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Germplasm Collection and Diversity Analysis in Yardlong Bean (*Vigna unguiculata* subsp. *sesquipedalis*) from Coastal Andhra Pradesh and Odisha

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Diversity in yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*), an under-utilized vegetable legume was collected from parts of North coastal Andhra Pradesh (Srikakulam and Viziznagaram districts) and adjoining regions of Odisha (Koraput and Gajapati districts). Substantial variation was observed among the 39 accessions collected. Most of collections had pods which were light green (28), some were light green with purple tip (6), and a few were dark green (4); one accession (IC582551, Jeypore, Koraput, Odisha) had purple pods with green tip. Variation in pod length ranged from 24-75 cm; fresh pod weight (10 pods) from 60-140 g and seeds/pod from 6.2-17. Pod length had the highest dispersion index (158%), followed by100-seed weight (127%), fresh pod weight (89%) and seeds/pod (83%). Accessions IC582850 and IC582863 had the longest pods (75 cm). A pure line selection from IC582850 (Jeypore, Odisha) is released for cultivation as 'Arka Mangala'. This pole type, photo-insensitive variety with green, smooth pods and a crop duration of 3-4 months recorded a pod yield of 25.7 t/ha with an increase of 24% and 30% pod yield over the check varieties 'Lola' and 'Vyjayanthi', respectively.

Key Words: Andhra Pradesh, Arka Mangala, Odisha, Pod trait diversity, Yardlong bean

Introduction

Yardlong beans are important vegetable legumes throughout the tropics and sub-tropics of Asia. Botanically classified as *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc. are believed to have been selected and developed for their long tender pods in South-East Asia, from vegetable types of *Vigna unguiculata* introduced there from India (Steele and Mehra, 1980). Known by several names, such as string bean, long-podded cowpea, asparagus bean, snake bean, Chinese long bean, pea-bean, bora, juro-kusasagemae (Japanese), dowgauk (Chinese) or sitaw (Filipino), yardlong beans are cultivated for their strikingly long drooping pods (30-90 cm) that are relished as a vegetable. Besides the tender pods, the young leaves and seeds are also eaten. Referred to as 'poor man's meat' in the Philippines, yardlong bean is commercially important in parts of Indonesia, Thailand, Philippines, Taiwan and China, while being a minor vegetable throughout its range of distribution. It is estimated that area under yardlong bean in China alone exceeds 250,000 ha annually (Rubatzky and Yamaguchi, 1997), while in Thailand it is grown on about 18,560-20,160 ha annually (Sarutayophat *et al.*, 2007). Yardlong beans are mainly a warm-season crop and capable of surviving extreme humidity and heat. They can be planted in a wide range of climatic conditions but are very sensitive to cold temperatures. Although cowpeas originated in Africa, this vegetable form has been introduced there only in recent times. It is now grown as a minor garden crop in many sub-tropical countries of Africa (especially West Africa) and America (*e.g.* Caribbean). It is popular in these countries also due to its beautiful, large violet flowers and the long drooping pods.

In India, yardlong bean is a less known under-utilized vegetable grown in the peninsular region particularly Kerala, Tamil Nadu, coastal Andhra Pradesh and Odisha. It is also cultivated to some extent in West Bengal, Assam and the North Eastern Hill (NEH) region. It is a highly self-pollinating, vigorous climbing annual, growing up to a height of three to four meters. It produces very long, slender and succulent pods that may be white, light green, dark green, brownish red or purple. Nutritionally, the tender green pods are rich in crude protein (3.5-5%), besides being a good source of vitamin

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A (941 IU) and C (13 mg), iron (2.5 mg), calcium (80 mg), phosphorus (74 mg) and dietary fibre (2 g) making it an excellent vegetable (Singh *et al.,* 2001). In Kerala's climate, yardlong beans may be cultivated throughout the year and significant research on this crop has been undertaken by the Kerala Agricultural University. Several high yielding varieties such as Lola, KMV-1, Mallika, Sharika, Vellayani and Vyjayanthi have been released for the long pods ranging from 40-60 cm. Even so, the yardlong bean is still a relatively minor legume crop, but its importance both as a vegetable and as a legume cannot be over-emphasized.

The Indian region is the secondary centre of diversity for cowpeas and over 3,000 accessions are conserved in the National Genebank (NGB) at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi. However, only a few of these are specifically designated as 'yardlong bean', collected from a few pockets in Odisha. Farmers in the North coastal region of Andhra Pradesh (Srikakulam and Vizianagaram) and adjoining regions of Odisha (Koraput and Gajapati) are known to cultivate yardlong beans for local consumption. However, these areas have so far not been adequately explored for this species, and hence, not much is known about its cultivation practices and extent of diversity. An exploration was, thus, undertaken to augment the few collections and fill these gaps in knowledge. The results of this study are reported in the following account.

Materials and Methods

Characteristics of the Surveyed Region

Vizianagaram and Srikakulam form the northern most districts of Andhra Pradesh located between 17º15´-19º 10´ N and 83º-84º 50´E. This region is rugged with hills and valleys with hill tops ranging from 300 – 1000 masl. The region falls under the upper Godavari region of the Eastern Ghats, with the soil varying from deltaic alluvial to red sandy loams and sandy clays. The vegetation comprises mainly dry deciduous forests with a few pockets of moist deciduous patches at high altitudes. Tribal groups including *Savara, Jatapu, Kuttiya, Gadaba, Yerkula, Konda Dora, Samanthas* and *Konda Kapus* reside in this area. The major rivers passing through are Nagavali and Vamsadhara. The climate is characterized by high humidity throughout the year. The South-West monsoon which follows the summer lasts up to mid October, while the North-West monsoon from mid October lasts to the end of November. Annual rainfall averages 1,000-1,100 mm**.** Maximum and minimum temperatures during the South West monsoon range from 33-35°C and 26-27°C, respectively.

Koraput and Gajapati districts of Odisha adjoining Andhra Pradesh are characterized by a warm/hot humid climate, an average rainfall of 1,200-1,710 mm and a temperature range from 34°C to as low as 7.5°C in the highlands. Soils are mainly red, mixed red and yellow, sandy loams and clay loams. More than 70% of the total population in the region comprises Scheduled Tribes with as many as 52 tribal groups including *Khonds, Bhatadas, Parojas, Bhumias* and *Bondas*. The topography consists of high land plateau with a number of hills and hillocks with an average height of 100-1000 masl. The whole area is drained by five major rivers namely Vamsadhara, Nagavali, Indravati, Kolab and Mackanad and several tributaries and small perennial streams.

Germplasm Collection

The potential areas for collection of yardlong bean germplasm were determined in consultation with Acharya N.G. Ranga Agricultural University (ANGRAU), State Horticulture Department, Andhra Pradesh, Odisha University of Agriculture & Technology (OUAT), Odisha, and Indian Institute of Horticultural Research (IIHR), Bengaluru. A farmer field was taken as a basic unit of germplasm collection. Random samples from the populations along with purposive samples of specific material were collected and stored in cotton bags. Seed samples were also collected from kitchen gardens, tribal shandys and farm stores. A unique collector number was assigned to each accession and passport information was documented along with geographical coordinates of the collection sites (latitude, longitude, elevation) which were recorded using Global Positioning System (Garmin 12, USA). Discussions with local farmers were conducted to obtain both ethnobotanical information and details on cultivation, processing and consumption practices. Fresh pod weight was recorded using a portable top pan balance at the collection site. Pod length and seeds/ pod were measured along with seed traits *viz.*, length, width and thickness.

Statistical Analysis

The statistics mean, median, standard deviation, minimum, maximum were used to summarize the distribution of data for each quantitative trait. Phenotypic dispersion index (Bramley, 2005) and phenotypic coefficient of variation (PCV) were used to quantify the

observed diversity. Pearson's coefficient of correlation was used to estimate the strength of association between the quantitative traits. PCV is the commonly used statistic to estimate dispersion. Its valid use however requires a trait to be normally distributed, which may not always be the case. Although we have reported the PCV in our results, we preferred to quantify and report diversity by the dispersion index, also called spread, defined as [(max - min)/median)]*100. This index, unlike PCV, does not require the trait to be normally distributed and provides a more realistic feel of the relative magnitude of diversity for a trait as it is based on the observed range (maximum – minimum) of the trait. The PCV, being based on the standard deviation, tends to provide an underestimation of underlying diversity. DIVA-GIS version 7.1.6 was used to understand spatial distribution and diversity available in pod and seed traits recorded *in situ*.

Results and Discussion

Cultivation, Processing and Consumption Practices

Thirty nine accessions of yardlong bean were collected from 17 villages in Srikakulam and Vizianagaram districts of Andhra Pradesh (AP) and 11 villages in Gajapati and Koraput districts of Odisha spanning an altitude of 28-903 m. Yardlong beans in the area are known by several names such as *Podugu chikkudu, Kampa chikkudu, Nela Chikkudu, Gaddi chikkudu, Lolugu chikkudu, Ankur chikkudu* in Telugu, and *Jhudunga, Barboti, Bodhi, Tupsilamba, Daspallia, Lamba, Dhala bodhi, Tupsigeda, Nalibodi, Alladi, Raisa, Jhuler, Ramba, Safed lamba* in Oriya. *Chikkudu* traditionally refers to the lablab bean in AP, and various names for yardlong bean, in the vernacular, are derived with the addition of different adjectives as '*podugu*' (long), *nela* (ground, trailing), *gaddi* (wild), *Kampa* (pole/pillar), *Lolugu* (village in Ghara mandal of Srikakulam district) where there is abundant cultivation of the crop), *Ankur* (name of seed company). Similarly in Odisha too, local names reflected the description of the pod *viz., Lamba, Tupsilamba* (long) and *Daspallia* (ten seeded).

The crop, usually sown in June-July with the onset of rains are harvested in November-December. In Odisha, the crop is sown a month later than in adjoining AP, and consequently harvested during December-January. The accessions were either climbing or trailing; and raised either as a pure/sole crop, as a mixed/inter-crop with other vegetables as okra, cowpeas, cucurbits, leafy greens or ginger or as a fringe crop on paddy bunds (Fig. 1). Climbing types were usually trailed onto erect bamboo supports with wooden sticks for trellising and to ensure straight pods for harvesting maximum yield. The pods, hanging in pairs, started to form about 40-45 days after sowing, the first pods became ready for harvest around 55-60 days after sowing. Fresh pods were picked every day or every alternate day depending on the growth rate of the pods and the genotype. Regular picking ensured continuous production over a period of three to four months, sometimes even extending to six months, depending on the genotype. The pods were picked at maximum length of the pods and before the seeds matured and expanded.

Pods were picked early in the morning after evaporation of surface moisture. A bit of stem was left attached to the pod while picking to avoid any injury at the severed end which was reported to accelerate post harvest disease/decay. Thereafter, pods were spread flat to prevent sweating and cleaned to remove debris as leaves, broken/diseased pods, flowers etc. Pods were sorted by length and loosely bundled for market. Fresh pods were handled carefully as they bruised easily. High quality pods were well-formed, straight, of uniform colour, fresh, tender and firm. Crispness was tested by bending the pods which snapped audibly.

The pods formed towards the end of the season were allowed to dry to provide seed for the next planting and freely exchanged with neighbouring villages. Although some farmers separated the varieties based on seed coat colour, usually a typical field was mixed; this diversity allowed farmers to get some yield despite environmental uncertainties and minimal inputs. Anthracnose and cowpea aphid borne mosaic virus were observed in pockets in fields in Gajarainivalasa, Satyavada, Baleru

Fig. 1. Yardlong bean as fringe crop in paddy fields

Sunigiri and Ramabhadrapuram in Srikakulam and Vizianagaram (AP) and Tahajang area in Koraput, Odisha but no appreciable yield losses were reported by farmers. The local types were said to yield less but over a longer period as compared to varieties being supplied by seed companies. The fresh produce was sold in local markets and village shandys (Fig. 2). Yardlong beans do not have a long shelf life and must be consumed within a couple of days of harvest. Post harvest acceptability is reduced due to rapid wilting of the pods on storage after picking.

The crisp, tender pods are eaten both fresh and cooked. The flesh of these stringless beans is softer than the vegetable cowpeas or snap beans and takes less time for cooking. At their best when young and slender at pencil thickness, they are usually cut into short sections for cooking purposes, being used in curries, stir fried alone or along with other vegetables. They are also made into *pakodis/bhajjis* after mixing in chickpea flour batter or used in cooked/fresh salads. A popular method is to chop them into very short cubes and fry them in an omelette. The women are intimately involved with all aspects of the yardlong bean cultivation. The beans are a vital constituent of their daily cookery and they are very interested and innovative in creating new recipes.

Fig. 2. Yardlong bean being sold in Jepore market

Diversity

All collections had indeterminate growth habit whether trellised or not, and variation was observed for fresh pod weight, pod length, pod colour and seed size, colour and weight. Most of the pods were light green (28; 72%), whereas some were light green with purple tip (6; 15.4%), and a few were dark green (4; 10%); one accession (IC582551, Jeypore, Koraput, Odisha) had purple pods with green tip (Fig. 3). Seeds were all kidney shaped and variously colored - red, dark red, red with a white tip, white with red or brown patches and black (Fig. 4). Descriptive statistical analyses on pod and seed traits recorded during the collection are presented in Table 1. Variation in pod length ranged from 24-75 cm; in fresh pod weight (10 pods) from 60-140 g and seeds/pod from 6.2-17. Hundred seed weight varied from 7.3-23.2 g. Pod length had the highest dispersion index (158%), followed by100-seed weight (127%), fresh pod weight (89%) and seeds/pod (83%). Accessions IC582850 and IC582863 had the longest pods (75 cm) followed by IC582861 (45 cm), IC582862 (40 cm), IC582872 (39 cm) and IC582841 (39 cm). Highest fresh pod weight was observed in IC582872 and IC582850 (140 g) followed by IC582873 (135 g) and IC582882 (120 g). Pod length was significantly correlated with seeds/pod and seed length. Seed length, seed width and seed thickness were significantly inter-correlated (Table 2). Hundred seed weight showed a significant correlation with seed length. The DIVA-GIS analysis corroborated the rich diversity

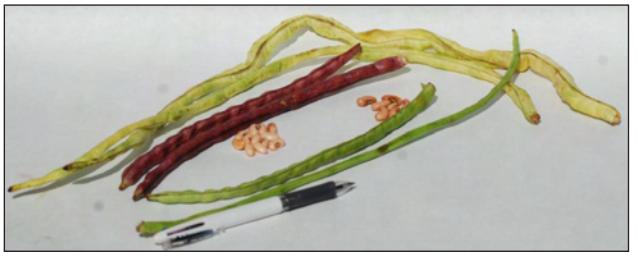

Fig. 3. Variation in pod colour and size

Fig. 4. Variation in seed colour

Table 1. Descriptive statistical analysis of pod and seed characteristics

	Mean	Median	Standard Deviation	Minimum	Maximum	Dispersion Index (%)	PCV (%)
Fresh weight (g)	93.0	90.0	21.2	60.0	140.0	88.9	22.8
Pod length (cm)	36.2	32.2	13.5	24.0	75.0	158.4	37.3
Seeds/pod	12.8	13.0	3.0	6.2	17.0	83.1	23.8
*Seed length (mm)	9.7	9.8	1.2	6.3	11.8	55.8	12.3
*Seed width (mm)	5.1	5.1	0.6	3.1	6.0	55.8	12.0
*Seed thickness (mm)	3.4	3.5	0.6	1.6	4.3	77.2	17.5
*100-seed weight (g)	12.6	12.6	3.9	7.3	23.2	126.6	30.7

*Dry seeds; PCV = Phenotypic coefficient of variation

Table 2. Inter-relationships between pod and seed traits

	Fresh wt	Pod length	Seeds/pod	Seed Length	Seed Width	Seed Thickness
Pod length (cm)	0.26					
Seeds/pod	0.19	0.45*				
Seed length (mm)	0.30	0.44*	0.04			
Seed width (mm)	0.24	0.28	0.04	0.59*		
Seed thickness (mm)	0.32	0.15	-0.30	0.44*	0.84**	
100-seed weight (g)	0.29	0.20	-0.04	0.52*	0.49*	0.47*

*Significant at 5%, ** Significant at 1%

available within the yardlong bean accessions in the areas explored. High Shannon diversity index (2.1-3.0; Fig. 5) was observed for fresh pod weight, pod length and seeds/pod from North-coastal Andhra Pradesh and adjoining Koraput region of Odisha.

Pod quality, a critical attribute in determining consumer preference/acceptability is judged on the basis of pod colour, length, succulence, firmness, crispness, tenderness and sweetness. However, desirable qualities differ in different markets. For instance, people in central Thailand prefer firm pods while those in the North-East favour fairly soft pods (Kongjaimun, 2013). Consumers in Thailand and Hong Kong prefer light green and extra long pods, and those in Brunei prefer dark green, short pods, while the European and Canadian markets prefer dark green, and medium pod length (Bounnhong, 1997). In coastal Andhra Pradesh green pods were largely common whereas in adjoining parts of Odisha, as in Kerala, both green and purple types were available in local markets. Purple types are known to retain the colour even on cooking, thus, lending colour to the cooked dish. Purple pods are believed to contain anthocyanins which are useful as antioxidants. Antitoxidant activity

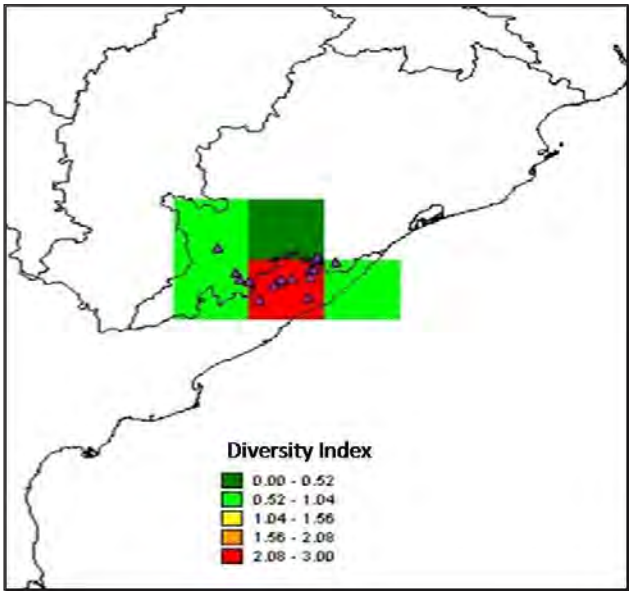

Fig. 5. Diversity Index

(AOA) is reported to be highly heritable in cowpea, with a strong relationship between AOA and seed coat colour (Nzaramba *et al.*, 2005), the pigmented varieties possessing favourable factors that enhance AOA. Purple

podded plants were also observed to be more tolerant to pests and disease as well as water stress conditions and to have a thicker skin, so possibly disliked by insect pests (Waluyo and Hardinaningsih, 2013).

The spacing between adjacent seeds in a pod contributes to a typical difference between yardlong beans and cowpeas. In the former, seeds are distributed throughout the length of the pod, thus making it fleshier, whereas in the latter, seeds are crowded next to each other in the pod. This is clearly suggestive of divergent selection during domestication and evolution of the crop. Present observations supported this. Seeds/pod was minimum in IC582867 (6.2) with a pod length of 28 cm, while IC582850 and IC582863 with a maximum pod length of 75 cm each had 17 seeds/pod dispersed along the entire length of the pod.

The few studies on yardlong bean in India have focused mainly on collections from Kerala with considerable diversity in local types with high genotypic and phenotypic coefficient of variation for pod yield/ plant, clusters/plant, pods/plant, pods/cluster and pod weight, and therefore scope for improvement through selection (Vidya and Oomen, 2002; Vidya *et al*., 2002; Resmi and Gopalakrishnan, 2004; Lovely and Radhadevi, 2006; Kumar and Devi, 2009). Globally, however, there is a good deal of focused research on several aspects of yardlong bean including genetic diversity (Gillaspie *et al.,* 2005; Sarutayophat *et al.,* 2007; Benchasri and Bairaman, 2010; Ullah *et al.,* 2011, , Mahmudul Huque *et al.,* 2012), genetics of pod/seed traits, domestication and QTL mapping (Kongjaimun *et al.,* 2012, 2013), host plant resistance (Brito *et al.,* 2011; Benchasri *et al.,* 2012;), optimum time for harvesting pods (Ofori and Klogo, 2005); and as a potential new crop (Coker *et al.,* 2007).

Given the many factors that currently constrain vegetable production, including climate change, increased urbanization and pressure on arable land, coupled with the growing interest in this under-utilized vegetable worldwide in recent years, it is appropriate to focus research on this vegetable that comfortably fits into most cultivation and production practices with little additional efforts, particularly in high rainfall states. The long pod character of yardlong bean has the potential for developing bush-type cowpea by hybridizing with grain type cowpea. The bush-type vegetable cowpea with semi-erect growth habit with long-succulent pods and long peduncles (40-50 cm long) protruding over canopy and holding pods above ground has an advantage of requiring no staking, thus reducing cultivation costs (Singh *et al*., 2003).

Substantial diversity is available in the collected germplasm, and their systematic evaluation would reveal their potential for contribution to yardlong bean/cowpea genetic improvement. In an effort to popularize this promising underutilized vegetable, a pure line selection from IC582850 (Jeypore, Koraput, Odisha) was released for cultivation as 'Arka Mangala' (Fig. 6). The variety recorded a pod yield of 25.7 t/ha with an increase of 24% and 30% pod yield over the check varieties 'Lola' and 'Vyjayanthi', respectively. A pole type photo-insensitive variety with green, smooth pods and crop duration of 3-4 months, it is suitable for both *kharif* and *rabi* seasons. This variety was taken up for trials in Kerala (KVK conducted farm experiments at Mookkannur and Ayur panchayaths of Ernakulam district) and has reportedly performed well in comparison to 'Lola', the prevailing variety, even being better resistant to diseases and pests (http://kvkernakulam.org.in/news100.html).

Fig. 6. Arka Mangala

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