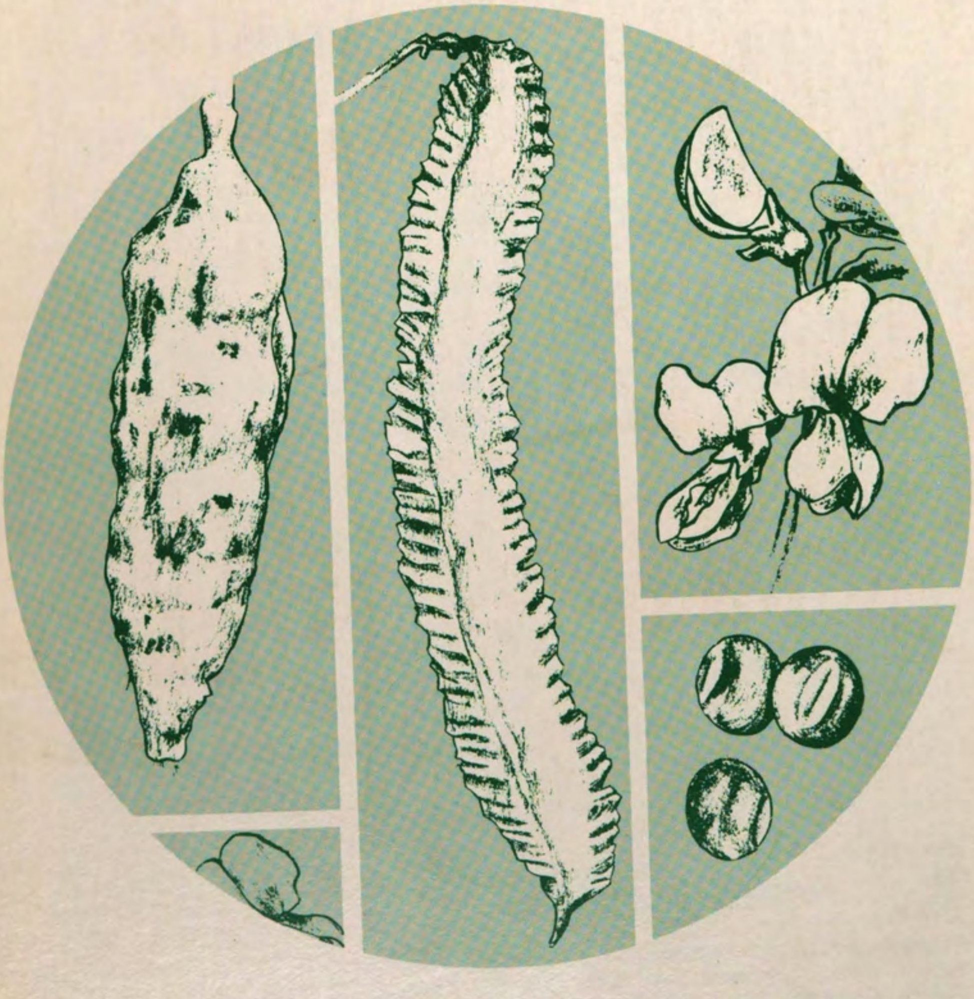
Winged Bean
GH-PROTEIN CROP FOR THE TROPICS

Second Edition



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The Winged Bean
A High-Protein Crop for the Tropics
Second Edition

Report of an Ad Hoc Panel of the
Advisory Committee on Technology Innovation
Board on Science and Technology for International Development
Commission on International Relations
National Research Council

NATIONAL ACADEMY PRESS
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Preface

In 1975 the National Academy of Sciences published a report on the winged bean, *Psophocarpus tetragonolobus*. At that time the plant was a little-known tropical legume grown almost exclusively in Papua New Guinea and Southeast Asia. The seemingly exceptional merits of the winged bean suggested that an in-depth examination of its characteristics and prospects be undertaken promptly and the results brought to the attention of the international development community.

The existing literature on the plant at that time was meager, much of it scattered through 60-year-old journals, mimeographed papers, and annual reports from experiment stations. To evaluate the available information and assess the potential of this plant, an international panel was convened at Airlie, Virginia, in October 1974. The panel was composed of specialists with experience in winged bean cultivation, in tropical agriculture, and in nutrition.

Although the panel was not expected to produce a comprehensive report on the winged bean, it was asked to consider such matters as

- The state of knowledge concerning the plant;
- The bean's promise as a crop plant;
- Significant data gaps and research needs; and
- A strategy for international research and testing to assess the crop's future.

Since 1975 when the report was published, the winged bean has sparked the interest of many scientists, agronomists, and others. The plant has now been introduced to more than 70 countries. The new information this has yielded warranted this updated edition of the report.

Virtually all of the agronomic and nutritional research needs listed in the first edition have received at least some attention. Furthermore, the taxonomic survey of the genus *Psophocarpus* recommended in the report has been undertaken by one of the world's foremost legume taxonomists, Dr. Bernard Verdcourt of the Royal Botanic Gardens at Kew, near London. In addition, the newsletter recommended by the earlier National Academy of Sciences panel is now an established publication, *The Winged Bean Flyer*. It is currently sent to about 1,000 researchers in more than 60 countries. A winged bean grower's handbook for Papua New Guinea farmers and comprehensive winged bean planting guides for Philippine and Thai farmers have also been produced. A 68-page collection of almost 300 abstracts of winged bean literature from 1900 to 1977 was published in 1978 by the International Grain Legume Information Centre in Ibadan, Nigeria.

A national program on the winged bean has been developed in the Philippines and the crop is now an officially designated target crop of the Philippine Department of Agriculture. The governments of Indonesia and Sri Lanka have also officially designated the winged bean as a priority research crop. The Southeast Asian Programme of the International Board for Plant Genetic Resources has been actively engaged in the collection, evaluation, documentation, and utilization of winged bean germ plasm.* In Ghana the bean has been adopted as a crop for its green pods, which fetch a handsome price in Ghanaian markets. Winged bean pods now also appear in the markets of Western Samoa and Hawaii.

The First International Symposium on Developing the Potential of the Winged Bean was held at Los Baños, Philippines, in January 1978. It was attended by almost 200 researchers from 26 countries on 6 continents. Eighty-seven scientists and researchers collaborated on more than 50 papers written specifically for the conference and comprising well over 900 pages of manuscript. The Second International Winged Bean Seminar was held in Peradeniya, Sri Lanka, in January 1981. This time more than 200 people from 36 countries attended and more than 100 scientific papers were presented.

Few crops have risen so quickly from total obscurity to the winged bean's current level of prominence. The interest in this formerly little-known plant has generated so much information in the last 5 years that a computerized Winged Bean Information and Documentation Service Center is operated by the Agricultural Information Bank for Asia in the Philippines.† The assumptions in the earlier report are so far largely standing up to scrutiny. The plant holds such promise that its former obscurity is baffling. As a result of all the new information, prospects seem favorable for the greatly expanded commercialization of the winged bean.

This second edition includes many new findings. It remains, however, an introduction to the plant and not a detailed review of all winged bean knowl-

*Winged bean germ plasm is stored at the Southeast Asian Regional Gene Bank, University of the Philippines, Los Baños, College, Laguna, Philippines, as well as at the Thai National Gene Bank, Thailand Institute of Scientific and Technological Research, 196 Phahonyothin Road, Bang Khen, Bangkok 9, Thailand.

†The Information and Documentation Service Center, *The Winged Bean Flyer*, the Second International Winged Bean Seminar, and some other activities were, at least in part, sponsored and coordinated by The International Council for Development of Underutilized Plants, 18 Meadow Park Court, Orinda, California 94563, USA.

edge. Its main purpose is to acquaint administrators and uninitiated researchers with the plant and its promise.

Initially compiled by Louis Lazaroff of the International Council for Development of Underutilized Plants, the report is based on contributions received from 32 winged bean researchers in different parts of the world (see list, page iii–iv).

The final manuscript was edited and prepared for publication by Noel Vietmeyer and F. R. Ruskin, assisted by Mary Jane Engquist, all of the National Research Council staff.

Warning

In the Ivory Coast, Indonesia, and elsewhere, virus diseases and nematodes that severely limit winged bean yields have been discovered (see Appendix A). The viruses are seed-borne, and until uncertainties over the potential spread of these diseases are resolved, precautions should be taken with seed introductions, and the widespread exchange of uncertified seed should be curtailed.

Contents

1 Summary

People in the hot, humid, tropical areas of the world need better plant sources of protein. But the soybean–the words's premier protein crop–grows well mainly in temperate climates. Although extensive research programs have been launched to adapt the soybean to tropical conditions, results have so far not achieved viable economic returns.

Some researchers are now hailing the winged bean (*Psophocarpus tetragonolobus*) as "a possible soybean for the tropics."

The winged bean is innately a tropical species. It is a poor man's crop that, until recently, was found chiefly in rural areas of Papua New Guinea and Southeast Asia. It grows in profusion in hot, humid equatorial countries such as Indonesia, Malaysia, Thailand, the Philippines, India, Bangladesh, Burma, and Sri Lanka.

The winged bean looks like a pole bean: a mass of twining, leafy stems climbing to heights of 4 m and more if the support is tall enough, set off by white, blue, deep-purple, or pink flowers that quickly develop into pods.

The pods are green, pink, purple, or red–20 cm long on average, and in some varieties as long as a man's forearm. They can occur in such abundance that they often enshroud the whole vine. Each pod has four sides and a square or oblong cross section. A distinctive flange or "wing" projects from each corner. When picked young, these pods lack noticeable fiber and make a succulent green vegetable that is eaten raw, steamed, boiled, stir-fried, or pickled to make a crisp, chewy delicacy.

But pods are only one of six different foods supplied by this plant, which has been described as "a supermarket on a stalk." With the winged bean, almost everything goes into the pot. Its leaves are cooked and eaten like spinach (they are rich in vitamin A, a deficiency of which blinds many tens of thousands of children each year in tropical countries); its succulent shoots resemble lacy thin asparagus; and its flowers, when steamed or fried, make a sweet garnish with the appearance and texture of mushrooms.

The winged bean seeds, however, have created the greatest interest internationally. They virtually duplicate soybeans in composition and nutritional value; both contain similar proportions of protein, oil, minerals, vitamins, essential amino acids, and other constituents. Once processed, both have similar high digestibility.

Mt. Hagen, Papua New Guinea. Young winged bean plant showing pods, leaves, root nodules, and a tuber. (N. D. Vietmeyer)

Perhaps the most unlikely feature of the winged bean is what, in some varieties, is produced underground. The plant's roots enlarge to form tubers the size of small carrots, if it is cultivated correctly.* Their firm, ivory-white flesh has a pleasant nutty flavor when cooked. Highland tribesmen in Papua New Guinea esteem it so highly that they hold winged bean sing-sings (feasts) at harvest time. Winged bean tubers can be boiled, steamed, baked, fried or roasted. Thai food scientists have deep fried and salted them to make tasty snacks. The true value of these tubers became apparent only recently when it was found that they are exceptionally rich in protein, containing two to four times as much as potatoes, more than eight times as much as cassava.

What is known today about the winged bean is roughly equivalent to what was known about the soybean 60 years ago, shortly before its large-scale commercial production in the United States. Many of the advances in the genetic improvement and the processing of soybeans for food and feed could have similar application to the winged bean.

The winged bean may one day become as significant as the soybean in world agriculture. However, its potential for the immediate future is as a subsistence crop or as a cash crop for small markets.

The winged bean is unlikely to rival the soybean in the near future, largely because all varieties now available require staking to produce economic amounts of seeds. They are climbing plants, which if left unstaked, tangle into heaps of intertwined stems that produce few pods or seeds. Staking is laborious and relatively costly to carry out on a mass scale. The hope is that stiff-stem dwarf varieties (having short internodes) will be found somewhere in the winged bean's native region. So far, none has been located.

The winged bean, as noted, is a humid-tropic plant. Varieties currently available grow prolifically in temperate areas, but because of the long summer day length, will not produce seeds. The winged bean's flowering is initiated when days are short.†

Like many legumes, the winged bean is able to convert nitrogen gas from the air into forms usable by plants. This is actually accomplished by soil bacteria belonging to the genus *Rhizobium*. The bacteria inhabit swellings (nodules) on the root surface. Within these nodules the rhizobia proliferate and thrive. They absorb air from the soil and "fix" the nitrogen. The plant, in turn, absorbs much of the nitrogenous product, which it transfixes to protein, some vitamins, and other nitrogen-containing compounds.

*The production of tubers may also depend on variety and climate.

†For North Americans this means that good harvests can be gained in south Florida but almost nowhere else in the continental United States. The winged bean thrives in Puerto Rico and its pods can already be found for sale as a vegetable in Hawaii.

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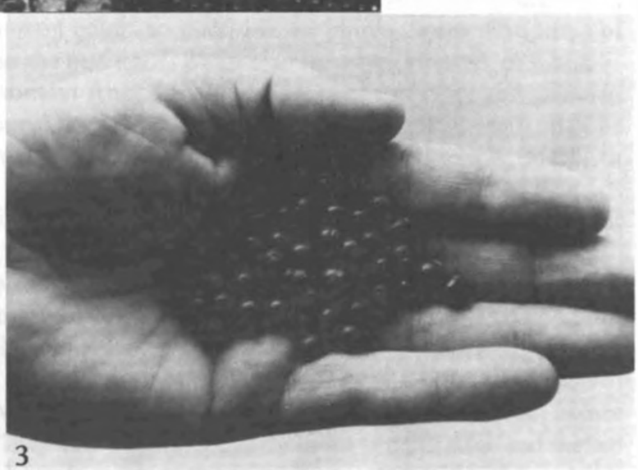

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Because of its wealth of edible products the winged bean has been called a "supermarket on a stalk." Shown clockwise from top left are: 1. the "winged" pod that is comparable to green beans in taste and nutritive value; 2. the leaves, which compare with spinach in taste and nutrition; 3. the seeds, whose composition is similar to that of soybeans; 4. the edible flowers, which are rich in sweet nectar; 5. the tubers, which are like a high-protein potato. All photographed in a village near Mt. Hagen, Papua New Guinea. (N. D. Vietmeyer)

2 Agronomy

The winged bean is a climbing, herbaceous perennial. Most varieties if supported can reach heights of 3–4 m.*

Stems are usually green, but some varieties have stems with shadings of purple, pink, or brown. Flower colors are usually blue, bluish white, or purple, but the range of possible colors varies from near white to deep purple.

Pods are four-cornered and rectangular or square in cross section, with wings at each corner. A few are essentially square, some are flat and broadest on the sutured surfaces (sutured surfaces are the ones that automatically split when the pod opens), and others are flat and broadest on the nonsutured surfaces. The pods can be 6–66 cm long. Pod colors range from green—the most common color—to pink, red, or purple. Some have wings of a different color than the pod itself. Wings may be wavy, serrated, or lobed.

Individual pods contain from 5 to 20 seeds. The seeds, shiny and globular, range in weight from 0.04 to 0.64 g. Depending on variety, seeds may be cream colored, greenish, various shades of brown, deep purple, black, or mottled.

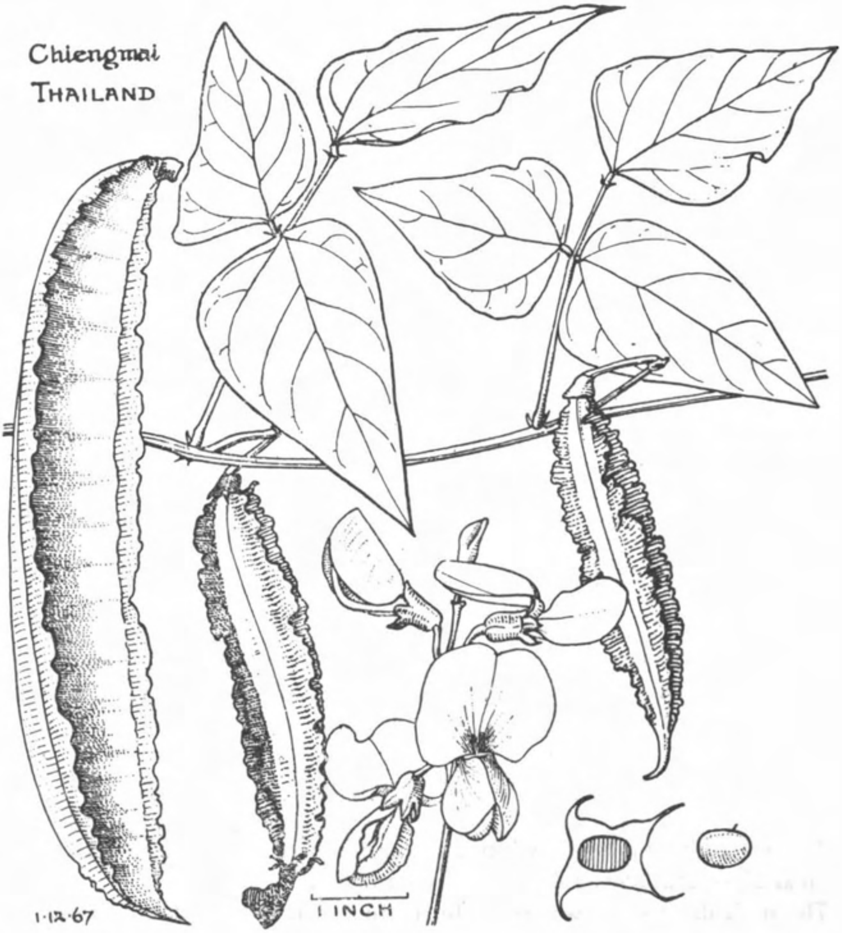
The winged bean is largely self-pollinating, but bees visit the flowers and as much as 20 percent cross-pollination has been noted.†

The pods develop in two stages. In the first, which takes about 20 days, the pod grows to almost its ultimate size. In the second, which takes about 44 days, the seeds swell and harden, while the surrounding pod shrivels, hardens, and dries out.

Pods can be harvested as a green vegetable early in the first stage, before much fiber forms. They can be gathered early in the second stage and shelled like peas to yield the soft, green, unripe seeds, or, after the pod has dried, they can be harvested for the hard, mature seeds.

Dried pods have a tendency to split open unexpectedly and drop the seeds on the ground. However, nonshattering types are known.

*Some specimens allowed to climb up trees have reached 10 m in height. (Information supplied by Brother G. Kraeger, Bangladesh.)
†Information supplied by Narong Chomchalow and A. Claydon.



Psophocarpus tetragonolobus: winged bean. Leaves, inflorescence with pale blue flowers and buds, and young and mature pods. The insets on the right are of a cross section of an old pod and seed. (Based on a drawing by G.A.C. Herklots)

Taxonomy

Psophocarpus is a genus with about nine species.* All but the winged bean, *P. tetragonolobus*, appear to be indigenous to Africa. Only *P. tetragonolobus* and *P. palustris* have been used for food. The other species have never been cultivated. Even *P. palustris* remains a semiwild plant, used in West Africa mainly in times of famine.

***Verdcourt and Halliday, 1978. These should not be confused with the winged beans of the genus _Lotus_ that grow in temperate regions, particularly around the Mediterranean.**

Native Habitat

The winged bean's origin remains in dispute. At least four sites have been suggested as possibilities: Papua New Guinea, Mauritius, Madagascar (the Malagasy Republic), and India. Centers of greatest diversity of the species are Papua New Guinea and Indonesia, although increasing numbers of varieties have recently been discovered in Thailand and Bangladesh.

The winged bean has been cultivated for generations in the humid tropics of South and Southeast Asia: India, Sri Lanka, Bangladesh, Burma, Malaysia, Thailand, Vietnam, Laos, Cambodia, the Philippines, Indonesia, and Papua New Guinea, for example.* In South Asia it is cultivated in Bangladesh, in at least eight Indian states extending from the north to the south, and in Sri Lanka, where it has been grown for generations in the wet zone as well as in the dry zone regions up to an elevation of 1,000 m.

In Papua New Guinea the winged bean is an important backyard and market crop in the Highlands and in the north coast provinces. The number of varieties and their use in certain tribal rites suggest that the winged bean has been cultivated in Papua New Guinea for centuries. The villagers differentiate varieties that produce high tuber yield from those that produce large amounts of pods. In some areas winged bean tubers are an important staple, but in most areas they are a seasonal food.

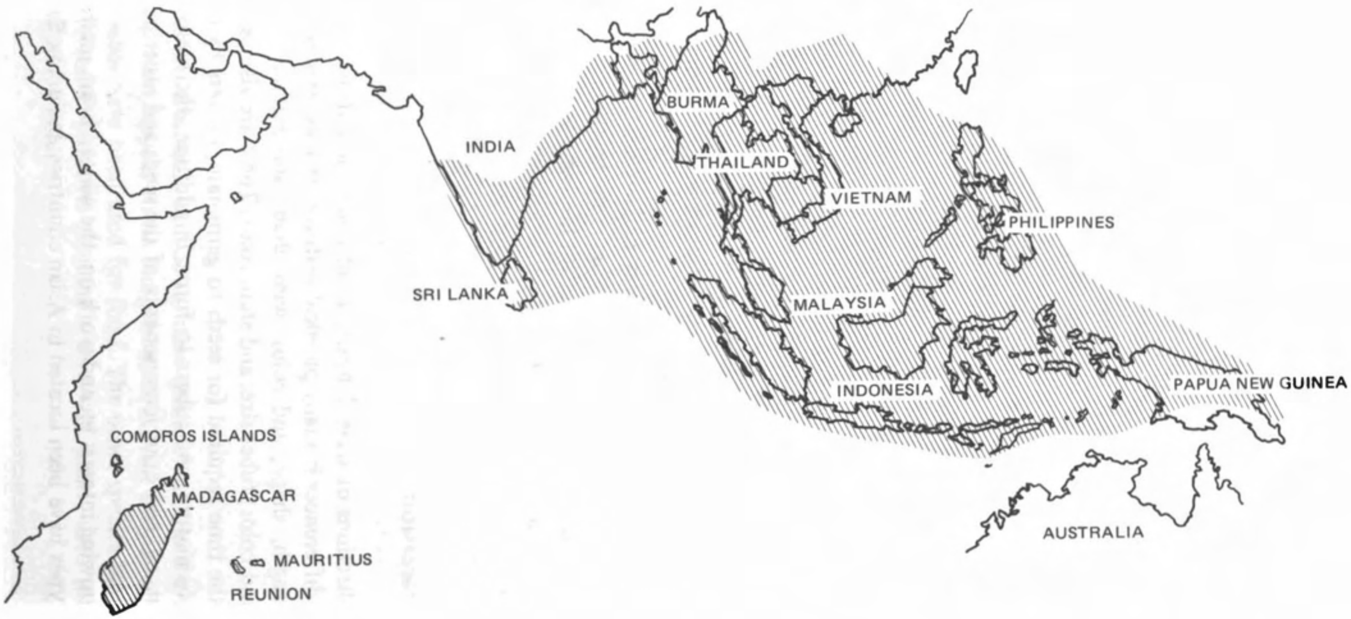
In Papua New Guinea, Burma, and now in Thailand, the winged bean is grown as a field crop. In virtually every other country where it is grown, it is a crop planted by the farmer or homeowner for his own use along the rice field borders, hedges, roadside fences, or in the backyard garden against the house or a nearby tree.

Biological Variation

Recent collections of winged beans in different parts of Asia have demonstrated wide differences in many physical features: leaf shape and size; flower color; pod length, shape, and color; wing shape and surface texture; seed shape, size, and color; tuber size; and stem color. There are also physiological differences: the time required for seeds to germinate, flowers to form, pods to set, seeds to mature, and tubers to form. In addition, there are variations in the protein, oil, and other components of the seeds and other parts of the plant.

With the growing interest in, and work on, the winged bean, many hitherto unrecorded types have been located in Asian countries, including Bangladesh,

*Although it has been widely cultivated, the winged bean has historically been considered a "poor man's crop," and has been generally neglected as a result.



Home territory of the winged bean.

Sri Lanka, Thailand, and Indonesia. The newly assembled collections include more than 500 winged bean types in Thailand, 200 in Bangladesh, and more than 100 in Indonesia. The actual number of varieties grown by Asian farmers, however, is not known.*

Environmental Requirements

Latitude The winged bean has traditionally been cultivated between latitudes of 20°N (Bangladesh, northern Thailand, and northern Burma) and 10°S (Melanesia and the Comoro Islands). However, in recent years the plant has been successfully introduced to subtropical and warm temperate latitudes. For example, plants are flourishing in Florida (in Gainesville, 29°N and Homestead, 25°N); Taiwan, 25°N; Western Australia (Perth, 32°S); and Queensland (Brisbane, 27°S).

In Thailand a few plants have been noticed flowering out of season, and these apparently day-length-neutral plants suggest that types can be found that will flower and yield seeds in temperate areas.

Altitude The plant is grown at sea level in many places and up to 2,200 m in the Highlands of Papua New Guinea. However, trials there have shown that germination and growth were poor, and flowering delayed, at altitudes of 1,600 m (at Wapenamunda) or above.†

Rainfall For good growth the plant requires ample and well-distributed moisture. It is traditionally cultivated in areas with annual rainfall of 700-4,000 mm. It thrives in hot, humid areas with 2,500 mm or more of annual rainfall.

The winged bean also displays some drought tolerance. In 1979 Thailand had its worst drought in history. Cornfields died but winged bean fields survived, although most plants did not grow well (the plants flowered poorly and the rhizobia perished). A few apparently drought-tolerant plants, however, did survive and yielded satisfactorily. Some drought-resistant specimens have also been observed in India.

Soil The winged bean appears to tolerate a wide range of soil conditions. It grows well in soils with low organic matter and in sandy loams or heavy clays. It does not do well in very alkaline or very acid soils. Its "ideal" pH limits are given as low as 5.5 and 4.3. (On acid soils, however, the plant is sus-

*International Board for Plant Genetic Resources, Regional Committee for Southeast Asia, 1979.

†Information supplied by R. A. Stephenson.

ceptible to aluminum toxicity.) In Homestead, Florida, most winged bean specimens thrive with a soil pH of 8.0.* Although in most areas farmers do not fertilize before planting winged bean, the plant responds well to potassium and phosphorus fertilization.

Temperature The winged bean withstands high temperatures but almost never survives frost. Temperature is as important as day length in controlling flowering. Continuous day temperatures higher than 32°C or lower than 18°C inhibit flowering even under otherwise suitable short-day conditions.†

Cultivation

Winged beans are grown mainly in small plots: subsistence or backyard gardens, the edges of fields, and against fences or walls. They are generally sown at the beginning of the wet season. Scarification is usually unnecessary. In moist soil the seeds swell within 4-5 days and germinate within 7-10 days. However, some researchers scarify the seeds between sheets of fine sandpaper, or soak them overnight in water or dilute sulfuric acid to make them germinate even more quickly and uniformly.

In many countries spacing of about 1 m between rows and 25-70 cm between plants is recommended. In Papua New Guinea planting densities in the order of 125,000-150,000 plants per hectare are reported to give best pod and seed yields.‡ Seeds are planted at a depth of 2-3 cm.

Staking the crop increases yields. In Nigeria staking more than doubled the yield of pods and seeds.§ In Malaysia staking was found to increase both seed and tuber yield.|| Stakes or trellises, 1.2-2 m tall, are generally used. Supports can be made of bamboo, wire, string, or pipe. Research is underway on the use of living plant supports such as fruit trees, leucaena, and *Sesbania bispinosa*. Thai researchers have had initial success with planting corn and winged bean together: the corn crop matures first and can be harvested; the winged bean then uses the corn stalks as support.**

Most winged bean varieties are sensitive to day length. They set flowers only when days are short. When sown at this time, they can flower very quickly

*Information supplied by A. A. Duncan.
†Wong and Schwabe, 1979.
‡Stephenson, 1980.
§Information supplied by K. O. Rachie.
||Wong, 1980.
**Information supplied by Narong Chomchalow. Leucaena is described in a companion report, *Leucaena: Promising Forage and Tree Crop for the Tropics*. *Sesbania bispinosa* is described in a similar report, *Tropical Legumes: Resources for the Future*. To order these reports see p. 45.

Since publication of the first edition of this report the winged bean has been grown on a large scale at the Suwan Farm, Pak Chong, Thailand. (Narong Chomchalow)

Pak Chong, Thailand, 1979. Part of 10 tons of winged bean grown by Thai scientists for large-scale testing by the European Economic Commission. (Narong Chomchalow)


Colombia


Thailand


Czechoslovakia


Hawaii

Since 1975 the winged bean has shown remarkable growth and yields in many widely diverse countries and climates where it was previously unknown. Clockwise from top left: Cali, Colombia (K. O. Rachie); Pak Chong, Thailand (Narong Chomchalow); Kpouébo, Ivory Coast (G. P. Ravelli); Bangalore, India (R. Rajendran); Kade, Ghana (S. Karikari); Paia, Hawaii (P. Woomer); and Prague, Czechoslovakia (F. Pospisil).

(4 weeks or less), even when the plants are small; at other seasons they may flower only after many months, when day length becomes suitable.

In Sri Lanka and Bangladesh, in contrast to most of Southeast Asia, the plant is treated as a perennial and allowed to regenerate from the underground parts for at last three successive seasons before seeds are planted again. In other countries the crop is treated as an annual and seeds are planted each year.

In the first month of cultivation, weeds must be controlled. Once established among the young plants, weeds become entwined and are difficult to remove.

Yield

Seed The winged bean seems capable of producing exceptional amounts of seed. There are at least 7 reports of yields of more than 2 tons of seed per hectare.* In experimental plots in Papua New Guinea, a yield in excess of 2 tons of seed per hectare is considered quite common.† There has been at least one report of seed yield of more than 3 tons per hectare‡ and one record of a yield of more than 4 tons per hectare.§ All these measurements, it should be emphasized, are extrapolated from small plots. The only large-scale commercial cultivation is in Thailand and the largest existing stand is about 25 hec-

TABLE 1. Yield of Edible Parts of the Winged Bean[a]

Plant Part	Greatest Yields Reported[b] (kg/ha)
Immature pods	34,700[c]–35,500[d]
Ripe seeds	2,000[e]– 5,000[f]
Tubers	5,500–11,700[g]

[a]Table based on Khan and Eagleton, 1978.
[b]Data based on Martin, 1980; Khan et al., 1977; Wong, 1976; Herath, 1980; Karikari, 1980; Khan and Erskine, 1978; Odor, 1980; Rachie 1974; and Robertson et al., 1980. Tuber yield is from farmers' plots; other yields are experimental.
[c]Jiminez, 1976. Measure is for fresh weight.
[d]Wong, 1975. Measure is for fresh weight.
[e]Khan, 1976.
[f]Khan, communication, 1979. Measure is for fresh weight.
[g]Khan et al., 1977. High yield was for harvesting UPS 122 on a farmer's field in Mt. Hagen in the Papua New Guinea Highlands. Similar estimates were obtained from subsistence gardens. Stephenson, unpublished communication, 1979.

*Vietmeyer, 1978.
†Information supplied by T.N. Khan.
‡Khan, 1980.
§Wong, 1975.

tares. In 1979—the drought year mentioned above—yields were only 600-1,400 kg per hectare in these fields.*

Pods Yields reported for the green (immature) pods harvested as a fresh vegetable range up to 35 tons per hectare.†

Tubers A field of tubers grown in the traditional manner by village farmers in the Highlands of Papua New Guinea yielded the equivalent of 11.7 tons per hectare.‡

Nodulation

The winged bean can develop large numbers of nitrogen-fixing root nodules, apparently often exceeding the number formed on other legumes. In Thailand as many as 1,000 nodules have been counted on a single plant.§

The high protein content in the seeds, pods, leaves, and tubers is probably caused by the plant's exceptional capacity to fix nitrogen. Most tropical soils evidently contain rhizobia suitable for inoculating the winged bean. Excellent nodulation without any need for inoculation appears to take place everywhere the crop has been grown. The bacteria involved are common *Rhizobium* types that inoculate many wild legumes and are sometimes spoken of as belonging to the cowpea group.||

Tuber Production

Several winged bean varieties form tubers.** Three tuber-forming varieties recorded in Indonesia and Nigeria do not flower under local conditions; in such cases the varieties are reproduced from the tubers themselves.††

Although ability to form tubers seems to depend primarily on the genetic variety, it is also affected by environmental factors such as temperature, day length, and certain cultivation practices. Many varieties, if left in the ground, will grow a new crop from the tubers.

When grown for tubers in Burma, the winged bean plants are spaced 10-20 cm apart and allowed to trail on the ground. In other countries where the tuber is cultivated, the plant is grown on stakes somewhat shorter in length

*Information supplied by Narong Chomchalow.
†Measured on a wet weight basis. Martin, 1980.
‡Khan et al., 1977.
§Information supplied by Narong Chomchalow.
||Ikram and Broughton, 1980 (a and b), and Masefield, 1973.
**Stephenson et al., 1979.
††Eagleton et al., 1980.

Large numbers of nodules are present along the roots of the winged bean; many hundreds have been measured on a single plant. (Narong Chomchalow)

In Ghana, winged bean is used as a cover crop in young oil-palm plantations (shown above) but also in food crops, including plantains, cocoyams, and citrus. Winged bean is also used to restore land badly eroded after diamond mining. (S.K. Karikari)

Winged bean tubers. 1. Market in Rangoon, Burma (A Claydon). 2. Port Moresby, Papua New Guinea (N.D. Vietmeyer). 3. Tuber harvest from approximately 1.5 m^2 of winged bean crop (T.N. Khan).

than those used when cultivating the plant for pods or seeds. Tubers are harvested from 5 to 12 months after sowing, depending upon variety, environmental factors, and cultivation practices. They are usually then 2-4 cm in diameter and about 8-12 cm long.

Use as Cover Crop

In Ghana the winged bean has proved particularly effective as a cover crop to protect the soil beneath plantation crops. It establishes well in comparatively poor soils, grows densely, crowds out weeds, and provides the plantation farmer with a source of food.* Although it tends to climb up the trees, it has been tested successfully in coconut, banana, oil palm, rubber, and cacao plantations. (The small-leafed *P. palustris* reportedly grows well as a ground cover and has been used in plantations in both Sri Lanka and Malaysia.†)

*Karikari, 1980.

†Samples from Sri Lanka, Malaysia, Thailand, and Nigeria labeled as *P. palustris* have recently been identified as *P. scandens*, so the identity of this small-leafed species is currently in doubt. (Information supplied by Nazmul Haq.)

3 Food Use and Nutritive Value

Edible legumes will play an increasing role in meeting food needs in times of food shortages and widespread malnutrition. For human nutrition the winged bean is a plant with outstanding qualities. With the exception of its stems and roots, all of its parts–leaves, flowers, shoots, immature pods, immature and ripe seeds, and tubers–are edible, palatable, and highly nutritious. Yet, for the most part, winged bean is still grown in Papua New Guinea and South and Southeast Asia as a subsistence crop in gardens or backyards. These regions, however, are typical of the humid tropical zone that encompasses large belts of Central and South America, the Caribbean, Africa, Oceania, and West Asia, where good sources of protein are limited and the plant is little known. It is uncommon for an edible crop with such high protein content to grow in these regions.

The amounts of major nutrients, such as protein, minerals, and vitamins, in the various winged bean parts are shown in Tables 2 through 6. The common characteristic of all parts of the winged bean is the relatively high protein content. Seeds and tubers are particularly protein rich.

Pods

Pods are the most popular part of the plant in most countries where the winged bean is grown. They are probably the easiest part of the winged bean to introduce as food. The young, tender pods may be eaten raw, sliced, or chopped. They may be used in salads, soups, stews, and curries, and may be boiled in water or coconut milk, or sauteed in oil. Their flavor is similar to that of green beans.

In Papua New Guinea pods too fibrous to eat whole are often steamed in oil drums or the "mumu" pit, or baked in open fires; the seeds and mucilage are then scraped out and eaten. Alternatively, the half-ripe seeds can be removed from the pod and cooked like green peas.

The composition of nutrients in the immature pods does not differ significantly from that found in green pods of other leguminous plants. The average protein content is 2.4 g per 100 g of edible portion.

TABLE 2. Composition of Different Parts of the Winged Bean

	Flowers	Leaves	Immature Pods	Unripe Seeds	Ripe Seeds	Tubers
Water[a]	84.2–87.5	64.2–85.0	76.0–93.0	35.8–88.1	8.7–24.6	54.9–65.2
Energy (mJ)[b]	0.17 (av.)	0.20 (av.)	0.19 (av.)	0.10–0.71	1.61–1.89	0.63 (av.)
Protein	2.8–5.6	5.0–7.6	1.9–4.3	4.6–10.7	29.8–39.0	3.0–15.0
Fat	0.5–0.9	0.5–2.5	0.1–3.4	0.7–10.4	15.0–20.4	0.4–1.1
Carbohydrate (total)	3.0–8.4	3.0–8.5	1.1–7.9	5.6–42.1	23.9–42.0	27.2–30.5
Fiber		3.0–4.2	0.9–3.1	1.0–2.5	3.7–16.1	1.6–17.0
Ash	0.8	1.0–2.9	0.4–1.9	1.0	3.3–4.9	0.9–1.7

[a] Values expressed as g per 100 g fresh weight show the ranges reported by authors cited in footnote to Table 4.
[b] mJ = megajoules. 4.184 mJ = 1,000 (dietary) kilocalories

The immature pod provides bulk of comparatively low energy content, but it is a beneficial vegetable because of the minerals and vitamins it contains.

Winged bean pods are cooked and eaten widely in many countries; no adverse effects have been reported and no antinutritional factors (see below) have been reported in cooked immature pods.

Seeds

The mature dry seeds are the most nutritious part of the winged bean. Their outstanding nutritive quality is based, above all, on their high protein content (30–42 percent) and their favorable amino acid composition. The seeds also contain high amounts of edible oil (15–20 percent). With the exception of the soybean and the peanut, no other commonly consumed food legume can rival the winged bean in the combination of protein and oil. Winged bean seeds can be steamed, boiled, fried, roasted, fermented, or made into milk, tofu (bean curd), or tempeh.

The winged bean seed contains about as much protein and nutritional energy as the soybean and some find it more palatable. Like most beans, mature winged beans contain antinutritional substances (see below), but somewhat less than in soybeans. Seeds should be soaked overnight, then boiled in water until tender. (The soaking liquid should be discarded.) If seeds are soaked in a hot, 1-percent sodium bicarbonate solution, the hard seed coats are more easily removed. (Mature seeds are more difficult to dehull by this process, since the cotyledons swell and press firmly against the hull.)

When fried or baked, winged bean seeds make a delicious nut-like snack. The high temperature breaks open the tough seed coat. It is not certain, however, whether this method of cooking removes the antinutritional substances contained in the ripe dried seed.

TABLE 3. Mineral Content in Different Parts of the Winged Bean [a]

	Leaves	Immature Pods	Ripe Seeds	Tubers
Potassium	80–436	205–381	1110–1800	550
Phosphorus	52–98	26–69	200–610	30–64
Sulfur			380	21
Calcium	113–260	53–330	80–370	25–40
Magnesium	54	58	110–255	23
Sodium	2.5–18	3.0–3.4	14–64	33
Iron	2.0–6.2	0.2–2.3	2.0–18.0	0.5–3.0
Manganese	1.5	2.2	4–25	10
Zinc	1.4	0.2	3.1–5	1.3
Copper	0.5	0.6	1.3	1.3

[a] Values expressed as mg per 100 g fresh weight show the ranges reported by authors cited in footnote to Table 4.

The quality of the protein of heat-processed seeds has been tested in several animal experiments. The values for the protein-efficiency ratio (PER) and for the net protein utilization (NPU) of winged bean seeds, as compared with the soybean and the peanut, are presented in Table 7. Both values for winged bean compare well with those for the soybean, indicating that the nutritive value of the two seed proteins is similar.

The amino acid composition is also similar to that in soybeans. Like most legume seeds, the winged bean is relatively deficient in the sulfur-containing amino acids.* Since the winged bean is rich in available lysine, it could supplement cereal diets, which are lysine deficient.

The high quality of the seed protein was evident in experiments conducted with children suffering from kwashiorkor. A mixture of winged bean plus corn, enriched with a small amount of skim milk, showed nutritional efficiency not significantly different from that found in a diet in which most of the protein was derived from cow's milk.†

Table 6 shows the fatty acid composition of winged bean oil compared with that of soybean and peanut oils. The oil is nutritionally of slightly lower quality than soybean oil. Its fatty acid composition resembles that of peanut oil in that it also contains higher amounts of long-chain saturated fatty acids. But it also contains approximately 60 percent of unsaturated fatty acids.‡

*When fed to rats, which have recently been shown, however, to have a 30-percent greater demand for sulfur-containing amino acids than humans.

†Cerny and Addy, 1973.

‡The first edition of this report listed parinaric acid as a component of winged bean oil. More recent analyses have shown that it is not parinaric but is gadoleic acid, which is sometimes also present in soybean oil and common in peanut oil. (Ekpenyong and Borchers, 1980; Garcia and Palmer, 1979.)

TABLE 4. Vitamin Content in Different Parts of the Winged Bean

	Leaves	Immature Pods	Ripe Seeds
Vitamin A IU	5,240–20,800	300–900	
Thiamin mg/100 g	3.6[a]	0.06–0.24	0.08–1.7
Riboflavin mg/100 g	2.6[a]	0.08–0.12	0.2–0.5
Pyridoxin	1.0[a]	2.0[a]	0.1–0.25
Niacin mg/100 g	15.0[a]	0.5–1.2	3.1–4.6
Folic acid μg/100 g	67[a]		25.6–63.5
Ascorbic acid mg/100 g	14.5–128	20–37	Trace
Tocopherols mg/100 g	3.5[a]	0.5†	22.8

[a]Values on dry weight basis. All the remaining values are expressed on fresh weight basis.

Data shown in Tables 2, 3 and 4 were reported variously by Bailey, 1968; Brown, 1954; Cerny et al., 1971; Claydon, 1975 and 1980; Ekpenyong and Borchers, 1980; FAO/USDHEW, 1972; IITA, 1971-74; Institute of Nutrition, Philippines, 1957; Jaffe and Korte, 1976; Kapsiotis, 1968; Pospisil et al., 1971; Rachie, 1974; Ravelli et al., 1980; Rockland et al., 1979; Sastrapradja and Aminah, 1975; Svabova and Cerny, 1977; Watson, 1971; Wong, 1975, and L. St. Lawrence, personal communication.

Winged bean oil contains behenic acid (as does peanut oil), but although this may reduce its digestibility, it seems unlikely to have other ill effects. Experiments conducted with both malnourished and well-nourished infants in whom full-fat winged bean flour was used for a period of 4 months gave no evidence of ill effects.* To the contrary, children in all these groups flourished.

Winged bean oil not only contains acceptable amounts of unsaturated fatty acids (especially linoleic), but, in contrast to soybean oil, the content of linolenic acid is quite low, giving winged bean oil the advantage of greater stability. Winged bean oil also contains a high measure of tocopherols (vitamin E)–an antioxidant that improves the utilization of vitamin A in the human body. Some varieties are reported to have levels higher than those of soybean or corn oils.†

Extracting oil from winged bean seeds leaves a high-protein meal. From extensive tests on three continents it has been learned that infants fed winged bean meal suffer little or no flatus discomfort.† Analysis has shown that the level of raffinose and stachyose (sugars that lead to flatulence) is less in winged bean than in soybean. A typical comparison of the two seed meals follows.‡

*Cerny, 1980.
†Information supplied by K. Cerny.
‡Information supplied by L. G. Chubb.

TABLE 5. Amino Acid Composition of Different Parts of the Winged Bean[a]

Amino Acid	Leaves	Immature Pods	Seeds	Tubers
Isoleucine	238–356	156–266	242–350	171
Leucine	450–713	282–430	453–564	229
Lysine	162–500	219–416	413–600	
Methionine	75–163	56–63	38–87	48
Cysteine			73–162	14
Total S-cont.	161–187	272	114–193	62
Phenylalanine	294–463	181–213	214–419	106
Tyrosine	238–456	119–125	195–431	72
Total aromatic	585–710	527	409–850	178
Threonine	247–300	175–231	256–300	
Tryptophan	58–131	59	47–69	150
Valine	300–402	188–319	242–344	
Arginine			400–469	
Histidine			169–183	

[a]Values expressed as mg per g N.
Data from Cerny et al., 1971; Chubb, 1980; Claydon, 1978; Ekpenyong and Borchers, 1980; Gillespie and Blagrove, 1980; Jaffe and Korte, 1976; Ravelli et al., 1980; Wong, 1975.

Sugars	*Winged Bean*	*Soybean*
Glucose	trace	trace
Galactose	trace	trace
Sucrose	5.0 percent	4.8 percent
Raffinose	1.0 percent	1.3 percent
Stachyose	2.5 percent	3.5 percent

In storage winged bean seeds show remarkable resistance to bruchid beetles, which are major pests of stored legumes. Experiments have shown that although the beetles lay eggs, the larvae that hatch die in their first or second instars after eating the seeds. The cause is not yet understood.*

Tubers

Winged bean tubers are popular in Burma and in the Highlands of Papua New Guinea. They can be boiled, steamed, fried or baked. The brown skin peels off readily (after about 40 minutes of cooking), leaving a white or cream-colored flesh that is firm and moist, with a distinctive nutty, earthy flavor. They are always eaten cooked.

*Dobie et al., 1979.

TABLE 6. Fatty Acid Composition of Seeds of Winged Bean, Peanut, and Soybean[a]

Fatty Acid	Winged Bean	Peanut	Soybean
14 : 0 Myristic	0.1–0.4	0.1–0.5	0.1–0.3
16 : 0 Palmitic	7.4–9.8	7.3–12.9	6.8–11.5
16 : 1 Palmitoleic	0.1–0.8	0.9–2.4	0.1–1.0
18 : 0 Stearic	2.8–6.9	2.6–6.3	1.4–5.5
18 : 1 Oleic	24.5–41.6	42.0–65.7	22.0–55.0
18 : 2 Linoleic	27.2–31.3	16.8–38.2	49.8–60
18 : 3 Linolenic	1.0–2.0	1.5	2–10
20 : 0 Arachidic	1.3–2.2	0.6–2.4	0.3–0.4
20 : 1 Gadoleic	2.5–4.0	1.1–1.4	0.6
22 : 0 Behenic	6.1–15.9	1.8–3.5	0.1–0.3
22 : 1 Erucic	0–0.8	–	–
24 : 0 Lignoceric	1.0–3.4	0.8–1.5	–
Solidifying point, °C	8–15	0–3	-7–-12
Iodine Value	82–95	81–106	125–138
% Unsaponifiable matter	2.4–2.9	0.4–1.0	0.7–1.6
Saponification value	176	188–196	188–196
% Free fatty acids	0.5	2.7	0.9

[a]Values as percentage whole oil.

Data from Cerny et al., 1971; Chubb, 1980; Claydon, 1980 and in press; Drew Foods, 1970; Ekpenyong and Borchers, 1980; Garcia and Palmer, 1979; Hilditch and Williams, 1964; and L. St. Lawrence, personal communication.

The tubers have an extraordinarily high protein content of 8-20 percent (dry weight) compared with 1-5 percent for cassava, potatoes, and the common cultivars of most root crops.* Not only is the protein content high, but the tubers are also rich in carbohydrates, which provide energy. This rare combination makes the winged bean tuber unusual among tropical root crops. Although the composition of the tuber protein appears poor because it is deficient in sulfur-containing amino acids, the high amount of crude protein could nevertheless make the winged bean tuber a valuable food in those regions where starchy, protein-deficient foods such as cassava, sweet potato, yam, and plantain are staples.

There is little information on the antinutritional (alkaloid negative) factors in winged bean tubers except that trypsin-inhibitor activity has been found and some tannin is present in the peel.†

*Protein contents of some other tropical root crops can also be fairly high. Yam and taro in particular, though varying widely between cultivars, often contain 6-8 percent protein, and occasionally more than 12 percent protein on a dry weight basis. (Information supplied by D.G. Coursey.)

†Sri Kantha et al., 1978.

TABLE 7. Nutritive Value of Winged Bean Seed Protein in Rat Diets

Protein Component of Diet	10% Protein PER	NPU	16% Protein PER
Winged Bean	1.6–2.38	55.0	2.00
Peanut	1.53	46.2	
Skim milk	3.04	73.2	2.37
Winged bean plus corn	2.70	65.7	2.20
Peanut plus corn	1.92	54.7	1.82
Soybean	2.1–2.4	56.0	

Data from Cerny et al., 1971; Ekpenyong and Borchers, 1980; Jaffe and Korte, 1976; Liener, 1972; Ravelli et al., 1980.

Leaves and Shoots

Winged bean sprouts and shoots may be eaten either raw or cooked as green vegetables. Usually only the top three sets of leaflets are eaten, since they are the most tender; they taste slightly sweet.

The crude-protein content of winged bean leaves is similar to that found in edible leaves of other plants such as cassava and taro. Young leaves have higher protein content and digestibility than mature leaves.*

The leaves have a relatively low lysine content but an uncommonly high content of tryptophan (see Table 5), a nutritionally essential amino acid. Even a small amount of winged bean leaves can thus greatly improve tryptophan-deficient diets– for example, those based on corn.

Adding cooked winged bean leaves to the diets of weaned infants and preschool children should be beneficial because of the favorable content of minerals, and especially of the vitamin A precursor beta-carotene. The amount of vitamin A equivalent in winged bean leaves (up to 20,000 international units per 100 g of edible portion) ranks among the highest ever recorded in green leaves of tropical plants.† This is important; in some developing nations many children go blind because of vitamin A deficiency.

Excessive consumption of raw winged bean leaves has been reported in Indonesia as producing dizziness, nausea, and flatulence.‡ Small amounts of cyanogenic glycosides have been found in the stems.§ Even though no such adverse effects have been reported from other countries, consumption of large amounts of *raw* winged bean leaves is not recommended, especially for small children. Properly cooked leaves, however, appear to be safe to eat, even in quantity.

*Ekpenyong and Borchers, 1980.
†Information supplied by K. Cerny.
‡Claydon, 1978.
§Teik, 1951.

Flowers

Flowers have a sweet taste because of the nectar they contain. When steamed or fried, they have the color and consistency of mushrooms. When lightly cooked, they make an attractive garnish.

Although not important nutritionally in terms of quantity, the protein content of the flowers appears to be fairly high compared with edible flowers of other better-known tropical plants such as banana and *Sesbania grandiflora*.*

Antinutritional Factors

Winged bean seeds are known to contain several antinutritional factors, of which the most closely examined have been the trypsin and chymotrypsin inhibitor.† Other antinutritive factors are amylase inhibitors, phytohemagglutinins, cyanogenic glycosides, and perhaps saponins.‡ Further studies, especially of the usual cooked products, are needed.

The winged bean seed-inhibitor activity can be safely eliminated only by using moist heat; for example, steaming the seeds in an autoclave at 130°C for 10 minutes. The same result can be achieved by soaking seeds for approximately 10 hours and then boiling them for 30 minutes.

Processing

Commercial processing of the winged bean is just beginning. Laboratory efforts to make flour from the seed are underway in certain parts of Asia and Africa and in the United States. Similarly, in Thailand and Ghana oil has been pressed from seed, with the oil seed cake being used experimentally for animal feed. A gruel for weaning infants has been produced in Ghana and Czechoslovakia. Mixed with corn, it provides the nutritive equivalent of milk. In Thailand a similar gruel made of winged bean meal, rice, and banana is being fed to refugees from Cambodia.

Because of the similarity of the winged bean seed to the soybean in chemical composition, interest has been expressed in duplicating many foods made from soy. Tempeh and tofu are made commercially in Indonesia from the winged bean seed. It is possible that these might even be improved through use of the white or cream-colored seed rather than the dark-coated seed now used.

*Information on *Sesbania grandiflora* is given in the companion report *Tropical Legumes: Resources for the Future*. For ordering information see page 45.
†Kortt, 1979; 1980.
‡Cerny et al., 1971; Jaffe and Korte, 1976; and Claydon, 1975.

Both a white milk and a chocolate-flavored milk have been made from the seed in Thailand and sterilized for longer shelf life. Researchers in Thailand also have made tasty snacks from winged bean tubers sliced thin, fried and salted, or softened in sugar syrup.

Immature winged bean pods are used in pickles commercially available in South India.*

One researcher in Indonesia has made a coffee substitute by roasting the seed (the grounds are edible), and a tobacco substitute from the dried leaf. These products can be expected to be free of alkaloids.

Sprouted winged bean seed can also be an alternative to mung bean sprouts for village or commercial use.

Use as Animal Feed

Except for occasional use of the dried haulm, there is only scattered information on the deliberate use of the winged bean plant as a livestock food. Unprotected plants, however, are eagerly and almost totally consumed by livestock.

Experiments are underway in Korea, Sri Lanka, and India to use the unprocessed vegetation as green silage. Work is in progress in Thailand and Malaysia to use the ground-up seed as a constitutent of animal and poultry feed. Experimental pellets for animal feed have been manufactured in Thailand using various parts of the plant, but these have tended to break apart in shipping and handling. A new, more stable pellet has now been developed, using 20 percent winged bean seed meal and 80 percent cassava flour. These feed pellets are eaten readily by livestock, but experiments are still needed to determine their nutritional value.

The dry pod residue left after the seeds have been threshed out has 10 percent protein and has been tested satisfactorily in animal feeds. In Thailand this pod residue is being used successfully as a medium for growing straw mushrooms (*Volvariella*).†

*Claydon, 1980.

†Information supplied by Narong Chomchalow.

Appendix A*

Pests and Diseases

When grown in mixed garden cultivation or shifting agriculture, the winged bean is unusually free of pests and diseases. Nevertheless, the plant is known to be susceptible to a number of pests and diseases, and the importance of these may become greater with larger stands of single varieties. There are, however, few detailed studies. Until disease- and insect-resistant varieties are identified, the danger of diseases in winged beans grown in monoculture can be limited by planting more than one variety, as in the more extensive acreage now planted with winged bean in Thailand.

A number of pests and diseases are identified in this appendix as a sort of "distant early warning" for readers. Details can be found in literature cited in Appendix B.

Insects

Insect predators vary in importance from one country to another, depending on the climatic and geographic regions.

The bean pod borer *Maruca testulalis* is the most widespread flower pest in Papua New Guinea and Thailand; it also attacks the stem end of the pods. *Lampides boeticus* attacks the flowers and pods. *Nezara viridula* infests the pods but causes no appreciable damage, while *Heliothis armigera* causes some pod damage in India.

The bean fly *Ophiomyia phaseoli* is sometimes a serious seedling pest. Larvae bore through the stems and mine the leaves. The black bean aphid *Aphis craccivora* is commonly found on shoots of young plants in Papua New Guinea, but it causes more severe damage in Guam where 2-20 percent damage may occur. *Polyphagotarsonemus latus* is another serious pest of shoots in Guam.

A number of pests feed on the leaves. Their effects depend on the climate, natural enemies, and growth stage of the plant. Young plants are attacked by *Ophiomyia phaseoli*, *Aphis craccivora*, and *Planococcus citri*. Under dry conditions spider mite damage by *Tetranychus* sp. and *Polyphagotarsonemus latus*

*The information in this appendix was furnished by T.V. Price, School of Agriculture, La Trobe University, Bundoora, Victoria 3083, Australia.

can be severe. The ladybird *Henosepilachna signatipennis* also causes extensive leaf damage through the feeding activities of both adult and larvae.

Chemical-control measures are not normally recommended for subsistence agriculture, although there have been trials with chemical sprays on experimental plots. Screening for insect-resistant lines would be the most promising method for control, especially since a large amount of germ plasm is available.

Viruses

Virus-like symptoms have been found in winged beans growing in Papua New Guinea, Indonesia, Ghana, Ivory Coast, Trinidad, and the Philippines.* These include *Psophocarpus* necrotic mosaic virus, *Psophocarpus* ringspot mosaic virus, and leaf-curl and little-leaf of unknown etiology. *Aphis craccivora* can transmit *Psophocarpus* ringspot mosaic virus and therefore has a dual role as pest and vector.

Leaves of plants affected with *Psophocarpus* necrotic mosaic virus are necrotic and distorted, show an occasional yellow mosaic pattern, and may have reduced leaf surface. Leaves of plants infected with *Psophocarpus* ringspot mosaic virus have light-green ringspots. Leaves infected with leaf-curl become dark green, thickened, and dwarfed; they curl downwards and show abnormal branching.

Knowledge of virus diseases and their control is still incomplete, but severe damage has occurred in Indonesia, Ivory Coast, and Ghana.

Fungal Diseases

False Rust "False rust" or "orange gall" is caused by the obligate fungal parasite *Synchytrium psophocarpi*.† The symptoms are the appearance of bright-orange pustules along the veins of young leaves and on stems, pods, and sepals of flowers. Infection leads to hyperplasia and galling, with abnormal branching at the nodes. The fungus attacks only *Psophocarpus tetragonolobus*. *Psophocarpus scandens* is immune. The disease occurs in Papua New Guinea, Philippines, Indonesia, and Malaysia. It has been suspected but not confirmed in West Africa.

The disease affects pod production and possibly seed yield. All Papua New Guinea varieties are susceptible,‡ but some disease-resistant varieties have been

*Fortuner et al., 1979; Fauquet et al., 1979.
†Drinkall, 1978; Drinkall and Price, 1979.
‡Price, 1980.

found in Indonesia.* The disease is a serious problem during the rainy season, when it can assume epidemic proportions.

***Pseudocercospora* Leaf Spot** *Pseudocercospora psophocarpi*† attacks the leaves; the first symptoms are yellow spots on the upper surface. The under surfaces have a whitish bloom, which becomes grey and finally black as the leaves mature. This is followed by necrosis of the entire leaf. The disease occurs in Papua New Guinea, Philippines, Malaysia, and Indonesia; it is especially destructive during the rainy season. All Papua New Guinea lines are susceptible.‡ *Psophocarpus tetragonolobus* is the only known host at present. Here, too, *Psophocarpus scandens* is immune. A similar disease is also caused by *Cercospora psophocarpicola* in Singapore§ and *Cercospora canescens* in Bangladesh.||

Powdery Mildew The symptoms of powdery mildew are powdery white patches on the leaves.** Only the imperfect *Oidium* stage of the fungus has been recorded. The disease occurs in the Highlands of Papua New Guinea and in Indonesia, but there is little information on its economic importance.

Collar Rot Collar rot affects seedlings 3-4 weeks old.†† The symptoms are wilting of the leaves followed by the death of the plant. The hypocotyl region of affected plants is usually constricted, with black necrotic lesions at soil level. This disease caused severe field losses in Papua New Guinea. *Macrophomina phaseolina, Fusarium semitectum, F. equiseti, F. moniliforme*, and *Rhizoctonia solani* were the main associated fungi. The disease was influenced by soil type, depth of sowing, and inoculum density. Shallow planting in well-drained soils has been recommended for control.

Miscellaneous Diseases

Root Knot The root-knot nematodes (*Meloidogyne incognita* and *Meloidogyne javanica*) can cause severe galling of roots; this not only damages the roots but also reduces tuber production and may affect pod and seed yield.‡‡

*Thompson and Haryono, 1979.
†Price and Munro, 1978.
‡Price, 1980.
§Price and Munro, 1978.
||Khan et al., 1977.
**Price, 1977.
††Price and Munro, 1978.
‡‡Fortunar et al., 1979; Price and Linge, 1979.

These nematodes are cosmopolitan and have a wide host range. Damage to winged bean has been reported in Papua New Guinea, Philippines, Ivory Coast, Indonesia, and Mauritius, but the problem arises wherever the plant is grown and is especially troublesome in sandy soils. Most of the Papua New Guinea lines are susceptible, and a screening for root-knot resistance of the winged bean world germ plasm collection is needed.

Thanetophorus cucumeris causes a leaf blight in Papua New Guinea, Sarawak, Sabah, and West Malaysia. *Mycosphaerella* sp. has been associated with a concentric ring spot in Papua New Guinea. *Choanephora cucurbitarum* is associated with flower blight in Papua New Guinea and Sarawak, and *Myrothecium roridium* with a leaf spot in Malaysia.

Colletotrichum lindemuthianum occurs in Papua New Guinea and *Colletotrichum gleosporides* (*Glomerella cingulata*) in the Ivory Coast.*

*Price, 1980.

Appendix B

Selected Readings

A 68-page collection of 293 annotated references to worldwide scientific literature on winged bean is available from the International Grain Legume Information Centre (c/o International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria). Entitled *The winged bean* (Psophocarpus tetragonolobus) *and other* Psophocarpus *species: abstracts of world literature 1900–1977*, it includes published and unpublished papers on all aspects of the crop. The entries are classified by subject; items within each category are arranged alphabetically by author. An author and a detailed subject index are provided.

A collection of papers presented at the first international conference on the winged bean (Manila, Philippines, January 1978) has recently been published: *The Winged Bean: Papers Presented in the 1st International Symposium on Developing the Potential of the Winged Bean*, Manila, Philippines, January 1978. It is available from the Philippine Council for Agriculture and Resources Research, Los Baños, Laguna, Philippines.

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