RECENT PROGRESS IN WINGED BEAN RESEARCH

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ABSTRACT

In spite of the considerable effort devoted to winged bean research for many years in various countries, climbing behaviour and short daylength requirement for flowering in this plant had limited research progress and commercial exploitation.

At Kyushu University, several completely photo-insensitive lines were successfully improved by selection, and one dwarf determinate type mutant with photo-insensitivity was also segregated from them. Strains characterized by photo-insensitivity and high green pod yield were also bred by crossing.

Introduction

Winged bean (*Psophocarpus tetragonolobus*) is a twining herbaceous perennial leguminous plant. The first description on winged bean was given by C. Plukenet in 1605 who observed the crop in Amboina Island, Indonesia, which indicates that the crop had been cultivated in Asia at least for more than 350 years, although its origin is still uncertain. The genus *Psophocarpus* is composed of 9 species, 8 of which excluding winged bean are native to Madagascar and Africa (Table 1), but the truly wild type winged bean has not yet been found anywhere. Winged bean has been cultivated widely in the Asian humid tropics and sub-tropics for centuries as a home garden crop. Since the National Academy of Sciences, U.S.A. (Anonymous, 1975) identified this under-utilized crop as a promising source of protein and oil in developing countries where protein malnutrition is a major problem and soybean does not grow well, worldwide investigations on various aspects of the plant have been initiated. In 1978 and 1981 two International Winged Bean Seminars were held, the first in Los Banos, Philippines and the second in Colombo, Sri Lanka, and more than 150 technical papers were presented there. The potential of the crop was further recognized and emphasized by the scientists who participated in these seminars.

The leaves, shoots, flowers, pods, unripe and mature seeds and tuberous roots of winged bean are all edible and nutritious as shown in Tables 2 to 4. Mature seeds of the crop contain about 34% protein and 17% oil on a dry weight basis, a composition similar to that of soybean. Tuberous roots of the crop contain a higher percentage (about 11%) of protein than any other tropical root crops such as taro, yam, cassava and sweet potato (Claydon, 1975). Green pods and young leaves also contain 3% and 7% protein, respectively.

In spite of the potential of this plant for the future and the considerable effort devoted to its research for many years, winged bean is still grown as a backyard crop. There are some factors limiting practical and economical cultivation, including the twining growth habit, hence support systems for the growth are required but they are labour-intensive and costly. The development of dwarf and erect plant types could promote the large scale cultivation of this crop. Another limiting factor is the photo-sensitivity for flowering during the growing season even in areas at lower latitudes

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Table 1 *Psophocarpus* species and their distribution (Newell and Hymowitz, 1979)

Species	Distribution
P. grandiflorus Wilczek	Ethiopia, Uganda, Zaire
P. lancifolius Harms	Burundi, Kenya, Malawi, Nigeria, Rhodesia, Rwanda, Tanzania, Uganda, Zaire, Zambia
P. lecomtei Tisserant	Central African Republic, Zaire
P. lukafuensis (DeWild) Wilczek	Zaire, Zambia
P. monophyllus Harms	Guinea Bissau, Guinee and Cote d'Ivoire, Mali, Upper Volta
P. obovalis Tisserant	Central African Republic, Sudan
P. palustris Desv.	West Africa from Senegal to North Cameroun, Sudan, Central African Republic
P. scandens (Endl) Verdc.	Central and East Africa from Nigeria to Angola, Mauritius, Comoro Island, Madagascar. (Cultivated in Jamaica, Brazil, India, Vietnam, Java and Papua New Guinea)
P. tetragonolobus (L.) DC.	(Cultivated in Africa, Asia, South Pacific islands and South America)

such as Sri Lanka.

The present paper describes the research activities on winged bean carried out at the university for more than one decade.

Germplasm collection

Some countries have a large collection of winged bean germplasm, namely India, Indonesia, Papua New Guinea, Philippines, Sri Lanka and Thailand (Herath, 1986). The collection at the university started in 1977 and still continues now. As of today, the total number of accessions in our Laboratory exceeds 300, some of which are gifts by courtesy of Prof. H. M. W. Herath, University of Peradeniya, Sri Lanka, Mr. H. Takada, Tropical Agriculture Research Center, Okinawa Branch, Japan, Dr. K. Somphontharuk, Kasetsart University, Thailand, Prof. T. Vorayos, MIAT, Thailand, Dr. G. E. Eagleton, University of Western Australia, Australia, Dr. K. J. Kim, Kon Kuk University, Korea, Dr. J. Ruegg, Institut fur Pflanzenbau, Switzerland and Prof. G. Shivashankar, University of Agricultural Sciences, Bangalore, India, and others which were collected by us from fields or home gardens or purchased at seed stores or markets in some Asian countries. These accessions include some well-known varieties such as the UPS series from Papua New Guinea, TPT series from Nigeria, etc.

Evaluation and selection of the accessions for the development of photo-insensitive lines for flowering

Due to its origin in the tropics or sub-tropics, winged bean is basically a short-day plant for flowering. In order to select the day-neutral types of the plant for flowering, which enable year-round harvest at lower latitudes and cultivation also in temperate zones in the summer season, the flowering response of all the accessions to long daylength was examined in open fields, greenhouses or the phytotron of the university (33.35°N).

Twelve accessions including UPS-31, -122, TPT-2 and -10 introduced from Okinawa

Table 2 Comparison of food value of mature seeds of winged bean with that of other leguminous crops (g/100g fresh weight) (Claydon, 1978)

	Winged bean	Soybean	Peanut	Cowpea
Moisture	8.7	10.2	7.3	11.5
Fat	15.3	17.7	45.3	1.6
Crude protein	36.6	35.1	23.4	22.7
Carbohydrate	35.6	32.0	21.6	61.0
Fiber	3.7	4.2	2.1	4.2
Ash	3.8	5.0	2.4	3.2

Table 3 Comparison of food value of tuberous roots of winged bean with that of other tuberous crops (g/100g fresh weight) (Claydon, 1978)

	Winged bean	Kudzu bean[a)]	Yam bean[b)]	Yam[c)]	Sweet potato
Moisture	56.5	68.6	87.4	76.4	72.3
Crude protein	10.9	2.1	1.6	1.9	1.0
Fat	0.4	0.1	0.2	0.2	0.3
Carbohydrate	30.5	27.8	10.3	19.9	25.6
Fiber	1.6	0.7	1.3	0.6	0.8
Ash	1.7	1.7	0.5	1.6	0.7

a) : *Pueraria lobata.* b) : *Pachyrhizus erosus.* c) : *Dioscorea alata.*

Table 4 Nutritious value of leaves, flowers and pods of winged bean (g/100g fresh weight) (Claydon, 1978)

	Leaves[a)]	Flowers[b)]	Pods[c)]
Moisture	78.1	87.5	89.6
Fat	1.6	0.5	0.4
Protein	8.1	2.8	2.7
Carbohydrate	10.8	8.4	6.7
Ash	1.4	0.8	0.6

a) : Top 3 sets, from 2-3 months old plants.
b) : Fully opened from 2-3 months old plants.
c) : Whole, 7-14 days after flowering.

in 1977 were all short-day plants. Out of 11 varieties of the UPS and SLS series from Prof. Herath, Peradeniya, Sri Lanka, UPS-99 was found to be a short-day plant at the constant temperature of more than 25°C, but able to flower under a 16 hr daylength regime when the temperature remained constant at 20°C. As this variety is not a completely short-day plant, it is not suitable for summer cultivation here. We used this variety as a parent material for crossing trials with other selected varieties.

Out of 10 varieties introduced from Thailand in 1980, only one individual found in the cultivation of a variety Ka-WB-11-2 was insensitive to photoperiod under the prevailing summer conditions in Japan. After evaluation of this selection for several years, we named it KUS-10, which corresponds to the system for identifying the varieties developed

by selection or crossing at the university. We thereafter selected completely photo-insensitive varieties such as KUS-1, -2 -3 and -4 from unknown varieties given by Dr. K. J. Kim and KUS-5, -6, -7, -8, and -9 from TPT-8 provided by Prof. H. M. W. Herath and Dr. J. Ruegg. Among them, KUS-8 is one of the most suitable varieties for cultivation in the summer season in Japan.

In 1981, Dr. D. E. Eagleton gave us 10 accessions from which we selected two varieties based on the color of young pods during the ten year trial. One variety which has bright red pods was selected from UPS-84 and another variety with deep black-purple pods was selected from EC-38826, although both are still sensitive to photoperiod. We maintain them without a name yet as parent materials for the cross-breeding program. UPS-62(F) and -99(F) are distinguishable by their flat pod shape, as seen in the cross section, from the original rectangular pod shape of UPS-62 and -99, respectively. Flat pods are excellent for mass and long distance transportation.

Cross-breeding

Cross-breeding trials were started in 1980 using 19 selected varieties characterized by their photo-insensitivity or high green pod yield potential in order to obtain new varieties having both characters. A total of 45 lines of hybrids was selected by the evaluation of the F_2, F_3 and F_4 generations. Further evaluation of the F_5 and F_6 generations resulted in the selection of KUS-12 from the progeny of the cross between USP-99 x KUS-6. We have also found some other promising varieties and their evaluation is still being continued.

Development of dwarf mutant

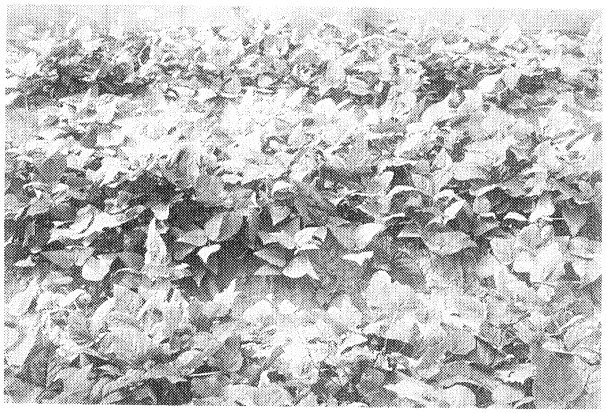
Most of the current varieties available so far showed an indeterminate, viny and climbing growth habit. In order to develop a self-supporting dwarf or determinate plant, mutation breeding using gamma radiation or EMS (ethyl methane sulphonate) treatment was attempted without success, however (Kesavan and Khan, 1978 ; Jalani, 1978). Only Prof. Shivashankar in India was able to obtain a semi-dwarf mutant using gamma rays and selection in M_2 and M_3 generations (Shivashankar and Suryanarayana Reddy, 1984). However, the mutant grown at the International Winged Bean Institute, Sri Lanka in 1987 and in India in 1989, did not appear to be a true dwarf.

Our mutation breeding program was initiated in 1985 in order to obtain an erect, determinate or dwarf mutant by means of gamma ray treatment or selection from mass cultivation.

KUS-4 and -8 were treated with gamma rays at 17.94 R/d or 40.92 R/d during growth for 95 days in 1985. Similar treatments were applied also in 1986 and 1987. We continued the treatments and evaluation of the M_2 and M_3 generations for 3 years, but a mutant with determinate or dwarf habit could not be developed.

In 1985 selection from the mass cultivation of about 100,000 individuals of KUS-8 was conducted in open field, but only one individual showing the determinate growth habit of the mutant was identified from which 30 seeds were harvested. Of the 30 seeds, 27 plants were able to grow and all of them showed a determinate growth habit. Other characters such as pod size, pod shape, pod color, days to first flowering, etc. are similar to those of KUS-8, its parent. After confirmation that the determinate growth habit was genetically stable and the plant was still insensitive to photoperiod after several years of cultivation, we named this mutant KUS-101. Figures 1 and 2 illustrate the growth of KUS -101 in the experimental field. The genetical stability of the characters of KUS-101 were also confirmed under tropical climate conditions in Sri Lanka by Prof. H. M. W. Herath (personal communication).

As winged bean plants are able to produce a large number of nitrogen-fixing root nodules with heavy weight (Masefield, 1973, etc.), it is suggested that the determinate



Figs. 1 and 2 KUS-101

mutant could be grown also as a cover crop under coconut or rubber and the green foliage and tuberous roots could be fed to livestock.

We have just begun another experiment to obtain a perfectly erect and dwarf variety by treating KUS-101 with EMS.

Tuberous root formation

Tuberous roots of winged bean are a highly prized food item in some parts of Papua New Guinea and Burma where they are peeled, baked or boiled and eaten as a snack (Poulter, 1982). It was reported that tuberous root formation of the plant was affected more by daylength than by temperature, and that short days are necessary to initiate it (Wong, 1981). Using the phytotron, we demonstrated that the tuberous root formation is induced by short days and by relatively low temperatures even under long days. Response to daylength varies with the varieties, and daylength requirement for tuberous root formation in photo-sensitive and insensitive varieties follows closely that for flowering in the respective varieties (unpublished).

Future program

Two other promising varieties were given by Prof. H. M. W. Herath. In one of them,

'SLS-84 cracked seed coat', the seed coat can be readily removed soon after soaking in water. This character is very useful for processing of the bean because the seed coat of winged bean is usually harder than that of soybean and unsuitable for the preparation of processed or preserved products. In the other, so-called "giant winged bean", length of the pods is 70 cm. We are currently initiating reciprocal crossing between KUS-101 and these varieties to obtain a dwarf variety with cracked seed coat and a dwarf variety with higher potential of green pod yield.

In the process of screening of the accessions, we have recently identified a variety with a certain degree of cold resistance, which was able to grow until early December in open field where the average temperature of the month was 8.1°C. Chandel *et al.* (1978) reported that they observed four accessions tolerant to frost under Delhi conditions. However, when we visited the National Bureau of Plant Genetic Resources, where their work had been carried out, in New Delhi, India, one scientist mentioned that he doubted that there were frost-tolerant varieties in India. More research for the development of cold-tolerant varieties of the crop is also necessary.

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Discussion

Miyoshi, K. (Japan): Is the photo-sensitive phase absent in your "photo-insensitive" line ?

Answer : The photo-insensitive lines also can flower under short daylength.

Saxena, M. C. (ICARDA) : 1. Could you please comment on the germinability and viability over prolonged storage of seeds of the winged bean genotype with cracked seed coat characteristics ? 2. Is your determinate mutant a morphological dwarf plant or does it have a true determinate flowering habit ?

Answer : 1. I did not study this aspect. I believe that the germination of "SLS-84 cracked seed coat" may be better than that of other varieties as the seed coat is cracked. It is still a short day plant and we cannot get the seeds under open field conditions. 2. It is a true determinate flowering habit mutant. Flowering is concentrated in a short period of time.

Singh, R. B. (FAO RAPA) : Great expectations were built for winged bean as an important bean crop and source of protein for the developing countries after the publication from PNAS and other reports in the late 1970s and early 1980s. Several international conferences were also organized during this period and an international institute of winged bean was established in Sri Lanka. However the euphoria died soon and the international institute had to be closed (it eventually became the National Institute of Beans including winged bean) as some of the high hopes aroused from this plant were not realized. One of the reasons of the setback was the non-availability of dwarf determinate plant type. Therefore, I would like to congratulate the speaker for his success in developing a mutant which is a true determinate dwarf type. This finding brings new hope for this species. I do hope that Dr. Okubo will share seed of the mutant (dwarf determinate) with winged bean workers throughout the world and monitor the progress/performance of this mutant.

Answer: Thank you very much, Dr. Singh. The dwarf determinate mutant is currently under consideration for registration by the authorities concerned of the Ministry of Agriculture, Forestry and Fisheries of Japan. Thereafter, within a year, it will be possible to distribute seeds to researchers involved in winged bean research.