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Vigna trilobata (Pillipesara) and *Vigna stipulacea* (*Minni payaru*): Exploring their potential utilization

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Abstract
Forage legumes play an invaluable part in forage and grassland farming. They are known for their ability to fix atmospheric nitrogen and their superior feeding values in comparison to that of grasses. Among the several species used, *Vigna trilobata* commonly known as pillipesara or jungli moth, and *Vigna stipulacea* popularly referred toas *Minni payaru* are widely cultivated as fodder or cover crop in various parts of India. These two species are most closely related and belong within section *Aconitifoliae*, subgenus *Ceratrotropis* of the Asian Vignas. They are native to Asia, being found in India, Indonesia, Bhutan, Myanmar, Pakistan, Sri Lanka, Taiwan, Vietnam etc. *Vigna trilobata* is also found naturalised in various parts of Africa, Australia and South America. The species are sown in India as a short-term pasture and green manure crop. Various medicinal and therapeutic properties are also attributed to them including in the treatment of liver disorders, fevers, eye ailments, dyspepsia etc. Both species are semi-domesticates and being crops of minor importance there are very few studies on the state of variability or in terms of their evaluation as a genetic resource. The fullest possible range of landraces and cultivars needs to be collected and conserved together with the conspecific wild-related species. The wild germplasm resources have a great potential for widening the genetic base of the Vigna gene pool by interspecific hybridization. The available genetic resources with valuable characters will therefore be required to make extended cultivation economically attractive.

Keywords: *Vigna trilobata, Vigna stipulacea*, taxonomy, collection, evaluation, conservation, utilisation

Introduction
Legume crops have a unique place in agriculture as a major source of protein for both humans and cattle and maintaining soil fertility through an in-built mechanism to fix atmospheric nitrogen. Among the legumes, *Vigna* is a large genus of the Fabaceae, comprising about 100 species that are widely distributed in the tropics of both hemispheres. Several of the species are economically, environmentally and agronomically important, being cultivated in arid and semi-arid regions and contributing widely to subsistence agriculture in Asia, sub Saharan Africa and the Americas. Cowpeas [*V. unguiculata* (L.) Walp.], mung beans [*V. radiata* (L.) Wilczek], and urd beans [*V. mungo* (L.) Hepper] are key dietary staples for many millions of people while adzuki beans [*V. angularis* (Willd.) Ohwi& Ohashi], bambara groundnuts [*V. subterranea* (L.) Verdn.], moth beans [*V. aconitifolia* (Jacq.) Marechal], and rice beans [*V. umbellata* (Thunb.) Ohwi& Ohashi] are important components in the regional diets of many communities. These economic *Vigna* species exhibit several attributes that make them particularly valuable for inclusion in many types of cropping systems. They can be grown successfully in extreme environments (e.g., high temperatures, low rain fall, and poor soils) with few economic inputs. Many of these species produce multiple edible products, which provide subsistence farmers with a food supply throughout the growing season as well as dry seeds that are easy to store and transport. Immature pods, leaves and tender shoots are edible; harvested dry seed of most *Vigna* crops may be consumed directly; and seeds of several crops are commonly used to produce sprouts and/or flour. Vigna products exhibit many excellent nutritional attributes that serve to complement diets comprised mainly of roots, tubers, or cereals. Many of the *Vigna* species are also valued as forage, cover, and green manure crops in many parts of the world. Additionally, plant residues can be used as fodder for farm animals.
Two *Vigna* species hitherto of minor importance, *viz*., *Vigna trilobata* and *Vigna stipulacea*, have gained in popularity in recent times as a short-term pasture/green manure/forage crop particularly in semi-arid conditions.

Vigna trilobata (L.) Verdc. (Syn. *Phaseolus trilobus* (L.) Schreb.; *Dolichos trilobatus* L.) is known by several names as *moth, jungli moth, mugun, mungan, pillipesara,* (India); *African gram, three-lobe-leaf cowpea, jungle moth bean* (English); *mukni* (Pakistan), is native to Asian countries like Bhutan, India, Indonesia, Myanmar, Pakistan, Sri Lanka, Taiwan and Vietnam but also cultivated in Africa, Western Australia and South America. In India, Pakistan and Sudan, it is grown as a short-term pasture and green manure crop. It is frequently mentioned in literature as used for forage or seeds collected particularly in times of food shortage (Hanelt, 2001) [11]. Ethnic groups in parts of India gather seeds for food (Roxburgh, 1874; Maxwell, 1991) [28, 21]. In the wild, *Vigna trilobata* is found throughout India from the foothills of the Himalayas down to the plains of Kanyakumari. The species if reported in Assam, Andhra Pradesh, Bihar, Gujarat, Maharashtra, Kerala, Karnataka, Uttar Pradesh, Madhya Pradesh, Tamil Nadu and Telangana. The species is grown as a cover crop and for fodder, with the tribal and local people often eating pods/seeds gathered from wild plants; the seeds are frequently cooked as a minor pulse. *Vigna stipulacea* is known as '*Minnipyaru'* or *'Sirupayaru*' in Tamil. This species is sown before paddy or in paddy fallows as a cover crop or green manure in Tamil Nadu and Andhra Pradesh where it is also harvested for both pods and seeds. Seeds of *V. trilobata* shatter easily, while those of *V. stipulacea* produce more seed that is easily harvested in abundance. *V. trilobata* is reported as being cultivated in several countries including Pakistan, the Sudan and Australia. The name *V. stipulacea* has not been used in Indian literature until very recent times and this species has traditionally been included in descriptions of *V. trilobata*. These two species, *Vigna trilobata* and *Vigna stipulacea*, which are not much known, little researched, and thus far inadequately utilized are very closely related and often mistaken for each other. Tomooka *et al*., (2002) [34] believe that the correct identity of the species that is cultivated and harvested should be *Vigna stipulacea*.

Despite the obvious importance of these two *Vigna* species, not much appears to be yet known about them and no systematic efforts have been made to develop specific crop varieties. Their potential for fodder and/or food is yet to be realised especially for the arid/semiarid regions. This chapter provides an overview of the current knowledge on*Vigna trilobata* and *Vigna stipulacea* including various aspects as their collection and conservation; cultivation, evaluation and utilisation, species affinities and breeding possibilities. Various strategies are detailed for '*Pillipesara*', '*Minnipayaru*' to become a potential commercial crop.

Taxonomy, Distribution, Domestication

The genus *Vigna*, belonging to family Fabaceae [subfamily Faboideae, tribe Phaseoleae, subtribe Phaseolininae], comprising about 100 species distributed in seven subgenera, is found in the tropical, subtropical and warm temperate areas of Asia, Africa and the Americas (Maxted *et al*., 2004; Tomooka *et al*., 2002) [20, 34]. *Ceratotropis*, with 22 species, is the only subgenus that has its centre of species diversity distributed across Asia. Four other subgenera (56 species) are distributed throughout Africa and two subgenera (23 species) obtain in the Americas. There are now 25 recognised species within subgenus *Ceratotropis*. They are collectively known as the Asian Vignas, and are categorised in three sections/sub groups based on seedling characteristics, size of floral parts, habit and habitat *viz.*, *Angulares* (12 species); *Ceratotropis* (7 species) and *Aconitifoliae* (6 species) (Tateishi, 1996b; Tomooka, 2002) [30, 34]. The Asian Vignas, which until 1970 were classified as *Phaseolus* (Verdcourt 1970) [38], represent a homogeneous and distinct group with a rich diversity in India (Arora 1985) [2]. They are an agronomically important taxonomic group, from which seven crops have been domesticated and are under cultivation in several countries (moth bean (*Vigna aconitifolia* (Jacq.) Maréchal), mung bean (*Vigna radiata* L. Wilczek), black gram (*Vigna mungo* (L.) Hepper), creole bean (*Vigna reflexo-pilosa* Hayata/*Vigna glabrescens* Marechal, Masherpa and Stainer), rice bean (*Vigna umbellata* (Thunb.) Ohwi& Ohashi), and adzuki bean *Vigna angularis* (Willd.) Ohwi& Ohashi) and Tuapea bean (*Vigna trinervia* (Heyne ex Wall) Tateishi and Maxted)). Besides these, two species within section *Aconitifolia*, *viz*., *Vigna trilobata* and *Vigna stipulacea*, although of minor importance, have also been brought into cultivation in recent times, and may be regarded as semi-domesticates.

Vigna trilobata (L.) Verdc. (Syn. *Phaseolus trilobus* (L.) Schreb.; *Dolichos trilobatus* L.), within section *Aconitifoliae*, is known by several names in India *viz*., as *moth, jungli moth, mugun, mungan, pillipesara ,jungle urd,* mageer, *kaattupayar, kodipayaru, kattucherupayar, kaattukodipayar, nadanpayar, naripayar, vallipayar, wazul mung, Mugani, Mudagparni, Mungawana, Trianguli, Mungesa, Jangli Moong Adabanmagi, Adavada, Magavala Kohesaru Ranmath, Ranwum Koshila, Kurangika, Shimbiparni, Vanmudga.* The presence of Sanskrit name reflects its antiquity in India.The species is grown primarily as a cover crop and the whole plant is used for fodder. The tender pods and seeds are gathered from the wild and eaten; the seeds are frequently also cooked as a minor pulse. *Vigna trilobata* is found in sandy soils and characterised by a very long taproot system. Along with its deeply lobed leaflets, the species shows characteristics of a xerophyte being adapted to dry areas. Variation in the *V. trilobata* genepool had resulted in the species being divided into two subspecies *viz*., *V. trilobata* ssp. *trilobata* and *V. trilobata* ssp. *pusilla*. The ssp. *pusilla* has recently been raised to the rank of a species *V. indica* differing from *V. trilobata* in various characteristics of which cylindrical seeds with truncated ends are most obvious.

Vigna stipulacea, also within the section *Aconitifoliae*, is a clearly differentiated species that appears most closely related to *V. trilobata*is known as '*Minnipyaru'* or *'Sirupayaru*' in Tamil. This species is characterised by extremely long peduncles (22-30 cm) that result in the flowers and pods rising conspicuously above the canopy. This characteristic could be the reason why the species has lent itself to easy harvest and why some harvested forms have been semi-domesticated. Traditionally, this species is sown before raising paddy or in paddy fallows as a cover crop or green manure in Tamil Nadu and Andhra Pradesh. It is also harvested for both pods and seeds. While seeds of *V. trilobata* shatter easily, those of *V. stipulacea* may be relatively easily harvested in abundance. However, both species have rather similar deeply lobed leaflets, which may explain why the two species are often confused with each other. Maxwell (1991) [21] has pointed out that *V trilobata* has both deeply lobed and entire leaflets.

Vigna trilobata from India is often confused with *V. aconitifolia*, *V. radiata* subsp. *sublobata* the wild progenitor of *V. radiata*, and *V. stipulacea*. Both *V. aconitifolia* and *V.*

trilobata can be distinguished from *V. mungo* and *V. radiata* by their small flowers; and from each other by the length of the peduncle, long in *V. trilobata* (5.2-6.3 cm) and quite short in *V. aconitifolia* (3-4cm). Whyte *et al*. (1953) [41] considered that *V. trilobata* is a wild ancestor of moth bean (*V. aconitifolia*). However, these two taxa are considered to be highly differentiated and quite distinct (Tateishi 1996, Tomooka *et al*. 1996) [30, 33]. 2n=2x = 22) and can be distinguished from the morphologically similar *V. aconitifolia* by virtue of large oval stipules, the latter having small, linear-lanceolate stipules. According to Marechal *et al*. (1978) [19], the morphology of *Vigna trilobata* is very similar to that of *V. radiata* var. *sublobata* (88.95 similarity) but may be differentiated by its smaller flowers, pods and seeds and a very long peduncle. Diagnostic characters that distinguish it from *V. stipulacea* are smaller stipels; shorter peduncle; more protruding orbicular hilum with more developed aril; epigeal germination. Diagnostic characters that distinguish *V. stipulacea* from *V. trilobata* are larger stipule, seed with less protruding oblong hilum with less developed aril; hypogeal germination.

Vigna trilobata is native to Asia (Bhutan, India, Indonesia, Myanmar, Pakistan, Sri Lanka, Taiwan, Vietnam). It has become weakly naturalised in areas with similar climate and soils to those found in its native distribution and now found in Africa (Ghana, Senegal, Sudan, Ethiopea); Australia (Western Australia); Indian Ocean (Madagascar, Mauritius); and South America (Peru). Tomooka *et al*. (2002) [34] have reported this species from India and Sagaing, Myanmar where it is found inland in sandy soils. The species found along coastline of dry zones is characterised by very long taproots. The species thrives in a wide range of conditions, especially near forest edges and on waste land; it flourishes in ruderal and ravine habitats from the plains of Kerala up to an altitude of 2000 m in the Himalayas. It is found as a trailing/twining herb in grasslands, on road verges, irrigated land, drain edges and banks of irrigation channels; it also occurs in rocky areas in dry and moist deciduous forests. The species is reported to occur at altitudes from sea level to 500 msl. The species grows at the lowest mean altitude of 57 m (near sea level to ~500m). This reflects its usual habitat on coastal sand dunes (Tomooka *et al*., 2002) [34]. For *Vigna stipulacea* the main centre of distribution is South-Asia. This species is recorded from India, Bangladesh, Sri Lanka, Myanmar, Vietnam, Indonesia as far east as Irian Jaya, Madagascar and Yemen. It is reported to occur at an altitude from near sea level (5m) to >700 m with a slightly higher mean of 189m and is a pioneer of secondary succession occurring along with grasses. It is found in open or lightly shaded habitats, particularly at the edge (bunds) of paddy fields or paddy fallows and even in paddy fields that have been abandoned. The species is well adapted to habitats with high or intermediate disturbance (Tomooka *et al*, 2002) [34]. The species is native to a largely tropical area extending from 24ºN in India to 9ºS in Indonesia. and from near sea level to at least 2000msl. Average temperatures in areas of occurrence average annual temperatures around 25-27 ºC. Annual rainfall at collection sites ranges from (520-) - 700-900 (-1440) mm, with a 5-7-month dry season. Companion species include *Panicum coloratum*, *Panicum maximum*, *Setaria incrassata*, *Clitoria ternatea*, *Desmanthus* spp., *Stylosanthes seabrana* among others.

Vigna trilobata and *V. stipulacea* both belong to the line consisting of species adapted to hot dry tropical lowland habitats (section *Aconitifoliaeae*) the group being typified by *V. aconitifolia* (moth bean). Based on the few archaeological and historical records, the Asian Vignas appear to have originated in either the Indian subcontinent (V. *aconitifolia*, *V. mungo*, *V. radiata*, *V. trilobata*) or the Far East (*V. angularis*, *V. umbellata*). Remains of *Vigna* species have been excavated from a site in Western Uttar Pradesh dated 3700-3000BP (Meadows, 1996) [22], at Navdatolidated 3500-3000 BC in Madhya Pradesh, Central India (Jain and Mehra, 1980) [12] and in Tamil Nadu dated 2500-2000BC (Vishnu Mittre, 1989) [40].

Collection and Conservation

The establishment of the ICAR-National Bureau of Plant Genetic Resources (NBPGR) in 1976provided the impetus for collection and conservation of Indian crop genetic resources and their wild relatives. Several efforts have been made to collect both *V. trilobata* and *V. stipulacea* (earlier collected as *V. trilobata*).At present the National Genebank at New Delhi holds 199 collections under the name of *Vigna trilobata* collected from different agro-ecological zones in Andhra Pradesh, Maharashtra, Tamil Nadu, Kerala, Gujarat, Rajasthan, Karnataka, West Bengal, Goa and Orissa (Fig.1). The species which was found being cultivated under the name *V trilobata*, in Tamil Nadu and Andhra Pradesh particularly in paddy fallows both as green manure as well as fodder for milch animals was confirmed to be *V. stipulacea.*

Besides the National Genebank at ICAR NBPGR, New Delhi, India, *V. trilobata* is included in several germplasm collections of *Vigna* spp., e.g. at the Australian Tropical Crops and Forages Genetic Resources Centre, Australia (52); International Livestock Research Institute, Ethiopia (58); National Institute of Agrobiological Sciences, Japan (33) and Southern Regional Plant Introduction Center, Griffin, Georgia, United States (2). Of the 371collections of *V. trilobata* being held in genebanks over the world, 70% are catalogued from India. Since enough quantities of seeds are produced, *ex situ* conservation is the most viable option.

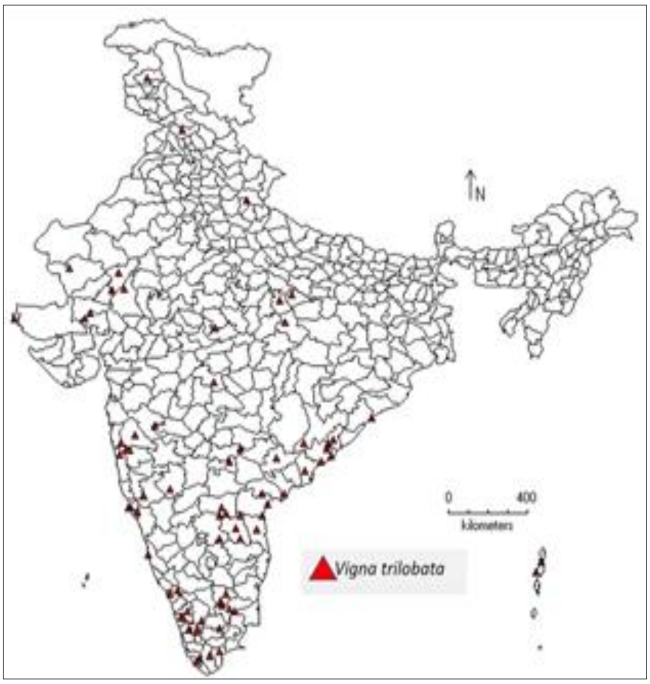

Fig 1: *Vigna trilobata* collection sites in India

Uses, Cultivation, Evaluation

V. trilobata is sown in India, Pakistan and African countries as a dual-purpose, short term pasture crop yielding good fodder and green manure. In India, as a herbaceous creeper, it grows into a short dense cover crop when sown thickly. It is capable of being cut thrice or even four times before being ploughed into the field. Sometimes, the green manure is grazed, and allowed to regrow for about a month before being incorporated. It also provides human food, the pods being eaten as a vegetable, and seeds cooked. Wild types are often collected by the tribals for use as a famine food. Pods are eaten as vegetable and cooked seeds are reported to be used as delicious food by tribals of Chhattisgarh. Its acceptance as a fodder species is very high with palatability greater than other fodder legumes as *Clitoriaternatea*, *Lablab purpureus*, *Macroptilium bracteatum, Macrotyloma daltonii* and *Stylosanthes seabrana.* No toxicity has been yet reported. *Vigna trilobata,* on assessment for its medicinal properties, is anti-oedemic, anti-inflammatory, a sedative, and used in urinogenital disorders. The roots and whole plant (panchang) are used as *tridoshshamak,* especially against *vat* and *pitta*, urogenital disorders, and intermittent fever. (Jain and Mehra. 1980) [12]. According to Ayurveda fruit is cooling, dry, bitter, aphrodisiac, astringent, styptic, anthelmintic and good for the eyes. Cures constipation, inflammations, fever, burning sensation, thirst, piles, dysentery, cough, gout, biliousness etc. Mungesa is one of the popular folk remedies in India. In many parts of India, the leaves and its decoction are used in case of fever and cough. It is also used in eye-diseases. Its use in Ayruvaeda are reported. Root extracts of *Vigna trilobata* are reported to cause a significant decrease in blood glucose level in diabetic rats that is comparable to that of standard drug Glibenclamide indicating it to be a potent antidiabetic drug and justifying its use in the traditional system of medicine. *Vigna stipulacea* is used as a pulse and green manure in India (Tomooka *et al*. 2008) [37]; forage, cover crop in India, Pakistan, Indonesia and Sudan (Maxted *et al*. 2004) [20] andseeds are roasted and eaten by humans in India (Janardhanan *et al*. 2003) [13].

Tomooka *et al*. 2006 a had previously considered that reports of *V. trilobata* being used as a food may have been the result of mistaken identification of *V. stipulacea*. However, based on field visits to South India it has been confirmed thatboth *V. trilobata* and *V. stipulacea* are used as an occasional food there and variation in *V. trilobata* suggests that it may in some placesbe semi-domesticated (Tomooka *et al*., 2011) [32].

Vigna stipulacea is confirmed as species being cultivated in Tamil Nadu and Andhra Pradesh particularly in paddy fallowsboth as green manure as well as fodder for milch animals ((Tomooka *et al*., 2011) [32]. In Tamil Nadu *V. stipulacea* is known as ‘*Sirupayaru’* or ‘*Minnipayaru’*. Farmers mentioned that 1 -1.5 litre extra milk per day was obtained when cows were fed with this fodder from *V. stipulacea* (Tomooka 2011) [32]. Market price of *V. stipulacea* seeds is 65-75 Rp/kg and sometimes reaches up to 100Rp/kg. Despite the labour required to harvest the pods due to seed shattering, both pods and seeds are harvested and eaten in Sambar and Chutneys. Seeds are sold in the markets at a rate of Rs 65/--120/- per kg. The seeds are broadcast at the end of March and the leaves and stems are cut and harvested at an interval of two months (ie., May and July). In September, the plants are ploughed into the soil as green manure before paddy rice planting. Plants were sown separately for seed production. In Tiruvarur province of Tamil Nadu, average area of cultivation of *V. stipulacea* is 30-40 acres per person. It was ascertained that almost all farmers in their village cultivated *V. stipulacea* in the former times. *V. stipulacea* is also called “*Nari Payar*” in some areas and used for the preparation of Dosai, which is usually prepared using fermented blackgram seed flour. The women reported that in contrast, when *V. stipulacea* seed flour was used there was no need to ferment before baking because it was very soft. *V. stipulacea* flour was also used for bread/roti baking. *V. stipulacea* in early stages stages grew faster than mungbean or blackgram, being more competitive to weeds. *Sirupayar* seeds were traditionally cooked in wedding ceremonies until about 20 years ago (Tomooka, 2011) [32]. Natural populations are also found due to regeneration from shattered seed. While *Vigna trilobata* is reported to be prone to pod borers, stinkbug damage, nematode damage and galls on stems. (Tomooka 2002) [34], *V. stipulacea* is resistant to many insects and diseases such as stinkbug and powdery mildew. *V. stipulacea* is also reported to grow faster (early flowering and maturity) than greengram and blackgram. The species also has high palatability (Tomooka *et al*., 2011) [32]. The species is not aggressive and hence not liable to weediness. The decrease of *V. stipulacea* cultivation was reported to be primarily due to high labour required for harvesting pods. In general, genetic erosion of traditional pulse landraces is rapidly proceeding in Tamil Nadu mainly due to an increase in the area of cash crops.

Cultural and Agronomic practices

Climate: *Vigna trilobata* requires warm climate for its optimal growth. It is mainly a kharif crop, but may be grown in all seasons, under hot and moist climate and high rainfall conditions, in open as well as partial shade where irrigation is assured. It grows best in areas where annual daytime temperatures are within the range 22 – 31 °C, tolerating temperatures between 18 °C – 35 °C. The crop prefers a mean annual rainfall in the range 700 – 900 mm, but tolerates between 520 - 1,440 mm. It performs best in full sun.

Soil requirements: The crop can be grown in a variety of soils including red lateritic soil, black cotton soil, and sandy loam soils of similar reaction (pH 6.5-9). However, well-drained, rich in humus, rice fallow clay soils and sandy loam soils are most suitable for its growth. Moderately tolerant of salinity, the crop produces 50% maximum growth in soil with electrical conductivity (saturated extract, ECe) of 9.7 dS/m.

Seed rate and sowing: Propagation is usually by seed with a seed rate is 12-15 kg/ha for green manure and 10 kg/ha for seed purpose. The seed is broadcast for green manure while recommended spacing for seed purpose is 30 x 10 cm in a well-prepared seed bed. Seeds are sown in furrows and covered with a thin layer of soil. Seeds of *Vigna trilobata* usually require scarification to improve germination. Before sowing, seeds should be treated with thiram or captan or carbandazim at the rate of 3 g/kg of seeds to protect them from soil-borne fungi. Field is prepared in the first week of May or June by deep ploughing once.

Fertilizer management: About 10 tonnes of FYM (farmyard manure)/compost per hectare is mixed uniformly in the field and harrowed twice to mix it well in the soil, and after a fortnight to a month, the field is harrowed twice or thrice and levelled to get a good tilth and facilitate proper drainage. The fertilizer schedule for pillipesara is 30:60:40 (NPK) per hectare, are applied at the time of sowing. Alternatively, 100 kg per hectare of DAP (di-ammonium phosphate) may be applied. Integrated nutrient management studies conducted at Pantnagar suggest that FYM @ 10 tonnes/hectare + 75% of recommended NPK (nitrogen, phosphorus, potassium) can be used in marginal soils.

Weeds, Diseases and Pest management: The crop may be kept weed free with the first weeding at 20-25 days and the second at 35-40 days after sowing. Red hairy caterpillar, galerucid beetle, and aphids damage this crop. Infestation can be controlled by dusting 10% aldrin dust at the rate of 25-30 kg per hectare or spraying 0.2% solution of endosulfanor M-45 twice at an interval of 10 days.

Water management: The crop is usually irrigated once in 3 to 4 weeks depending on the soil moisture. The crop does not tolerate waterlogging.

Maturity, Harvest and Threshing: Flowering starts after 40-45 days of sowing and within four to five days of flowering, fruiting also begins. Flowering and fruiting continue till October-November. With a good crop one may obtain up to 5-6 tonnes of green biomass/ha and 450-500 kg of seed/ha. Green matter may be incorporated within 60 DAS while seeds may be collected from 150 DAS. Green matter may be incorporated 55-60 days after sowing while seed may be harvested 150 days. After the pods are collected, plants are pulled out and incorporated into the soil. During the fallow season, it is allowed to grow for 45-50 days before it is incorporated into the soil. In the Ongole tract of Andhra Pradesh, pillipesara, a common legume on the dry lands, is reported to give an average out-turn of 28 q of green fodder per hectare. In the Godavari, deltaic areait is a common practice to sow pillipesara on field bunds and take a cut two months later. With the staggered sowings on different bunds at monthly intervals, a continuous supply of green fodder can be obtained upto February-March. Experiments at Coimbatore indicate a green matter production of 18.3 t/ha in 45-60 days of the crop in *kharif* with a Nitrogen contribution of 201 kg/ha to the succeeding paddy crop (Abrol and Palaniappan, 1988) [1]. Populations and yields generally decline following the year of sowing, largely due to competition from weeds and perennial grasses. Seeds are collected in November after the colour of the pods change to black or brownish black in September-October. Pods are usually hand-picked for collection of seed and then sun dried, threshed and stored. Seeds remain viable for up to two years.

Evaluation experiments

Diversity in morphological characters of 206 accessions of 14 wild *Vigna* species from India was assessed by Bisht *et al*. (2005) [4]. These included 10 accessions of *V. trilobata* from parts of West Bengal, Orissa, Chhattisgarh, Gujarat and Madhya Pradesh. Data on 45 morphological traits, both qualitative and quantitative, were recorded using descriptors developed by both IPGRI and NBPGR. In an evaluation study of *Vigna stipulacea*, at the NBPGR, Hyderabad, the range of variation observed for several characters included plant height (58-88 cm), days to flowering (40-48), number of primary branches (3-7), number of pods per cluster (4-10), peduncle length (20-40 cm), number of pods per plant (15-90) and 100 seed weight (0.2-1.1g); (under publication). In a separate study to assess the performance and suitability of different crops under low cost greenhouse hydroponic fodder production systems, the highest biomass weight was recorded in pillipesara within five days, followed by cowpea, lucerne and horse gram among the legumes (Krishna Murthy *et al*., 2017) [15]. This result is encouraging especially for those small and marginal farmers where common grazing lands are decreasing due to changing land use patterns. A trial in Queensland, Australia comparing the nitrogen mineralization rates of six legume species found that the mineralization rate of *V. trilobata* was faster than that of leucaena (*Leucaena leucocephala* (Lamk) de Wit), but slower than lucerne (*Medicago sativa* L.). The leaves and young stems of *V. trilobata* contained per 100 g dry matter: nitrogen 2.3 g, lignin 7.7 g and polyphenols 1.9 g; and that stems and leaves incorporated in the soil decomposed fairly rapidly. Two weeks after incorporation, 13% of the added N had been mineralized, rising to 27% after 6 weeks, and 42% after 12 weeks (Ref).Farmers in the Sudan broadcast 30 kg/ha when the crop is grown for fodder; the amount increased to 60 kg/ha when it is grown as a green manure. It is ploughed into lines to control weeds. A study on atmospheric nitrogen fixation of various forage legumes and their rotational effect on the yield of subsequent cotton crops in the Gezira Research Station, the Sudan, revealed that forage yield of *V. trilobata* was higher than the yield of butterfly pea (*Clitoria ternatea* L.), lablab (*Lablab purpureus* (L.) Sweet), groundnut (*Arachis hypogaea* L.), mung bean (*Vigna radiata* (L.) Wilczek), cowpea (*Vigna unguiculata* (L.) Walp., and soya bean (*Glycine max* (L.) Merrill) [Zaroug *et al*., 1980]. Populations of *V. trilobata* growing exclusively on sandy soils are known to have a well-developed tap root system and have shown a high level of salinity resistance even in its seedling stage before the deep tap root system developed (Tomooka *et al*., 2011). Sources of resistance to powdery mildew caused by *Erysiphe polyponi DC* have been identified in *V. stipulacea* (Tomooka *et al*. 2006a) [31]. *Vigna trilobata* has shown resistance to *mungbean yellow mosaic viruses* (*MYMV*) (Nagaraj *et al*., 1981; Pandiyan *et al*., 2008) [25, 26] which augers well when new sources of resistance are always essential. Systematic characterisation and evaluation of all the accessions being held in the NBPGR National Genebank is underway for establishing their correct identities and assessing their potential for use as green manure or forage crop.

Plate 1: *Vigna stipulacea* in natural habitat (paddy field); inset: leaf variation; 2. Bunch of pods collected at exploration site; 3. Variation in pods and peduncle colour; 4. Crop in NBPGR experimental plot; 5. Close view of leaves, flowers and pods;6.Stipule morphology; 7. Flower; 8. Seeds

Germplasm Utilisation

Wild germplasm is not usually a preferred source of useful genes for breeding because its use requires repeated backcrossing to eliminate unwanted genes. Even so, wild species are sometimes a source of many useful genes not found in the cultigen gene pools. By the schemes of Lawn (1995) [18], Tateishi (1996) [30], Tomooka *et al*., (2014) [35] and others, *V. trilobata* and *V. stipulacea* fall within the secondary gene pool of both mungbean and urdbean. Both *V. triobata* and *V. stipulacea* are self-pollinated with 2n=2x=22. It is generally accepted that most cultigens of the subgenus Ceratotropis are predominantly inbreeding. However, the flower structure of these Asian Vignaspoints to the possibility of some pollination by insects (Tomooka *et al*., 2002) [34]. The extent of cross pollination if any is yet to be worked out. The yellow flowers are borne at the apex of racemes arising from the leaf axils on long peduncles usually above the canopy. Bracts are ovate, acute, and deciduous while the campanulate calyx is linear-lanceolate. The corolla is much exerted (5-6.5 mm) with diadelphous stamens. Anthesis in general happens early in the morning. Flowering and fruiting occur from September to October, extending to November. Under well-watered conditions, flowering and seed set is continuous but sparse. However, under moisture stress, plants respond with denser flowering, far greater seed production and a reduction in vegetative growth.

There are no released varieties reported for *Vigna trilobata* or *V. stipulacea*. Current crop improvement goalsfor pillipesara include selecting/breeding for (1) better biomass index, (2) improving the nitrogen fixation, (3) enhancing nutritional quality, (4) abiotic and biotic stress resistance and (5) agronomic superiority. Given that there are as yet no systematic breeding programmes for pillipesara, a beginning could be made to achieve these objectives through systematic evaluation of the extent and nature of the variability already available in the existing germplasm and utilizing the information to develop through pre-breeding, lines more acceptable to the plant breeders. This could then be followed by attempts at hybridization through conventional means or otherwise. The success of any breeding programme depends upon a critical understanding of the various aspects such as the pollination behavior, frequency of pollination, nature and direction of the crosses, ploidy status of species involved in the cross, natural crossing rates, gene flow, patterns of genetic diversity and minimum population size, all of which are vital key components in formulating action plans. Thus far, there have been very few studies of the breeding system for these species. This is an important and challenging task.

Viable hybrids can be obtained between several species: *V. radiata* is probably the most satisfactory seed parent. It crosses with the wild *V. radiata var. sublobata* reciprocally, and with *V. trilobata V. angularis*, *V. umbellate* and *V. mungo* as seed parent only. *V. trilobata* crosses as pollen parent successfully with *V. mungo*, *V. radiata* and *V. aconitifolia*, but reciprocal crosses fail. as pollen parent. *V. aconitifolia* has not been widely investigated but it has been crossed as a seed parent with *V. trilobata*.

V. trilobata can cross with *V. aconitifolia*, *V. radiata* and *V. mungo* when used as the pollen parent, suggesting close affiliations with these species. It has been proposed as a wild ancestor of moth bean (*V. aconitifolia*) (Jain and Mehra. 1980) [12]. The hybrid with *V. radiata* is somewhat fertile (Dana 1966) [8], and from the F_1 with *V. aconitifolia* an amphidiploid has been produced (Biswas and Dana, 1976). Crosses between *V. radiata* and *V. trilobata* have also been reported by Chavan *et al*. (1966); Bharathi *et al*. (2006) [3] and Pandiyan *et al*. (2012) [27].

Sidhu (2003) [29] produced interspecific hybrids of *V. radiata* with *V. mungo* and *V. trilobata*. Though the crosses between *V. radiata* and *V. trilobata* were successful, the seeds produced between *V. mungo* and *V. trilobata* had poor germination, andthe germinated seedlings did not survive. The cytological analysis revealed irregular chromosome behavior at diakinesis and/or at metaphase I. Crosses between *V. radiata* × *V. umbellate* have been made to transfer resistance to MYMV and other desirable traits into mung bean (Vermaand Brar 1996) [39]. *V. mungo* has also been reported to cross successfully with *V. trilobata* (Dana 1966) [8]; with *V. glabrescens* (Dana 1968; Krishnan and De 1968) [9, 16], *V. trilobata* (Dana 1966) [8], and *V. dalzelliana* (Chavanetal. 1966). Further crosses with wild species in the subgenus *Ceratotropis* may reveal further possibilities for inducing introgression into the cultigens of this subgenus.

Cross ability barriers and their circumvention

Like other crops, in *Vigna* also, several cross-ability barriers have been reported, the most common being cross-incompatibility, embryo abortion at early growth stage, in viability of F_1hybrids, and sterility of F_1hybrid and subsequent progenies. Meiotic irregularities have also been reported to be a major factor for cross-incompatibility. Sidhu (2003) [29] produced interspecific hybridization of *V. radiata* with *V. mungo* and *V. trilobata*. So, differences in style length may not be a major cross ability barrier incase of *Vigna* species, since the long-styled female parent *V. radiata* could be successfully crossed with short-styled male parent *V. trilobata*. Over the last one and a half decades, convincing evidence at both morphological and molecular levels has emerged for utility of wild progenitors and related species as donors of productivity alleles (Kumar *et al.* 2011) [18]. With better understanding of the processes involved in pollen stigma interaction, pollen germination, pollen tube growth, and fertilization, the ability to overcome cross ability barriers and produce viable and fertile interspecific hybrids has increased tremendously. Several procedures are currently available to circumvent these barriers including reciprocal crossing, repeated pollination, hormonal treatment of flower buds prior to or after pollination, use of different accessions of both the species, polyploidization followed by hybridization, poly ploidization of the inter specific F_1 hybrid, use of bridge species, and, most importantly, embryo rescue. Ploidy level induction of plant cells by colchicine treatment has been used as a useful technique in plant breeding aiming at enhancing biomass yield and resistance to stresses (Glowacka *et al*. 2010; Wu *et al*. 2012) [10, 42], as well as helping in resolving interspecific hybrid sterility problems (Miyashita *et al*. 2009) [23]. Using this technique, successful crosses have been attempted between *V. radiata* × *V. mungo* (Pande *et al*. 1990) [14] and *V. radiata* × *V. trilobata* (Dana 1966) [8]. Integrated breeding using conventional and genomic tools and alien gene detection through molecular and cytogenetic approaches will help in successfully employing the alien gene transfer technologies for the genetic amelioration of various *Vigna* species.

These two species being semi-domesticates for most part are still growing under conditions not very much different from those of their wild relatives. Under conditions of low input management, the evolution has been for the survival of the crop species itself rather than for grain yield from the breeders' point of view.

Future Perspectives

Given the many positive attributes, of being high-yielding, exceedingly palatable, tolerant of grazing and drought, and an alternative minor pulse/vegetable among others, both *V. trilobata* and *V. stipulacea* show excellent promise as pioneering green manure and pasture legumes in the arid/semi-arid regions. With their adaptability to a wide range of ecological habitats including the ability to thrive under arid/drought conditions and in sandy/saline soils/cracking clay soils, these species merit detailed investigation to understand adaptive mechanisms. Concomitantly, some limitations to wider utilisation of these species include low seed yield potential, limited value for cut-and-carry, low harvest index, indeterminate growth habit, photo and thermo-sensitivity, shattering of ripe pods and seed dormancy and lack of persistence as compared to grasses. Suitable genetic resources with valuable characters will therefore be required to make extended cultivation economically attractive. These two semi-domesticated dual-purpose species are yet only of local/regional importance. Being less known they are less collected and even less studied. Their collection, evaluation and conservation thus become a major priority assuming importance in the wake of changing climate and loss of habitats of native species. However, in view of the insufficient information on extent of genetic diversity and variation of phenotypic traits in these two species, some strategies are listed below to enhance their wider adoption, commercial exploitation and utilisation in crop breeding in the country.

- Expeditiously collect the fullest possible range of cultivated and wild types especially from areas hitherto unexplored. By selective sampling, one is likely to collect taxonomically/genetically more variable populations. These species mainly occur under conditions of low input management systems with only indirect benefits of cultivation, so, they are also more easily subject to erosion/loss from their natural habitats due to changes in land use patterns, farming practices, market forces and displacement by major cash crops and/or introduction of new species with forage potential.
- Comprehensively characterise, evaluate and screen the available germplasm for desirable traits particularly biotic/abiotic resistance (salt/drought; MYMV /downy mildew/insect pests); and agronomic traits such as pods per cluster, clusters per plant, high biomass, vegetative growth, palatability, leaf/seed protein etc., towards a more effective utilization as food, fodder and green manure. The potential for improvement by straightforward direct selection of genotypes is enormous.
- As environmental concerns relating to use of nitrogen fertilizers are becoming more prominent, it would be strategic to assess the agronomic potential of these species in depth through adaptive trials; screen germplasm for patterns of Nitrogen accumulation; study the genetic diversity of symbiotic bacteria growing in association with these species of marginal lands as well as the process of symbiosis under stress environments. As seen earlier, there are reports of stress-adapted symbiotic bacteria producing nodules on stress-adapted *Vigna* species.
- Consider the possibility of introduction to different crop ecosystems such as coconut or banana plantations especially in areas such as the Malnad region where a deficit of dry matter production has been reported; explore the possibility of conversion to legume straws/hay for efficient utilisation of crop residues.
- Enhance research to improve the establishment and stand through seed treatments for uniform germination since dormancy is sometimes a problem.
- Initiate low cost hydroponic fodder production technology, which could play key role in intensive fodder production especially for those landless dairy farmers who are left with few options once common grazing areas have drastically declined. Pillipesara has been reported to record the highest bio mass within five days. Merely trying to increase the area under fodder may not be a viable option, it entails developing strategies to bridge the huge gap between demand and supply.
- Introduce the species to diversify in mixed farming systems.
- Develop a package of cultivation practices for different ecozones and specific cropping systems to encourage and ensure wider use.
- These species have a great potential for widening the genetic base of *Vigna* gene pool and contributing new and useful genes to legume breeding; the transfer of saline tolerance, *MYMV* and *downy mildew* resistance through interspecific hybridization both through conventional means as well as by using biotechnological tools is a distinct possibility/ offers great choices.
- Stress-adapted symbiotic bacteria are reported to produce nodules on stress-adapted Vigna species. Therefore, conducting genetic diversity studies of bacteria growing symbiotically with wild Vigna species of marginal lands and studies on the process of symbiosis under stress environments is also a high priority.
- Tomooka *et al*., (2014) [35] have suggested that rather than improving stress resistance of existing domesticated species, it may be more appropriate to domesticate wild species well adapted to stress environments. They propose that 'neo-domestication' could be achieved by conventional mutation breeding together with screening by TILLING, as the causative change of the mutation resulting in a domestication gene is usually 'loss-of-function' type. The 'neo-crops' could play an important role in areas unsuitable for growing other crops to increase world food production. Candidate species with potential for neo-domestication include *V. trilobata* that can grow under very severe drought conditions enabled by a very deep taproot system and *V. stipulacea* that has been found to be little affected by pests and diseases in the absence of pesticides in a NIAS experimental field.

Considering the limitations of traditionally cultivated fodder crops, it is imperative to develop viable strategies sustained by appropriate research to introduce various non-traditional fodder crops to marginally productive farms and denuded community lands particularly in the wake of changing climatic conditions. The use of *Vigna trilobata and Vigna stipulacea* assembled by the NBPGR in biosystematics, evolutionary studies, and in establishing species relationships or their utility in breeding for resistance to abiotic and abiotic stresses and the paucity of such collections in gene banks points towards to the need for more concerted efforts to enrich such genetic resources. The long-term potential to be of use in crop improvement programmes is substantial.

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