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REVIEW ARTICLE

ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY AND BREEDING OF WINGED BEAN (*Psophocarpus tetragonolobus* (L.) DC.)

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ABSTRACT

Winged bean belongs to the legume family Fabaceae, sub-family of Papilionoideae, tribe *Phaseoleae,* genus *Psophocarpus* and species *Psophocarpus tetragonolobus. Psophocarpus tetragonolobus* is a twining, perennial herb that's characterized by its tuberous roots and its winged pods. Psophocarpus comes from a Greek word that means "noisy fruit." The winged bean also known as cigarillas, goa bean, four-angled bean, four-cornered bean, manila bean, princess bean, star bean, kamrangi bean, pea, dragon bean, and is a tropical herbaceous legume plant. There are two types of varieties *viz.*, 1) Day-Neutral - Blooms during longer days, allowing out of season production. 2) Pang Daeng Nawk – Short day-length variety from northern Thailand, produces long, tender pods (30 cm). Winged bean is a climbing plant similar in appearance and growth habit to pole beans. Winged beans are also known as Goa bean or princess bean. As with other legumes, these bean plants can help add nitrogen to your soils. They are propagated by seed, but stem-cutting under mist may also be used for propagation. There is a serious germination problem with winged bean seeds, but germination can be improved by scarification. Winged bean is adapted to tropical conditions and is grown in Southeast Asia, Papua New Guinea, various Pacific Islands, and Africa. The tender pods are the most widely consumed part of the plant, especially throughout Asia, but the leaves, stems, flowers, seeds, and tuberous roots are all nutritionally valuable and are used as food. Winged bean is another of the legumes with elevated seed oil content; varieties typically average 15% oil, with protein levels of 30–37%. The tuberous roots are a good source of energy in the form of starch, and they contain 8–10% protein. Many tuberous legumes are underutilized, with little or no research attention given to their genetic improvement, thereby limiting their potential to support food, nutritional, and economic security. Understanding and exploiting the potential of winged bean will enhance its role in regions where it can be cultivated. This crop is utilized as seeds and as tuberous roots, as both have high nutritional value. Winged bean is popularly known as *"*One Species Supermarket*"* for its nutrient-dense green pods, immature seeds, tubers, leaves, and mature seeds. This underutilised crop has potential beneficial traits related to its biological nitrogen-fixation to support low-input farming. Reliance on a handful of "major" crops has led to decreased diversity in crop species, agricultural systems and human diets. To reverse this trend, we need to encourage the greater use of minor, "orphan", underutilised species. The crop originated in South-East Asia or perhaps Papua New Guinea. It is widely grown in hot humid equatorial countries throughout Southeast Asia and East Africa, and is an important leguminous vegetable crop in Thailand, Burma, Laos, Malaysia, Vietnam, Indonesia, Bangladesh, Sri Lanka, Ghana, and Nigeria. Although the young pod of the winged bean is the most popularly consumed part, the rest of the plant parts are also edible when appropriately prepared. In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Winged Bean are discussed.

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INTRODUCTION

Winged bean belongs to the legume family Fabaceae, sub-family of Papilionoideae, tribe *Phaseoleae, g*enus *Psophocarpus* and species *Psophocarpus tetragonolobus* (Bassal *et al*., 2020; Singh *et al*., 2022; Chankaew *et al.,* 2022; Wikipedia, 2024). *Psophocarpus tetragonolobus* is a twining, perennial herb that's characterized by its tuberous roots and its winged pods (Bassal *et*

al., 2020). Psophocarpus comes from a Greek word that means "noisy fruit." (Bepary *et al.,* 2023). The winged bean (*Psophocarpus tetragonolobus*), also known as cigarillas, Goa bean, four-angled bean, four-cornered bean, manila bean, princess bean, star bean, kamrangi bean, pea, dragon bean, and is a tropical herbaceous legume plant (Joanna, 2023; Wikipedia, 2024). The winged bean is also known as Goa bean, versatile legume or wonder legume, God-sent vegetable, four-angled bean, princess pea, and four-cornered bean (Bepary *et al.,* 2023). Winged bean in English is known as: Winged Bean, Goa Bean, Princess bean; Kannada: Shembe kaayi; Bengali: Charkoni-sem; Tangkhul: Tengnoumanbi; Mizo: Chawngbepui, Bepui-thla-nei; Assamese: Kordoi urohi (Sophia, 2024). The Asian common names are *viz*., Burmese: pe saung ya; Chinese: si leng dou; Hindi: chaukoni sem; Japanese: shikaku mame; Khmer: prâpiëy; Lao: thwàx ph'uu; Malay: kachang belimbing; Tagalog: segidilla; Thai: ถั่วพู thua phuu and Visayan: kalamismis, kabey (Anon, 2024). Common names of winged bean in different countries are Winged bean, Goa bean, princess bean, four angled bean, asparagus bean, asparagus pea, princess-pea, supermarket bean, short day asparagus pea, pois asperge, pois carré, haricot ailé, pois ailé, dólico de Goa, frijol alado, judia careta, calamismi, flügelbohne, Goabohne, sikaku mame, pe saung ya, hto pong, ku bemya, si leng dou, si jiao dou, sz kok tau, Goabønne, ketjipir, Goanpapu, fagiolo quadrato, prâpiëy, thwàx ph'uu, kecipir, kethipir, ketjeepir, kachang botol, kacang botol, kacang kelisa, kachang botor, kacang botor, kacang sirek, kechang bolon, kachang belimbing, fava de cavalo, vingböna, segidilla, sigarilya, sigarillas, sigadillas, sigidiyas, thua phuu, dau rong, kalamismis, kabey, asbin, as bin (Growables, 2024). There are two types of varieties *viz.*, 1) Day-Neutral - Blooms during longer days, allowing out of season production. 2) Pang Daeng Nawk – Short day-length variety from northern Thailand, produces long, tender pods (30 cm) (Anon, 2024).

Winged bean is a climbing plant similar in appearance and growth habit to pole beans. Winged beans are also known as goa bean or princess bean (Ibuki *et al*., 1983). As with other legumes, these bean plants can help add nitrogen to your soils. They perform best in South Florida when grown during the winter. In North and Central Florida these plants perform best when grown in the fall. Winged bean plants need short days to initiate flowering; however, they are sensitive to frost (Ibuki *et al*., 1983). The pointed, 3 to 6 inch-long leaves are produced on weak vining stems. Four angled leaf-like "wings" run lengthwise to the pods. Bean pods are 6 to 9 inches long when mature. They are prepared and eaten the same way as bush snap beans. When they are mature, seeds are round and green and similar to soybeans. Some varieties of this plant produce a large tuberous root that can be eaten cooked or raw. Winged bean roots and seeds are high in protein (Ibuki *et al*., 1983). Plants are short day for flowering. They are propagated by seed, but stem-cutting under mist may also be used for propagation. There is a serious germination problem with winged bean seeds, but germination can be improved by scarification. There is a need to develop early, photoinsensitive varieties of winged bean that are free of antinutritional factors and are resistant to biotic and abiotic stress. These are the major objectives for the improvement of the crop (Kalloo, *1993*). Winged bean is adapted to tropical conditions and is grown in Southeast Asia, Papua New Guinea, various Pacific Islands, and Africa. The tender pods are the most widely consumed part of the plant, especially throughout Asia, but the leaves, stems, flowers, seeds, and tuberous roots are all nutritionally valuable and are used as food. Winged bean is another of the legumes with elevated seed oil content; varieties typically average 15% oil, with protein levels of 30–37%. The tuberous roots are a good source of energy in the form of starch, and they contain 8–10% protein (Allen, 2013).

With climate change and an increasing world population, research is needed into nutritious and diverse crops with the ability to grow under stressful or suboptimal conditions. Half of the world's calorie intake comes from just three crops (wheat, rice, and corn), yet these cereals are relatively poor in protein and some micronutrients. Legumes complement cereals in the diet; they supply considerable protein, essential amino acids, and micronutrients, and serve as a substitute for meat when this is unavailable or unaffordable. Several legumes are grown for forage, with the high protein content being of benefit to the livestock (Yang *et al*., 2018). In addition to the nutrient content, legumes have evolved the ability to fix atmospheric nitrogen, meaning that fertilizer input can be lower, legumes can often tolerate poor soils, and they can improve the soil for subsequent crops. This poses advantages for resource-poor farmers who cannot obtain or afford fertilizers; however, legumes remain understudied relative to cereal crops (Yang *et al*., 2018). One example of an underutilized legume is the winged bean which has been recognized by a number of authors and institutes as having much promise for nutritional security in the coming decades. Winged bean is an annual or perennial vine that thrives in hot and humid tropical conditions. It is grown widely, but mainly on a local scale, throughout much of Asia, especially India, Southeast Asia, Indonesia, and Papua New Guinea, as well as in some parts of Africa. Considerable morphological variation exists in winged bean especially in Southeast Asia, Indonesia, and Papua New Guinea (Yang *et al*., 2018). One notable feature of the winged bean is the potential for almost all parts of the plant to be eaten, from the seeds, pods, and flowers, to the leaves and tuberous roots, with the stems and leaves used as fodder. It also serves well in crop rotation because of the nitrogen fixation capability. As with several underutilized crops, however, there are anti-nutrition factors in winged bean (specifically trypsin inhibitors), requiring thorough soaking, rinsing, and cooking of the dried beans, which may deter more widespread adoption of winged bean. Protein content of the winged bean seeds is high and comparable to that of soybean. Content of essential amino acids is generally as high as, or higher than, soybean. It is also relatively high in vitamins A and C, calcium, and iron. In countries where protein deficiency is high, or access to meat protein is low, winged bean is a candidate for helping to diversify diets and improve nutrition. Three wild relatives of the winged bean are cultivated, but on much smaller scales; two in Eastern Africa (*P. palustris* Desv. and *P. grandiflorus* R.Wilczek) and one in Southeast Asia, Brazil, and Jamaica (*P. scandens* (Endl.) Verdc.). Knowing more about the relationships between the species of *Psophocarpus* is important to inform future winged bean breeding and improvement (Yang *et al.,* 2018). Crop improvement can also come from selectively breeding different varieties with complementary qualities, for example morphological characteristics, nutrition, abiotic tolerance, and pest resistance. An understanding of the partitioning of genetic variation in crops is therefore important to begin to identify and locate genetically distinct varieties and potentially understand the genetic basis of traits of interest (Yang *et al*., 2018). Protein content of the winged bean seeds is high and comparable to that of soybean. Content of essential amino acids is generally as high as, or higher than, soybean. It is also relatively high in vitamins A and C, calcium, and iron. In countries where protein deficiency is high, or access to meat protein is low, winged bean is a candidate for helping to diversify diets and improve nutrition.

Three wild relatives of the winged bean are cultivated, but on much smaller scales; two in Eastern Africa (*P. palustris* Desv. and *P. grandiflorus* R.Wilczek) and one in Southeast Asia, Brazil, and Jamaica (*P. scandens* (Endl.) Verdc.). Knowing more about the relationships between the species of *Psophocarpus* is important to inform future winged bean breeding and improvement (Yang *et al.,* 2018). Crop improvement can also come from selectively breeding different varieties with complementary qualities, for example morphological characteristics, nutrition, abiotic tolerance, and pest resistance. An understanding of the partitioning of genetic variation in crops is therefore important to begin to identify and locate genetically distinct varieties and potentially understand the genetic basis of traits of interest (Yang *et al*., 2018). The winged bean, also known as the Goa bean, Four-angled bean, and Dragon bean, is a legume native to New Guinea. It is a commonly grown bean in Southeast Asia and Papua New Guinea, but is usually cultivated as a small-scale crop. Winged bean is a climbing perennial plant that looks and grows similarly to the common pole/string/long bean, *Phaseolus vulgaris* (Tuquero and Takai, 2018). Pods are distinctly different from those of the common string bean as they resemble a wing/star-like shape. There are many varieties of winged bean varying in length, width, and color (usually green or purple) of pods (Tuquero and Takai, 2018). In the Mariana Islands, winged bean is a popular crop, locally known as 'sigidiyas.' Many parts of the plant are consumed, including immature bean pods, leaves, and tubers. Locally, immature bean pods are consumed the most as they are used as a fresh, or cooked, vegetable in a wide variety of local dishes. Immature pods for consumption are usually harvested 2-3 weeks after fruit set while they are still tender and not very fibrous (Tuquero and Takai, 2018).

Winged bean is popularly known as *"*One Species Supermarket*"* for its nutrient-dense green pods, immature seeds, tubers, leaves, and mature seeds. This underutilised crop has potential beneficial traits related to its biological nitrogen-fixation to support low-input farming (Tanzi *et al*., 2019). Reliance on a handful of "major" crops has led to decreased diversity in crop species, agricultural systems and human diets. To reverse this trend, we need to encourage the greater use of minor, "orphan", underutilised species. These could contribute to an increase in crop diversity within agricultural systems, to improve human diets, and to support more sustainable and resilient food production systems. Among these underutilised species, winged bean has long been proposed as a crop for expanded use particularly in the humid tropics. It is an herbaceous perennial legume of equatorial environments and has been identified as a rich source of protein, with most parts of the plant being edible when appropriately prepared (Tanzi *et al*., 2019). There is a strong case for an increased utilisation of vegetables and pulses to improve, above all, human nutrition. Winged bean can be grown as both, given its edible green pods, immature seeds, tuberous roots, leaves, and mature seeds. This underutilised crop has potential beneficial traits related to its nodulation and nitrogen-fixation activity that could support low-input farming and improve soil conditions. This review has explored past findings related to the controlling mechanisms underlying traits like growth, flowering, and yield of the different edible parts of winged bean. To date, several production and plant architectural constraints remain unresolved. These include the indeterminate growth habit, photothermal sensitivity, inconsistent productivity for edible parts, anti-nutritional content of seeds, and winged bean nodulation. This review has provided some suggestions on a fresh approach to resolve these constraints (Tanzi *et al*., 2019). Improvement programmes for winged bean should keep in mind the prevalent practices used in traditional regions of production, especially winged bean cultivation methods and ways of consumption. Research efforts should prioritise the development of high yielding cultivars of high palatability and nutritional value, with the design of ideotypes for vegetable pod and tuberous root production, currently the most important uses for winged bean. Research should also continue into the improvement of yield, nutritional value, and marketability of mature seeds. Concerted winged bean improvement programmes would require a panel of winged bean accessions to be shared among research institutes, for generating information that can be made available and shared in a coordinated manner. Regarding this, it is crucial to firstly track viable material shared or retrieved from gene banks, with a labelling system consistent across research groups, and secondly to utilise a common set of descriptors and procedures to phenotype the germplasm (Tanzi *et al*., 2019). Many people in sub-Saharan Africa suffer from protein malnutrition; this results in negative health and economic impacts. Winged bean is a tropical underutilized legume with beneficial nutritional characteristics such as high protein content, which may help to alleviate these problems (Adegboyega *et al.,* 2019).

Natural products, particularly those extracted from plants, have been used as therapy for different diseases for thousands of years. The first written records on the plants used in natural medicine, referred to as "medicinal plants", go back to about 2600 BC. A thorough and complete understanding of medicinal plants encompasses a multiplex of overlapping and integrated sciences such as botany, pharmacognosy, chemistry, enzymology and genetics. Winged bean is a perennial herbaceous plant characterized by its tuberous roots and its winged pod twinning and a perennial legume rich in proteins, oils, vitamins and carbohydrates. Besides nutrients, winged bean also contains bioactive compounds that have therapeutic activities like anti-oxidant, anti-inflammatory, antinociceptive, antibacterial, antifungal, antiproliferative and cytotoxic activity, a few of which already been reported. This plant can also be used as a medicinal plant for future benefits (Bassal *et al.,* 2020). Over time and since the dawn of societies, humans have learned to probe and categorize plant materials to meet the essentials of life. Herbs and their extracts were used for their healing powers. The medicinal plants sector has undergone a remarkable evolution, especially during the last decade. The global market is moving more and more towards products of natural origin. Plants that are used in natural medicine were referred to as "medicinal plants" (Bassal *et al*., 2020). During the 19th century, several alkaloids isolated from unique plant species were used as medicinal drugs such as atropine from "*Atropa belladonna*" (Solanaceae), saclin from "*Salix*" species (Salicaceae) and morphine and codeine from "*Papaver somniferum*" (Papaveraceae). Subsequently, the bioactive secondary metabolites derived from plants were widely used as drugs in their original and modified forms. A direct relationship between the use of herbal plants and modern drugs isolated from these plants has been established, where 88 compounds isolated from seventy-seven medicinal plants were then introduced into the current treatments. Nowadays, most of the world's population still depends on plants for their primary health care according to the World's Health Organization (WHO). In this review, we will discuss the chemical constituents, biological properties and benefits of *Psophocarpus tetragonolobus* (Bassal *et al*., 2020). *Psophocarpus tetragonolobus* is also called *Lotus tetragonolobus*, asparagus pea, Goa bean, four-angled bean and winged bean. Winged bean is a tropical leguminous

plant that is listed as one of the underutilized legumes and it is an underexploited food source for the tropics. *P. tetragonolobus* is known as "poor man's food" since the leaves, flowers, roots, and pods are eaten raw or cooked. Apart from being an edible plant, the fruits are reported to have anti-inflammatory, antioxidant, and anti-nociceptive activities (Bassal *et al*., 2020). Winged bean is a rambling, nitrogen-rich, leguminous crop of the Old-World tropics (Eagleton, 2020).

Many tuberous legumes are underutilized, with little or no research attention given to their genetic improvement, thereby limiting their potential to support food, nutritional, and economic security. Understanding and exploiting the potential of winged bean will enhance its role in regions where it can be cultivated. This crop is utilized as seeds and as tuberous roots, as both have high nutritional value. The Genetic Resources Center (GRC) of the International Institute of Tropical Agriculture (IITA), based in Ibadan, Nigeria is focusing on understanding the genetic diversity in our collection and evaluating key traits to build a platform for pre-breeding and breeding (Abberton *et al.,* 2021). Winged bean is a tropical legume belonging to the family Fabaceae and tribe Phaseoleae, with chromosome number of 2n = 2x = 18 (Abberton et al., 2021). The likely origins of winged bean are in Papua New Guinea, Mauritius, Madagascar and India. The genus Psophocarpus contains nine species, eight of which are wild (Abberton *et al.,* 2021). Winged bean is a twining perennial plant that is cultivated as an annual and has highly nutritious tuberous roots and quadrangular pods, whose length can be up to 30cm long with longitudinal wings subtended on its vegetative part. The pods contain 5-20 seeds, which can vary in colour from white, through varying shades of yellow and brown to black or mottled. Psophocarpus tetragonolobus is commonly called "princess pea," "Goa bean," "asparagus pea" (for their delicate asparagus-like flavour of young, immature pods), "four-angled bean," "Manila bean," "supermarket bean," or "winged bean " (Abberton *et al*., 2021). Apart from the stalk, almost all the entire plant is fit for human consumption. The tender pods are the most widely eaten part of the plant (and best eaten when immature) (Abberton *et al*., 2021). The tubers contain a high amount of protein in dry weight (20%) (2). The seeds contain a high percentage of crude protein content ranging between 29.8% and 42.5% (Abberton *et al.,* 2021). It was observed that a higher capacity for nodulation and nitrogen fixation in winged bean than in any other tropical legumes such as cowpea, common bean, groundnut, soybean, etc. The exceptionally high protein level in the various plant parts could be attributed to the high nodulation and nitrogen fixing rates (Abberton *et al.,* 2021). Winged bean is rich in tocopherol, an antioxidant that increases vitamin A use in the body. The tubers can be used as a root vegetable, similar to potato, and have a nutty flavour. They are also much richer in protein than potatoes. The dried seeds can be useful as flour and also to make a coffee-like drink. Winged bean can also be used to produce winged bean milk made from water, winged beans, and emulsifier. The milk has similar characteristics as soymilk. Winged bean provides many opportunities for economic benefit. Mature winged bean seeds can command high prices (Abberton *et al*., 2021).

Winged beans are grown as a vegetable legume crop in Thailand. All parts of the plant, including pods, seeds, leaves, flowers, and tubers are edible and are rich in protein and nutrients. Although the major consumption of winged bean is based on pod and tuber yields, only the people of Myanmar and Indonesia utilize winged bean tubers as food materials. The usefulness of the winged bean as an alternative crop for staple food and feed can shed some light on the impact of winged bean (Sriwichai *et al.,* 2021). Winged bean is an important tropical vegetable legume with high nutritional value that can be grown in humid, tropical countries such as Indonesia, Malaysia, Bangladesh, and Thailand. The winged bean can be cultivated in all of Thailand's provinces, and produces edible pods, seeds, leaves, flowers, and tuberous roots that are rich in protein. As a tropical legume, its seeds contain high amounts of protein and oil and it is often referred to as the 'soybean of the tropics'. Young pods of the winged bean are consumed in raw, steamed, boiled, stir-fried, or pickled forms. In Southeast Asia, young pods are generally cooked in a variety of ways or consumed as a side dish or salad. In Myanmar, the crop is also popularly grown specifically for its young tuberous roots (Sriwichai *et al.,* 2021). Today's ever-growing global population has increased the demand for animal-sourced feed, particularly in developing countries. Today's food-feed materials compete worldwide as human food and livestock feed, and commonly contain the same ingredients. Protein and carbohydrate sources, such as maize, cassava, and bean have fueled high feed prices, which in turn has generated new interest in alternative N sources for livestock feed. Therefore, food-feed production systems must be integrated for livestock-crop production. In this type of crop system, farmers would harvest produce for human consumption, whereas crop residue or byproducts would be utilized as feed for livestock. Recent research on the potential of winged bean production has provided a framework for continued study of the winged bean as an alternative, staple crop for both food and feed, particularly within low input cropping systems of the tropics and subtropics. The objective of this study, therefore, was the evaluation of the dual purpose of the winged bean based on pod tuber yields (Sriwichai *et al.,* 2021).

The crop originated in South-East Asia or perhaps Papua New Guinea. It is widely grown in hot humid equatorial countries throughout Southeast Asia and East Africa, and is an important leguminous vegetable crop in Thailand, Burma, Laos, Malaysia, Vietnam, Indonesia, Bangladesh, Sri Lanka, Ghana, and Nigeria. Although the young pod of the winged bean is the most popularly consumed part, the rest of the plant parts are also edible when appropriately prepared. Winged bean seeds contain high protein (30–37%) and oil (15–18%) contents. In addition, the winged bean tuber contains roughly 20% protein and 25–30% carbohydrates. As a viable candidate for diversifying diets, roasted or boiled tuberous roots are capable of improving the nutritional security of the people in tropical regions. The crop has received scientific praise for its nutritional content, as comprehensively described in 'The winged bean: high-protein crop for the humid tropics' from the National Academy of Science in 1981. The winged bean is one of the most important legume crops due to its high protein value and multipurpose usage. As a vegetable legume crop, the winged bean holds a unique position in the world of food and agriculture. It has been introduced to more than 80 countries worldwide (Chankaew *et al.,* 2022). Winged bean is a protein rich, underexploited leguminous vegetable of the tropics. Winged bean grows abundantly in hot and humid equatorial countries. In Asia, the major producing countries are India, Burma, Sri Lanka, Indonesia, Malaysia, Thailand, Philippines, Indo-China, China and is also extending to Papua and New Guinea. It has high nitrogen fixing capacity with multiple nodules present in the root system and the leaves contains superior quality of protein. This underutilized vegetable has an ability to fight malnutrition and provide dietary supplementation (Singh *et*

al., 2022). It has been observed that proteins present in legumes have low nutritive value, which is mainly attributed to low amounts of sulphur-containing amino acids, less digestible proteins and anti-nutritional factors. Thus, winged bean is recommended for commercial cultivation to enhance diversity in field conditions and improve soil health. When it reaches the plate of hungry people, it leads to improvement in human health and consequently helps in solving the malnutrition problems (Singh *et al*., 2022).

Winged bean is a leguminous crop being cultivated for consumption and economic values. The crop has the potential to enhance food and nutrition security in tropical regions, especially in sub-Saharan Africa (SSA) Most parts of the winged bean plant, including immature pods seeds, leaves, flowers, and tubers, are edible and are rich in protein and other nutrients. The crop can be grown as a grain legume, green vegetable, tuber crop, forage, and as a cover crop. Winged bean has a higher percentage of crude protein (30–38%) in the seeds when compared to other legumes like cowpea (*Vigna unguiculata*—23%), pigeon pea (*Cajanus cajan*—22%), and lima bean (*Phaseolus lunatus*—23%). The tuberous root contains about 20% protein and 25–30% carbohydrates. The fresh young bean pod contains Vitamins C and B6, niacin, riboflavin, and other minerals such as iron, copper, manganese, and calcium. Roasted and boiled tuberous roots have been reported to improve the nutritional needs of the peoples of Malaysia, Myanmar, Papua New Guinea, Indonesia, Ghana, and Nigeria. Aside from nutritional benefits, it has the ability to fix atmospheric nitrogen to soil, thus making it a good option as a cover crop (Shonde *et al.,* 2023). Winged beans, also known as Goa beans, are an edible legume native to the tropical climates of Southeast Asia. They are a popular food crop in Thailand and India due to their high protein content, ease of cultivation, and delicious flavor. The plant grows quickly and has abundant flowers that attract beneficial insects. Its long vines can be trained to climb trellises for a vertical garden. Here is everything you need to know about growing and eating winged beans (Baylis, 2023). Winged beans are a type of legume that is native to the tropical climates of Southeast Asia. They are attractive, with green pods that curve outward at their edges and resemble wings. The pods grow up to 10 inches long and contain four or five edible seeds. Winged beans are known for their high nutrition content, containing as much as 25 per cent protein, fiber, and vitamins (Baylis, 2023). Winged beans have existed since ancient times, with many cultures believing them to hold special properties. In Ancient Greece, winged beans were believed to be a symbol of fertility and thus were often used in religious ceremonies dedicated to the gods. It is also thought that soldiers ate them in the Trojan War to increase their strength and vitality (Baylis, 2023). They have been cultivated in India since at least 500 BC, where their popularity spread throughout the region due to their nutritional benefits. Today, they can be found growing wild in Bangladesh, Cambodia, China, India, Indonesia, Myanmar, Nepal, Sri Lanka and Thailand (Baylis, 2023).

It's a unique legume native to Papua New Guinea and South East Asia. It's grown in tropical regions of Africa and hot, humid, equatorial regions of South and Southeast Asia. The plant is famous for its serrated four wings and can grow up to 15-20 cm long. The beans are sweet and have a crunchy texture, and the seeds can be dried and used as a popular ingredient in cooking. They, however, should be cooked long enough (about 3 hours) to help destroy the antinutrients in them (trypsin inhibitors and hemagglutinins). Nearly every part of the plant is edible, including flowers, leaves, roots, and pods. The pod is, however, the most eaten part and can be consumed even when raw and unripe. Flowers are common for coloring pastry and rice, while young leaves can be used as a leaf vegetable, similar to how you would eat spinach. Nonetheless, each part is nutritious, containing vitamins A, and C, iron, protein, and calcium, among others. This plant can also be used as an animal feed (Joanna, 2023). Winged bean is a viny, leguminous, vegetable crop of humid regions in Southern Asia and New Guinea. In 1975, a review of 36 underexploited tropical plants by a US National Academy of Sciences select committee highlighted winged bean's promiscuous nodulation and nitrogen fixation across tropical soil types; its high protein content in all plant parts; and favorable amino acid and fatty acid composition in the mature seed. The panel recommended an expanded research effort. This led to a comprehensive assessment of the agronomic potential for production of winged bean's edible components—vegetable pods; seed; tuberous roots, and leafy shoots—in countries across its traditional geographic range and beyond. Research since then has continued to investigate three key limitations to winged bean's expanded use: a relatively high moisture requirement; indeterminate growth habit and delayed maturity, exacerbated by daylength sensitivity; and hard-seededness that constrains germination and food-processing possibilities (Eagleton *et al*., 2023). The winged bean is a tropical legume from the south and southeast Asia, often cultivated for its health benefits. Wing beans are mainly grown for their nutritious beans, roots, leaves, and shoots. They are an excellent source of protein, fiber, minerals, vitamins, antioxidants, and other phytochemicals essential for good health. Besides, they are low in calories, making them ideal for maintaining a healthy weight or losing weight (Joanna, 2023).

The winged bean is known as the four-angled bean, Goa bean, which is an underutilized, non-conventional, and multipurpose tropical legume crop cultivated in Southeast Asia and Papua New Guinea. This bean crop is termed a "single species supermarket"or "one stalk supermarket,"as all the components of this plant, including pods, immature seeds, flowers, leaves, tubers, and mature seeds, are consumable (Bepary *et al*., 2023). Its composition and nutritional values are comparable to those of soybeans; hence, it is also known as the "soybean of the tropics." Winged bean seed is a good source of oil, dietary protein, fat- and water-soluble vitamins, minerals, bioactive compounds, anti-nutritional factors, and toxic compounds. The winged bean is one of the important sources of bioactive compounds such as vitamin C, vitamin E, polyphenols, and flavonoids, which can act as antioxidants. Consumption of winged beans has been shown to have anti-inflammatory, antimicrobial, anticarcinogenic, antitumoral, antimutagenic, anti-allergic, anti-aggregate, and anti-ischemic properties. Winged bean seeds and parts can be transformed into consumable form by using the processing methods, namely, soaking, cooking, germination, baking, roasting, fermentation, and so forth, which reduce the anti-nutritional factors and toxic compounds and improve the nutritional value (Bepary *et al*., 2023). The processing of winged beans is considered essential to produce products such as curries, soups, pickles, milk, tofu, tempeh, and so forth. Being a protein-rich crop, it can alleviate malnutrition and poverty in the developing countries of the world. Before the commercial utilization of winged beans for human consumption, it is very much important to critically

examine the biochemical composition of the bean critically, so that processing into products will become viable in terms of nutritional and sensory quality (Bepary *et al*., 2023). The winged bean is an important but under-utilized legume that has the potential to resolve the global food and nutritional security problems in the future because of its nutritional potential and multiple uses. Moreover, the information with respect to its nutritional composition, anti-nutritional factors, health benefits, bioactivity, processing, and food uses is scant under a single entity (Bepary *et al*., 2023). The winged bean is called the four-angled bean or Goa bean, which is an underutilized, non-conventional, and multipurpose tropical legume cultivated in Southeast Asia and Papua New Guinea (Bepary *et al*., 2023).

The winged bean goes by multiple names such as dragon bean, princess bean, goa beans, asparagus pea, four-sided beans, Hunan winged bean, four-cornered bean, and many more! The winged beans are native to Southeast Asia and thrive in tropical climates since they require a long growing season. There are, however, day-neutral varieties that are suitable for growing in a temperate area (Klein, 2023). Winged beans grow on vines and will need a structure to support the climbing stems. Provide these beans with a trellis on the north side of your garden and you'll be picking beans into late summer. The blue flower it produces will attract many beneficial insects and pollinators. As its most common name suggests, the bean pods have four frilly wings that run the length of the bean (Klein, 2023). These unusual winged bean plants are quickly gaining popularity amongst gardeners and for good reason. If you are interested in growing your own food this plant is an especially interesting choice because the entire plant is edible, even the tuber! The mature bean is a rich protein source and has more protein than similar beans such as cowpeas, chickpeas, mung beans, etc. It has a similar protein content to soybeans and can be used in many of the same ways (Klein, 2023). Winged beans are known by multiple names including four-cornered bean, Hunan winged bean, cigarillas, manila bean, four-angled beans, and goa bean. They are native to South Asia and are thought to have originated in New Guinea. The common garden winged bean is grown as a perennial in tropical climates, but can also be grown as an annual in most of the United States (Klein, 2023a). The winged bean pod resembles a broad bean with four ruffled wings that run the length of the pods. Inside, the winged bean seeds are hidden away, although most harvest the pods before they produce mature seeds. The leaves appear similar to those of string bean plants and the bright blue flowers produced look like pale blue versions of the snap pea flower. The tubers bear a striking resemblance to sunchokes. Winged bean is a pole bean and as such grows as a vine. These plants are not only used as food for people but are also used as feed for fisheries and for livestock because of their high protein content (Klein, 2023a).

Winged bean (2n = 2x = 18, 26) also known as the Goa bean, Four-angled bean, Four-cornered bean, Manila bean, Cigarillos and Dragon bean. Winged bean is an annual or perennial vine that thrives well in hot and humid tropical conditions. It is a tropical perennial vine species that is cultivated mainly at a subsistence scale in hot and humid countries across India, Southeast Asia, and the Western Pacific islands, with a presence in a number of African countries as well (Tiwari *et al*., 2023). The winged bean is popularly known as *"One Species Supermarket"* because of its nutritionally rich green pods, tuberous roots, leaves, immature and mature seeds. Leaves are eaten like spinach, flowers as salad and tubers as processed or raw food and seeds are used in different form of processed food (Tiwari *et al*., 2023). Initial interest was drawn to high crude protein and oil content in seeds, which are comparable to soybean. Its vining nature and nitrogen fixation activity has made it be used as a cover crop and also incorporated into rotation or intercropping systems. As such, winged bean could be a good candidate for diversifying diets to improve nutritional security, based on complex and more sustainable agricultural systems. Besides its nutritional qualities, winged bean is also a potential crop to have climatic resilience for suboptimal weather conditions. It can tolerate adverse crop growing situations like drought, flood, heat and biotic stresses as well to a greater extent than other major staple crops (Tiwari *et al.,* 2023). The winged bean also known as cigarillas, goa bean, four-angled bean, four-cornered bean, manila bean, princess bean, star bean, kamrangi bean, pea, dragon bean, is a tropical herbaceous legume plant (Wikipedia, 2024). Winged bean is widely recognised by consumers and farmers in South Asia and South East Asia for its variety of uses and disease resistance. Winged bean is nutrient-rich and all parts of the plant are edible. The leaves can be eaten like spinach, flowers can be used in salads, tubers can be eaten raw or cooked, and seeds can be used in similar ways as the soybean. The winged bean is an underutilised species but has the potential to become a major multi-use food crop in the tropics of Asia, Africa, and Latin America (Wikipedia, 2024). *Psophocarpus* species have tuberous roots and pods with wings. They can climb by twining their stems around a support (Wikipedia, 2024). A sustainable supply of plant protein is critical for future generations and needs to be achieved while reducing green house gas emissions from agriculture and increasing agricultural resilience in the face of climate volatility. Agricultural diversification with more nutrient-rich and stress tolerant crops could provide the solution. However, this is often hampered by the limited availability of genomic resources and the lack of understanding of the genetic structure of breeding germplasm and the inheritance of important traits. One such crop with potential is winged bean, a high seed protein tropical legume which has been termed 'the soybean for the tropics' (Ho *et al.,* 2024). Winged beans are a tropical species belonging to the Fabaceae family. The unusual, four-pointed seed pod grows on climbing vines reaching 3 to 4 meters in height and is an herbaceous plant commonly sown in home gardens (Specialtyproduce, 2024). Winged beans are found in locations worldwide, earning them many different regional names, including four-angled beans, Goa bean, asparagus pea, four-cornered bean, mauritius bean, princess bean, winged pea, tropical legumes, kacang botol in Malaysia, kecipir, kacang belimgbing, and kacang botor in Indonesia, dau rong translating to dragon's bean in Vietnam, and urizun and shikaku-mame in Japan. Winged beans are famous for their versatility and sustainability, as the entire plant is edible. The vining plants are disease-resistant and nutrient-dense, and the plants can be eaten raw or cooked, depending on the recipe and preference. Winged beans are primarily grown for their edible pods and seeds, widely produced worldwide in tropical regions (Specialtyproduce, 2024).

Growing Regions: The diversity of winged bean crop has been observed in Papua, New Guinea, Mauritius and India, but maximum variation occurs in Papua and New Guinea. In India, it is grown mainly in eight states, including Assam, Manipur, Mizoram, Kerala, Tamil Nadu and Karnataka by the tribals as a backyard crop. The encouraging results of trials provide a ray of hope for its successful cultivation in North Indian plains also. Winged bean grows in hot, humid, equatorial countries of Southern

Asia, Melanesia and the Pacific area. It can be grown from sea level up to frost-free altitudes of about 2000 m above sea level, with its main presence found in India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Vietnam, Cambodia, Malaysia, Indonesia, Philippines and PNG (Tanzi *et al.,* 2019).

Cultivation: Winged bean is usually cultured in tropical countries. *Psophocarpus tetragonolobus* can live at a wide range of altitudes (from 0 to 2000 m) and in different types of soils, even those with a low amount of nutrients. This is due to the presence of symbiotic bacteria, mainly *Rhizobium* strains, in nodules at the roots, which can concentrate nitrogen transported to the plant as allantoic acid and allantoins. Winged bean cannot withstand soils with pH < 5.5 or water-soaked. Before planting, seeds must be soaked in water, and fungicides are commonly applied. The distance between seeds is around 50 cm. It is self-pollinating plant, but cross-pollination can also occur (7.6%). In the first 6 weeks, *Psophocarpus tetragonolobus* grows slowly, and after 10–12 weeks of planting, the fruit can be harvested. With respect to pods and seeds, it produces the highest yield in the first year of plantation, so it is planted annually. However, this plant is long living, and it was shown that the tuber yield is much better in the second-year plantation 369 to 392 g for each plant compared to 80 to 230 g in the first year (Bassal *et al*., 2020).

Winged beans require a warm, humid climate for germination and growth. Soil should be well-draining and enriched with compost or manure before planting. The seeds should be planted 1–2 inches deep in rows 3–4 feet apart. Water deeply and regularly for the first few weeks, then reduce watering once the plant is established. Winged beans grow best in full sun, but partial shade is tolerated in hot climates (Baylis, 2023). Widely distributed through the tropics and subtropics, winged bean thrives in hot, wet climates, although a dry period is favorable to fertilization and the production of mature pods. It can, however, be grown in the tropics at elevations up to 2100 m. Winged bean is drought sensitive; mulching helps to retain soil moisture in drier seasons and enhances tuber development in both wet and dry seasons. Short-day varieties will begin flower and fruit production when day length decreases (normally a day length of 12 hours or less is required for flower initiation). With adequate moisture, day-neutral varieties can be produced year round. Winged Bean thrives in hot humid tropics; however, it can be grown with success as an annual in temperate regions if day-neutral strains are chosen. Scarify the seeds (nick or scratch the seed coat or rub seeds on a rough surface) and soak overnight prior to planting. Plant seeds 2-2.5 cm deep, 7-8 cm apart in rows 30-40 cm apart, in a sunny location, after danger of frost is past. Winged Bean is a vigorous vine; use a trellis support for improved leaf and pod yields. Plants allowed to trellis and those with plucked flowers have enhanced tuber production. Winged Bean does well in a variety of soils except in sand or high salinity environments. Manuring or fertilizing every 2-3 weeks is recommended to sustain pod development. Wood ash or other potash fertilizer enrichment often improves yields (Echocommunity, 2024).

Winged bean plants are perennial, meaning they live for several years. Choose a permanent position where plants can grow undisturbed by regular digging. Winged bean plants are best grown in full sun. Choose a location that will receive at least 6 hours of full sun each day. Winged bean plants need a well drained soil enriched with plenty of organic matter. Prepare soil by weeding it thoroughly, digging it over to loosen it and adding aged animal manure or compost. Keep the area free of weeds until planting. Scarifying seeds prior to planting will improve the speed and success of germination. Scarification involves intentionally damaging the hard outer coating of the seeds to allow water to reach the seed's embryo. Use a sharp knife to make a shallow nick in each seed's shell, or gently wear away a section of the husk using fine sandpaper or a nail file. Winged bean is a tender crop that's sensitive to frost. Do not transplant seedlings or sow seeds outside until all danger of frost has passed. Winged bean plants may need watering during the growing season. Water when the soil is dry about 5 cm below the surface. Water deeply in the early morning or late afternoon. Avoid watering the leaves of plants to avoid fungal diseases. If soil was well prepared no extra fertiliser should be necessary. Winged bean requires a trellis or other strong support to grow on. Tie plants gently to the support using twine or plant ties. Make sure you have the support in place when you sow seed or transplant seedlings to avoid disturbing the plant's roots later. Winged bean plants may die back in cold weather. Cut plants back just above ground level in late autumn, or prune off dead foliage when new leaves emerge in spring. Winged beans should be ready to harvest in approximately 120-240 days. All parts of the winged bean plant can be eaten, including the leaves, flowers, pods, young seeds and tuber. The immature seed pods are the most commonly eaten part of the plant. Pods are ready to harvest when they are between 5cm and 10cm long. Harvest pods by cutting with snips/secateurs. Harvest regularly to encourage more pods. Pods are best eaten soon after harvest. Store pods short term in a perforated plastic bag in the fridge. Young leaves can be harvested and used in salads or cooked as a substitute for spinach. Harvest the top three sets of leaflets on a shoot along with the stem by cutting them with clean, sharp secateurs or snips. Flowers can be harvested when fully open and used to colour and flavour rice dishes. Harvest tubers when plants die back in autumn. Use a garden fork to gently lift the tubers from the bed, shaking off any excess soil. Tubers will grow larger in cool climates. Like all plants, winged bean is susceptible to some pests, diseases and other problems (TSC, 2024; Growables, 2024).

Harvesting: Most winged bean varieties mature approximately 60-90 days after planting. Fruits (pods) are often harvested when immature and tender within approximately two weeks after flowers begin to fruit. On Guam, 'Short day' varieties will only produce fruits approximately between the months of November through May. 'Day neutral' varieties may be able to produce all year round (Tuquero and Takai, 2018). Immediately after harvest, fresh immature winged bean pods should be cooled and stored at 50°F (10°C) at 90 percent relative humidity to slow down water loss and decay (Tuquero and Takai, 2018). Harvesting of shoots and leaves is done while they are still tender. Green pods can be harvested from about 10 weeks after sowing. Fresh pod yield ranges between 5-10 t/ha. Tuberous root yield range between 5-10 t/ha while the seed yield ranges from 1 to 1.5t/ha. Winged bean can be stored in a plastic bag tightly tied at the neck to keep them fresh. The shelf life of the pods can be increased to 4 weeks under storage temperature of 10°C and the 90% relative humidity (Tiwari *et al*., 2023). The young pods of winged beans are most tender and flavorful when harvested at about 4–5 inches long. The entire plant can be harvested as the pods mature, or just the pods can be picked. Winged beans are ready to harvest about 2–3 months after planting. The leaves and flowers of winged beans are also edible and can be added to salads or stir-fries (Baylis, 2023). Young leaves of large, maturing plants can be used at any

time, but especially during the off-season when vegetative growth is abundant and the plants are not in bloom. The periodic harvest of up to 10 percent of the foliage is not likely to reduce flowering and seed yield. During the period of production of pods, only light harvesting of leaves should be done. Pods are usually harvested 2-3 weeks after fruit set while they are still tender and not very fibrous. They grow rapidly after the flowers are produced and reach their mature size in about 21 days. As the pods begin to mature, they lose their shiny appearance and develop fiber. Tubers are harvested from 5 to 12 months after sowing, depending upon variety, environmental factors, and cultivation practices (Growables, 2024). Seeds are easily removed from dry pods. Pods can be split apart by various means. Seeds store well in dry, cool, dark locations (Anon, 2024).

Yield: In Malaysia, vegetable pod yields up to 35 t ha^{-1} over a 25-week growing period have been obtained from solidly trellised, branching cultivars. Ratoon the crop through a further two cycles covers the cost of the trellising. Tubers from un-trellised field crops in Myanmar, and of staked, pruned garden crops in highland PNG have been estimated to produce crude protein yields of at least 300 kg ha^{-1} and 600 kg ha^{-1}, respectively. Synergies between the gene-pools and cultural traditions would be expected to expand the range, raise the yield and stabilize the quality of tuber crop production. Branching winged bean cultivars have significant potential for benign, high-nitrogen cover and forage crops. Promiscuous nodulation and the development of storage root-systems compensate for slow initial top growth which then accelerates to produce a substantial yield of highly digestible leaf protein and vitamins. Hard-seededness and daylength-sensitive phenology are significant, surmountable, barriers to an expanded role for winged beans (Eagleton**,** 2020).

Pests and Diseases: Winged Bean is relatively free of insect pests. It is susceptible to attack, however, by a number of fungi including leaf spot and powdery mildew that may spread rapidly. In some regions nematodes cause heavy yield losses (Echocommunity, 2024). Bacterial leaf spot is a disease that causes irregularly shaped brown spots on all above-ground parts of a plant. The spots at first appear to be wet but become dry and scab-like over time. Leaves and flowers can fall prematurely. Water plants at soil level (not on the leaves), dispose of fallen leaves and fruit and practice crop rotation. Downy mildew is a fungal disease that causes yellow to grey-brown patches on leaves, especially the undersides. Water plants at soil level (not on the leaves), remove and destroy affected leaves and do not overcrowd plants to ensure adequate air flow. If problems persist, spray with a homemade milk spray or fungicide. Powdery mildew is caused by fungal spores reproducing on the leaves of plants. First showing as white spots on leaves, affected areas can spread quickly to cover the entire leaf surface. While rarely fatal, powdery mildew can reduce yields. Water plants at soil level (not on leaves) to prevent spreading spores, allow good air flow between plants, remove affected leaves and if necessary spray with an appropriate fungicide or homemade spray (Fig.1) (TSC, 2024). May include mites, nematodes and powdery mildew.Plant roots are badly damaged by root knot nematodes (as are most beans) (Growables, 2024). Winged bean is relatively free of insect pests but is susceptible to attack by fungi including powdery mildew and leaf spot that may spread rapidly. In some regions, nematodes cause heavy yield losses (Anon, 2024).

Bacterial leaf spot	Downy mildew	Powdery mildew

Fig. 1. Diseases of winged bean

Frost damage can cause leaves to wilt and go black. Do not plant seedlings in the garden until all danger of frost has passed in spring, and harvest plants before winter. Prune all frost-damaged leaves to avoid them rotting on the plant (TSC, 2024).

Processing: Winged bean seeds and parts can be transformed into consumable form by using the processing methods, namely, soaking, cooking, germination, baking, roasting, fermentation, and so forth, which reduce the anti-nutritional factors and toxic compounds and improve the nutritional value. The processing of winged beans is considered essential to produce products such as curries, soups, pickles, milk, tofu, tempeh, and so forth (Bepary *et al*., 2023).

Storage: Winged beans should be stored in an airtight container in a cool, dry place. If they are stored correctly, they can last up to two weeks. Storing them at temperatures between 32 and 41 degrees Fahrenheit is best. After harvesting, removing any dirt or debris that may have attached itself to the beans during this process is important. You can also store them in the refrigerator, but they should be used within a few days of being placed there. Once cooked or frozen, they can last for up to three months. Label and store the beans properly so you do not confuse them with any other legume. You can enjoy these delicious green beans for months with proper storage techniques (Baylis, 2023). Immediately after harvest, fresh immature winged bean pods should be cooled and stored at 50 °F (10 °C) at 90 percent relative humidity to slow down water loss and decay. The dried seed (bean) can be stored for long periods under cool, dry conditions (Growables, 2024). In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Winged Bean are discussed.

ORIGIN AND DISTRIBUTION

Winged bean or Goa bean is a twining perennial but is grown as an annual. Tropical southern Asia—Papua New Guinea, Mauritius, Madagascar, and India—are the origin of the winged bean. It has been introduced to the Pacific islands and the West Indies. It is grown in Burma, India, Thailand, Vietnam, the Philippines, Malaysia, Indonesia, New Guinea, Sri Lanka, Ghana, and Nigeria (Kalloo, 1993). It is originated in New Guinea and South East Asia, distributed to North East India, Myanmar, and Malaysia (Mia, 2016.). Whether the closest African relative of winged bean is a member of the *P. palustris–P. scandens* group (as seen in the cpDNA ML analysis and most morphological analyses) or not (our cpDNA Bayesian analysis and the ITS analysis) is unclear, but given the large genetic distance it seems that winged bean should probably be considered in a different section. This suggests that identification of the direct progenitor of winged bean still eludes us that the progenitor of winged bean is a now-extinct Asian species, is true. Alternatively, winged bean as a crop could be morphologically indistinct from a progenitor so individuals are all identified as the cultivated taxon. No sequence differences in the four winged bean samples were observed and it is not unusual for a crop to exhibit very low sequence variation relative to wild relatives due to the genetic bottleneck typically associated with a domestication event. In this study, this is not because the four sequenced individuals are especially closely related to each other; instead these are present in different regions of the microsatellite-based PCA (Yang *et al.,* 2018).

Its centre of origin, though, is still a matter of dispute. Two contrasting hypotheses have been suggested. The first hypothesis suggests the origin of *P. tetragonolobus* to be the African continent, with either in situ domestication and migration (by human activity) of the domesticated species east, or trans-domestication of an African progenitor species from which winged bean has been derived later in the Indian Ocean rim of Asia. In support of an Africa-centric hypothesis, the chromosome number and karyotype pattern of winged bean are consistent with five *Psophocarpus* species from Africa: namely *P. scandens*, *P. grandiflorus*, *P. palustris*, *P. lecomtei*, and *P. lancifolius.* Attempts have been made to determine the possible wild African progenitor, identified as *P. grandiflorus* based on its morphological resemblance and shared susceptibility to the fungus *Synchytrium psophocarpi* or as *P. scandens*, following the more recent phenetic and cladistic analyses. The second, alternative, hypothesis postulates that *P. tetragonolobus* is a species distinct from current African members of the genus and arose through a mechanism of allopatric speciation preceding any purposeful or unwitting processes of domestication. The main limitation of this hypothesis, which shifts the origin of winged bean towards the east, is the lack of wild forms of this species in Asia or Melanesia (Tanzi *et al.,* 2019). It is believed that the linguistic and historical evidence pointed to the origins of winged bean on the western fringes of the Indian Ocean, while it was placed it in hypothesised Indian centre of crop domestication. Itb was also a Melanesian centre of origin based on the discovery of a significant centre of genetic diversity for winged bean in the highlands of PNG. The results showed that none of the four *P. tetragonolobus* accessions—originally from Nigeria, Liberia, and Malaysia—fell into any of the other three groups comprising of *Psophocarpus* genus members. The authors suggested the possibility that Verdcourt and Halliday were right in that winged bean could have a distinct history from the rest of the African species, and for which the progenitor has been lost or remains undiscovered. On the other hand, in contrast to attempts by earlier researchers, they reported success in hybridising winged bean with *P. scandens*, which could support this species as the closest relative after all, and whose progeny could form a bridge for future trait introgression from the African material (Tanzi *et al*., 2019).

Winged bean, a domestic plant, is distributed in South East Asia, in the countries situated between India and Papua New Guinea, along with some African countries. The relation between *Psophocarpus tetragonolobus* and other *Psophocarpus* species is mainly identified depending on morphology. However, comparing the genetic makeup of these plants will be a more reliable approach that can help to identify the wild ancestor of this plant. Till now, different theories are suggested concerning the origin of this plant. Southeastern Asia was suggested as an origin because the plant was cultivated in this area for a long time. However, the progenitor was not known and it was assumed to be extinct. Papua New Guinea is another possible origin due to the large repertoire of genetic varieties of plants in this country. Winged bean was also found to be similar to some African plants in terms of morphology, cytology and pathology (Bassal *et al.,* 2020). Southeast Asia is considered the origin of this crop due to its long history of cultivation, but the progenitor was supposed to have vanished. Papua New Guinea is considered to be another possible center of origin as large number of large genetic variation exit in this country. It is widely distributed in equatorial countries such as Papua New Guinea, India, Burma, Philippines, Indo-China, China, Malaya, Indonesia, Sri Lanka, Thailand, and in a few Pacific Islands where hot and humid climates exist (Bepary *et al.,* 2023). The native habitat of winged bean is yet uncertain. Controversy exists among the workers about the origin of winged bean. The plant is cultivated especially in the tropical areas. The countries like Indonesia, Papua New Guinea, Myanmar and India are the probable centres of origin (Tiwari *et al.,* 2023).

Winged beans are thought to be native to New Guinea as it is home to the most diversity of the species, but much of the plant's history is unknown. Some scientists point to Southeast Asia as the center of origin, and a few also mention Mauritius, a small island off the coast of Madagascar. Regardless of its center of origin, Winged bean species have been found throughout Southeast Asia, Southern Asia, and tropical Africa since ancient times. Today Winged beans have the highest concentration in Asia, Southeast Asia, and tropical Africa. The species is also grown in Australia, South America, Central America, and in Hawaii and Florida in the United States (Specialtyproduce, 2024). The Winged Bean's historical origin is uncertain. Many authors place the origin in the Papua New Guinea and Indonesian island regions where many genetic strains of Winged Bean exist. Winged Bean, also known as Asparagus Pea, is intensively cultivated in Burma and India, and it has been successfully introduced into other southeast Asian regions like Malaysia, Thailand, and Bangladesh and into West Africa and the West Indies (Echocommunity, 2024). Most likely originating from New Guinea, the species grows abundantly in the hot, humid equatorial countries of South and Southeast Asia, as well as tropical Africa. It is widely known in Southeast Asia and Papua New Guinea, but only cultivated on a small scale (Wikipedia, 2024).

TAXONOMY

Winged bean belongs to the legume family Fabaceae, sub-family of Papilionoideae, tribe *Phaseoleae, g*enus *Psophocarpus* and species *Psophocarpus tetragonolobus* (Bassal *et al.,* 2020; Singh *et al*., 2022; Chankaew *et al.*, 2022; Wikipedia, 2024). *Psophocarpus tetragonolobus* is a twining, perennial herb that's characterized by its tuberous roots and its winged pods (Bassal *et al*., 2020). Psophocarpus comes from a Greek word that means "noisy fruit." (Bepary *et al.,* 2023). Taxonomy is the branch of the sciences which is concerned with the study of plants, their identification, nomenclature and correct identification on the basis of the certain parameters. Taxonomy is the core of the all the branches. Fabaceae family is the family which is also known as the leguminoseae family; pods of the family are termed as the legumes and they are the characteristic features of the family. Although all over the world, around the 750 genera are reported. All the members of the leguminosae are full of economic importance and they are widely used for food, fodder and fuel; and the timber is also very useful and it is used for the several purposes. Some of the members are annuals and ephemeral and the life cycle of theses members is very short and the seeds and plant parts are buried in the soil and they are the best sources of the nitrogen fixation and they impart nitrogen values in the soil; overall the genera are very useful and they need conservation (Agrawal *, 2020*). *Psophocarpus* has about nine species, of which *P. tetragonolobus* and *P. palustris* are used for food. Out of four wild species, three—*P. palmetsorum* (2x = 20), *P. palustris* Desv. (2x =18), and *P. scandens* (Endl.) Verde (syn. *P. longipedunculatus* Hassk.)—are cultivated in Africa (Kalloo, 1993). Winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is one such crop. All parts of the plant can be eaten, from the roots to the seeds, and is high in protein as well as other micronutrients. The goal of our study was to identify the wild progenitor and analyze the partitioning of genetic variation in the crop. We used molecular phylogenetic analyses (cpDNA and nuclear ITS sequencing) to resolve relationships between all species in the genus, and population genetics (utilizing microsatellites) to identify genetic clusters of winged bean accessions and compare this to geography. We find that winged bean is genetically distinct from all other members of the genus (Yang *et al*., 2018).

Synonyms (Growables, 2024)

Botor tetragonoloba (L.) Kuntze,
Botor tetragonolobus (L.) Kuntze,
Dolichos ovatus Graham,
Dolichos ovatus tetragonolobus L.,
Psophocarpus tetragonolobus (Stickm.) DC.,
Psophocarpus longepedunculatus Hassk.

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 (Growables, 2024).

BOTANICAL DESCRIPTION

A twining perennial herb. Tap root modified into tuber, large. Stem: Weak, glabrous. Leaf**:** Compound, trifoliate. Inflorescence**:** Axillary raceme. Flower: Complete, hermaphrodite, zygomorphic, papilionaceous. Clayx**:** Sepal 5. Corolla**:** papilinaceous composed three types of petal viz. standard, wing and keel, aestivation vexillary. Androecium**:** Stamen 10, monadelphous. Gynoecium**:** Carpel one, ovary superior, placentation marginal. Fruit**:** a pod, linear oblong. Chromosome number**:** 2n=18, 26 (Mia, 2016).

Winged bean is a climbing twinning plant (climb up to 3–5 m). It has green trifoliate leaves made up from three leaflets of ovate to deltoid shape. It produces 2.5 to 3.5 cm wide flowers with colors ranging from purple, white and blue, blue to red. The pollen grains are spheroidal with a polar axis that measures between 42.3 and 51.6 cm and an equatorial axis that measure between 43.4 and 49.9 cm. Its roots are tuberous; a tuber ranges in size between 8 and 12 cm in length and 2 to 4 cm in width. It produces elongated pods (the fruit) with four corners and at each one the pod bears a wing, hence the name of winged bean. Each pod ranges from 15 to 30 cm in length, and it is about 3 cm in width. At the cellular level, a study of seven plants of winged bean from Okianawa (Japan) revealed that its cells have thick cell walls with plasmodesmata. Cotyledonary cells analysis was done after flowering. At day 30, starch granules in amyloplasts are observed. Also, the cells contained tubular rough endoplasmic reticulum and vacuoles containing dense flocculent material. At day 45, lipid and protein bodies appear (Bassal *et al*., 2020).

The plants are herbaceous perennial but mainly grown as annual. It is a vine crop with climbing nature and a wiry stem, which attains a height of 4 m and above, if the stacking provided is tall enough. The stem is usually green but certain varieties have stem with a shade of purple, pink or brown. Leaves are trifoliate, alternate, subtended by a stipule oval to ovate on the entire margin. The inflorescence is axillary, raceme and bearing many flowers. The calyx tube is long, inflorescence is axillary and 4-10 flowered raceme. The height of the vines varies between 3 and 4 meters. The colour of flower varies from white to deep purple, basically, blue, bluish white etc. Maximum flower opening is between 10 AM to 12 noon. The plant bear pods of different length and shape. Based on the shape, pods are of four types namely, rectangular, semi-flat, and flat on sides, flat on suture. The pods are 4 angled, 15-22 cm long, 2-3 cm broad with each angle continued into a much crisped and papery wing. Pod wings may be undulated, dented or serrate. An individual pod contains 5-20 seeds; the seeds are smooth, shiny and globular in shape with an average weight

of 250 mg. They burst out from ripe pods and the colour of seed changes to brownish at the time of ripening. Seeds are round in shape that emits an aroma which is similar to asparagus (Singh *et al*., 2022).

The winged bean is a creeping perennial herb that can grow up to 3–5 m tall. It has green trifoliate leaves and 2.5–3.5 cm flowers that range in color from purple, white, blue, and red. Its roots are tuberous; a tuber ranges in size between 2 to 4 cm in width and 8 and 12 cm in length (Prasanth *et al.,* 2016). The pods are four-sided with fringed wings and have a size of 6–30 cm x 3cm (length xwidth), bearing 5–20 seeds per pod (Venketeswaran, 1990). The green pods are tender and contain young seeds, which can be prepared as an excellent vegetable. The mature pod is transformed into wood after dehydration, which contains edible seeds. The dimensions of winged bean seeds are 6.38–8.53 mm, 6.13–7.71 mm, and 5.77–6.85 mm, respectively. The physical properties of winged bean seeds are as follows: sphericity: 0.84–1, thousand-grain weight: 221.76–261.26 g, surface area: 99.60–197.38 mm^3, bulk density: 843.6–892.03 kg/m^3 , true density: 1101.89–1238.93 kg/m^3, porosity: 24.03%–28% (Bepary *et al.,* 2023).

The plants are herbaceous perennial but mainly grown as annual. They are climbing in nature along with wiry stem that climbs to a height of 4 m and above if the stacking provided is tall enough. The stem is usually green but certain varieties have stem with a shade of purple, pink or brown. Leaves are trifoliate, alternate, subtended by a stipule oval to ovate on the entire margin. The inflorescence is axillary, raceme, bearing many flowers. Inflorescence is axillary and is 4-10 flowered racemes. Calyx tube is long. It is a vine crop. The height of the vines varies between 3 and 4 meters. The colour of flower varies from white to deep purple, blue, bluish white etc. The plant bear pods of different length and shape. Based on the shape, pods are of four types namely, rectangular, semi-flat, flat on sides and flat on suture. Pods have frilly borders having green, pink, purple or red colour which is 6 and 9 inches in length. Pods are 4 angled, 15-22 cm long, 2-3 cm broad with each angle continuing into a much crisped and papery wing. Pod wings may be undulated, dented or serrated. Individual pod contain 5-20 seeds. The seeds are smooth, shiny and globular in shape with an average weight of 250 mg. Seeds are burst out from ripe pods and the colour of seed changes to brownish at the time of ripening. Seeds are round in shape that emits an aroma which is similar to asparagus (Tiwari *et al*., 2023). Winged bean grows as a vine with climbing stems, up to 3-4 m in height. It is a herbaceous perennial, but can be grown as an annual. Leaves are compound with 3 leaflets. The leaflets are more or less triangular, tapering to an acute point, about 3-6 in long and almost as wide at the widest point. The large flowers are pale blue, but vary in color in cultivars. They are larger than green bean flowers, a little more than 1 inch long, and hang in loose clusters of 2-10 flowers. The bean pod is easy to identify - it is typically 6-9 inches long and has four wings with frilly edges running lengthwise. The skin is waxy and the flesh partially translucent in the young pods. When the pod is fully ripe, it turns an ash-brown color and splits open to release the seeds. The beans themselves are similar to soybeans in both use and nutritional content. The fruits are used as a vegetable but the other parts (leaves, flowers and tuberous roots) are also edible. The young shoots and leaves may be eaten raw or cooked as vegetables (Sophia, 2024). Edible roots, leaves, fruits, seeds and flowers; food coloring, flour, oil, milk, tofu; livestock forage, cover crop. Height of the plant is 10-13 ft (3-4 m). Plant habit: Weak vining stems; similar to the common pole/string/long bean. Short-lived herbaceous perennial; often grown as an annual. Leaves are 3-6 in. (8-15 cm) long; pubescent or glabrous; trifoliate; borne alternately on erect stiff petioles; subtended by a short stipule; three leaflets are similar; range in shape from oval to ovate-lanceolate. Flowers are White, blue, deep purple or pink; terminal or axillary racemes to 6 in. (15 cm) long; bear two to many flowers; calyx consists of five sepals united into a tube of two lobes. Pods are diverse; usually green or purple, sometimes with specks; 6-9 in. (14-22.8 cm) long; 1.5 in. (4 cm) broad; four angled leaf-like wings running lengthwise to the pods. Seeds are round; smooth; coat color range: cream, black, brown, purple and mottled. Tubers are fibrous; starchy; edible; generally small; weighing seldom more than 1.8 oz (50 g); Diameter: 0.75-1.5 in. (2-4 cm) in; length 3-5 in. (8-12 cm). Days to harvest of pods: 60-90 days; seeds/beans: 180-270 days; tubers: 120-240 days (Growables, 2024).

The winged bean is a perennial herbaceous vine that climbs by twining to the left. https://www.growables.org/informationVeg/BeanWinged.htm#BibliographyGrows in hot, humid, equatorial countries of Southern Asia, Melanesia and the Pacific area. It can be grown from sea level up to frost-free altitudes of about 2000 m above sea level, with its main presence found in India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Vietnam, Cambodia, Malaysia, Indonesia, Philippines and Papua New Guinea. 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. (c. 1981). 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. Winged beans are grown commercially in South Florida to a limited extent. They are found in home gardens where they are grown both as a novelty and as a food crop. Those interested in trying this vegetable should prepare the soil, plant the seed, and care for the plants just as for pole beans (Growables, 2024). The winged bean plant grows as a vine with climbing stems and leaves, 3–4 m (10–13 ft) in height. It is an herbaceous perennial, but can be grown as an annual. It is generally taller and notably larger than the common bean. The leaves can be 15 cm (6 in) long. The shape of its leaves ranges from ovate to deltoid, ovate-lanceolate, lanceolate, and long lanceolate. The green tone of the leaves also varies. The stem is most commonly green, but sometimes boasts purple. The large flower is pale blue. The bean pod may be smooth or rough, depending on the genotype. It is typically 15–22 cm (6–8+½ in) long, rectangular in cross-section (though sometimes appearing flat), and has four wings with frilly edges running lengthwise. The skin is waxy and the flesh partially translucent in the young pods. The colour of the pods may be cream, green, pink, or purple. When fully ripe, the pod turns an ash-brown colour and splits open to release the seeds (beans). The seed shape is often round; oval and rectangular seeds also occur. Seeds may appear white, cream, dark tan, or brown, depending on growing and storage conditions. The beans themselves are similar to soybeans in both use and nutritional content (being 29.8% to 39% protein) (Wikipedia, 2024).

Winged bean is a self-pollinating plant but mutations and occasional out-crossing may produce variations in the species. The pre-treatment of winged bean seeds is not required in tropical climate, but scarification of seeds has shown to enhance the germination rate of seedlings. Seed soaking may also increase speed to germination, as is typical, and may be used in conjunction with scarification. Seedlings under natural field conditions have been reported to emerge between five and seven days. Winged bean can grow at least as fast as comparable legumes, including soy. Plants flower 40 to 140 days after sowing. Pods reach full-length about two weeks after pollination. Three weeks after pollination, the pod becomes fibrous; after six weeks, mature seeds are ready for harvest. Tuber development and flower production vary according to genotype and environmental factors. Some winged bean varieties do not produce tuberous roots. The winged bean is a tropical plant, and will only flower when the day length is shorter than 12 hours, although some varieties have been reported to be day-length neutral. All varieties of winged bean grow on a vine and must grow over a support. Some examples of support systems include: growing against exterior walls of houses, huts, buildings; supporting against larger perennial trees; stakes placed in the ground vertically; and structures made from posts and wires. Winged bean can be grown without added fertiliser as the plant has a bacterium on the nodules of the roots that fixes nitrogen and allows the plant to absorb nitrogen. Factors that influence nitrogen fixation include, *Rhizobium* strain, interactions between strain and host genotype, available nutrients and soil pH (Wikipedia, 2024).

The winged bean plant grows as a vine with climbing stems and leaves, 3–4 m in height. It is an herbaceous perennial, but can be grown as an annual. It is generally taller and notably larger than the Common bean. The bean pod is typically 15–22 cm (6–9 in) long and has four wings with frilly edges running lengthwise. The skin is waxy and the flesh partially translucent in the young pods. When the pod is fully ripe, it turns an ash-brown color and splits open to release the seeds. The large flower is a pale blue. The plant is one of the best nitrogen fixers with nodulation accomplished by the soil bacterium *Rhizobium*. Because of its ability to fix nitrogen from the atmosphere, the plant requires very little or no fertilizers. Being a tropical plant, it is sensitive to frost. Most plants will not flower if the day length is more than 12 hours, meaning they will not produce pods in most temperate zones, although day length neutral cultivars do exist. The seeds have a hard coat and it helps to soak them before planting to hasten germination. The plant grows very quickly, reaching a length of four meters in a few weeks (NCBI, 2024). Winged beans are small to medium in size, generally harvested between 10 to 22 centi meters in length, but if left to develop fully, the pods can extend over 30 centi meters in length. The pods bear a distinct, angular, square-like shape comprised of four feathery sides with frilled edges. The surface ranges in color from green, dark purple, purple-red, to ivory, depending on the variety, and can have a smooth or rough, waxy texture along the elongated panels. Young pods showcase their signature hues, but as they ripen, they will turn brown, harden, and burst open to expel the seeds. The pod's interior is a slender cavity filled with a few round to oval seeds. The seeds can be ivory, green, brown, or speckled and have a crunchy, fleshy consistency. Young Winged bean pods and seeds can be eaten raw and have a tender, crisp, and succulent nature. The pods are less fibrous than other legumes and soften with cooking. Winged bean pods and beans have a vegetal, subtly grassy, and sweet taste, often compared to the flavor of asparagus. The entire plant is edible, including the pods, seeds, leaves, roots, and flowers (Specialtyproduce, 2024). Botanical Description is given in Fig. 2.

		
Seed	Seedling	**Growing plant**
		
Young plant	**Leaf**	**Plant with flower**

Continue ….

		
Flower bud	**Flower**	**Pods with flower**
		
Flowers	**4 Angled immature pod**	**Pods**
		
Pods	**Pods**	**Pods**
		
Pods	**Pods**	**Pods**
		
Pods	**Pods**	**Short pods**

Continue …..

Harvesting

Harvesting

Edible pod with seeds

Pods with seeds

Pods with seeds

Pods with seeds

Seeds

Seeds

Seeds

Rhizobium nodules on roots

Tubers

Tubers

Fig. 2. Botanical Description

Pollination: It is considered to have a cleistogamous floral system, which would usually imply autogamy, with self-pollination having been observed to take place before the large flowers open in the morning hours. Such observations have been supported by experiments with bagged flowers, suggesting that insects are not required for pollination. Nonetheless, analysis of phenotypic markers (*e.g*. stem colour) have revealed a 7.6% of out-crossing during the wet season in Papua New Guinea (PNG), facilitated by carpenter bees (*Xylocopa aruana*). In support of this study, pollen obtained from fully opened flowers was found to be viable for approximately 24 h, while the stigma remained receptive for 33 h, providing evidence for possible cross-pollination events (Tanzi *et al.,* 2019). Winged bean is self-pollinating and will not cross with any other vegetable. Information on possible insect cross-pollination between different varieties of winged bean is unavailable (Ashworth 1991) (Anon, 2024).

GENETICS AND CYTOGENETICS

A study on 24 accessions of winged bean was done and identified that ISSR markers were more efficient than RADP markers. Consequently, studied ISSR markers in 45 accessions to understand genetic variability, and the results of genetic distance and genetic identity between the accessions of winged bean showed a close relationship and narrow genetic background. On the other hand, strengthened the genetic resources for *Psophocarpus tetragonolobus* by producing a *de novo* transcriptome assembly and annotation of two Sri Lankan accessions (denoted herein as CPP34 [PI 491423] and CPP37 [PI 639033]), developing simple sequence repeat (SSR) markers, and identifying single nucleotide polymorphisms (SNPs) between geographically separated genotypes. Another transcriptomic study was done on seedling from winged bean (Ibadan Local-1) and identified around 1900 microsatellites and around 1800 conserved orthologous loci, also Wong et al. sequenced transcriptomes of plants from Malaysia and found 9682 SSR markers, among which 18 were validated for nine accessions, these sets of microsatellite markers could be used to contribute to genetic linkage maps in winged bean, with the integration of single nucleotide polymorphisms (SNPs) markers for higher density (Bassal *et al.,* 2020). Very limited information on the genetics and genomics of the winged bean has been reported. The genome size of winged beans is large (2n = 2× = 18; 1.22 Gbp/C) and until now a genetic linkage map of the winged bean is not available. All previous studies of molecular genetics and genomics of the winged bean have been related to genetic diversity using first and/or second-generation DNA markers (RAPD and ISSR markers, ISSR, and SSR. As a result, there exists no study on the molecular breeding of the winged bean, due to a lack of genomic tools (Chankaew *et al.,* 2022).

There are only a few reports on inheritance of traits in winged bean. The winged bean parents, W054 and TPT9, used in this study were strikingly different in several traits related to flower, pod, and seed. Pod anthocyanin content, pod length, seed width, and seed length were considered as quantitative traits, while pod color, calyx color, wing color, banner color, and seed color were considered qualitative traits. Interestingly, these qualitative showed high variation in the F_2 mapping population. Some F_2 individuals showed color variants that did not present in their parents, particularly flower color (wings and banner). Transgressive segregation of these traits suggested that coloration in those organs is controlled by more than one gene and that W054 and TPT9 each possess different genetic loci contributing to coloration in those organs. A previous study demonstrated that pod wing color is controlled by a single gene in which purple is dominant to green. In contrast, our study showed that green pod wing is dominant to purple pod wing (Figure 3) (Chankaew *et al.,* 2022). In this study, correlation analysis of the flower-, pod-, and seed-related traits in the F_2 population was determined. Moderate to high and significant correlations were found between coloration of these traits. These results suggest that these traits are controlled by pleiotropic locus/loci or linked loci. It has been reported that genes controlling stem color and calyx color, and pod wing color and pod speck color are linked (Chankaew *et al.,* 2022).

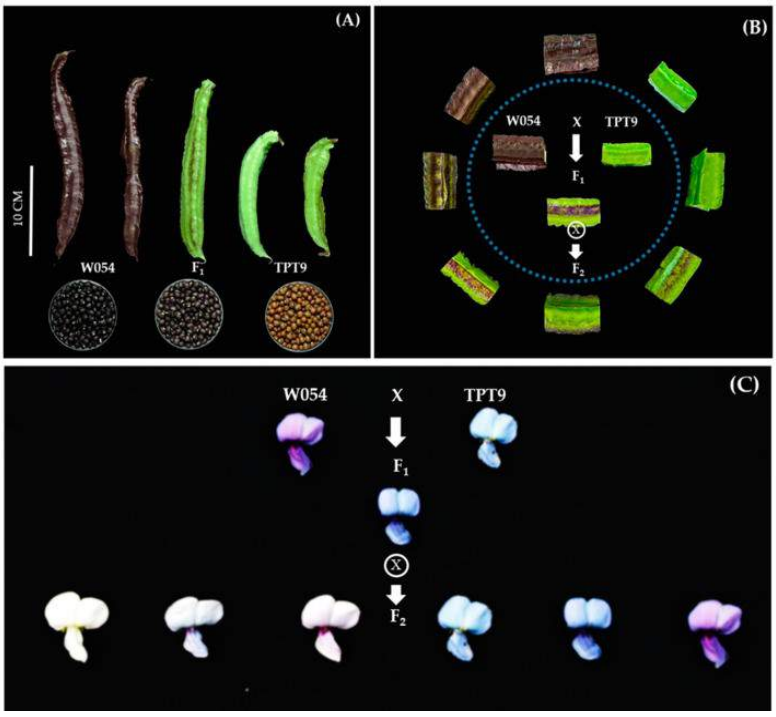

Fig. 3. The phenotypes, parental and progenies, of the W054 × TPT9 cross. The pods and seeds of W054, TPT9, and F_1 progeny are shown in (A**), the pod colors of W054, TPT9, F_1 progeny, and diversity of eight types are located in the surrounding F_2 population (**B**), and the wing and banner colors of W054, TPT9, F_1 progeny, and six types of F_2 population are shown in (**C**)**

Winged bean is a dicotyledonous plant, taxonomically classified under the Fabaceae family, Papilionoideae subfamily. It has a diploid genome ($2n = 2x = 18$), consisting of a karyotype with three pairs of short and six pairs of long chromosomes, recently determined at around 1.22 Gbp/1C in size, while previous estimation by flow cytometry suggested a haploid genome size of 782 Mbp (Tanzi *et al.,* 2019). Winged bean is a self-pollinating crop and has a diploid genome (2n =2x =18) of nine pairs of chromosomes (three pairs of short and six pairs of long) with a genome size of 1.22 Gigabase pairs (Bepary **et al**., 2023).

GENETIC DIVERSITY

Winged bean is an important vegetable with high nutritional value. Evaluating the genetic diversity is very helpful for scientific utilization for breeding and the germplasm resources for preservation. In this paper, we estimated the genetic distances of 45 accessions of winged bean using ISSR markers. The results demonstrated that winged bean germplasms had a little genetic variation with genetic dissimilarity coefficients ranging from 0.73 to 0.97. And the accessions could be divided into four groups. Our study is a few reports to evaluate the genetic diversity of different winged bean germplasms using the molecular marker, and the results provide a useful basis for germplasm research and breeding of winged bean (Chen *et al.,* 2015). Winged bean is one such crop. All parts of the plant can be eaten, from the roots to the seeds, and is high in protein as well as other micronutrients. The goal of our study was to identify the wild progenitor and analyze the partitioning of genetic variation in the crop. We used molecular phylogenetic analyses (cpDNA and nuclear ITS sequencing) to resolve relationships between all species in the genus, and population genetics (utilizing microsatellites) to identify genetic clusters of winged bean accessions and compare this to geography. We find that winged bean is genetically distinct from all other members of the genus. We also provide support for four groups of species in the genus, largely, but not completely, corresponding to the results of previous morphological analyses. Within winged bean, population genetic analysis using 10 polymorphic microsatellite markers suggests four genetic groups; however, there is little correspondence between the genetic variation and the geography of the accessions. The true wild progenitor of winged bean remains unknown (or is extinct). There has likely been large-scale cross-breeding, trade, and transport of winged bean and/or multiple origins of the crop (Yang et al., 2018). We find that winged bean is genetically distinct from all other members of the genus. We also provide support for four groups of species in the genus, largely, but not completely, corresponding to the results of previous morphological analyses. Within winged bean, population genetic analysis using 10 polymorphic microsatellite markers suggests four genetic groups; however, there is little correspondence between the genetic variation and the geography of the accessions. The true wild progenitor of winged bean remains unknown (or is extinct). There has likely been large-scale cross-breeding, trade, and transport of winged bean and/or multiple origins of the crop (Yang *et al.,* 2018).

Understanding the genetic diversity of a plant species is important for producing genetic improvement for better characteristics and benefits. Moreover, analyzing the variability in traits between plants of different origins, and comparing those traits to the genome and transcriptome may help in molecular breeding to produce plats of winged bean with desirable agronomic traits (Bassal *et al.,* 2020). The genetic resources for winged bean are not rich because its ancestor is not yet identified. Nevertheless, the comparison of its genome with other legumes that were fully sequenced can be interesting (Bassal *et al.,* 2020). A considerable amount of diversity exists in the germplasm lines of winged bean, thus providing scope for the plant breeders to seek for improvement of the seed, vegetable, tuber yield and quality aspects. This promising vegetable offers resistance towards the adverse impact of abiotic stresses and can withstand marginal upland conditions. It can be introduced in the marginal upland areas as a source of income, especially for resource poor house holds in these regions (Singh *et al.,* 2022).

Winged bean is an underutilized legume with the potential to contribute to nutrition and food security globally, particularly in sub-Saharan Africa (SSA). However, more attention needs to be paid to exploiting its full potential due to a lack of adequate knowledge of the existing genetic diversity in the available winged bean germplasm. To bridge this gap, thirty accessions of winged beans sourced from the Gene Bank of the International Institute of Tropical Agriculture (IITA), Ibadan, were evaluated for seed morphometric and selected agro-morphological traits at three agro-ecological zones in Nigeria. The data obtained were subjected to analysis of variance (ANOVA), principal component (PC) analysis, cluster analysis, and correlation analysis. Significant differences ($p < 0.05$) were observed among the accessions for all measured traits. The first two PCs accounted for 88.2% of the variation observed among the accessions for all measured traits. Accessions were grouped into three clusters based on the agro-morphological traits and three clusters under the multi-spectral imaging (MSI) system. TPt-31 had the highest seed yield per plant, pod weight per plant, and early maturity, while TPt-7 had an extended flowering and maturity period, the highest number of pods per peduncle and pods per plant, as well as the lowest seed yield. These accessions could be a good resource for future winged bean improvement programs. The result also confirmed that the MSI system is an invaluable tool for discriminating among accessions of the same crop species. The findings of this study provide insight into the genetic diversity of winged bean germplasm, which could contribute to improving its yield and quality in SSA and globally (Bhadmus *et al*., 2023).

The capability of winged bean to support food and nutrition security in sub-Saharan Africa is recurrently being affected by several constraints, which include a lack of genetic improvement. The dearth of adequate information on the level of available genetic diversity in winged bean germplasm has been a major setback in planning appropriate improvement programs. Fifteen winged bean accessions were assessed for genetic diversity using 10 quantitative traits and 10 simple sequence repeat (SSR) markers. The accessions were laid out in RCBD with three replicates for two growing seasons. Leaf samples were obtained from 10 plants representing each accession for SSR marker genotyping. The accessions exhibited significant ($p < 0.05$) differences for measured traits. Broad-sense heritability estimates varied from 10.31% for days to first plant maturity to 72.67% for pod weight. Pod weight had a positive and significant correlations with pod length (0.53, $p < 0.05$), pod width (0.70, $p < 0.01$), and number of seeds per pod (0.64, $p < 0.01$). However, the number of seeds per pod was negatively correlated with days to maturity (-0.71, $p < 0.01$). Number of seeds per pod was positively predicted by pod weight, seed thickness, and days to maturity. Cluster analysis delineated the accessions into two distinct groups. Average number of alleles of 4.2, gene diversity of 0.25, and polymorphic information content of 0.22 were recorded. Analysis of molecular variance revealed intra-accession variation of 95% as compared to inter-accession variation of 5%. Two primary genetic groups were identified and only three accessions, namely TPt-6, TPt-126, and TPt-48, showed genetic purity. The results of this study provide the basis for exploiting the existing diversity for winged bean improvement (Shonde *et al*., 2023).

Assessing the genetic diversity of the available winged bean germplasm is the starting point for bringing winged bean into the limelight of leguminous crops of economic importance. This exercise is essential for elucidating the extent and level of genetic variability in the available genetic resources and assisting in the identification of the genes that control the expression of essential biological functions that could be exploited for its improvement. The knowledge of genetic diversity helps crop improvement experts to identify and select progenitors with good characteristics for the development of superior progenies towards targeted breeding objectives (Shonde *et al*., 2023). Genetic diversity in crops can be assessed using classical and molecular approaches. Of the two, molecular assessment has proven to be more accurate, effective, and reliable. Although the classical approach which is based on the differentiation in the morphology of the crop has been helpful, the highly significant genotype by environment interaction (GEI) effect on the expression of many important agronomic traits that are polygenic in nature has been the major setback in the use of this approach. The molecular approach, which involves the use of molecular markers and a good understanding of agro-morphological variations that exist in the germplasm of a crop has greatly facilitated the development of improved genotypes with desirable agronomic attributes. Of the molecular markers that have been used for profiling winged bean, simple sequence repeats (SSRs) markers have been the most preferred since single nucleotide polymorphisms (SNPs) markers are yet to be developed. SSRs are co-dominant, abundant in genomes, and highly polymorphic and are preferred for crops where SNPs are not available yet (Shonde *et al.,* 2023). The diversity of this crop has been observed in Papua, New Guinea, Mauritius and India. However, maximum variation occurs in Papua, New Guinea. In India, it is grown in the states like Assam, Manipur, Mizoram, Kerala, Tamil Nadu, Jharkhand, Chhattisgarh and Karnataka by the tribal peoples as a backyard crop. The results of trials encourage its successful cultivation in North Indian plains also. Large number of germplasm lines has been introduced to India by NBPGR, New Delhi (Tiwari *et al.,* 2023).

BREEDING

Germplasm

Winged bean is analogous to soybean in yield and nutritional quality, proving a valuable alternative to soybean in tropical regions of the world. The presence of anti-nutritional factors and high costs associated with indeterminate plant habit have been major concerns in this crop. But occurrence of good genetic variability in germplasm collections offers precious resources for winged bean breeding. However, lack of germplasm characterization is hindering such efforts. From a genomic standpoint, winged bean has been little studied despite rapid advancement in legume genomics in the last decade. Exploiting modern genomics/breeding approaches for genetic resource characterization and the breeding of early maturing, high yielding, determinate varieties which are disease resistant and free of anti-nutritional factors along with developing consumer friendly value-added products of local significance are great challenges and opportunities in the future that would boost cultivation of winged bean in the tropics (Lepcha *et al*., 2017).

Available genetic resources at national bureau of plant genetic resource are Promising accessions for green vegetable also possessed semi-dwarf plant habit, condensed internodes, early flowering (97-105 days), medium long tender pods of pale green or green colour and very good fruiting. Among them six were indigenous collections *viz*. IC 17004, IC 17006, IC 26169. IC 26942, IC 26944 and IC 26949; and 13 were exotic collections -EC 27884, EC 38826-1, EC 38954, EC 38955, EC 38957, EC38957 A, EC38959, EC 114273-1, EC 116887, EC 116886, EC 116884, EC118031 and EC118345. Five accessions were double podded *viz*. IC 17006, IC 26949, EC 27884, EC 38955 and EC 116887 and triple podded accession was EC 116889. The four promising accessions for green forage production were IC 15018, EC 27884, EC 27885 and EC 111074. These were promising fodder types possessing traits like vine habit, quick growth and regeneration, with abundant vegetative growth. The foliage is light green to dark green in colour. For tuber yield (under north Indian plains) the promising accessions were IC 17006, EC 27884, EC 27885, EC 38958, EC 38959, EC 111073 and EC 116886. The accessions tolerant to early frost (under north Indian plains) were IC 25100, IC 25102, EC 111073, EC 111074, EC 121909 and EC 38959. These exhibited relatively better tolerance to ground frost during early winter in north Indian conditions. The accessions found to be photosensitive under Delhi conditions are IC 15018, EC 121909, EC 121910, EC 121914 and EC 121915 (Tiwari *et al.,* 2023).

Breeding

The utilization of most legumes for human consumption in the present day is low relative to cereal crops. Winged bean is a valuable legume due to the presence of soybean-equivalent nutrients. Early work identified that winged bean has favorable agronomic features suitable for cultivation in the tropics with high average yield, and foods prepared from winged bean serve as an effective measure to meet the protein demand of the consumer. The seed oil meets all the required edibility parameters and is comparable with any other good-quality edible oil on the market. Recent work utilizing genomic, transcriptomic and metabolomic data are starting to reveal more about this crop, meaning it is now easier to genetically improve this plant for further utilization (Mohanty *et al.,*2020).

Ten-winged bean accessions—six accessions obtained from introduced sources and four accessions obtained from local Thai varieties—were laid out in randomized complete block design (RCBD) with three replications at the Agronomy Field Crop Station, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand from September 2019 to April 2020 and from October 2020 to April 2021. Data, including total pod weight, number of pods, pod length, 10-pod weight, and tuber weight were recorded, and the proximate nutrient and mineral contents in the tubers were also determined. The results revealed that the principal effects of year (Y) and genotype (G) were significant for total pod weight and the number of pods. Moreover, the Y × G interactions were principal effects upon the total pod weights and tuber weights. The results indicated that superior genotype and

appropriate environmental conditions are key elements in successful winged bean production for both pod and tuber yields. The winged bean accessions W099 and W018 were consistent in both experimental years for pod and tuber yields at 23.6 and 18.36 T/ha and 15.20 and 15.5 T/ha, respectively. Each accession also proved high in tuber protein content at 20.92% and 21.04%, respectively, as well as significant in fiber, energy, and minerals. The results suggest that the winged bean accessions W099 and W018 can be used for dual-purpose winged bean production in Thailand (Sriwichai *et al.,* 2021). All the winged bean cultivars grown in Thailand are either landraces or selections from landraces. Seeds that growers use for cultivation may also be from other provenances or geographic regions that have perhaps traveled with a farmer's relatives. Additionally, no genetic improvement program for the crop currently exists. Moreover, the yield potential was not evaluated, nor was an assessment of winged bean accessions on commercially desired traits such as pod length, pod tenderness, taste, and pod color, which directly affect consumer preferences (Sriwichai *et al.,* 2021).

All winged bean cultivars are landraces or selections from landraces. Molecular markers and genetic linkage maps are pre-requisites for molecular plant breeding. The aim of this study was to develop a high-density linkage map and identify quantitative trait loci (QTLs) for pod and seed-related traits of the winged bean. An F_2 population of 86 plants was developed from a cross between winged bean accessions W054 and TPT9 showing contrasting pod length, and pod, flower and seed colors. A genetic linkage map of 1384 single nucleotide polymorphism (SNP) markers generated from restriction site-associated DNA sequencing was constructed. The map resolved nine haploid chromosomes of the winged bean and spanned the cumulative length of 4552.8 cM with the number of SNPs per linkage ranging from 36 to 218 with an average of 153.78. QTL analysis in the F_2 population revealed 31 QTLs controlling pod length, pod color, pod anthocyanin content, flower color, and seed color. The number of QTLs per trait varied between 1 (seed length) to 7 (banner color). Interestingly, the major QTLs for pod color, anthocyanin content, and calyx color, and for seed color and flower wing color were located at the same position. The high-density linkage map QTLs reported in this study will be useful for molecular breeding of winged beans (Chankaew *et al*., 2022).

Crop improvement is the practice to improve the crops against various biological stresses, yield attributing traits and quality parameters. Breeders have future perspective of crop improvement in the case of winged bean because of the presence of large numbers of diverse germplasm lines. Identification of traits governing yield and yield attributing traits, quality and oil content related traits are the primitive practices for the future breeding program for the improvement of winged bean. Introgression of these traits from wild crop relatives and working germplasm lines into cultivars may provide strength to the winged bean cultivation across the globe. Furthermore, molecular marker based genotyping of the winged bean may also give strength to understand the genetic diversity pattern and also in the identification of the trait of intersect for incorporation into leading crop cultivars through marker–assisted backcross breeding (Tiwari *et al.,* 2023). Crop improvement can also come from selectively breeding different varieties with complementary qualities, for example morphological characteristics, nutrition, abiotic tolerance, and pest resistance. An understanding of the partitioning of genetic variation in crops is therefore important to begin to identify and locate genetically distinct varieties and potentially understand the genetic basis of traits of interest. In this investigation we addressed the following two objectives. First, using a molecular phylogenetic approach, we investigate the relationships between members of the genus *Psophocarpus*, in particular focusing on identifying the close relative(s) of winged bean. Second, employing population genetic approach and using microsatellite markers to resolve the partitioning and levels of genetic variation in the crop. From agronomic standpoint, winged bean has been little studied despite rapid advancement in legume genomics in the last decade. Exploiting modern enomics/breeding approaches for genetic resource characterization and the breeding of early maturing, high yielding, determinate varieties which are disease resistant and free of anti-nutritional factors along with developing consumer friendly value-added products of local significance are great challenges and opportunities in the future that would boost cultivation of winged bean in the tropics (Tiwari *et al.,* 2023).

Varieties

On Guam, the most popular local winged bean variety is cultivated seasonally or left in the field to grow year-round. Like many winged bean varieties, the popular 'local green' variety is a 'short day' plant. 'Short day' plants usually only produce flowers and fruits when day length (sunlight) periods are less than 12 hours a day. On Guam, 'short days' usually occur from October through March. The popular 'local green' short day variety can be found in markets November through May. Other plants that require longer sunlight in a day (more than 12 hours) to produce flower and fruit are known as 'long day' plants. 'Day neutral' plants can flower and fruit regardless of the length of sunlight throughout the day. Such varieties are virtually unknown to most local producers. Day neutral winged bean varieties will enable local growers to produce winged beans throughout the year. The three varieties grown for the variety trial included Local Green ('short day' variety), Iriarte ('day neutral' variety), and Shikaku Mame ('day neutral' variety) (Tuquero and Takai, 2018). It is generally cultivated by the tribal peoples but now it is adopted by the other farmers. In last decades, the presence of quality proteins, minerals, vitamins, bioactive compounds and edible oil contents made it an important crop. However, the availability of the large number of diverse germplasm lines make the change of breeding strategy for the varietal development and improvement. In context to varietal development of the winged bean using diverse group of germplasm, varieties like IWB-1, IWB-2, AKWB has been released (Table 1) (Singh *et al*., 2022; Tiwari *et al*., 2023).

There are many varieties of winged bean varying in length, width, and color of pods. Echo mentions these varieties 'Bogor', 'Chimbu', 'Day Neutral', 'Flat', 'Ribbon', 'Siempre' and 'Square' in their 2006 research in finding a niche to determine which part(s) and attributes of these plant parts will be of greatest benefit to farmers. Varieties differ in how much of a particular plant part they produce (Growables, 2024).

Table 1. List of winged bean varieties released

Varieties	Developing year and Release	Economic part	Seed yield (Qt./ha)	Specific features
AKWB-1	1991, CVRC	Green pods and Seeds	10-12	It is dual purpose variety used as vegetable and pulse.
IWB-1	2016, CVRC.	Seeds	11-13	High yielding, medium duration variety and test weight is 36-38gm.
IWB-2	2021, CVRC	Green pods and Seeds	13-14	This variety amenable for seeds, green pods and fodder.
Chhattisgarh Pankhiya Sem-2	2017, SVRC	Green pods and Seeds	10-12	It is dual purpose variety performing well under badi situation at tribal people of Chhattisgarh

USES

The leaves, shoots, flowers, seeds, fruits, and tubers of the winged bean are all consumed and thus, the plant is described as a "supermarket on a stalk." Mature seeds are the most nutritive part; they are consumed boiled, fried, or roasted and are used for milk and toffee preparation (Kalloo, 1993). Winged bean has a wide range of uses and most parts of the plant are consumed, depending on where the crop is cultivated. The young pods are a popular edible part across all cultivation areas, eaten raw or as a cooked vegetable, and in Indonesia mature seeds are roasted like peanut and boiled. In PNG, immature seeds are consumed due to their pea-like taste. In Myanmar, Thailand, and PNG, boiled, steamed, baked, fried or roasted tubers are also consumed. Leaves and flowers are also consumed and younger parts are particularly appreciated when infected with the fungus *S. psophocarpi* in Java, Indonesia. Green or purple young pods have been reported, with presence or absence of specks. The seed coat colour has been reported to range from cream, black, brown to purple and mottled colours (Tanzi *et al*., 2019). Winged bean is consumed mainly in South Africa, Southern Asia, India and Malaysia. All the parts of winged bean plants can be eaten, including the pods (raw or pickled, consumed largely in India, flowers (used in salad and to color dishes, leaves (prepared and eaten similar to spinach), roots (tubers. raw or cooked especially in Burma, Ghana, Papua New Guinea, Thailand and Indonesia) and seeds. The seeds are processed and consumed in diverse ways: Unripe seeds are eaten in soups; mature seeds can be eaten roasted, or dried and grounded to produce flour. Furthermore, oil can be extracted from the seeds and used in cooking or frying food (Bassal *et al.,* 2020). In Thailand, the winged bean is an underutilized crop that Thais consume in a variety of ways. Immature pods are used for salads, soups, and direct consumption. Tuber roots are typically roasted or boiled and consumed directly or made into confectionaries. In Thailand, winged beans are generally grown on smaller commercial scales that supply young pods to local markets. The summer market price of winged beans ranges between USD 8 to 10 per Kg. However, while the winged bean has the potential to become an important economic food crop in Thailand, very little research has been conducted on it over the past few decades (Sriwichai *et al*., 2021). The winged bean is popularly known as 'One Species Supermarket' because of its high nutritionally rich green pods, tuberous roots, leaves, immature and mature seeds. Leaves are eaten like spinach, flowers as salad,tubers as raw or processed food and seeds are used in different forms of processed food. Owing to its vining nature and nitrogen fixation ability, it used as a cover crop and also incorporated into rotation or inter-cropping systems. As such, winged bean could be a good candidate for diversifying diets to improve nutritional security, based on complex and more sustainable agricultural systems (Singh *et al*., 2022). Besides nutritional qualities, winged bean is a potential climatic resilient crop for adaptation in suboptimal weather conditions, like drought, flood, heat and biotic stresses as compared to other major staple crops. Increasing awareness about the role of agro-biodiversity in sustainability, socio-economic resilience and human health has resulted in re-diversifying agro-biodiversity through utilization of neglected and underutilised crop species. Realizing the importance of such crops, the US National Academy of Sciences (NAS) constituted a committee in 1974 to carry out 'an extensive survey of underexploited tropical plants' as possible crops for the future and winged bean was identified for promotion among agricultural research communities with exceptional merits (Singh *et al.,* 2022).

Winged beans are an incredibly versatile ingredient, and can be used in a wide range of dishes. In Thai cuisine, they are often stir-fried with garlic and chilli peppers and served as a side dish. They can also be boiled, steamed or sautéed and added to soups or salads for a nutritious boost. For a delicious vegetarian main course, try making a stir-fry with winged beans, mushrooms and carrots. This dish can be served over cooked white or brown rice for an easy meal that packs in plenty of flavor and nutrition. Winged beans can also be used in savory dishes like omelettes and frittatas. Simply sauté the beans with garlic, onion and other vegetables of your choice and add them to your egg mixture before cooking. This is a great way to enjoy all the health benefits of winged beans while enjoying a delicious meal. No matter how you choose to use them, winged beans are sure

to make any dish more flavorful and nutritious. Enjoy exploring all the possibilities that this versatile ingredient has to offer! (Baylis, 2023).

Winged Bean has a wide range of uses and most parts of the plant are consumed. 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. In Papua New Guinea leaves and flowers are consumed as part of salads. Flowers are also used to color food products, like rice and pastries. 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. Pods are a popular edible part across all cultivation areas, eaten raw or as a cooked vegetable. At the 10-15 cm stage they are eaten and prepared much as are bush snap beans. Best cooked by steaming or by boiling in water a minimum of 10 minutes. When the pods are soft enough, they are seasoned and served. Immature winged bean pods are used in pickles commercially available in South India. Winged bean seeds can be steamed, boiled, fried, roasted, fermented, or made into milk, tofu (bean curd), or tempeh. Both a white milk and a chocolate-flavored milk have been made from the seed in Thailand and sterilized for longer shelf life. Sprouted seed can also be an alternative to mung bean sprouts. In Indonesia mature seeds are roasted like peanuts and boiled. Immature seeds are consumed due to their pea-like taste in Papua New Guinea. Tubers: 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. Highland tribesmen in Papua New Guinea esteem it so highly that they hold winged bean sing-sings (feasts) at harvest time (Growables, 2024).

Seeds can be processed to produce oil, similar to soya bean oil, used for culinary purposes, illumination and soap. Expressed oil cakes are fed to livestock. 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. It has been used as a cover crop in young oil-palm plantations, also in food crops including plantains, coco yams, citrus and further to restore land badly eroded after diamond mining (Growables, 2024). The leaves, shoots, flowers, pods and seeds are all edible. The root tuber is white and firm and averages 20 percent protein. In Papua New Guinea, the tubers are eaten roasted and have a pleasant, slightly nutty taste; they can also be eaten raw. Young pods, harvested while still tender and bendable, can be boiled and served like french beans or dipped in sauces and curries. The green seeds from both immature and mature pods are consumed, while ripe seeds can be roasted before eating. The nutritional composition of winged bean seeds is comparable to that of soybean with approximately 30 percent protein.
In Indonesia, dried seeds are fermented to prepare a meat substitute called “tempeh” or processed to produce tofu. Protein-rich bean milk and flour are useful dietary treatments for protein-deprived children. Flowers eaten steamed or fried have the color and consistency of mushrooms (Anon, 2024).

The entire winged bean plant is edible. The leaves, flowers, roots, and bean pods can be eaten raw or cooked; the pods are edible even when raw and unripe. The seeds are edible after cooking. Each of these parts contains vitamin A, vitamin C, calcium and iron, among other nutrients. The tender pods, which are the most widely eaten part of the plant, are best when eaten before they exceed 2.5 cm (1 in) in length. They are ready for harvest within three months of planting. The flowers are used to colour rice and pastry. The young leaves can be picked and prepared as a leaf vegetable, similar to spinach. The nutrient-rich, tuberous roots have a nutty flavour. They are about 20% protein; winged bean roots have more protein than many other root vegetables. The leaves and flowers are also high in protein (10–15%). The seeds are about 35% protein and 18% fat. They require cooking for two to three hours to destroy the trypsin inhibitors and hemagglutinins that inhibit digestion. They can be eaten dried or roasted. Dried and ground seeds make a useful flour, and can be brewed to make a coffee-like drink (Wikipedia, 2024). Smoked pods, dried seeds, tubers (cooked and uncooked), and leaves have been sold in domestic markets in South East and South Asia. Mature seeds can command a high price. Winged bean is a potential food source for ruminants, poultry, fish, and other livestock. For commercial fish feed, winged bean is a potentially lower-cost protein source. In Africa, fish meal is especially scarce and expensive. The African sharp tooth catfish, a highly valued food fish in Africa, can eat winged bean. In Papua New Guinea highlands region where winged beans thrive, the husks are fed to domesticated pigs as a dietary supplement (Wikipedia, 2024).

Winged beans have a vegetal, subtly sweet, asparagus-like flavor suited for fresh and cooked preparations. The entire plant is edible, including the flowers, stems, leaves, seeds, and pods. When young and fresh, Winged bean pods can be sliced and tossed into salads, dipped into fish sauce as a snack, or lightly coated in mayonnaise as a side dish. The young seed pods can also be pickled for extended use, stir-fried with other vegetables, steamed and served as a simple dish, or added to sambals and dals. In Southeast Asia, Winged beans are popularly simmered into soups, stews, and curries. The seeds are commonly cooked with catfish, snakehead fish, or grouper in Vietnam, and the broth is flavored with tamarind for a tangy taste. The seeds can also be blended with water to create a milk similar to soy, or the pods can be fried into tempura. In Indonesia and Malaysia, Winged bean pods can be found smoked for a savory taste, and the seeds are dried for longer storage. Beyond the pods and seeds, Winged bean flowers have a delicate lavender to light blue hue, used in dishes to color rice. The young leaves can also be lightly cooked and served as a side dish, and the cooked tubers develop a consistency similar to potatoes and have a nutty, earthy flavor. Whole, unwashed Winged beans will keep for 2 to 5 days when stored in an airtight container in the refrigerator (Specialtyproduce, 2024).

This climbing legume vine produces edible nutritious leaves, flowers, pods, green seeds, dried seeds, and (in some varieties) edible tuberous roots. Dried seeds have been used in Indonesia to prepare a fermented meat substitute food product called "tempeh" or, if processed, "tofu." Protein-rich milk and flour, derived from Winged Bean seeds, have become useful dietary treatments for protein-deprived children. In Bangladesh, Winged Bean stems and leaves are used as cattle forage. Winged Bean is a good nitrogen-fixer species, and it is used for intercropping with bananas, sugarcane, taro, and other species (Echocommunity, 2024). Several parts of the plant may be eaten raw: sprouts, leaves, flowers, and young pods. Avoid heavy consumption of raw leaves, however, as excessive consumption of raw leaves leads to dizziness, nausea and flatulence. Cooked leaves are safe in large quantities. Dried seeds can be steamed, boiled, fried, roasted, fermented, or made into milk, tofu (bean curd), or tempeh. Tubers can be boiled, steamed, or baked (Echocommunity, 2024). Winged Bean sprouts and shoots may be eaten raw or cooked as green vegetables. The top three sets of leaflets are the tender ones; they taste slightly sweet. Pick young stems and leaves for additives to soups and curries or for separate servings. First green pods often are ready for consumption 6-10 weeks after sowing. Young flexible pods (3-10 cm/1-4 in long, depending upon the variety grown) are best for eating. The half-ripe seeds can be removed from the pod and cooked. Save some pods for ripened dry seeds that provide a nutritious pulse. Flowers may be eaten raw; fried or steamed they have the color and consistency of mushrooms. Dig tubers after pod ripening. Allow to air dry for a few days for easier peeling prior to cooking *(*Echocommunity, 2024*).*

Winged beans were one of the four main legume species cultivated in Papua New Guinea before colonial rule. The trailing vines were planted in the Mount Hagen township in the Western Highlands Province and the Asaro Valley near Goroka, the capital of the Eastern Highlands Province. Winged bean plants were viewed as a luxury food source as the entire plant was edible and provided a significant amount of protein for indigenous diets. The tubers were especially valued and were traditionally harvested at one time during the season, an event that was celebrated throughout the entire community. On harvest days, it was customary for the tubers to be roasted in earthen ovens, releasing a nutty, pleasing aroma. While the tubers were cooking, the community would gather and celebrate the harvest, using the tubers as a meal representative of the sharing between community members. In the modern day, Winged bean plants are still cultivated in Papua New Guinea, but they have become overshadowed by the introduction of European crops. Winged bean tubers and pods can still be seen at cultural festivals known as sing-sings. These annual celebrations are meant to gather tribes together to share and learn about the cultural traditions of each people group. One of the most famous sing-sings is known as the Goroka Show, an annual sing-sings held in the town of Goroka. This sing-sings can sometimes attract over one hundred tribes, and each tribe wears outfits representative of their culture and performs their own song and dance (Specialtyproduce, 2024).

NUTRITION VALUE

The chemical composition of dry seeds of four varieties, pods, stalks and leaves of winged beans was determined. The seeds had a high range of protein (27.8-36.6%) and fat (14.8-17.9%), which were similar to soybeans. the seeds contained high phosphorus, calcium and magnesium. The leaf was highest in protein content (33.7%) of all the parts studied except for the seeds. The protein and fat content of pods decreased as pods ripened. the calcium content in the leaf was much higher than in the other parts. Protein was extracted sequentially with 2% NaCl, 30% isopropyl alcohol, 4% lactic acid and 0.5% KOH from dry seeds of four varieties of winged beans. The NaCl extract showed the highest range of protein concentration (60.2-77.6%). The NaCl extract was separated into two fractions based on solubility in water. the amino acid composition of the flour from the seeds and of the two fractions from the NaCl extract were determined. Contents of lysine, aspartic acid, glutamic acid and leucine were large, while the sulfur-amino acid content was small. Trypsin and chymotrypsin inhibitory activities of 2% NaCl extract from the seeds were determined, and chymotrypsin inhibitory activity was higher than the trypsin (Ibuki *et al*., 1983).

The proximate composition (fat, moisture content, crude protein, ash, and carbohydrate) and antinutrient (tannin and phytate) level of winged bean seeds and tubers were determined using 50 accessions. In the processed seeds, accession Tpt17 had the highest protein content (40.30%) and Tpt48 the lowest (34.18%). In the unprocessed seeds, Tpt17 also recorded the highest crude protein (31.13%) with Tpt125 having the lowest (28.43%). In the tubers, protein content ranged from 19.07% (Tpt42) to 12.26% (Tpt10). The moisture content in the processed seeds ranged from 8.51% (Tpt42) to 6.72% (Tpt6); in the unprocessed seeds, it was between 8.53% (Tpt53) and 3.76% (Tpt14). In the processed seeds, the values of ash ranged from 4.93% (Tpt126) to 4.45% (Tpt15-4); in the unprocessed seeds, it ranged from 4.98% (Tpt17) to 4.55% (Tpt125). In the processed seeds, the fat content ranged from 18.91% (Tpt51) to 14.09% (Tp43) while in the unprocessed seeds, the values ranged from 19.01% (Tpt15) to 13.87% (Tpt3-B). The crude fiber in the processed samples ranged from 13.82% (Tpt6) to 10.40% (Tpt125) while in the unprocessed seeds, it ranged from 7.29% in Tpt51 to 4.83% in Tpt11. Carbohydrate content in the processed seeds ranged from 26.30% (Tpt3-B) to 20.94% (Tpt125) and 39.76% in Tpt3-B to 34.53% in Tpt18 in the unprocessed seeds. The tannin and phytate contents showed remarkably significant differences. In the tubers harvested, significant variation was observed in the parameters evaluated. Winged bean flour could be formulated into various meals for children and adults to reduce malnutrition in sub-Saharan Africa (Adegboyega *et al.,* 2019).

Winged bean plant is appreciated for the high nutrients composition, especially with respect to proteins, vitamins and minerals; the tubers are starchy with high percentage of proteins 17 to 20% (by weight) compared to other vegetables, the leaves and flowers contain from 5 to 15% proteins (by weight), the seeds are highly nutritious with 32 to 37% proteins, which is similar to the amount of proteins found in soy beans and higher than that found in other beans. The seeds also contain 23 to 40% carbohydrates, vitamins like vitamin B_1, B_2, B_3, B_6, B_9 and in vitamins C, A and E. The mature seeds contain 14 to 25% fats by weight, of which 94% are in free form, whereas the rest are complexed with carbohydrates and proteins. Winged bean is rich in minerals including calcium, iron, phosphorous, potassium, sulfur, sodium, magnesium, zinc, manganese, boron, barium, copper, chromium and

strontium. *Psophocarpus tetragonolobus* contains 54 to 75% of unsaturated fatty acids, of which 38.6% are mono-unsaturated and 36.9% are polyunsaturated and no *trans* fatty acids are found. Winged bean oil contains 30 to 40% saturated fatty acids which represent more than the content observed in soybean. Oleic and linoleic acids represent nearly 50% of unsaturated fatty acids. Unsaponifiable lipids are mainly represented by β-sitosterol (66.4%) and stigmasterol (25.1%). Moreover, winged bean oil was found to be better than soybean oil, because of its high oxidative and high thermal stabilities (Bassal *et al*., 2020).

Winged bean contains many anti-nutritional factors: trypsin inhibitors, chymotrypsin inhibitors (WCI), hemagglutinins, amylase inhibitors, phytates, phytic acid, flatulence factors, hydrogen cyanide, saponins, tannins and other phenolic compounds. Table 2 shows the main phytochemicals of *Psophocarpus tetragonolubs* responsible of its anti-oxidant and anti-inflammatory activities (Bassal *et al.,* 2020).

Table 2. Main metabolites responsible of the biological activity of *Psophocarpus tetragonolobus*

Metabolites	Activity	Plant Part
Phytate	Anti-nutritional factors, affinity for specific blood cell antigens	Seed
Tannin	Nonspecific enzymes inhibitors, hemagglutinin activity	Seed
Psophocarpin	Chemotrypsin inhibitory activity	Seed, pods
Lectin	Hemagglutinin activity	Mainly in seed, roots
Albumin 1 (WBA-1)	Kunitz-type trypsin inhibitors	Seed
Phaseolin	α-amylase inhibitor	Seed

The immature pods contain 1% to 3% protein, as well as several vitamins and minerals. The winged bean's mature seeds contain protein levels of 28% to 45% [9], oil of roughly 14% to 19%, and carbohydrates of 34% to 40%. Moreover, its raw tubers contain 12% to 19% protein and 1% to 4% fat. The immature wing bean pods represent its major form of consumption, as they are rich in minerals and vitamins, particularly vitamin A (Sriwichai *et al*., 2021). Winged bean has been recognized as a crop having much promise for nutritional security in the coming decades. Winged bean tubers are notably rich sources of starch, protein, and B-complex vitamins. Winged beans provide adequate amounts of proteins, minerals and vitamins. In addition, thiamine, pyridoxine (Vitamin B-6), niacin, and riboflavin are some of the B-complex vitamins embedded in these beans. Some of the essential minerals such as iron, copper, manganese, calcium, phosphorus, magnesium is concentrated in them. Manganese is utilized in the human body as a cofactor for the powerful antioxidant enzyme, superoxide dismutase. Winged bean green leaves, are an excellent source of fibre, vitamin A, C and minerals. Hundred grams of fresh leaves provide 45 mg of vitamin C (75% of recommended daily value) and 8090 IU of Vitamin A (270% of RDA). Fresh, young winged bean pods are one of the finest sources of folates. Hundred grams beans provide 66 µg or 16.5% of daily requirement of folates. Folate along with vitamin B-12, is one of the essential components of DNA synthesis and cell division. Adequate folate in the diet around conception and during pregnancy may help prevent neural-tube defects in the new-born baby. Fresh winged beans contain quite a good amount of vitamin-c as 18.3 mg/100g, or 31%. Vitamin C is a powerful water soluble antioxidant, and helps in building immunity against infections, maintaining blood vessel elasticity, and offers some protection against cancers when adequately provided in the diet. Tender, immature pods of winged beans are one of the very low-calorie vegetables as 100g beans carry just 49 calories (Singh *et al.,* 2022).

The average moisture, carbohydrate, protein, fat, crude fiber, and ash content of 138 genotypes of winged bean seeds were found as 9.09 ± 1.73%, 26.81 ± 6.88%, 34.98 ± 4.63%, 18.01 ± 2.27%, 10.24 ± 5.49%, and 4.16 ± 0.41%, respectively. Leaves of winged beans are good sources of vitamins such as vitamin C (14.5–128 mg/100 g), thiamine, riboflavin, niacin, vitamin B 6, folate, vitamin A (5240–20,800 IU), and vitamin E. The seed of winged beans is rich in calcium, iron, phosphorus, zinc, and copper. The anti-nutritional factors, namely, trypsin inhibitor, chymotrypsin inhibitor, phytic acid, saponin, tannin, oxalate, and flatulence saccharides of winged bean, were reported to be in the range of 40–99.5 TIU/mg of pro-tein, 86.4–109.6 CIU/mg of protein, 4.09%–9.96%, 0.6%, 0.77%–0.97%, 0.5%, and 0.04%–0.18%, respectively (Bepary *et al.,* 2023).

The winged bean is one of the important sources of bioactive compounds such as vitamin C, vitamin E, polyphenols, and flavonoids, which can act as antioxidants. Consumption of winged beans has been shown to have anti-inflammatory, antimicrobial, anticarcinogenic, antitumoral, antimutagenic, anti-allergic, anti-aggregate, and anti-ischemic properties (Bepary *et al.,* 2023). Being a protein-rich crop, it can alleviate malnutrition and poverty in the developing countries of the world. Before the commercial utilization of winged beans for human consumption, it is very much important to critically examine the biochemical composition of the bean critically, so that processing into products will become viable in terms of nutritional and sensory quality. The winged bean is an important but under-utilized legume that has the potential to resolve the global food and nutritional security problems in the future because of its nutritional potential and multiple uses. Moreover, the information with respect to its nutritional composition, anti-nutritional factors, health benefits, bioactivity, processing, and food uses is scant under a single entity (Bepary *et al.,* 2023). Nutritive value of winged beans per 100g is given in Table 3 (Tiwari et al., 2023).

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 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. The seeds, comparable to soybean in composition and nutritional value and contain similar proportions of protein (30-40%), carbohydrates, oil (15-20%), minerals, vitamins, essential amino acids and other constituents. The leaves are rich in vitaminss A and C, calcium and iron. They also have a relatively low lysine content but an uncommonly high content of tryptophan, a nutritionally essential amino acid (Growables, 2024).

Table 3: Nutritive value of winged beans (*Psophocarpus tetragonolobus*) per 100g

Major Source	Nutrient Value	Percentage of RDA
Energy	49 Kcal	2.5%
Carbohydrates	4.31 g	3%
Protein	6.95 g	12%
Total Fat	0.87 g	3%
Cholesterol	0 mg	0%
Vitamins		
Folates	66 µg	16.5%
Niacin	0.900 mg	6%
Pantothenic acid	0.059 mg	1%
Pyridoxine	0.113 mg	9%
Riboflavin	0.100 mg	8%
Thiamin	0.140 mg	12%
Vitamin A	128 IU	4%
Vitamin C	18.3 mg	30%
Electrolytes		
Sodium	4 mg	<1%
Potassium	240 mg	5%
Minerals		
Calcium	84 mg	8%
Copper	0.051 µg	5.5%
Iron	1.5 mg	19%
Magnesium	34 mg	8%
Manganese	0.218 mg	9%
Phosphorus	37 mg	5%
Selenium	1.5 µg	3%
Zinc	0.39 mg	3%

(*Source*: USDA National Nutrient data base)

Winged beans have high reported protein content: green pods-2%, raw leaves-5%, dried seeds-30%, dried roots-25% (about 10 times the content of potato tubers), stems and leaves as forage-6%. Seed protein digestibility and composition rivals that found in soybeans. Winged bean seeds are noted as a rich source of the antioxidant, tocopherol, a substance important in vitamin A utilization *(*Echocommunity, 2024*)*.

Nutritional value per 100 g of mature seeds is given in Table 4.

Table 4. Winged beans, mature seeds, raw (Wikipedia, 2024)

Nutritional value per 100 g	
Energy	1,711 kJ (409 kcal)
Carbohydrates	41.7 g
Dietary fiber	25.9 g
Fat	16.3 g
Saturated	2.3 g
Monounsaturated	6 g
Polyunsaturated	4.3 g
Protein	29.65 g
Vitamins	**Quantity; %DV†**
Vitamin A	0 IU
Thiamine (B1)	86%; 1.03 mg
Riboflavin (B2)	35%; 0.45 mg

Niacin (B3)	19%; 3.09 mg
Pantothenic acid (B5)	16%; 0.795 mg
Vitamin B6	10%; 0.175 mg
Folate (B9)	11%; 45 µg
Vitamin C	0%; 0 mg
Minerals	**Quantity %DV†**
Calcium	34%; 440 mg
Iron	75%; 13.44 mg
Magnesium	43%; 179 mg
Manganese	162%; 3.721 mg
Phosphorus	36%; 451 mg
Potassium	33%; 977 mg
Sodium	2%; 38 mg
Zinc	41%; 4.48 mg

Tender, immature pods of winged beans are one of the very low-calorie vegetables; 100 g beans carry just 49 calories. Mature winged bean seeds, however, has 409 calories per 100 g and compose relatively high protein content equivalent to that of soybean protein. Fresh, young bean pods are one of the finest sources of folates. 100 g beans provide 66 µg or 16.5% of daily requirement of folates. Folates, along with vitamin B-12, is one of the essential components of DNA synthesis and cell division. Adequate folate in the diet around conception and during pregnancy may help prevent neural-tube defects in the newborn baby. Fresh winged beans contain quite a good amount of vitamin-C. 100 g beans provide 18.3 mg, or 31% of vitamin-C. Vitamin-C is a powerful water-soluble antioxidant, and when adequately provided in the diet, it helps build immunity against infections, maintain blood vessel elasticity, and offer some protection against cancers. Also, winged beans provide adequate amounts of minerals, and vitamins. Some of the essential minerals such as iron, copper, manganese, calcium, phosphorus, magnesium are concentrated in them. Manganese is utilized in the human body as a co-factor for the powerful antioxidant enzyme, superoxide dismutase. Thiamin, pyridoxine (vitamin B-6), niacin, and riboflavin are some of the B-complex vitamins embedded in these beans. Winged bean leaves, used as greens, are an excellent source of fiber, vitamin-C, vitamin-A, and minerals. 100 g of fresh leaves provide 45 mg of vitamin-C (75% of recommended daily value) and 8090 IU of vitamin-A (270 % of RDA). Winged bean tubers are notably rich sources of starch, protein, and B-complex vitamins. 100 g of root provides 11.6 g of protein in comparison to 2.02 g/100 g and 1.36 g/100 g protein content in potato, and cassava respectively (Myonlinevipani, 2024.).

Winged beans are a source of copper to develop connective tissues, iron to produce the protein hemoglobin for oxygen transport through the bloodstream, and manganese to assist in amino acid metabolism. The plants also provide fiber to regulate the digestive tract, phosphorus to repair tissues, magnesium to control optimal nerve functioning, potassium to balance fluid levels within the body, and other nutrients, including zinc and B-complex vitamins (Specialtyproduce, 2024).

HEALTH BENEFITS

Winged bean was used since a long time as a medicinal plant in different countries: its fruits and roots were used as medicines that increase strength, and as treatment of ulcers in New Guinea. Moreover, its leaves were used as treatment of small pox and its tubers were used in the treatment of vertigo in Malaya, both for external use. Nowadays, different studies were done to investigate the anti-oxidant, antimicrobial, anti-inflammatory and anti-proliferative activities of different extracts from this plant (Bassal *et al*., 2020). Due to all the positive nutrition benefits offered by winged bean could be a replacement in various food formulations as a functional ingredient. Moreover, winged bean has been commonly used in traditional medicine for many years. Winged bean possess bioactive phytochemicals with antioxidant properties, so it's considered a putative promising resource for treating diseases related to oxidative stress and inflammatory reactions. Thus, this plant can serve as sources of health-promoting nutrients and phytochemicals for human and animals (Bassal *et al*., 2020).

Winged beans are a good source of dietary fiber and contain high levels of essential minerals such as iron, magnesium, copper, potassium and zinc. They also provide vitamins A, B1, B2, and C. Winged beans are rich in protein, making them an important addition to vegetarian or vegan diets. Furthermore, they are low in calories and fat-free, making them a healthy choice for those on weight loss diets. Winged beans are also beneficial in reducing inflammation and promoting digestive health. Additionally, research has shown that the compounds found in winged beans may help protect against cancer and other diseases. The flavor profile of the Winged beans is earthy and nutty with a hint of sweetness. There are also notes of umami, which gives it an interesting and unique flavor that can enhance any dish. The texture is firm yet tender when cooked, making it an ideal addition to many different meals. Its high protein content makes it an excellent meat substitute, and its versatility makes it easy to pair with various dishes (Baylis, 2023). This bean can prevent diabetes, cancer, and asthma, boost immunity, and promote women's and men's reproductive health (Bepary *et al*., 2023).

Joanna (2023) has reported thev following health benefits:

Boosts immunity: Winged beans are high in vitamin C and vitamin A, which are both essential for boosting the immune system and helping the body fight diseases. The antioxidant properties of vitamin C help fight free radicals that can otherwise damage the cells and cause disease. It also stimulates the activity of white blood cells, which are part of the body's defense system. On the other hand, Vitamin A protects the mucous lining in the body, thus preventing the entry of any disease-

causing pathogens. It also fights inflammation, another crucial role in maintaining a strong and healthy immune system. Winged beans are also a good source of B vitamins which can support a healthy immune system by maintaining healthy cells.

Promotes healthy eyes. Besides boosting the immune system, the vitamin A in winged beans can promote healthy eyes and vision. According to the American Academy of Ophthalmology, vitamin A is important for the production of certain pigments that help your cornea see the full spectrum of light. Low vitamin A stops the production of these pigments leading to vision problems, including night blindness. Vitamin A also helps moisturize your cornea, keeping it hydrated and preventing injury. Additionally, winged beans are one of the best sources of vitamin B1 or thiamine, which has been shown to promote eye health and prevent various eye problems, including glaucoma and cataracts. Thiamine also helps grow and heal muscles and nerves in the eye, which is responsible for sending signals to the brain, helping you maintain proper coordination between your eyes and the brain.

Helps with digestion: Fiber is one of the primary nutrients in winged beans, and it helps promote regular bowel movements and can prevent constipation. In addition, they are rich in prebiotic fiber, which helps nourish the beneficial bacteria in the gut and support a healthy digestive system. Fiber can also help lower cholesterol by binding to cholesterol particles in the small intestine and preventing it from being absorbed into the bloodstream.

Builds muscle: Building some muscles is good not just for athletes but just about anyone looking to improve their health. Building muscles can help manage blood sugar, build strength and stamina, improve joint stability and strength, and improve balance and coordination. One way to boost muscle growth is to eat foods high in protein like winged beans. Consuming adequate amounts of protein is also essential for muscle growth and recovery, especially for people who engage in regular physical activity or strength training.

Boosts hemoglobin levels: Winged beans are rich in iron which is essential for the formation of hemoglobin. Hemoglobin is a protein found in red blood cells that helps carry oxygen from the lungs to every part of the body as well as transport carbon dioxide from the body to the lungs.

Improves skin elasticity: The vitamin C in winged beans is essential for maintaining healthy and good-looking skin. Vitamin C stimulates collagen production, a key protein in the skin. Collagen provides structure and strength to your skin. It also rejuvenates the skin by promoting hydration, improving elasticity, and preventing premature signs of aging. Winged beans are also a good source of vitamin A, another antioxidant that can protect the skin from free radical damage and reduce the appearance of sagging skin, wrinkles, and hyper-pigmentation.

Beneficial during pregnancy: The beans possess adequate amounts of folic acid, essential for pregnant mothers. The nutrient facilitates the healthy development of the fetus and prevents tube defects. Furthermore, iron is crucial during childbirth since it reduces the chances of maternal blood loss and low birth weight.

Boosts energy levels: This legume boosts energy levels since it contains nutrients such as Phosphorus and sugars such as fructose and lactose. Generally, Phosphorus promotes the absorption and regulation of B vitamins, which facilitates the production of ATP, a form of energy needed in the cells.

Promotes weight loss: As mentioned earlier, winged beans are an excellent source of protein and fiber. These nutrients can boost your weight loss efforts in various ways, including: Protein reduces appetite, making you eat a few calories. Also, protein increases metabolism, which increases the number of calories you burn. This is because your body burns more calories when you eat protein, as it needs mor energy to digest than when you eat any other food. Additionally, protein helps to build and maintain muscle mass, which is necessary for burning calories and fat. Conversely, fiber helps keep you full and satisfied after eating, making you less likely to overeat.

Promotes bone health: Winged beans are an excellent source of calcium, the main mineral found in bones and teeth. They also contain Phosphorus, which helps the body to use calcium and build strong bones. Generally, eating a diet that includes winged beans can help to promote bone health and prevent osteoporosis.

Prevents diabetes: Diabetes is a condition that results in too much sugar in the blood. If not controlled, this sugar can damage your organs, including kidneys and eyes and increase the risk for other complications. Fiber, calcium, and vitamins, such as vitamin D, contained in winged beans help to lower the chances of diabetes by keeping glucose metabolism in the body in check. Furthermore, these nutrients assist the pancreas to optimally produce and distribute insulin, which helps regulate blood sugar levels leading to a balance of sugar in the blood, thus preventing diabetes.

Prevents DNA damage: Typically, the beans are rich in antioxidants and phytochemicals, which aid in protecting against DNA damage. One study found that legumes such as beans prevented DNA damage associated with UV radiation.

Boosts nutrient deficiency: Loaded with nutrients, as mentioned above, winged beans can be categorized as a natural source of essential nutrients. As such, regular consumption of these beans can boost various deficiencies in your diet. Notably, the legume is filled with essential vitamins like vitamins A, C, and D and B vitamins and minerals such as copper, Phosphorus, magnesium, calcium, manganese, and iron.

They can lower blood pressure: Winged beans are rich in potassium, an essential mineral in lowering blood pressure. It helps balance sodium levels in the blood, which, if too high, will raise your blood pressure. Potassium also helps ease tension within the arterial walls causing blood pressure to drop. Various studies have also shown that increased dietary potassium intake can improve blood pressure in people with hypertension.

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