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Winged Bean: A Wonder Legume Vegetable

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Winged bean (*Psophocarpus tetragonolobus* (L.) DC) is a dicotyledonous plant, belonging to the *Papilionoideae* subfamily of the family *Fabaceae*. It is a multipurpose legume grown for its edible pods, seeds and tubers. It grows well in hot and humid equatorial climates and is primarily grown in Asian countries such as India, Burma, Sri Lanka, Indonesia, Malaysia, Thailand, the Philippines, Indochina, China, and Papua New Guinea. While Southeast Asia is traditionally recognized as the place of origin for this crop due to its extensive history of cultivation, the original ancestor plant is believed to have disappeared. Another potential centre of origin is Papua New Guinea, as this country exhibits significant genetic variation for winged beans. In India, it is predominantly grown in North-Eastern states such as Nagaland, Mizoram, Meghalaya and Manipur. It is also often found in Eastern states like Bihar, Jharkhand, Odisha, and Hilly areas of Chhattisgarh, Madhya Pradesh, Karnataka and Tamil Nadu in cultivated form or as wild.

Winged bean is a self-pollinating crop with a diploid genome set of 2n = 2x = 18 consisting of nine pairs of chromosomes. It is a creeping perennial herb and can reach heights of 3–5 meters. The plant has green trifoliate leaves and blooms with flowers measuring 2.5–3.5 cm, displaying various colours including purple, white, blue, and red. They have tuberous roots, each typically ranging in size from 2 to 4 cm in width and 8 to 12 cm in length. The winged bean pods are four-sided and consist of fringed wings from which the name winged bean is derived. They come in sizes of 6–30 cm in length and 3 cm in width, and each pod contain 5 to 20 seeds. These green pods are tender and house young seeds. As the pods mature, they transform into a woody texture after dehydration and within them, edible seeds are found. The dimensions of winged bean seeds typically fall within the ranges of 6.38–8.53 mm in length, 6.13–7.71 mm in width, and 5.77–6.85 mm in thickness.

Winged bean for nutritional and food security

The winged bean has the potential to enhance dietary diversity and boost nutritional security through the implementation of more intricate and sustainable agricultural practices. With protein content similar to that of milk, winged beans can effectively address protein deficiencies, especially in infants. These beans are abundant in key nutrients, with 35.23 grams of protein, 16.10 grams of fat, 11.04 grams of crude fibre and 27.09 grams of carbohydrates per 100 grams. Additionally, they supply significant quantities of vital minerals, including 584.74 milligrams of potassium, 521.09 milligrams of phosphorous, 340.49 milligrams of calcium, and 5.66 milligrams of iron per 100 grams. Its seeds, immature pods, leaves, flowers, and tubers, are edible. Mature seeds, in particular, contain 29 to 37% protein and 15 to 18% oil. Additionally, the leaves of winged beans serve as an excellent source of vitamins, including vitamin C (14.5 to 128 mg/100 g), thiamine, riboflavin, niacin, vitamin B6, folate, and vitamin A (5240 to 20,800 IU). Despite their proteins having a lower nutritional value ascribed to factors such as deficient sulphur-containing amino acids, proteins that are less easily digestible and the presence of anti-nutritional compounds, winged beans offer a valuable source of nutrients, comparable to soybeans. Furthermore, the seed oil extracted from winged beans matches the quality of other premium edible oils. This oil, abundant in Tocopherol (Vitamin E) and predominantly composed of unsaturated fats, offers a valuable source of dietary fats. Some varieties of winged bean oil even surpass soybean and corn oils in terms of Vitamin E content, making it a nutritious choice. When cooked, winged beans exhibit nutritional excellence, as evidenced by their protein-to-efficiency ratio and net protein utilisation values comparable to soybeans. While moderate amounts of anti-nutritional factors such as tannin, phytate, total polyphenols, and oxalates are naturally present in winged beans, proper processing can render them edible and useable with a low glycaemic index. Moreover, research suggests that winged beans are linked to various health benefits, including diabetes prevention, cancer inhibition, asthma relief, immune system enhancement, and support for reproductive health in both women and men. These attributes highlight the substantial potential of winged beans in addressing nutritional requirements and advancing food security.

Cultivation of winged bean

The cultivated area under winged beans in India is estimated to be around 10,000 hectares. It is mainly cultivated in the Northeastern states of Tripura, Manipur, Mizoram, and Assam, as well as in the western state of Maharashtra. Winged beans thrive in tropical climates with warm temperatures, ample humidity, and well-drained soils. The Northeastern region of India offers ideal climate and soil conditions, making it a perfect environment for cultivating winged beans. Furthermore, winged beans hold a special place in the culinary traditions of various tribes in Northeastern India, making them a popular and cherished food item in the local cuisines. To prepare the land effectively, ploughing to a depth of 3-4 cm is recommended, ensuring finely tilled soil structure. Optimal soil conditions range from sandy to heavy clay, with well-drained sandy loam soil enriched with organic matter and a pH level between 4.3-7.5. The crop thrives in a hot and humid climate, with temperature tolerance between 15.4–27.5°C and annual rainfall ranging from 700–4100 mm. Flowering typically occurs in mid-September to October, but extreme temperatures above 32°C or below 18°C can inhibit flowering, and the crop thrives well at elevations up to 2,000 meters above sea level.

Winged bean propagation is primarily through seeds, with a recommended seed rate of 15-20 kg per hectare. Soaking the seeds for 1-2 days before sowing is essential due to their hard seed coat. Sowing to a depth of 3–4 cm usually results in germination within 5-7 days. The ideal mean temperature for growth is 25 °C, and a North-South orientation of the trellis ensures proper sunlight exposure. Spacing varies with commercial crops at 90 × 90 cm and seed crops at 45 × 45 cm, while dwarf varieties can be spaced at 30 × 20 cm. The sowing of winged beans typically coincides with the onset of the monsoon in June-July. However, for tuber production, sowing should occur in August-September to avoid excessive vegetative growth and rotting of tubers.

As a leguminous crop, winged bean can enrich the soil with nitrogen, eliminating the need for nitrogen-fixing bacteria. It requires 20 tonnes/ha of farmyard manure (FYM) and a fertilizer mixture of N:P:K at a ratio of 50:80:50 kg/ha. Phosphorus (P) and potassium (K) are applied at sowing, with the remaining nitrogen (N) top-dressed at 40 to 60 days after sowing. Weed control is crucial, with one round of hand weeding required at 15-20 days after sowing, even though winged beans establish plant cover rapidly. Staking is vital for indeterminate stem growth in winged bean. Different methods are employed based on the intended use of the crop. Staking also supports vine growth and enhances seed production.

While there are no major insect pests affecting winged beans in India, fungal diseases like false rust and leaf spot, as well as pests like *Maruca testulalis* (legume pod borer), *Hermoceplachna signatipennis* (bean leaf beetle), and root-knot nematodes, can pose threats. Implementing plant protection measures is advisable to minimize potential yield losses. Biological control measures by introducing natural predators like parasitic wasps specific to each pest, while utilizing neem oil sprays to disrupt their life cycles. Vigilant manual inspection and removal of larvae and beetles, along with crop rotation can curtail infestations. Pheromone traps designed for *Maruca testulalis*, companion planting with insect-repelling species, and regular monitoring for early signs of infestation are equally crucial components of an integrated strategy to ensure the protection of winged bean crops.

Harvesting should be done while shoots, leaves, and pods are tender, with green pods ready for harvest approximately 10 weeks after sowing. Fresh pods, tuberous roots, and seeds yield 5-10 t/ha, 5-10 t/ha, and 1-1.5 t/ha, respectively. Proper post-harvest management, including storage in plastic bags at 10°C and 90% relative humidity can prolong the shelf life of winged bean pods for up to 4 weeks, preserving their freshness.

Breeding of winged bean

Breeding programs on underutilized crops such as winged bean face challenges in terms of resource allocation and research priorities. Breeding efforts are primarily focused on elevating its nutritional profile. These endeavours are driven by the goal of increasing protein content while simultaneously reducing fat content in varieties. Beyond nutrition, there is a strenuous push to develop winged bean varieties that can thrive well in various adverse environmental conditions such as drought and salinity.

The process of breeding engirdles several methods to bring about these improvements. Selection is the first step, involving carefully choosing individual plants or lines with desired traits, whether it be higher yields, enhanced disease resistance, or superior quality. Hybridization is another pivotal technique. Here, two different parent plants are crossed to generate better offsprings. UPS 122 variety, for instance, emerged from the hybridisation of parents with distinct adaptations to drought and salinity.

Mutation breeding, a method involving exposure to radiation or chemicals to induce mutations, has yielded promising results. These mutations can bestow beneficial traits such as resistance to pests and diseases or enhanced nutritional content by treating the seeds with various mutagens. 'Vinh Long 1' is a winged bean variety that combats bean aphids. In a more modern approach, marker-assisted selection influences genetic markers to identify and select plants with specific desirable traits.

Researchers are employing this method to develop winged bean varieties with combinations of traits, including high yield, disease resistance, and tolerance to abiotic stresses. This precise technique is being used to craft winged bean varieties that can resist both bean aphids and whiteflies, ensuring the continued evolution and improvement of this valuable crop.

Tolerance and suitability of winged bean to environmental stress

Apart from its nutritional benefits, the winged bean also shows promise as a resilient crop, capable of adapting to challenging environmental conditions such as droughts, floods, high temperatures, and biotic stresses, in contrast to other primary staple crops. One of the most critical abiotic stressors that the crop can withstand is drought. The crop's extensive root system enables it to tap into water sources from deeper soil layers and it ensures high water use efficiency, allowing it to generate more biomass while conserving water resources effectively.

Patel et al. (2022) revealed that by subjecting winged bean varieties to hydro-priming, halo-priming and osmo-priming, the plants exhibited improved germination and seedling performance when faced with drought stress. Furthermore, the winged bean exhibits resilience to salinity and waterlogging, rendering it well-suited for cultivation in coastal regions and areas with inadequate drainage systems. It also demonstrates a degree of adaptability to both high and low temperatures. Singh et al. (2017) showed that winged bean varieties exposed to salt stress exhibited higher germination rates and more robust seedling growth than their non-stressed counterparts thus, showcasing better salinity tolerance. Nangju and Baudoin (2019) found that winged bean plants could endure waterlogging stress for up to 10 days without displaying any signs of damage, underscoring their resilience to waterlogged conditions. However, winged bean is inherently a tropical crop and cannot endure prolonged exposure to freezing temperatures. All these inherent properties of the winged bean make it an excellent candidate to counter the ongoing misfortune of climate change whereas certain traditional crops which were cultivated earlier during summers have now been rendered uncultivable due to a lack of heat stress tolerance.

In addition to its capacity to endure abiotic stresses, the winged bean displays relative resistance to pests and diseases, making it an excellent choice for low-input agricultural systems. It is a crop that demands relatively little upkeep and can thrive in various climatic conditions. This characteristic renders it an eco-friendly crop choice for farmers in both industrialized and developing nations.

To sum up, the winged bean is a highly nutritious and versatile crop, holds immense potential for addressing food security and nutrition challenges. Its seeds are rich in protein, essential fatty acids, carbohydrates, vitamins, and minerals. Also, it exhibits remarkable tolerance to various environmental stresses, including drought, salinity, and waterlogging, making it a resilient choice in the face of climate change. Additionally, its sustainability as a legume crop reduces the need for nitrogen fertilizers and pesticides. However, the cultivation and consumption of winged bean face challenges such as limited awareness, restricted availability of seeds and inputs, high cultivation costs, and an underdeveloped market.

Nevertheless, there is a growing interest in winged bean with investments from governments, research institutions, and private companies aimed at overcoming these challenges and harnessing its potential to enhance food security and nutrition in the future.

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