Vigna Genetic Resources

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1. The genus *Vigna*

The *Vigna* species grow in warm temperate and tropical regions globally (Fig. 1). *Vigna* is most closely related to *Phaseolus*, hence Asia *Vigna* (subgenus *Ceratotropis*) was treated as *Phaseolus* until 1970 (Verdcourt, 1970).

2. African *Vigna* Cultigens (subgenus *Vigna*)

Vigna cultigens were domesticated from African *Vigna* (subgenus *Vigna*), Eurasian *Vigna* (subgenus *Plectotropis*) and Asian *Vigna* (subgenus *Ceratotropis*). Two species, **cowpea (*Vigna unguiculata*)** and **bambara groundnut (*Vigna subterranea*)** were domesticated from African *Vigna* probably in West Africa (Figs. 2 & 3). Four sections are proposed in Africa *Vigna*, sections *Vigna*, Macrodontae, Catiang and Reticulatae (Maréchal *et al*. 1978).

3. Eurasian *Vigna* Cultigen (subgenus *Plectotropis*)

Fully domesticated form of *Vigna vexillata* (named as Tuber Cowpea) was recently found cultivated in Bali and Timor, Indonesia (Karuniawan *et al*., 2006). The domesticated form shows a prominent seed size increase, loss of pod shattering and loss of seed dormancy (Fig. 4). Tuber cowpea is cultivated for its tuber but also seeds are a human food. Root protein content is ca. 15% which is about 2.5 times higher than that of yam (6%), 3 times higher than that of potato (5%) and sweet potato (5%) and 5 times higher than that of cassava (3%). It takes 115-120 days from sowing to harvesting. The upper vegetative parts are used as fodder in Timor. There is also a herbarium sample designated as a *V. vexillata* cultivar from Papua New Guinea (Henty in Verdcourt 4960A (K)PNG, New Guinea, Henty's plantation, 1976) (described as a personal communication with Pasquet, in Karuniawan *et al*., 2006).

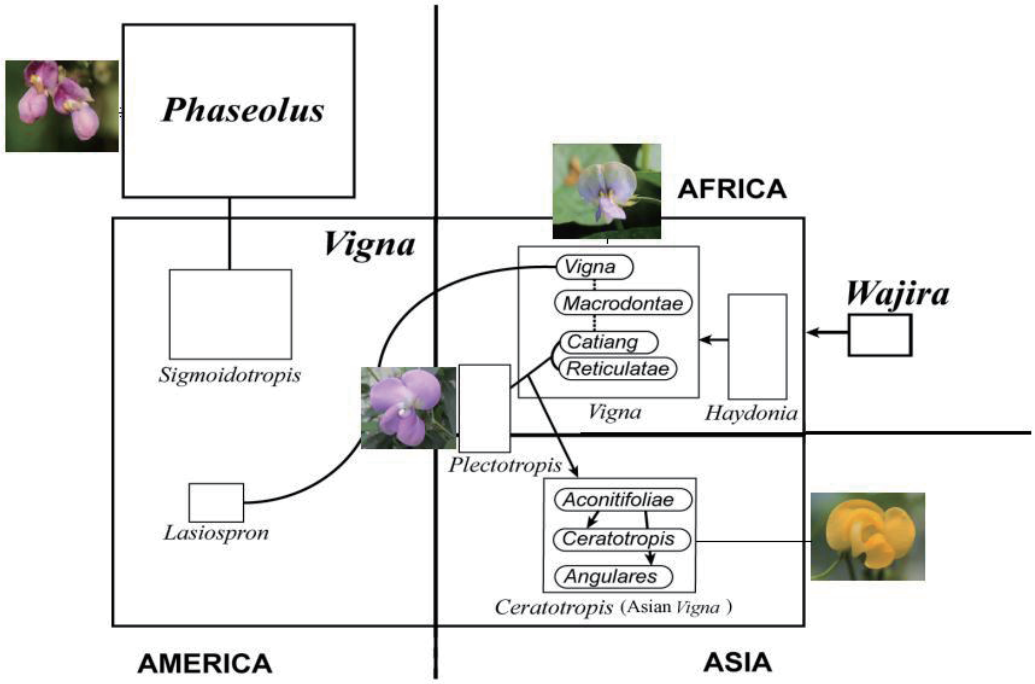

Fig. 1. Relationships among *Phaseolus*, African *Vigna* (subgenus *Vigna*), Eurasian *Vigna* (subgenus *Plectotropis*) and Asian *Vigna* (subgenus *Ceratotropis*).

Fig. 2. Cowpea (*Vigna unguiculata*) domesticated from African *Vigna* (subgenus *Vigna*) probably in West Africa.

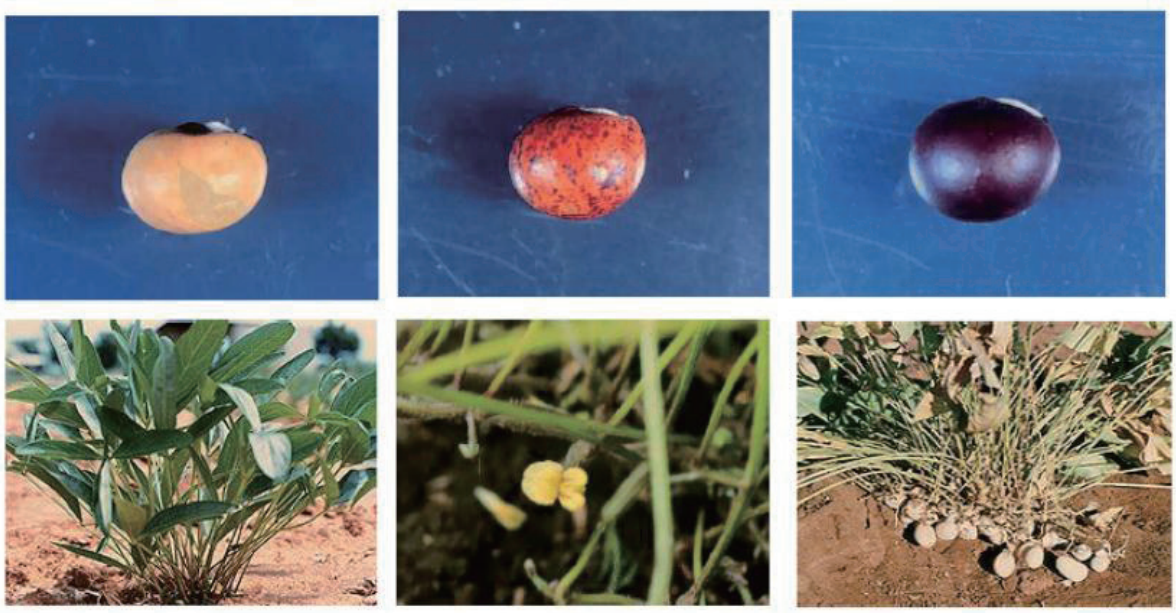

Fig. 3. Bambara groundnut (*Vigna subterranea*) domesticated from African *Vigna* (subgenus *Vigna*) probably in West Africa.

4. Asian *Vigna* Cultigens (subgenus *Ceratotropis*)

Six species have been fully domesticated from 21 species of Asian *Vigna* (subgenus *Ceratotropis*). Mung-bean (*Vigna radiata*), black gram (*Vigna mungo*) and moth bean (*Vigna aconitifolia*) are considered to have been domesticated in India (Tomooka *et al*., 2002, 2005 and 2006). Rice bean (*Vigna umbellata*) and creole bean (*Vigna reflexo-pilosa* var. *glabra*) were domesticated in Southeast Asia and azuki bean (*Vigna angularis*) in East Asia, most probably in Japan (Tomooka, 2009).

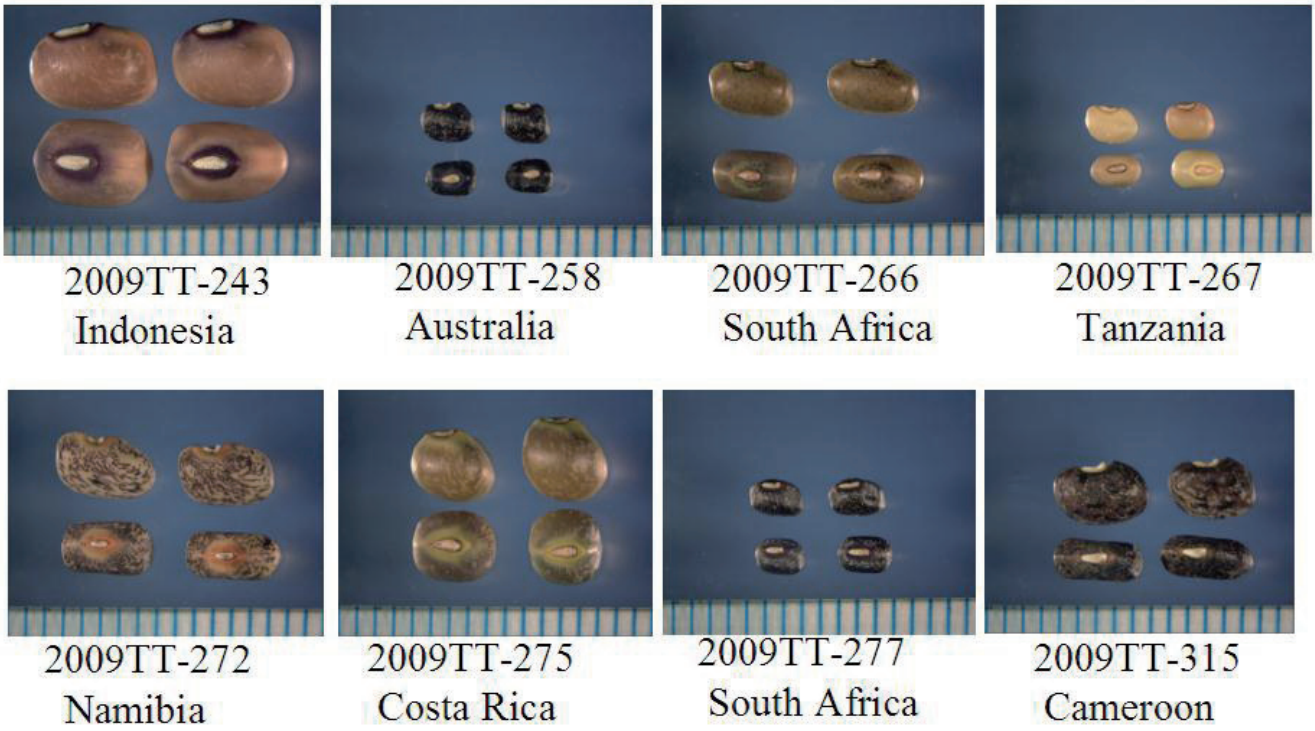

Fig. 4. Seed diversity of *Vigna vexillata*, an Eurasian *Vigna* (subgenus *Plectotropis*).

2009TT-243 : Domesticated form (Tuber cowpea)

2009TT-258, 266 and 267 : *V. vexillata* var. *angustifolia*

2009TT-272 : *V. vexillata* var. *lobatifolia*

2009TT-275 : *V. vexillata* var. *macrosperma*

2009TT-277 and 315 : *V. vexillata* var. *vexillata*

Fig. 5. Mungbean (*Vigna radiata*) domesticated from Asian *Vigna* (subgenus *Ceratotropis*) in India.

Fig. 6. Moth bean (*Vigna aconitifolia*) domesticated from Asian *Vigna* (subgenus *Ceratotropis*) in India. Upper row: cultigen, Lower row: putative wild form.

Mungbean (*Vigna radiata*) cultivation spread to all hot and warm Asian countries in ancient times, hence considerable diversification is recognized (Fig. 5). The cultivation of mungbean occurred in southwestern Japan until 1950s. In contrast, cultivation of black gram and moth bean has been restricted in South Asia.

Black gram (*Vigna mungo*) is an important pulse especially in South India. In Tamil Nadu State, southern India, mungbean is usually cultivated on rainfed dryland field mixed with sorghum. In contrast, black gram is frequently found cultivated in a wetter places such as on the ridge around paddy rice field and/or in an irrigated field.

Moth bean (*Vigna aconitifolia*) is the most drought and heat tolerant cultigen among Asian *Vigna* (Tomooka *et al*., 2006). The wild ancestral form and cultivated form have not been distinguished taxonomically. However, the first author recognized the existence of a putative wild ancestral form during Tamil Nadu State field trip in 2009 (Tomooka *et al*., 2009). During that trip, moth bean cultivars with erect growth type was also found cultivated in the northern part of Tamil Nadu State. Therefore, domestication of *V. aconitifolia* has attained non shattering, loss of seed dormancy, seed size increase and erect plant type.

Fig. 7. Rice bean (*Vigna umbellata*) domesticated from Asian *Vigna* (subgenus *Ceratotropis*) in Southeast Asia.

Rice bean (*Vigna umbellata*), a lesser known Asian crop, shows considerable and similar seed color variation to that of azuki bean (Figs.7 and 8), and is sometimes used as a substitute of azuki bean. It has been domesticated probably in the mountainous region of Southeast Asia (Tomooka, 2009). The cultivated form shows an indeterminate twining growth form and is cultivated with other crops such as foxtail millet (*Setaria italica*) and/or maize (*Zea mays*). It is the most important protein source in hilly regions of Southeast Asia, south China and Nepal-Bhutan slash and burn type agro-ecosystems. Sporadic cultivation has been reported in southwestern Japan, where it is also associated with slash and burn type agriculture. The morphological and DNA level diversity is the highest in Myanmar-Nepal region and the lowest in Japan-Korean region (Tian *et al*., in preparation).

Azuki bean (*Vigna angularis*), the second most important legume in Japan after soybean, is considered to have been domesticated in Japan based on archaeo-botanical evidence, present-day diversity of cultivated and wild azuki bean, and the frequent and stable existence of an intermediate weedy forms (Fig. 8, Vaughan *et al*., 2005, Tomooka, 2009). For the cultivated genepool, it is worth mentioning that a genetically distinct group is found cultivated in Bhutan-Nepal highland area (Zong *et al*., 2003, Xu *et al*., 2008). While the cultivation of rice bean is associated with slash and burn type cultivation, azuki bean cultivation seems to be associated with paddy rice based cultivation system.

Creole bean (*Vigna reflexo-pilosa* var. *glabra* = *Vigna glabrescens*) is the only one tetraploid (2n=44) *Vigna* species reported so far. As this species was first treated as a hairless variety of mungbean (*Vigna radiata* var. *glabra*), overall morphology of creole bean is similar to that of mungbean. The cultivation of creole bean has been reported from Mauritius, West Bengal, Vietnam and the Philippines. It has a thick erect hairless stem and shows vigorous vegetative growth. Pods are also hairless. Although creole bean is not well known, it has the potential to be a new crop. It shows a high level of resistance to several pests and diseases such as powdery mildew, cucumber mosaic virus, and bean fly. According to the distribution of wild ancestral species (*Vigna reflexo-pilosa* var. *reflexo-pilosa*), mainland Southeast Asia seems to be the domestication center. *V. reflexo-pilosa* is reported to be an allotetrapoid, and one of the genome donor species has been estimated to be *Vigna trinervia* (Egawa *et al*., 1996).

5. Wild *Vigna* Genetic Resources

Wild species adapt to various environments in the course of diversification or specialization. Some wild species can grow in extreme or marginal environments and therefore are expected to harbor genes not found in crops. Some *Vigna* species growing under marginal environment are listed below. During past 10 years, the collection of wild Asian *Vigna* species has been extensively conducted by the NIAS genebank (Appendices I and II, Vaughan *et al*. in this proceeding). The most comprehensive collection of the Eurasian *Vigna* (*Vigna vexillata*) is in the seed bank of the Royal Botanic Gardens of Belgium. According to Maxted *et al*. (2004), more than 20 species of African *Vigna* species are apparently not conserved in any ex-situ collection even though several of these species have ethno-botanical uses.

Fig. 8. Azuki bean (*Vigna angularis*) domesticated from Asian *Vigna* (subgenus *Ceratotropis*) in East Asia, most probably in Japan.

5-1. Wild Asian *Vigna*

There are 21 species described in Tomooka *et al*. (2002) and 20 of these species are successfully conserved in the NIAS genebank. One species not conserved in the NIAS genebank, *V. khandalensis* is conserved in Tamil Nadu Agricultural University, India.

Two types of populations have been recognized in ***Vigna trilobata***. One is a beach population (Fig. 9) and the other is a dry inland population (Fig. 10). The beach population is characterized by the plants having thick small entire leaflets. Inland population is characterized by plants having thin broad deeply lobed leaflets. Both populations grow exclusively on sandy soil habitats and have well developed deep tap root system. The salt resistance screening experiment revealed that *V. trilobata* showed the highest level of resistance even in its seedling stage before deep tap root system developed. In Tamil Nadu State, India, people eat mature or immature seeds and vegetative parts are also used as fodder.

Fig. 9. Beach population of *Vigna trilobata* in Sri Lanka.

Fig. 10. Inland population of *Vigna trilobata* in Tamil Nadu State, India.

Surprisingly, ***Vigna exilis*** is always found on limestone rock mountain (Fig. 11). The plants can grow directly on the limestone outcrop. It has a very slender stem and seed.

Vigna riukiuensis is a cliff species found only in Taiwan (China) and islands of Okinawa prefecture, Japan (Fig. 12). The plants develop deep thick root system having small and thick shiny leaflets. The level of salt tolerance at the young seedling stage is about the same as that of *Vigna trilobata*. This species also has heat tolerance compared with azuki bean cultivar "Tanba Dainagon" (Egawa *et al*., 1999. Fig.12). Recently, accessions having a high level of resistance to soybean cyst nematode were found in Tokachi Agricultue Experiment Station where azuki bean breeding is conducted.

Fig. 11. *Vigna exilis* growing on the limestone rocky mountains in Thailand.

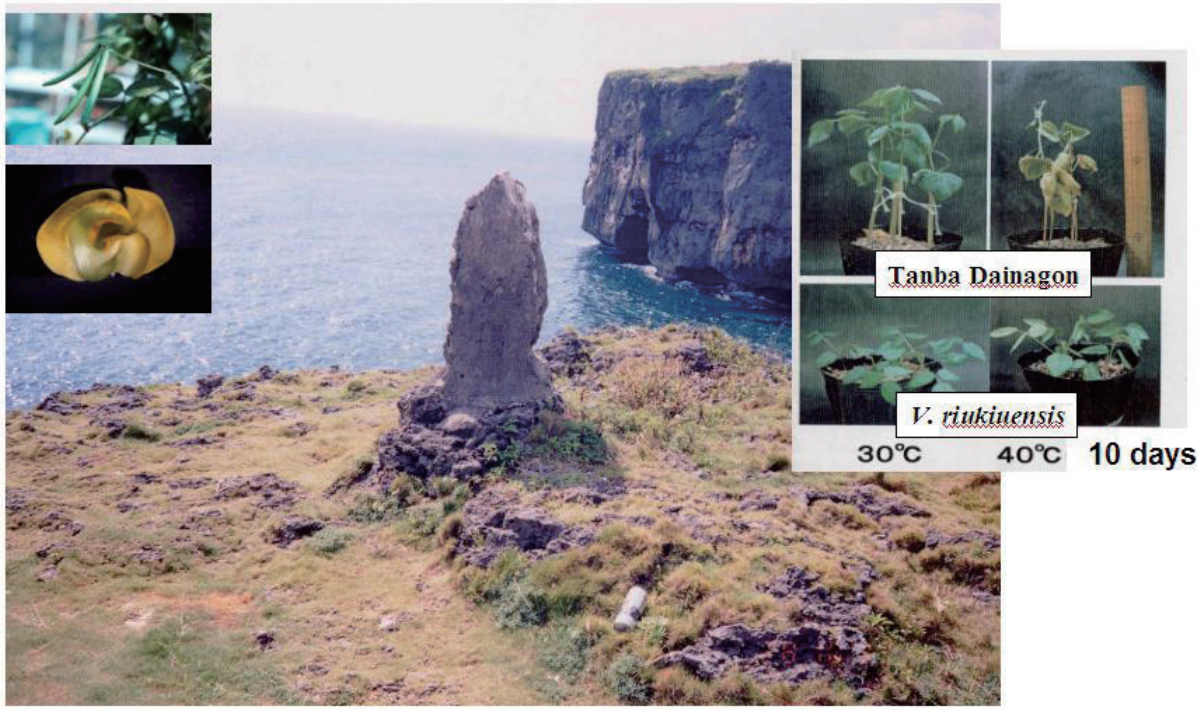

Fig. 12. *Vigna riukiuensis* (hina azuki) growing on the cliff of Ishigaki island, Okinawa, Japan.

5-2. Wild Eurasian *Vigna*

Vigna vexillata

Wild *Vigna vexillata* has been reported to be used mainly for its edible tuber and sometimes for its seeds in Africa (Senegal, Ethiopia, Sudan, South Africa), East and North East India, northern Australia and Southeast Asia (Duke, 1981, Lawn and Cottrell, 1988, Sasikumar and Sardana, 1988). Wild *V. vexillata* is an extremely polymorphic species and several taxonomic varieties are described (Fig. 4). Maréchal *et al*. (1978) described 6 taxonomic varieties, i.e., var. *vexillata*, var. *macrosperma*, var. *angustifolia*, var. *dolichomena*, var. *yunnanensis* and var. *pluriflora*. By examining the seedling morphology of *V. vexillata* including germination habit, Vanderborght (1989) found that American accessions showed epigeal germination whereas African (Except Nigerian) and Australian materials were hypogeal. He also proposed that var. *macrosperma* could be raised at a specific rank. Isozyme and RAPD data did not support the proposal of Vanderborght that *V. vexillata* var. *macrosperma* could be raised to a separate species, but detected the genetic differentiation between American and African materials (Spinosa *et al*., 1998). Pasquet (2001) proposed a new treatment of *V. lobatifolia* as a new variety of *V. vexillata* (var. *labatifolia*).

They have been considered to be a potential source of resistance genes against pod-sucking bug, *Clavigralla tomentosicollis*, the bruchid, *Callosobruchus maculatus*, the pod borer, *Maruca vitrata*, and cowpea mottle carmovirus (Birch *et al*., 1986, IITA 1988, Ogundiwin *et al*., 2002), hence extensive efforts have been conducted to produce inter-specific hybrids with cowpea (Barone and Ng, 1990). However, it was reported that there was a strong cross incompatibility between these two species.

5-3. Wild African *Vigna*

***Vigna luteola* (hairy pod cowpea)** is a wet land species (Fig. 13). It prefers to grow in habitats near rivers or marshes environment. In the USA, *V. luteola* is cultivated as a wet land fodder crop. Animals prefer this legume as fodder. There has not been any report of toxicity to animals. In Australia, aboriginal people have used this plant as a root crop (Lawn *et al*. 1988). Among seven wild *Vigna* species tested, *V. luteola* showed highest trypsin inhibitor activity, tannin and lectin contents. Bruchid resistance was reported. Under wet subtropical climatic condition in Australia, *V. luteola* gave the highest dry matter production when compared with other leguminous crops. Under mono-cropping condition on clay soil with appropriate cultivation managements, *V. luteola* attained 4t/ha dry matter production. In Indonesia, *V. luteola* produced 1-2.5t/ha dry matter when grown under low sunlight conditions between coconut trees.

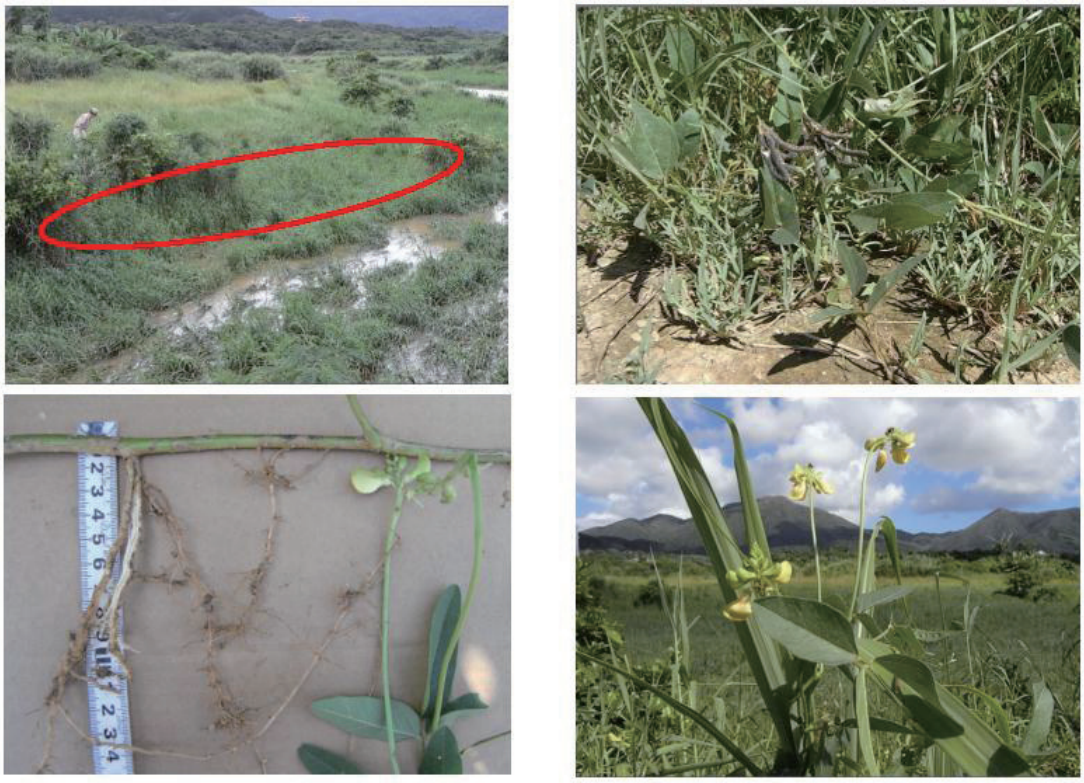

Fig. 13. *Vigna luteola* (hairy pod cowpea) growing along a river of Ishigaki island, Okinawa, Japan.

***Vigna marina* (beach cowpea)** is a sandy beach species (Fig. 14). On the islands of Indian Ocean (the Maldives), seeds of *V. marina* are cultivated and eaten by human (Padulosi & Ng, 1993). In Australia, aboriginal people used its root as a food (Lawn *et al*., 1988). The plant has been used as fodder, cover and/or green manure crop. In West Africa, a subspecies, *V. marina* subsp. *oblonga*, was described (Padulosi & Ng, 1993). This subspecies grows on sandy beach habitat with rather narrow oblong leaflet. According to RAPD analysis, *V. marina* subsp. *oblonga* is more closely related to *V. luteola* than *V. marina* (Sonnante *et al*., 1997).

V. marina is reported to be cross compatible with *V. luteola* (Maréchal *et al*., 1978). Based on the large seed size and low pod shattering characters, *V. marina* may have experienced domestication by human. According to the preliminary salt tolerance screening using seedling stage plants, *V. marina* showed by far the highest level of salt tolerance (Tomooka, unpublished data). The young plants could survive for at least 1 months under submerged condition of 400mM NaCl solution. Unlike other *Vigna* species, *Sinorhizobium* spp. not *Bradyrhizobium* spp. forms nodules on *V. marina* roots (Umezawa, personal communication). The isolated *Sinorhizobium* strains showed extremely high level of salt tolerance. The isolates could grow even in a nutrient solution with 3.5% NaCl (approximately the same concentration as sea water).

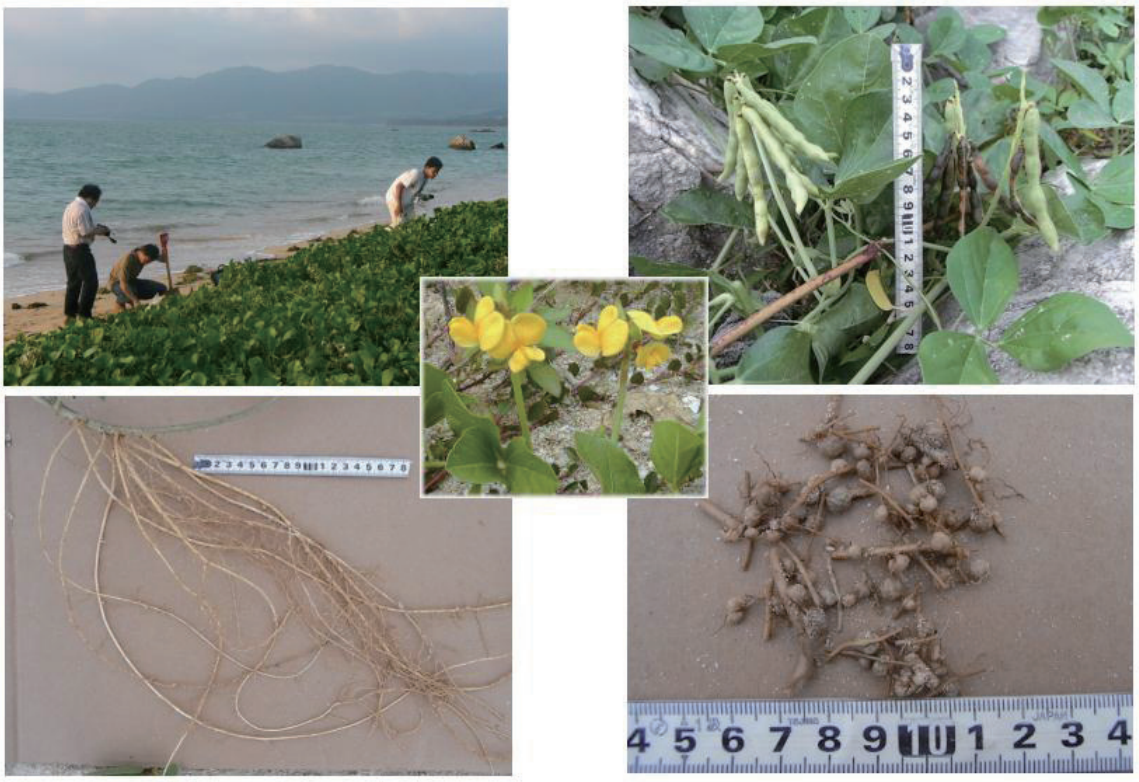

Fig. 14. *Vigna marina* (beach cowpea) growing on sandy beach of Ishigaki island, Okinawa, Japan

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