International Journal of Plant Breeding and Genetics

ISSN 1819-3595

Academic Journals Inc.

www.academicjournals.com

International Journal of Plant Breeding and Genetics 9 (1): 13-21, 2015
ISSN 1819-3595 / DOI: 10.3923/ijpbg.2015.13.21

Phaseolus spp.: Valuable but Underutilized Genetic Resource in Nigeria

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ABSTRACT

The genus *Phaseolus* (bean) has been reported to be of great economic importance in human and animal nutrition. In Eastern and Southern Africa, it is the second most important source of dietary protein. It is considered one of the best non-meat sources of iron, providing 23-30% of the daily recommended levels of iron from a single serving and has been associated with several health benefits. However, it is highly underutilized in Nigeria and its potentials to contribute to food security and poverty alleviation are not fully exploited. This could be due to the need for prolonged cooking and the presence of antinutritional compounds. This study was an investigation into the status of the crop based on available information from Plateau and Taraba states. Data was collected during expedition through direct observation, individual interviews and field visits using questionnaire with the principal respondents being farmers, traders and consumers of the crop. Most of the respondents were between 45-54 years. Only 13.7% had tertiary education. Majority (82.76%) use only the seeds and were generally aware of 5-8 landraces or varieties. The most important factor limiting the use of this crop is prolonged cooking time. About 55% believed the crop had average contribution to household income, while 44.8% opined that it had average contribution to women empowerment. The most common processing technique aimed at reducing antinutrients and associated discomfort was soaking. It is evident that there is limited knowledge of this crop even amongst respondents from the two states in Nigeria were it is believed to have a wider cultivation and consumption. Also genetic improvement is urgently needed in softening its seed coat and reducing the antinutritional contents for greater acceptability. This will only be possible through increasing its genetic diversity probably through mutation and selecting for these traits from available genotypes.

Key words: *Phaseolus vulgaris*, *Phaseolus* spp., neglected and underutilized species, Nigeria, genetic diversity, plant genetic resources

INTRODUCTION

Plant genetic resources are seeds and planting materials of traditional varieties and modern cultivars, crop wild relatives and other wild plant species useful as food, feed for domestic animals, fibre, clothing, shelter and energy. They are the biological basis of food security and directly or indirectly support the livelihoods of every person on earth. Local communities and researchers rely upon genetic resources to improve the quality and output of food production. When these resources are eroded, humankind loses potential means of adapting agriculture to new socio-economic and environmental conditions. The most significant of these erosions in the recent decades have resulted from the introduction of desirable plant varieties (Vellve, 1993; Clunies-Ross, 1995).

The genus *Phaseolus* (bean) has been reported to be of great economic importance in human and animal nutrition. Five species have been domesticated and these include *P. vulgaris* (Common bean), *P. lunatus* (Lima bean), *P. acutifolius* (Tepary bean), *P. coccineus* (Runner bean) and *P. polyanthus* out of which *P. vulgaris* is the most widely cultivated (Laing *et al*., 1984) and studied. *Phaseolus vulgaris* makes up half of the grain legumes consumed worldwide (Broughton *et al*., 2003) and is ranked the third most important grain legume worldwide superseded only by soybean (*Glycine max*) and peanut (*Arachis hypogea*) (Stoilova and Berova, 2009). In Eastern and Southern Africa, it is the second most important source of dietary protein and the fourth in tropical America, where it is also the third most important source of calories after maize and cassava (Wartmann *et al*., 1998; Rao, 2001). It is considered one of the best non-meat sources of iron, providing 23-30% of the daily recommended levels of iron from a single serving (Shimelis and Rakshit, 2005) and is also a good source of dietary fibre (Anderson *et al*., 1994). Meiners *et al*. (1976) and Messina (1999) described it as a good source of essential vitamins, minerals and phytochemicals. In animal nutrition, Achi *et al*. (2007) reported significant weight gain in birds fed with meals made of *P. lunatus* seeds which is a cheaper and more affordable source of protein in poultry farming compared to fishmeal, soybean and groundnut that are used as conventional poultry feeds in the tropics (Ojewola and Udom, 2005). *Phaseolus* forms a good source of income for farm families. Although largely grown for subsistence (mainly by women), approximately 40% of production of *P. vulgaris* is marketed at a market value of 452 million dollars (David *et al*., 2000).

The consumption of beans has been associated with several health benefits including reduction of cholesterol level (Rosa *et al*., 1998), coronary heart diseases (Anderson *et al*., 1999; Bazzano *et al*., 2001), favourable effects against cancer (Hangen and Bennick, 2002), decrease of diabetes and obesity (Geil and Anderson, 1994), high antioxidant capacity (Heimler *et al*., 2005) and anti-mutagenic as well as anti-proliferative effects (Aparicio-Fernandez *et al*., 2006). Epidemiological studies (Correa, 1981; Kolonel *et al*., 2000) confirmed highly significant inverse correlation between *P. vulgaris* intake and age adjusted mortality for colon, breast and prostate cancers.

In addition, Shimelis *et al*. (2006) examined the physico-chemical properties and pasting behavior of the starch extracted from *P. vulgaris* and reported that the starch has useful technological properties for many applications both in the food industry and some non-food applications like in paper and textile industries. The seeds of *P. vulgaris* are highly sensitive to crude oil toxicity and its germination on bio-remedied crude oil-imparted agricultural lands is good biological indices for evaluation of the rehabilitation of such lands (Aboaba *et al*., 2007).

Despite its importance, *Phaseolus* spp. is highly underutilized in Nigeria (Audu and Aremu, 2011) where its potentials are not fully exploited to contribute to food security and poverty alleviation. The level of underutilization is also shown in the fact that it is poorly documented and researched; is adapted and grown in few agro-ecological niches; have no known existing seed supply system and is produced with no external input. In addition, while there is paucity of information on the consumption of *P. vulgaris* in West Africa for instance, consumption in East and Southern Africa exceeds 50 kg per person per year and reaches 66 kg per person in parts of Kenya

(Wartmann *et al.*, 1998). In Uganda, it is a major food security crop, readily available and popular among both urban and rural population with the per capita consumption in Uganda at 58 kg (David, 1999).

Across the globe, the factors that have limited its use have been the need for prolonged cooking and the presence of antinutritional compounds some of which include phytic acid, flatulence factors, saponins, lectins and toxin factors (Lyimo *et al.*, 1992). Flatulence producing oligosaccharides induce flatulence due to the absence of α-galactosidase in humans, leading to the anaerobic fermentation of the constituent oligosaccharides by microorganisms to produce carbon dioxide, hydrogen and methane (Price *et al.*, 1988). Phytic acid binds trace element and macronutrients such as zinc, calcium, magnesium and iron in the gastrointestinal tract, making dietary minerals unavailable for absorption and utilization by the body. Beans also form complexes with proteins, proteases and amylases of the intestinal tract, thus inhibiting proteolysis (Tabekhia and Luh, 1980). Most of these antinutritional factors are however heat labile and inactivated by cooking which also enhances digestion and assimilation of proteins and starch (Kigel, 1999).

Although Gwary *et al.* (2012) reported collections of *P. vulgaris* from both field and storage facilities in the Sahel Savanna Agro-ecological Zone (AEZ) of Nigeria, the legume is poorly known in Nigeria except in the Mid-altitude AEZ (particularly Plateau State and parts of Taraba State) where it is relatively widespread and grown by farmers for the local markets. This study was an investigation into the status of the crop with a view to provide information on this poorly researched and utilized species in Nigeria that is currently lacking.

METHODOLOGY

The study focused on two states: Plateau (8°24'-9°31'N, 9°00'-10°38'E) and Taraba (6°25'N, 9°36'E) states both within the Mid-altitude AEZ. Data was collected during expedition through direct observation, individual interviews and field visits using questionnaire with the principal respondents being farmers, traders and consumers of the crop. The study sought to highlight the status of the crop by providing answers to the following research questions:

1. What part of the plant is used?
2. What special techniques are employed in processing the seeds for consumption?
3. How many varieties of the crop are available?
4. What factors currently limit its use?
5. What is the extent of production?
6. What is the degree of consumption?
7. What is the level of perceived nutritional value?
8. What is its contribution to household income?
9. How much does it contribute to women empowerment?

Questions 5-9 were scored 3 for low, 5 for average and 7 for high. The questionnaire also assessed some demographic parameters (age, marital status, educational attainment and occupation) of the respondents. The data generated was analysed using descriptive statistics.

RESULTS AND DISCUSSION

Socio-demographic characteristics of the respondents: The socio-demographic characteristics of respondents (Table 1) showed that a number of the respondents (37.93%) were between ages

Table 1: Socio-demographic characteristics of respondents

Variable	Frequency (n = 29)	Percentage
Age (years)		
15-24	5	17.24
25-34	4	13.79
35-44	7	24.14
45-54	11	37.93
55-64	2	6.90
Marital status		
Single	11	37.93
Married	16	55.17
Widowed	2	6.90
Divorced		
Occupation		
Trader	10	34.48
Farmer	8	27.59
Civil servant	4	13.79
Students	6	20.69
Education attainment		
No formal education	5	17.24
Primary education	8	27.59
Secondary education	12	41.38
Tertiary education	4	13.79
Adult education		

45-54 years followed by ages 35-44 years with a percentage of 24.14. A greater percentage (55.17%) of the respondents was married, while most were traders and farmers with percentages of 34.48 and 27.59, respectively. On the educational attainment, 13.79% had tertiary education, 41.38% had secondary education, while 17.24% had no formal education.

Respondent's knowledge on *P. vulgaris*: Table 2 shows the knowledge of the respondents on *P. vulgaris*. While some of the respondents (13.79%) use both the seeds and leaves, 82.76% use only the seeds while 34.48% use only the leaves. Generally, the respondents opined that there are 5-8 landraces known with majority of respondents (48.28%) reporting five landraces.

Table 2 shows that cooking time, cost, antinutritional factors, taste and appearance when cooked have been highlighted by respondents as factors which limit the crop use with cooking time being the highest rated limiting factor (89.66%). However, Kigel (1999) reported great variability in *Phaseolus* gene pool with regard to the cooking characteristics of the seeds and this can be exploited for genetic improvement. Cooking time is known be to affected by seed hardness and seed coat permeability (Hohlberg and Stanley, 1987) while Agbo *et al.* (1987) showed differences in micropyle size and in other microstructural characteristics that are related to seed coat permeability and water uptake by the seed. Seed coat permeability, seed hardness and water absorption are affected by environmental and genetic factors as well as genotype×environment interaction (Ghaderi *et al.*, 1984; Escribano *et al.*, 1997). Stamboliev *et al.* (1995) corroborated this when they reported that higher rainfall was associated with thinner seed coat and shorter cooking time due to changes in seed coat characteristics and permeability to water. The cooking time and seed hardness increased when bean was grown in soils rich in calcium and magnesium and with higher average annual temperature (15-24°C), compared to soils poor in magnesium and phosphorus and with lower temperatures ranging from 11-18°C (Paredes-Lopez *et al.*, 1989).

Table 2: Respondent's knowledge on *Phaseolus vulgaris*

Variable	Frequency (n = 29)	Percentage
Plant part used		
Seed	24	82.76
Leaf	10	34.48
Seeds and leaves	4	13.79
Number of available landraces		
5	14	48.28
6	8	27.59
7	5	17.24
8	2	6.90
Factors limiting use		
Cooking time	26	89.66
Taste	5	17.24
Antinutritional factors	9	31.03
Cost	11	37.93
Appearance when cooked	2	6.90
Extent of production		
Low/restricted	20	68.97
Average/relatively widespread	9	31.03
High/very widespread	-	-
Perceived nutritional value		
Low	6	20.69
Average	9	31.03
High	14	48.28
Contribution to household income		
Low	5	17.24
Average	16	55.17
High		
Contribution to woman empowerment		
Low	15	51.72
Average	13	44.83
High		
Processing techniques used		
Soaking	18	62.07
Parboiling	7	24.14
Fine grinding	-	-
Dehulling	-	-

The antinutritional factors in *Phaseolus* spp. are inherited quantitatively with the environment having significant effects on their quantity in seed varieties hence limiting chances of breeding through classical breeding efforts. Angenon *et al.* (1999) therefore suggests that gene engineering can contribute significantly to *Phaseolus* improvement especially where conventional breeding cannot readily provide solutions. Similarly, Nwokolo and Smartt (1996) suggested genetic transformation of *Phaseolus* through gene engineering for the sulphur-containing amino acids (methionine and cysteine) which is currently deficient. Success in such genetic transformations have been reported by Tabe and Higgins (1998) where genetic transformation resulted in enhanced seed methionine levels in several grain legumes including *Glycine max, Vicia narbonensis* and *Lipinus angustifolium*. Methionine-rich seed proteins and their corresponding genes have been

Table 3: Seed characteristics of some accessions of *P. vulgaris*

Accession number	Location	Seed phenotype	100 seed weight (g)
Cnb21	Mangu, Plateau State	Brown	21
Cnb22	Mangu, Plateau State	Black	20
Cnb27	Jos, Plateau State	Pinto	35
Cnb211	Sardauna, Taraba State	Black	21
Cnb215	Sardauna, Taraba State	Red	33
Cnb214	Mangu, Plateau State	Cranberry	24
Cnb216	Bokkos, Plateau State	Pinto	34

identified in *Bertholletia excelsa*, *Helianthus annuus* and *Zea mays*. Caution must however be exercised when performing genetic manipulations on these antinutritional factors as they have some beneficial effects to the plants (Ali and Muzquiz, 1998).

On the extent of production, 68.97% of the respondents reported low production, 48.28% considered *P. vulgaris* a crop with high nutritional value while 55.17% believe that it makes an average contribution to household income. As regards women empowerment, 44.83% of the respondents consider it as making an average contribution to empowering women.

Table 3 shows the seed characteristics of some accessions of *P. vulgaris* collected. Empirical observation of *Phaseolus* spp. shows many different phenotypes with regard to seed colour and size.

Reports show there is a higher genetic diversity in the Mesoamerican gene pool than the Andean gene pool (the two centres of origin of the crop) for both the wild and domesticated populations (Papa and Gepts, 2003; McClean *et al.*, 2004). Andean beans have been distinguished from the Mesoamerican beans on the basis of morphological and biochemical differences such as seed size, seed proteins as well as various types of molecular markers (Gepts, 1998). Adesoye and Ojobo (2012) have also reported a broad genetic base in few cultivars analysed for genetic diversity from the Mid-altitude agroecological zone of Nigeria. Morphological variations are also found in the growth habit, pigmentation, pod, seed and phenology (Leakey, 1988; Singh, 1989) of all *Phaseolus* spp. studied. On the basis of allozyme data, the genetic diversity of *P. lunatus* is evenly distributed between the Mesoamerican and Andean gene pools (Maquet *et al.*, 1997) and at the molecular level, *P. polyanthus* is said to be closer to *P. coccineus* by nuclear DNA comparison (Pinero and Eguiate, 1988) but more similar to *P. vulgaris* by chloroplast DNA comparison (Llaca *et al.*, 1994) indicating *P. polyanthus* probably originated from a cross that involved *P. vulgaris* as the maternal parent, with successive backcrosses to *P. coccineus* as the paternal donor (Schmit *et al.*, 1993; Llaca *et al.*, 1994).

CONCLUSION

Information on *Phaseolus* spp. in Nigeria is sparse with only very few people having knowledge of the crop. Limited researches have been conducted on the landraces grown in Nigeria compared with other legumes. The few farmers of the crop grow them with no external input and no seed supply system exists making the crop very expensive. Conservation of *Phaseolus* germplasm in genebank is very insignificant and no known effort being made to improve on the factors limiting the crop's use.

Few studies in Nigeria have shown heritable diversity in various germplasms studied. More researches aimed at understanding the genotypes and genotype×environment interaction with a view to improving on the factors currently limiting the use of this crop is highly recommended as species of the genus are possible candidates for food security. Effort should be made towards conserving available germplasms to check possible genetic erosion of available landraces.

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