SOYBEAN PRODUCTION AND RESEARCH IN TAIWAN

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Abstract

Soybean is a crop of economic value in Taiwan. There are three crops each year, spring crop planted in mid-February to mid-March; summer crop in June to July; and fall crop in late September to mid-October. Of these crops, the fall crop is planted mainly in the Kaohsiung-Pingtung area. Generally two cultural practices, conventional method and stubble planting, are used in soybean production. The stubble planting is predominantly for the fall crop.

In 1982, the acreage and value of soybean were only 0.85% and 0.24% of the total national crop land and value, respectively. In contrast to the pre-war years, the soybean production significantly increased from 3,500 tons on 6,100 hectares (average 600 kg/ha) in 1936-1945 to 63,000-67,000 tons on 40,000-50,000 hectares (average 1,500-1,700 kg/ha) in 1964-1973.

This increase resulted from the extensive effort mady by research institutions in the improvement of variety, physiology, cultural practices, nutrition, and pest management. However, further increase in production is expected to be difficult due to the constraints in 1) competition from the low-priced, imported soybean and from other crops; 2) high labor cost; and 3) unfavorable weather conditions. Nevertheless, the government is striving toward the increase of soybean production through the conversion of paddy land for soybean along with price supporting program, cost reduction and research.

Soybean is a crop of economic value in Taiwan. Although the production had once increased tremendously since the end of World War II, a large part of the supply still relies on imports every year to meet the demand for oil and feedstuffs. Great efforts have been made by the government to increase the soybean production in order to reduce imports as much as possible. This goal, however, has never been fulfilled because of the government policy for rice self-sufficiency. Due to the excessive supply of rice in recent years, more farmland is being allocated to the planting of soybean and other feed grain crops. Thus soybean production is expected to increase hereafter.

Production

Soybean production, as viewed by the national crop production, is of relatively minor importance in Taiwan. Its largest acreage averaged about 6% of the total cropland in the period of 1959-1968 and dropped to 0.85% in 1982, accounting for 1.7% and 0.24% of the national crop value respectively.

Soybean production has fluctuated tremendously over the last three decades. The period of peak output ran from 1964 to 1973 with 63,000-67,000 tons produced on nearly 40,000-50,000 hectares. These figures contrast strikingly with those in 1936-1945, when an average of only 3,500 tons was harvested from 6,100 hectares annually (Table 1) . This significant rise in soybean production was made possible largely by the expansion of acreage; also important was the significant increase in yield per hectare, from less than 600 kg/ha in 1936-1945 to 1,500-1,700 kg/ha after 1964, through varietal and cultural improvements as well as disease and pest control. However, yield began to decline in the last decade, with only 50,000 tons produced on 30,000 hectares in 1977. A continuous decline in both acreage and production was so prominent that there were only 12,043 tons harvested from 7,782 hectares in 1982.

Soybeans can be grown in any part of the island, especially in the southern Kaohsiung-Pingtung

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Table 1 Soybean production in Taiwan

Year	Planted area (1,000 ha)	Yield (ton/ha)	Production (1,000 ton)	%	Import (1,000 ton)	%
1936—1945	6.1	0.568	3.5			
1959—1963	56.5	0.913	51.3	29.1	124.9	70.9
1964—1968	51.5	1.303	67.0	21.2	248.8	78.8
1969—1973	40.2	1.572	62.8	9.6	590.6	90.4
1977	30.1	1.717	51.7	7.3	655.1	92.7
1978	24.5	1.668	40.8	4.3	959.4	95.7
1979	19.3	1.644	31.8	2.8	1,103.8	97.2
1980	15.3	1.692	25.9	2.7	939.0	97.3
1981	10.3	1.543	15.9	1.4	1,113.4	98.6
1982	7.8	1.549	12.1	1.0	1,150.4	99.0

From Taiwan Agriculture Yearbook.

area which accounts for 70%-80% of the total acreage and 75-85% of the total production (Table 2). Soybeans are mainly grown as a fall crop in this area (Table 3), with the yield per hectare being 5-10% higher than the national average. The recent decline in soybean production is naturally more drastic in the Kaohsiung-Pingtung area.

Supply and demand

The supply and demand of soybeans vary significantly from year to year. The total supply consists of local produce and imports. In 1959-1963, it was only 176.2 thousand tons, of which the local produce accounted for 29.1% (Table 1). The amount of imports has increased enormously since 1969; it reached 1.15 million tons in 1982, leaving the local produce to only 1% of the total supply. The marked increase of soybean imports is due to the lifting of import control in 1966 as

Table 2 Soybean production in Kaohsiung-Pingtung area, Taiwan

Year	Planted area (1,000 ha)	Yield per ha (ton/ha)	Production (1,000 ton)
1936—1945	—	—	—
1959—1963	33.0(58.4)	0.954(104.5)	31.4(61.2)
1964—1968	38.3(74.4)	1.405(107.8)	53.8(80.3)
1969—1973	32.6(63.3)	1.668(106.1)	54.3(86.5)
1977	24.3(80.5)	1.585(106.5)	58.2(85.2)
1978	17.1(69.7)	1.809(105.4)	43.9(84.9)
1979	13.7(70.7)	1.845(109.3)	31.5(77.2)
1980	10.8(70.5)	1.782(108.4)	24.4(76.7)
1981	6.3(61.1)	1.814(107.2)	19.6(75.7)
1982	4.2(55.0)	1.663(107.8)	10.5(66.0)

Note :Figures in parentheses are % of the corresponding national total in that year or of the average in that period.

Table 3 Soybean production in different planting seasons in Taiwan

Year	Crop	Planted area (1,000 ha)	Yield/ha (ton/ha)	Production (1,000 ton)
1967—1971		46.0	1.488	68.3
	Spring	6.1	1.221	7.5
	Summer	5.1	1.224	6.2
	Fall	34.8	1.570	54.6
1977		30.1	1.717	51.7
	Spring	4.1	1.447	6.1
	Summer	3.3	1.324	4.3
	Fall	22.6	1.825	41.3
1978		24.5	1.668	40.8
	Spring	5.3	1.326	7.1
	Summer	3.3	1.320	4.4
	Fall	15.8	1.857	29.4
1979		19.3	1.644	31.8
	Spring	3.6	1.324	4.8
	Summer	2.4	1.290	3.1
	Fall	13.3	1.794	23.9
1980		15.3	1.692	25.9
	Spring	2.7	1.462	3.9
	Summer	2.2	1.332	2.9
	Fall	10.4	1.827	19.1
1981		10.3	1.543	15.9
	Spring	2.8	1.452	4.1
	Summer	1.5	1.199	1.7
	Fall	6.0	1.669	10.0
1982		7.8	1.549	12.0
	Spring	2.2	1.440	3.2
	Summer	1.5	1.372	2.1
	Fall	4.1	1.675	6.7

From Taiwan Agriculture Yearbook.

well as the increase of local demand for oil and feedstuffs (oil meal) .

The use of soybeans is multiple. A survey in 1977-1978 (Chiang, 1979) showed that 90.18% of soybeans were processed into oils, 9.23% into beancurd and milk, 0.5% into soy sauce and 0.09% into fermented food; only a negligible amount was for direct uses, i. e. beansprouts and cooked beans.

The projected demand for soybeans in 1982 in the same report was 1.08 million tons, which agreed closely with the actual supply of 1.16 million tons. It must be pointed out, however, that the total supply shown in Table 2 does not reflect the actual consumption of that year. The actual consumption includes reserved stocks, and the total amount of local produce and imports is also partly reserved as stoks.

Methods of culture

Planting time

Because of the subtropical climate in Taiwan, soybeans can be grown all the year round. Generally, there are three crops: spring crop planted in mid-February through mid-March, summer crop in June through July, and fall crop in late September through mid-October. The fall crop is the major and predominant crop in southern Taiwan, while the spring and summer crops are planted in other parts of Taiwan because of the difference in cropping systems and relatively low temperatures in the winter (Table 3) .

Varieties used

Soybean varieties released and adopted for commercial production by the farmers are Shih-Shih, Palmetto, Wakashima, Tainung 4 , Kaohsiung 3 and 8 , and Tainung 15. Their major characteristics and planting areas are listed in Table 4 (Cheng and Chan, 1968; Chan, 1981; Thseng and Chan, 1980) .

Planting methods and field management

1 Conventional method Land preparation and spacing: The conventional method is generally applied to spring and summer crops. The land is plowed twice, compost and basic fertilizers are applied at the second plowing and followed by harrowing and levelling. For better drainage, a plant bed 1.0-1.2 m wide is usually prepared. Spacings vary with planting seasons and varieties used. The row spacing is usually 40-50 cm with plants 10-20 cm apart. Spring crop is spaced wider than the summer crop because of a longer vegetative growth. The row spacing for the fall crop is 40 $\times$ 10 cm. Drilling is the general practice with a seeding rate of 50-70 kg/ha.

Fertilization: Fertilization of soybeans is practiced as early as possible. As basic fertilizers, all of phosphorus and potassium and half of nitrogen are applied during land preparation: the remaining nitrogen is applied 2 weeks after germination by topdressing. Liming is not a common practice in the southern and western parts of Taiwan because of the presence of alkaline soils. In other acid soils 1.5-3.0 ton/ha of $Ca(OH)_2$ or 2.0-5.0 ton/ha of $CaCO_3$ are used, depending on the acidity of the soil.

The amount of fertilizer recommended to the farmers is N 10-30 kg/ha, P_2O_5 40-90 kg/ha, K_2O 30-75 kg/ha, and compost 10-20 ton/ha.

The fertilizers used in the different crops are more or less the same except that more nitrogen is applied for the fall crop.

Weed control: Hand-weeding is mainly practiced because farms are small. The first cultivation is made two weeks after seed germination when soybean plants are 15-20 cm tall. Topdressing of nitrogen is completed at the same time. A small ridge is formed after cultivation. The second cultivation is performed 15-20 days after the first one.

Chemical control of weeds is not common. Linuron, Stomp and Lasso are used for pre-emergence and Kusagard for post-emergence applications.

Irrigation and drainage: Soybeans are irrigated when soils are dry. No irrigation is performed right after seeding because poor germination may result from seed decay. The first irrigation is generally made 10-15 days after seedling emergence or after the first cultivation. Irrigations at the flowering and pod-setting stages are most important to increase the yield significantly. Drainage may be needed if soybeans are grown in paddy fields, particularly for the soybean crops grown in spring and summer which are rainy seasons.

2 Rice-stubble planting method Rice-stubble planting is a special cultural method for soybeans in Taiwan and of particular significance because it is commonly performed for the fall crop in the Kaohsiung-Pingtung area which is the producing center.

Soybeans are planted immediately after the harvest of the second rice crop without land preparation. A small opening is dug right beside each rice stubble with a small spade. Three to four seeds are dropped into the opening and then the spade is removed. No soil cover is needed. The seeding rate is about 100-120 kg/ha. As the soybeans are planted at each rice stubble, the spacing is naturally the same as for rice which is 22.5 cm $\times$ 22.5 cm or 27 cm $\times$ 13.5 cm. However, every tenth row should be left unplanted to facilitate field operations thereafter.

After the sowing of soybeans, rice straw is spread over the paddy field to prevent the loss of soil moisture and to control the weeds as well. Some farmers burn the rice straw right after its spread.

This practice is said to promote seed germination, but there is no scientific evidence for it.

No tillage is practiced. Irrigation is applied two weeks after the sowing of soybeans and at the flowering and pod-setting stages.

Fertilizers are applied two weeks after germination in the amounts of N 10-20 kg/ha and P_2O_5 30-40 kg/ha without K_2O.

Harvesting

Soybeans are harvested by uprooting the whole plant by hand or cutting the plant near the ground with a sickle and then treshed by a power tresher. Soybean seeds are dried under natural sunshine for 3-4 days until the moisture content is reduced to about 13%. In case of rainy days, soybean seeds may be dried by dryers for 1.0-1.5 days.

The harvesting time varies with the planting seasons, from May to July for the spring crop, September to November for the summer crop, and January to early February for the fall crop.

Disease and pest control

Due to the hot and humid weather in Taiwan, soybean diseases and insects are prevalent and sometimes cause severe damage to the crop. The major ones and the chemicals for their control are listed below:

Diseases and insect pests	*Chemicals for control*
Rust (*Phakopsora pachyrhizi* Sydow)	Dithane M-45, Bayleton
Bacterial blight (*Pseudomonas glycineum)*	——
Bacterial pustule (*Xanthomonas phaseoli)*	——
Purple speck (*Cercospora kikuchii)*	Maneb
Virus	——
Root miner (*Melanagromyza dolichostigma)*	Disyston, PSP204, Thimet
Stem miner (*M. sojae)*	ditto
Leaf miner (*Phytomyza atricornis)*	ditto
Black cut worm (*Agrotis ypsilon)*	ditto
Blister beetle (*Epicauta hiriconis)*	ditto

Soybean research and extension systems

Research institutions

A number of institutions are engaged in soybean research, such as the National Taiwan University (NTU), National Chung Hsing University (NCHU), Pingtung and Chiayi Institutes of Agriculture, Taiwan Agricultural Research Institute (TARI), and Kaohsiung, Hualien and Tainan District Agricultural Improvement Stations (DAIS). Their geographical locations are shown in Figure 1.

NTU had cooperated with Kaohsiung DAIS in breeding research to develop high-yielding and daylength-insensitive varieties, and also worked on genetics, physiology and cultural practices. However, it has not implemented any active research program in recent years except for some studies on soybean seed physiology.

NCHU is interested in soybean breeding and genetics research, particularly in interspecific hybridization, quantitative genetics, yield components analysis, and some physiological studies.

TARI and Kaohsiung DAIS are responsible for breeding such soybean varieties that are high-yielding, resistant to rust and daylength-insensitive. TARI is recently engaged in research on the nitrogen fixation of soybean nodule bacteria and on the physiological aspects of low yield. Other DAISs do the breeding work in cooperation with TARI and Kaohsiung DAIS.

Besides, the Pingtung and Chiayi Institutes of Agriculture also conduct soybean research in the fields of breeding and genetics, photoperiod, nutrition, and cultural practices. Their interests are not

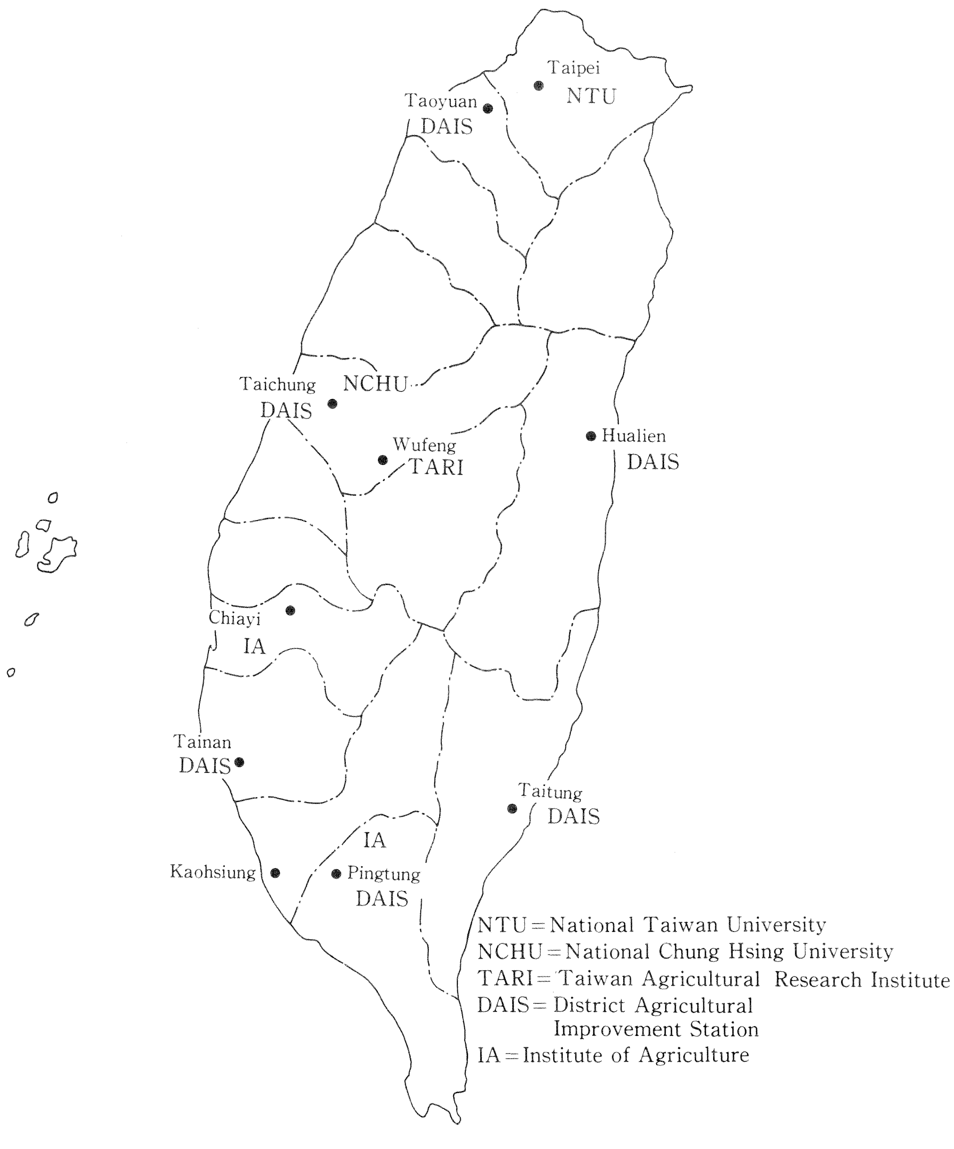

Fig. 1 Location of soybean research and extension institutions.

consistent, depending largely on the grants available.

The Asian Vegetable Research and Development Center (AVRDC) , an international organization, is very active in soybean research in the fields of breeding, pathology, physiology, nutrition, etc. to solve production problems not only for Taiwan but also for other Asian countries.

Other organizations contributing a great deal to soybean production are: 1) the Council for Agricultural Planning and Development (CAPD) which, at the national level, maps out overall plans for soybean production and makes funds available to various research institutions, and 2) the Provincial Department of Agriculture and Forestry (PDAF) which handles research and extension programs.

Table 4 Soybean varieties released in Taiwan and their characteristics

Variety	Year released	Days to maturity (days)	Plant height (cm)	Flower color	Pod color	Pubescence color	Seedcoat color	Hilum color	Yield (ton/ha)	Disease resistance (reaction)	Adapted area and season	Other
San-Kuo	1956	86—124	46—10	P	Tan	Tawny	Dark yellow	Brown	1.4—3.0	Resistant to PS and DM	Northern, Summer	Sensitive to daylength
Shih-shih	1957	80—95	25—40	P	Tan	Gray	Yellow	Brown	1.6—2.0	Resistant to PS, DM and SMV	Any season	Insensitive to daylength and temperature
Palmetto	1957	83—127	55—100	P	Tan	Light brown	Brown	Black	1.3—2.5	Resistant to PS and DM	Summer and Fall	Sensitive to daylength and temperature
Wakashima	1960	91—120	50—80	P	Tan	Tawny	Light brown	Brown	1.5—3.0	Virus susceptible	Fall	Sensitive to temperature
Talientto	1949	80—95	50—70	W	Tan	Tawny	Brown	Dark brown	2.1—3.0	Resistant to PS	Fall	Sensitive to temperature
Acadian	1960	90—95	30—35	P	Dark brown	Tawny	Brown	Brown	1.4—2.0	—	Fall	Sensitive to daylength
Nungyuan 1	1958	92—100	35—40	W	Brown	Light brown	Yellow	Black	1.2—2.0	—	Fall	
Chunghsing 1	1964	107—122	36—58	P	Brown	Gray	Yellow	Dark brown	2.5—4.5	Resistant to rust	Eastern, Fall	Insensitive to daylength and temperature
〃 2	1964	107—113	35—95	W	Tan	Light brown	Yellow	Brown	2.9—3.7	ditto	ditto	ditto
〃 3	1967	84—96	47—51	P	Dark brown	Tawny	Yellow	Brown	2.2—2.6	ditto	Spring and Summer	ditto
NTU-KS 5	1963	85—100	35—50	W	Tan	Tawny	Yellow	Brown	1.5—2.5	Rust susceptible	Fall	Vigorous growth
Kaohsiung 1	1959	80—90	40—60	P	Dark brown	Tawny	Yellow	Dark brown	1.0—1.8	Rust and DM susceptible	Spring and Fall	Drought tolerant
〃 2	1959	90—105	60—80	P	Brown	Tawny	Brown	Dark brown	1.6—2.7	Resistant to rust	Fall	Sensitive to daylength
〃 3	1971	90—115	30—60	W	Dark brown	Tawny	Yellow	Brown	1.2—3.0	Resistant to rust	Any season	Large-seeded
〃 8	1980	87—110	38—65	W	Dark brown	Tawny	Yellow	Brown	1.6—3.5	ditto	ditto	Insensitive to daylength and temperature
〃 S—9	1982	97—120	40—60	W	Brown	Tawny	Yellow	Brown	1.0—3.2	Resistant to rust and DM	Spring and Fall	Vigorous growth
Tainung 1(R)	1963	110—120	60—80	P	Tan	Tawny	Yellow	Brown	1.5—2.9	Resistant to rust	Northern, Summer	Lodging resistant
〃 2(R)	1963	110—120	55—82	P	Tan	Tawny	Yellow	Brown	1.5—3.0	ditto	ditto	—
〃 3	1967	85—113	30—54	P	Brown	Light brown	Yellow	Brown	1.8—2.8	Resistant to rust and SMV	Spring and Fall	—
〃 4	1970	93—112	25—54	P	Brown	Tawny	Yellow	Brown	1.2—2.3	Resistant to rust	ditto	—
〃 15	1980	88—102	33—58	P	Brown	Gray	Yellow	Brown	1.3—1.7	Rust susceptible	Southern, Summer	Salt tolerant
Hualien 1	1980	100—115	35—60	P	Brown	Tawny	Yellow	Brown	1.5—3.2	—	Eastern, Summer	Lodging resistant

W = White, P = Purple, PS = Purple Speck, DM = Downy Mildew, SMV = Soybean Mosaic Virus

Extension service

Responsible for agricultural extension are the District Agricultural Improvement Stations (DAISs) . There are six such DAISs located respectively in Taoyuan, Taichung, Tainan, Kaohsiung, Hualien and Taitung. They operate under the PDAF but technically work in close cooperation with TARI. Any findings by research institutions are transferred to DAISs for local evaluation and the results thereof are disseminated to farmers.

DAISs are also responsible for seed multiplication. The breeder's seeds of a new variety are provided by the research institutions to the DAISs for multiplication of foundation seeds. Then, the registered seeds are produced by reliable farmers selected and guided by the DAISs. Some foundation seeds may also be multiplied by the Taiwan Seed and Seedling Improvement Station.

Major research programs completed

Variety improvement

A total of 22 soybean varieties have been developed in the last two decades by NTU, NCHU, TARI, and Kaohsiung and Hualien DAISs. Six of them are introductions, and the remaining are selections from hybridization (Table 4) . All varieties are daylength-insensitive and mature early. Days to maturity are generally less than one hundred so that they can be fitted into the rice-rice-soybean cropping system in the major soybean-producing areas. Rust resistance is essential for newly developed varieties. For exampe, Tainung 3 and 4 and Kaohsiung 2, 3 and S-9 are all moderately resistant to rust. The sources of resistance are mainly from PI200492, PI230970 and PI230971.

Breeding and genetics research

Breeding and genetics are the major fields of soybean research in Taiwan. An extensive review has been made by Thseng and Chan (1980) . Breeding scheme, heritability, yield components analysis, correlation between agronomic characters, and heterosis are the major subjects.

1 Selection scheme: Soybeans are very sensitive to daylength and temperature so that the selection scheme is extremely important in developing varieties best suited to the cropping system. There are controversies about this matter. According to Yu *et al.* (1965) , most characters of the lines selected from F_2 populations grown in different seasons showed different coefficients of variability and the genetic differences were expressed more evidently in the spring crop. They suspected that the disruptive selection scheme might not be the best approach. Other scientists agreed with them by obtaining larger genetic variances and higher heritability for most characters in the spring crop, but indicated that some lines selected by disruptive selection produced high yields in both spring and summer crops, and were stable in different years (Lu *et al.* ,1967) . By using the same scheme, Tsai *et al.* (1967, 1970) also obtained lines adapted to both spring and fall crops. Hence, they strongly suggested that the use of disruptive seasonal selection was advantageous. The same results were obtained by Thseng and Ling (1977a, 1977b) who indicated that the disruptive selection scheme might have three advantages: (1) shorten the breeding period; (2) make selected lines more flexible to the environment; and (3) reduce the seed storage problem. They suggested that selection be made in the spring or summer and propagation in the fall. Continued research is required if the time of soybean production is to be shifted to spring and summer seasons.

2 Heritability: The estimates of heritability vary so greatly that care must be taken in the use of it. The h^2 estimates obtained by various workers are under entirely different environmental conditions, such as year, location, experimental design, spacing, single plant or plot basis, etc. Some of them are expounded in broad sense, while others in narrow sense. In general, the h^2 estimates of plant height, 100-seed weight, days to flowering and days to maturity (Thseng and Ling, 1977b; Yu, 1964) , unit seed weight, number of nodes on main stem (Tai, 1964) are high, while the seed yield estimates are generally low. The h^2 estimates are higher from the crosses of determinate ×

indeterminate types than from the crosses between the same growth types (Thseng, 1980) .

3 Yield components analysis and correlation between characters: Yield components analysis and correlation studies may facilitate the selection of high-yielding varieties. The results, however, vary greatly because the materials and planting seasons are different. Most results show that genotypic correlations are higher than phenotypic correlations which in turn are higher than environmental correlations for most agronomic characters (Tang, 1963; Tai, 1964; Yu *et al.* , 1965; Tsai *et al.* , 1970; Thseng and Ling, 1977a, 1977b) . One group of characters (number of branches, number of seeds per pod, number of pods per node) is negatively correlated with another group of characters (unit seed weight, number of nodes on main stem, number of nodes per branch) . However, characters within one group are positively correlated (Tai, 1964) . Other negative correlations are found between 100-seed weight and days to flowering, plant height, plant weight, number of branches, number of pods, days to flowering and pod-setting duration (Yu *et al.* , 1965), days to maturity as well as days to flowering with characters such as plant height, number of branches, number of pods, number of seeds and plant weight (Tsai *et al.* , 1967) . Other correlations between characters are generally positive.

With respect to yield components, the most significant ones are the number of branches, number of nodes, number of pods, 100-seed weight (Tang, 1963; Yu *et al.* , 1965; Tsai *et al.* , 1967, 1970) , plant height and plant weight (Tsai *et al.* , 1967, 1970) . Thseng and Ling (1977b) found that the vegetative growth was negatively correlated to the yield in the spring crop, but not in the fall crop, because of an over-vegetative growth resulting from long day, high temperature and abundant rainfall.

In progenies of determinate × indeterminate types, only the correlations between yield components are significant. However, in crosses between the same growth types, the correlations are significant not only between yield components but also between agronomic characters (Thseng, 1980) .

4 Growth type: The growth type of soybeans may be classified into determinate, indeterminate and semi-determinate. However, Thseng and Hosokawa (1972) classified it into determinate, semi-indeterminate and indeterminate based on the degree of growth habits (DGH) expressed in terms of the increase in node number after the first flowering. Thseng and his colleagues in Taiwan suggested that for developing high-yielding soybean varieties, the use of the semi-indeterminate type would be advantageous because of its longer flowering and podding time as well as the flexibility in yield potential against adverse growing conditions in the main soybean crop (fall crop) season(Thseng and Lee, 1976) .

5 Heterosis: The use of heterosis to increase the yield of soybeans is of interest. Most of the F_1 hybrids exhibit heterosis in plant weight, number of branches, leaf area, leaf weight, number of leaves, and thickness of leaf (Thseng, 1978) , total dry weight, seed weight, number of pods and seeds per plant (Chan and Tsuar, 1982) . However, in most cases, 100-seed weight shows negative heterosis.

In the use of genetic male sterility in hybrid seed production, Chan (1975) found that the percentage of pod setting was 63% if manual pollination was made by removing the corolla of male sterile flowers. It was only 6.2% to 15.5% if pollination was made without the removal of the corolla. Bees are not suitable for increasing the natural crossing rate (1.4%) . Thus, genetic male sterility is useful only in making manual crosses for breeding purposes and not for producing commercial hybrid seeds.

6 Cytology: Efforts in soybean cytological and taxonomic research have been limited. Further progress in soybean production is expected to be more difficult. Wild species may be of value. The morphology and cytology of 12 different soybean species and interspecific crosses between *G. max* and *G. gracilis* and between *G. usseriensis* and *G. formosana* have been studied in Taiwan (Cheng, 1962a, 1962b, 1963a, 1963b, 1963c; Lu, 1966; Lu and Thseng, 1968; Tang and Chen, 1959; Tang and Li, 1963; Tang and Tai, 1962) . Attempts to overcome the barrier of other interspecific crosses have not been successful (Chan, 1969) .

Physiology, nutrition and cultural practices

1 Photoperiod and temperature sensitivity: In Taiwan, 9-12 hr is the critical photoperiod for normal plant growth (Cheng, 1963; Lu and Yen, 1975) . Different varieties respond differently to daylength, ranging from 4-14.5 hr, and temperature (Shee, 1966b) . Most of the varieties from high latitude are daylength-insensitive, and those from lower latitude are sensitive. Sensitive varieties mature too late in the spring crop while insensitive varieties are generally temperature-sensitive and mature too early in the summer with resulting low yields (Lu, 1957; Lu and Tsai, 1964) . The days to flowering are prolonged due to low temperature on the one hand and high temperature with longer daylength on the other. However, the effect of high temperature on maturity is not very significant under short daylength but will delay maturity under longer daylength (Lu and Yen, 1975) . Shee (1964) found that the longer the daylength the smaller the seed size. This explains why soybean seeds produced in the spring crop are relatively smaller.

In a series of studies, Shee (1970a) indicated that the substance produced by photoperiod treatment for inducing flowers did not translocate itself. One branch of a sensitive soybean plant subjected to longer photoperiod did not flower while another branch of the same plant left untreated flowered, or *vice versa*. Another interesting result is that when the branch of the sensitive variety, Palmetto was grafted onto that of the intensitive variety, Shih-Shih and was grown simultaneously with the branch of Shih-Shih on the same plant under 16 hr photoperiod, the daylength sensitivity was not altered (Shee, 1970b) .

The daylength sensitivity of some soybean varieties has been identified (Lu, 1954, 1969; Shee, 1966a) as shown in Table 4.

When soybeans were grown under low temperature, Wu (1977, 1978, 1980) found that the pollen development was retarded and plant height, number of branches, number and size of pods, leaf area, leaf dry weight, chlorophyll content were all reduced. The root system was also severely affected.

2 Physiology of different leaf-types: There are three different types of soybean leaf, i. e. , broad, intermediate and narrow. Attempts to use the narrow leaf type and to understand its physiology have been made. Chan (1967) found that the narrow leaf type had smaller stomata, larger aperture and lower transpiration so as to be more tolerant to drought. Lu and Muh (1979) indicated that the physiological characters differed significantly among different leaf types, e. g. , AGR : intermediate > broad > narrow ; CGR : intermediate and narrow leaf types were the largest in the spring and summer crops respectively; LAI: the intermediate type was the largest while the narrow leaf was the smallest. The canopy of different leaf type varieties affected the growth and yield of soybeans (Su *et al.* , 1971) .

Seeds, deteriorated under high temperature (42^0 C) and humidity (100%) , show no change in protein content but a slight reduction in oil content. Deteriorated seeds germinate poorly, plant growth is retarded, and all agronomic characters are reduced. The adverse effects of seed deterioration on yield components result in lower yields (Wu, 1977) .

The relationship between O_2 uptake, C_2H_2 reduction and H_2 evolution as affected by water stress has been evaluated in soybean nodule. The relative efficiency of nitrogen fixation in soybean nodule is not affected, the absolute rates of C_2H_2 reduction and H_2 evolution decrease with increasing water stress. The water stress also increases the respiratory cost in soybean nodule (Sung, 1982) .

3 Nutrition: Soybean nutrition studies were mostly conducted in the 1960s.

Lin *et al.* (1960, 1962) found that there was no significant response to NPK if soybeans were planted in paddy fields because of the residual effect of fertilizers applied to rice, and suggested as optimum fertilizer levels N: P_2O_5: K_2O = 5: 20: 20 kg/ha. Potassium might increase the number of soybean branches (Fong, 1964; Yu and Hsu, 1962) and urea could be used as foliar application at the concentration of 1/600 - 1/850. In acid soils, the application of Mo or liming increased soybean yields because of the increase of nitrogen fixation by nodule bacteria. However, it did not affect the absorption of P, K and Ca. If both Mo and lime were applied, the effect of Mo would greatly diminish as soil pH became higher after liming (Lee *et al.* , 1967) .

There would be a higher dry matter production if the growth rate of soybeans at the vegetative stage could be increased. The dry matter production is positively related to the yield. The response of soybeans to fertilizers, particularly nitrogen, generally takes place at the early growth stages (Liu, 1982) .

4 Cultural practices: Most researches on soybean culture are conducted at DAISs and TARI. Spacings and seeding rates for various crops are the common topics. In conventional cultural practices, the spacing of 40 × 20 cm or 40 × 10 cm is the best for both spring and summer crops (Hualien DAIS, 1960; Chan and Cheng, 1971) . However, Tang (1970) indicated that soybeans would yield better if closer spacing (20 × 10 cm) was used. For the fall crop, the adequate spacing is 30 × 10 cm (Tainan DAIS, 1971) .

Stubble-planting is used for the fall crop. Soybeans are planted at the same spacing as rice. The spacing of 27.0 × 13.5 cm is better than 22.5 × 22.5 cm, with two plants per hill (Chen and Hung, 1968; Chen and Li, 1969) .

Weed control in soybean fields is very limited. Preforan 30 and Prometryne are as effective as Lasso and TOK-25 (Cheng, 1973) . Additional weeding is necessay for maintaining the normal growth and yield of soybeans in continuous cropping with repeated application of the same herbicides (Wang *et al.* , 1975) .

Diseases

More than 40 soybean diseases caused by fungi, bacteria, nematodes and/or viruses have been recorded in Taiwan (Tsai *et al.* , 1979) . Among them rust is the most important (Han, 1959a; Chu and Chuang, 1961; Yang, 1977) . Downy mildew, purple seed stain, and bacterial pustule are commonly observed in soybean fields, but they are not as prevalent as rust (Han, 1959a; Chu and Chuang, 1961) .

1 Disease control: Soybean rust (*P. pachyrhizi*) is one of the factors limiting the yield (Chan, 1977) . It is especially destructive in the spring and fall crops and also prevalent in the summer crop (Liu, 1966; Yang, 1977) . Complete defoliation may occur in case of heavy infection. Yield losses of 23-50% are recorded in the field (Chan, 1977; Chan and Tsuar, 1975; Liu, 1966) and 90% in the nursery (Yang, 1977; Yeh and Yang, 1975) . No highly resistant cultivar is currently available (Liv, 1966; Yang, 1977) . The spraying of fungicides such as Bayleton, Maneb, Zineb, Mancozeb, Plantvax, Saprol and Sicarol gives satisfactory control (Chan and Tsuar, 1975; Hu *et al.* , 1975; Hung and Liu, 1961; Jan and Wu, 1971; Liu, 1966; Yang, 1977; Yen and Yang, 1975; Wang, 1961) .

The vegetable soybean cultivars in southern Taiwan are very susceptible to downy mildew (*Peronospora manshurica*) (Chu and Chuang, 1961; Han, 1959a) . However, no fungicide has yet been officially recommended to the farmers to control this disease. They usually use Dithane M-45 to prevent its spread.

Purple seed stain (*Cercospora kikuchii*) occurs islandwide, and is serious in the spring crop in central Taiwan (Han, 1959b) as rainfall is abundant before harvest. Heavily infected seeds decrease the germination ability. Differences in resistance are observed among soybean varieties. The disease is controlled by spraying the fungicide Mancozeb (400 ×) at 10-day intervals once symptoms appear. Seed treatment with fungicides has also been reported as effective. The use of high quality or clean seeds will prevent seedling infection and reduce primary inocula. Bacterial blight (*Pseudomonas syringae* pv. *glycinea*) is severe under cool and humid conditions. Chu and Chen (1968) reported that the varieties Sanko and TK5 were less susceptible than Tainung 2 and 64-91.

Other diseases such as soybean mosaic virus disease, witches' broom (MLO) and those caused by root-knot nematodes (*Meloidogyne javanica, M. incognita*) have also been recorded but not yet become a problem (Tsai *et al.* , 1979) .

2 Studies on pathogens: Few studies on pathogens have been reported. The uredospores of soybean rust germinate well at 21° C in free water. The germinability decreases drastically within three weeks at room temperature. However, cold storage at 5° C prolongs the germinability up to

46 days. Light is necessary for the formation of infection pegs to penetrate host epidermis (Hsu and Wu, 1968) . Lin (1966) found that collections of the soybean rust organism varied in pathogenicity and virulence among non soybean hosts. Based on the lesion types of five soybean differentials, three races of *P. pachyrhizi* have been identified at TARI (Yeh, 1983) .

Insects

Fifty-seven species of soybean insects have been recorded in Taiwan. Stem and root miners, green stink bugs, scarab beetle and Kanzawa spider mites are the most important.

1 Bionomic studies: Bionomic studies on the stem miner (*Melanagromyza sojae*) (Wang, 1979, 1980) , root miner (*Ophiomya centrosematis*) (Lee, 1958, 1976; Lee and Wang, 1968) , bean root miner (*O. phaseoli*) (Lin *et al.* , 1977) , bean leaf roller (*Hedylepta indicata*) (Anonymous, 1981) , green stink bug (*Negara viridula*) have been reported. Information contained therein can be used for the study of control measures.

2 Chemical control: The use of chlorinated hydrocarbon compounds such as BHC, Endrin, Dieldrin and Heptachlor is banned due to their residue problems. The application of granular insecticides upon seeding or the spraying of insecticides on plants to control miners, aphids and spider mites has been the major control measure since 1968. Monocrotophos, Demathoate, and Chlorinate give satisfactory control when sprayed at one-week intervals starting 7 days after germination (Chang, 1971; Chen, 1953; Lee, 1962) . Disyston, Thimet, Furadon, Temik, Folimat and PSP are commonly used by the farmers at present.

3 Biological control: Biological control of soybean pests has been studied at TARI since 1970. However, efforts are concentrated on the survey of the species of parasitoids of bean leaf rollers and stem and root miners. The parasitoids reported are: six species for the stem miner, four species for the root miner, and four species for the bean leaf roller (Chiu and Chou 1977; Chou *et al.* , 1981) . Three species of parasitoids for the green stink bug (*Trissolus* sp. , *Telenomus* sp. and *Gymnosonia* sp.) and two species for the mantid have also been recorded (Wang, 1979, 1980) .

There are 24 species of natural enemies of Tranuchoideae found in Taiwan for Kanzawa spider mites. Among them, two predatory bugs (*Stethorus loi* and *Oligota oviformis*) , gall midge (*Arthrocnodax* sp.) and two predatory mites (*Amblyseius longispinosus* and *A. ovalis*) are important with regard to their potential to reduce the population of pest mites (Chiu and Chou 1977; Chou *et al.* , 1981) .

4 Pheromone : The use of a synthetic sex pheromone of the tobacco cutworm (*Spodoptera litura*) to trap male moths in the fields has been attempted. However, its effectiveness is reduced under cool and wet conditions (Chiu and Chien, 1979) .

5 Variety resistance : Screening of soybean germplasm for resistance to beanflies or miners shows that no variety is highly resistant (Chan *et al.* , 1973) . However, differences among varieties are observed. Lo *et al.* (1981) reported that 24 varieties/lines were resistant to Kanzawa spider mites and that the length, intensity and growth angle of leaf hairs were highly correlated to the population density of spider mites on the plant.

Major constraints in soybean production

The supply of soybeans in Taiwan depends solely on imports.

The major constraints attributable to the downhill trend of soybean production have been discussed in detail (Cheng, 1971; Thseng and Chan, 1980; Wan and Cheng, 1969) .

Import of low-priced soybeans

Soybean production in Taiwan has never been sufficient to meet local needs in the past three decades. The shortage is mainly due to the import of low-priced soybeans. This greatly affects the marketing price of locally-produced soybeans and thus makes the soybean-growing non profitable.

Competitive crop in soybean-producing center

Another factor responsible for the decline of soybean production is the marked increase of adzuki bean production as a substitute for soybeans in Pingtung County — the soybean-producing center.

Although 90% of the adzuki beans were originally produced in this area, a constant balance between the acreages of soybeans and adzuki beans had been maintained before 1976 at the ratio of 9: 1. However, the acreage of adzuki beans increased from 5,855 hectares in 1976 to 17,354 hectares in 1981, particularly in Pingtung County (Table 5) . The shift is due to higher profits from growing adzuki beans (Huang, 1980) , which are produced for export to Japan under contract.

Table 5 Acreages of soybean and adzuki bean

Year	Taiwan province				Pingtung County			
	Soybean (ha)	Adzuki bean (ha)	Total (ha)	% adzuki bean	Soybean (ha)	Adzuki bean (ha)	Total (ha)	% adzuki bean
1970	42,749	1,986	44,735	4.4	28,390	1,420	29,810	4.8
1971	40,151	2,655	41,806	6.2	27,422	2,218	29,640	7.5
1972	36,123	5,475	41,598	13.2	24,658	4,229	23,387	20.2
1973	36,491	6,878	43,369	15.6	23,422	6,362	29,784	21.4
1974	44,454	4,714	49,168	9.6	28,872	4,242	33,115	12.8
1975	41,446	5,021	46,467	10.8	29,074	4,601	33,675	13.7
1976	35,548	5,855	41,403	14.4	26,635	5,469	32,104	17.0
1977	30,117	10,975	41,092	26.7	20,503	10,415	30,918	33.7
1978	24,473	19,692	44,165	44.6	13,729	18,423	32,152	57.3
1979	19,333	18,254	37,587	48.6	10,806	16,764	27,570	60.8
1980	15,329	16,369	31,698	51.6	8,386	14,700	23,086	63.7
1981	10,312	17,354	27,666	62.7	4,476	15,293	19,769	77.4

From Chiang, 1979 and Taiwan Agriculture Yearbook.

Unfavorable growing conditions in the tropics

Soybeans are grown mainly as a winter crop after the harvest of the second rice crop in Taiwan. The winter time is dry, short in daylength and low in temperature, which is not favorable for soybean growth. Nor are spring and summer suitable for soybean plantings because of abundant rainfall, high temperature and pest problems. These environmental stresses render soybean production in the tropics low-yielding and difficult.

High cost of production

The average yield of soybeans in Taiwan is 1,500-1,600 kg/ha, which is not very low in comparison with that in other Asian countries. However, the high labor cost, small farm size, low input in soybeans as a side-crop and unfavorable weather conditions have resulted in an ever-higher cost of production, making soybeans difficult to compete with other crops.

Measures for promotion of soybean production

The local soybean output accounted for only 1% of the total demand in Taiwan for the year 1982. It is far from the projected national goal for soybean production. The government made its utmost efforts both from the economic and technological angles to increase the production in order to reduce imports.

Price support

For the purposes of stimulating the farmer's interest in growing soybeans and offsetting the adverse effect of soybean imports, the government set up a Grain and Feed Development Foundation in 1972. An amount of NT$40 was surcharged on each metric ton of imported grains. The funds thus raised were partly used to establish a guaranteed price program for soybeans. However, the program was not very effective because the support price was too low to be attractive and the scope of its applicability was rather limited. Since 1982, the government has raised the support price to NT$25 per kg and made the program applicable to any soybean-growing area. The program is expected to become more attractive to soybean growers and thereby make the soybean more competitive with other crops provided that the funds for the program are available.

Expansion of acreage

For decades, the major area for soybean production has been limited to the southern part of Taiwan as a fall crop. Expansion of its acreage in that area is rather difficult. In 1982, a landuse readjustment program was announced by the government to cope with the over-production of rice. The shift of paddy cultivation to that of soybean and other feed-grain crops has since been emphasized. In other words, the soybean is no longer limited to the winter cropping; it can be planted in paddy fields to replace rice as spring and summer crops. On the other hand, various incentives such as NT$10,000 per hectare subsidies and low-interest loans are provided to encourage farmers to grow grain crops other than rice. This policy will undoubtedly serve to expand the acreage of soybeans.

Change in the aim of variety improvement

To match the readjustment of farmland uses, the aim of soybean variety improvement must also undergo a change. This calls for the development of such varieties that are adapted specifically to spring and summer seasons in order to fit the new cropping pattern. Attention will still have to be paid to the daylength-and temperature-insensitive varieties.

Soyban rust poses a risk in soybean production. The presently available sources of resistance are not entirely adequate for protecting the crop against the disease. Continued search for adequate sources of rust resistance is encouraged.

Reduction of production cost

The labor cost accounts for 41.5% of the total production cost (Thseng and Chan, 1980) . Under such a pressure, emphasis is being placed on the development of farm machinery for feed grain crops and on the study of labor-saving cultural practices. On the other hand, an integrated cultivation method, including the use of improved varieties, new cultural techniques, proper pest control, and adequate fertilization and irrigation, should be stressed in order to increase the yield and reduce the cost.

Prospects

In 1978, the highest target of soybean production was set at 170,000 tons to be harvested from 85,000 hectares, but actually only 40,824 tons were produced on 24,473 hectares. This downward trend of soybean production may continue for some time.

Great strides have been made by the government in its efforts to reduce rice production and allocate more paddy land for the planting of soybeans and other feed grains. Thus, there will be much more room for soybean acreage expansion in the spring and summer seasons if incentives are attractive enough and readily available to farmers. A reasonable 100,000 tons of soybeans with quality preferred by local consumers can be produced.

In this context, the variety improvement program should be aimed at developing such varieties as can be fitted to the spring and summer seasons and have a higher protein content and other specific qualities to meet the need of making soybean milk and beancurd for domestic markets. Researches on labor-saving cultural practices, pest control, mechanization and other related fundamental studies should also be strengthened to reduce the production cost and make soybeans more competitive against other crops.

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Discussion

Bhatnagar, P. S. (India) : 1. In your presentation you mentioned that 90% of the soybean produced was utilized for oil. Is the defatted soybean flour used only for cattle feed or also for human food? 2. Could you give the reasons why you changed your breeding objectives in order to increase the acreage planted to soybean ?

Answer : 1. Defatted soybean meal is chiefly used as pig feed and not for human food, except a small amount which is used for the manufacture of soy sauce. 2. Emphasis is placed on the breeding of varieties that are tolerant to high temperature and high rainfall in order to plant them in the summer and spring which coincide with a period of the year when the temperature and precipitation are high.

Dutt, A. K. (India) **Comment** : In Taiwan there are three planting periods, February, June-July and September. Moreover the cultivation of soybean is restricted to the southern part of the country and soybean is not grown in the highlands. In India, soybean can be grown in June to September all over the country provided that the land is well drained and there is no waterlogging. In the southern part of the country and in the Sunderbans soybean can be grown as a winter crop even at tropical latitudes provided suitable cultivars are available.

Carangal, V. R. (IRRI) : 1. You described stubble-planting. Since labor is expensive what is the potential of machine planting as a substitute for stubble-planting?
2. You indicated that the government is now encouraging the cultivation of soybean instead of rice. Are you going to replace the first or the second rice crop in the rice-rice-soybean system since the breeding objectives would be different ?

Answer : 1. Indeed labor cost is high in the case of stubble-planting and the use of machines for planting is increasing. Strictly speaking, the practice described is not exactly stubble-planting but some type of labor-saving cultivation because the machine-planted soybeans are not necessarily at or near the rice stubble. On the other hand some hand-operated planter is also used but not popular. 2. Under the land use readjustment program, the farmers are encouraged to plant soybeans in paddy fields to replace the first or second rice crop. Since the yields of the second rice crop are lower than those of the first crop, farmers are likely to grow soybeans in the summer to replace the second rice crop. Thus the breeding objectives for soybean will be good adaptability to high temperature and heavy rainfall while the requirements for the spring crop of soybean would be tolerance to high temperature and daylength-insensitivity.