seems that in a spring type relatively late flowering and accelerated seed ripening result in high fertility, but in a summer type accelerated flowering and maturation may raise fertility. The spring and summer types show similar patterns of character association, but they may differ in the relation of flowering and seed ripening to yield characters.

The scores given by the X and Y vectors (obtained by summing up the values of six characters standardized and weighted according to the loadings) showed correlations with bean yield as follows:

	Spring type	Summer type
Score X	0.643	0.736
Score Y	0.533	-0.148

When the X and Y scores were combined so as to maximize the correlation of the combined value with bean yield, $X+1.68Y$ and $X-0.26Y$ were such combinations for the spring and summer types, giving correlation coefficients 0.826 and 0.753, respectively. These high correlations indicate that a major part of the seasonal yield variation can be accounted for by variations in such phases of character association as shown by the X and Y vectors.

These computations suggest that a variety expresses its inherent yielding capacity when it is grown under a condition that promotes maturation. Such a condition is found in the spring season when seeding is made a few weeks before the seeding time known to promote flowering most strongly. In the summer season, it is late June to early July, while the seeding time bringing about the minimum number of days to flowering is in September. In varieties of spring type which are weakly sensitive to photoperiod, accelerated maturation results in an increase of vegetative characters, but in photoperiod sensitive varieties of summer type, it increases seed fertility.

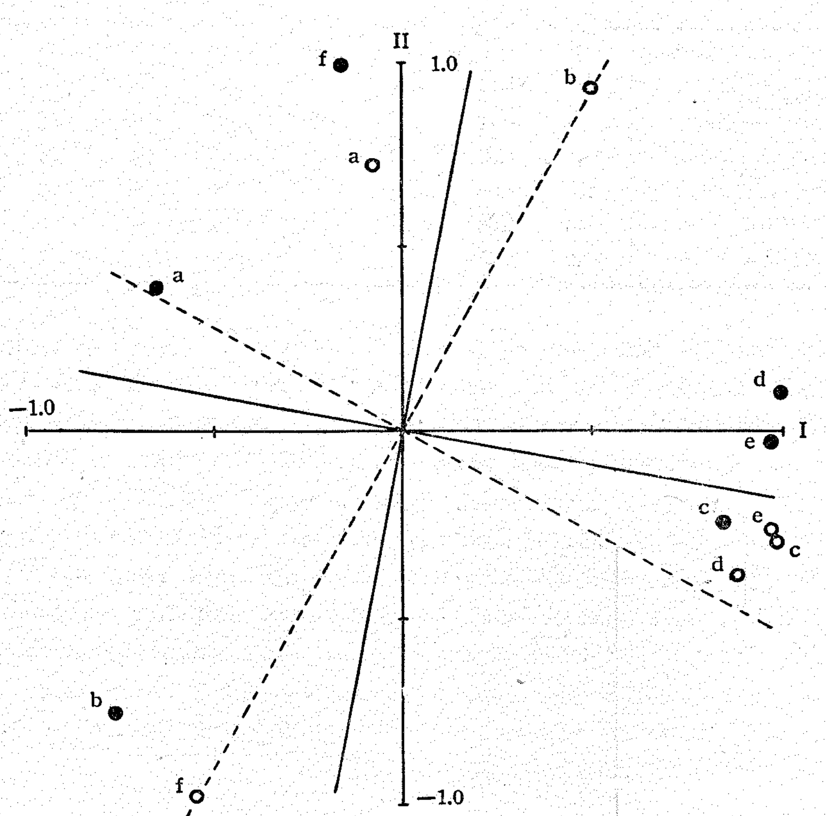

Fig. 4. Six characters scattered by the first and second component vectors extracted from seasonal correlations and rotated axes.

a) Days to flowering	b) Days to maturity
c) Plant height	d) Branch number
e) Pod number	f) Fertility
●—Spring type	○—Summer type

Discussion

Since the pioneer work of Garner and Allard (1920), soybean is known to be a short-day plant. The varieties seem to be mostly photoperiod sensitive, though their sensitivity varies widely. It is known that in most varieties not only flower initiation but also the development of flower organs and seeds are promoted by short days (Fukui and Matsumoto 1961). Fukui and Gotoh (1959) proved this by anatomical observation. Among the varieties, photoperiodic responses at different developmental stages are, though not completely, on the whole positively correlated (Parker and Borthwick 1951, Fukui *et al.* 1962, Nagata 1960, etc.). In this respect, soybean differs from other short-day plants like photoperiodically sensitive rice varieties, in which flower initiation only is promoted by short days, the subsequent developmental processes being almost neutral.

The response to temperature may also differ according to varieties, as has been observed by various workers (Parker and Borthwick 1939, Fukui and Yarimizu 1952, etc.). We found that the flowering-promoting effect of short-days could be intensified under low temperatures in winter (15°–20°C), particularly in varieties with long growth periods. Not only such a response was found, but also within certain limits, the higher the temperature, the higher would be the growth rate, and different developmental stages would respond to temperatures differently. Therefore, temperatures may modify growth and development both directly and indirectly through their effect on photoperiodic responses. Some workers (*e. g.*, Nagata 1960) are inclined to think that the varieties do not differ much in temperature response. Such a conclusion may be drawn when different phases of temperature responses counteract each other.

The responses of soybean varieties to day-length and temperature thus seem to be a complex of multi-factorial variations, which may be analysed by a special statistical technique. Although a lot of experimental efforts have been directed toward varietal variations in photoperiod and tempeature responses, the relationship between yield and those responses does not seem to have been successfully analysed. What we observe in experiments are "phenologicals", that cannot be directly related to conceived physiological factors. For instance, the relationship between the days of growth period in different seasons and various responeses might be such one that is shown by a "response surface".

In Japan, it has early been known that soybean varieties are differentiated into two seasonal types, "summer soybean" and "autumn soybean". The former types are known to be less sensitive to photoperiod than the latter (Nagata 1958, etc.). The present writers have found that the adaptive seasons of soybean culture at Taichung are represented by February-March and June-July seedings. Basing on seasonal changes in bean yield, varieties introduce from different countries were found to be adaptive either to spring or to summer season, or inadaptive to both. When measured by the requirement for a certain short-day (T. D. M. degree), varieties adapted to spring season (spring types) were less sensitive to photoperiod than those adapted to summer season (summer types). These types may be compared with "summer soybean" and "autumn soybean" in Japan, respectively.

Our estimate of temperature response (shortening of the days to flowering due to 1°C rise in average temperature, in %) tended to be negatively correlated to photoperiod sensitivity, varieties of spring type showing higher response than those of summer type. The adaptability to a season of a variety might be in the first place determined by its photoperiod and temperature responses and the resultant growth period. Accordingly, bean yields in different seasons could be to some extent explained by a combination of estimates for these characters, though yield fluctuate widely in response to various minor environments.

Our studies of seasonal correlations of characters showed that in varieties of spring type the number of days to flowering and that from flowering to maturity were negatively correlated with certain vegetative characters, indicating that acceleration of maturation may promote their development. When spring-type varieties are grown in summer and flowering is strongly accelerated, however, reduced fertility results in a low bean yield. In photoperiod sensitive varieties of summer type, the number of days to flowering and that from flowering to maturity did not show a significant correlation with the vegetative characters. When they are grown under the long days of spring, they vigorously perform vegetative growth but have a low fertility and a small bean number.

By rotating to "simple structure" the component vectors extracted from seasonal correlations of characters, we postulated that the basic pattern of character association did not differ much between spring and summer types. In both types, the days from flowering to maturity, fertility and vegetative characters showed a triangular interrelation, indicating that when seed maturation is promoted, the vegetative characters would in a phase of correlation develop, and in another phase fertility would increase. However, fertility and vegetative characters are negatively correlated. Therefore, a physiological condition that properly promotes seed maturation seems to increase yield. In many crop plants, we find that when maturation is accelerated, vegetative character are reduced. The positive correlation between vegetative characters and accelerated seed maturation is opposite to the developmental pattern usually found in other crop plants. This suggests the complexity of interrelations between responeses to outer conditions and yield in soybeans.

In general, it may be said that soybean is sensitive to outer conditions and its yield is unstable. The results of varietal experiments made in different countries indicate that variances due to interactions of varietal genotypes with seeding date, locality, year, etc. are so large that real varietal differences often become insignificant. We have also obtained such results. This indicates the sensitivity of varieties to day-length, temperature and other conditions at different stages of development. Therefore, our classification of introduced varieties into spring, summer and inadaptive types basing on their records cannot be reliable for individual varieties. It may be accepted as a general picture that two adaptive seasons of soybean culture, "spring" and "summer" seasons, exist in Taiwan, and introduced varieties are either adaptive to one of the two seasons, or inadaptive to both. Our recent breeding experiments suggest further that when particular genotypes are used, another adaptive season may be found in autumn. This will be discussed elsewhere.

The two adaptive seasons of soybean culture in Taiwan may be compared with the first and second crop-seasons of rice. In rice, the first and second seasons seem to be naturally determined by a complex of climatological factors. According to Mr. K. M. Lin of the Taichung Agricultural Impprovement Station who kindly showed us his unpublished data, when a set of rice varieties (photoperiod insensitive) were repeatedly grown throughout the year, it was generally found that January-February (first crop) and June-July (second crop) seedings produced a higher yield than those made in other months, though the plants were equally irrigated, fertilized and were protected from diseases and pests. When seeded in the period from March to May, the plants enjoy high temperatures similary as in the second crop, grow quite well, and reach maturity in July to August. The reason why the yield declines in this season is not well known, though it may be suggested that the activity of seed ripening is lowered due to mutual overshadowing of the leaves. The physiological basis for the occurrence of two soybean seasons coulda be partly explained only. It may by inferred as a working hypothesis that in a tropical condition, such two adaptive seasons occur in different grain crops as the result of various physiological responses to climatological conditions.

Summary

Soybean is a new crop in Taiwan. Many varieties introduced from the U. S. A., Japan and other Asian countries were tested throughout the year, repeating seeding at one month interval. The yield data showed that some varieties were adapted either to February-March (spring type) or to June-July (summer type) seedings, while others were inadaptive in any season. For each variety, sensitivity to day-length (requirement for a certain short-day, in "T. D. M. degree") and an index of temperature response (shortening of the days to flowering due to 1°C rise, in %) were estimated from the data of the growing-season experiment. Varieties adapted to spring season were generally less sensitive to day-length, but more sensitive to temperature than those adapted to summer season. Varietal variations in spring and summer yields could be partly explained by linear combinations of those estimates of photoperiod and temperature responses, mean number of days to flowering and that from flowering to maturity. Within-varietal correlations of characters due to seasonal variation were studied by using the technique of principal component analysis. It was found that yield might depend on a triangular interrelation of the days from flowering to maturity, fertility and vegetative characters. In varieties of spring type, when seed maturation is promoted, vegetative characters develop, while in those of summer type fertility may be raised. A varietal trial continued for three years showed that yield fluctuated in a wide range bringing about large variety-environment interactional variances. The responses of soybean varieties to outer conditions seem to be a complex of multi-factorial variations. It was suggested that the two adaptive seasons of soybean culture in Taiwan may be compared with the first and second crop-seasons of rice.

臺灣之大豆育種的研究

1. 引進品種之栽培季節及適應性

盧英權 蔡國海 岡彥一

筆者等曾自美國、日本及東南亞各國引進多數大豆品種實施週年栽培觀察試驗結果，發現有春作與夏作適應的栽培季節相當於水稻一期作與二期作。引進品種中有部份適應於春作或夏作栽培，另有部份品種不適應於任何季節栽培。春作型品種對於日照感應概低，惟其溫度反應較夏作型品種爲大。春作與夏作產量之品種間變異，可由感光與溫度反應，平均開花日數及成熟日數間所估計之直線關係能作部份的說明。又應用主成份分析法分析性狀間之品種內相關由於季節變異的結果，發現大豆產量係由於成熟日數，稔性及營養生長性狀三者間之互相關係而產生。春作型品種種實成熟被促進時生長性狀亦發達，但是夏作型品種的稔實性隨而提高。經三年間產量比較結果顯示大豆引進品種受品種與環境之交感作用，對於產量有至大的變動，即大豆品種對於外界條件之反應似受複雜之多項因子變異所形成。

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