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Hyacinth bean: A gem among legumes

State of the art in *Lablab purpureus* research

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Office and subscriptions
CSIC, Institute for Sustainable Agriculture
International Legume Society
Apdo. 4084, 14080 Córdoba, Spain
Phone: +34957499215 • Fax: +34957499252
diego.rubiales@ias.csic.es

Publishing Director
Diego Rubiales
CSIC, Institute for Sustainable Agriculture
Córdoba, Spain
diego.rubiales@ias.csic.es

Editor-in-Chief
Carlota Vaz Patto
Instituto de Tecnologia Química e Biológica António Xavier
(Universidade Nova de Lisboa)
Oeiras, Portugal
cpatto@itqb.unl.pt

Technical Editor
Aleksandar Mikić
Institute of Field and Vegetable Crops
Novi Sad, Serbia
aleksandar.mikic@nsseme.com

Front cover artwork
Lady Lablab
by Andrey Sinjushin

EDITORIAL

It is our pleasure to present the 13th issue of the journal Legume Perspectives *devoted to hyacinth bean (*Lablab purpureus*), coincidentally, during the International Year of Pulses (2016). A minor legume of African origin is historically associated with diverse cultures. It has stood the test of time as a major pulse in drought prone areas, where it accounts for major proportion of pulses and fodder. This issue outlines hyacinth bean's origin, distribution, cultivation, nutritive aspect, performance under diverse abiotic stresses, resistance to pests and diseases, collection and characterization of germplasms and breeding to enhance quality and yield. Sincere thanks to all the researchers for their valuable contributions, and editorial team for its efforts in bringing out this issue as a part of the International Legume Society's endeavor to promote legume research globally...*

V. Rangaiah Devaraj and Mohd Naeem

Managing Editors of Legume Perspectives *Issue 13*

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A gem among legumes

Hyacinth bean is a versatile multipurpose plant that offers food, fodder, green manure and some traditional home remedies. With wider distribution in tropics and subtropics, the plant has fed various communities over centuries, particularly in drought-prone regions. Although reasonable genetic resource of over 4000 landraces are conserved by various agencies, molecular analyses revealed limited diversity. During the last century, its performance under drought offering relatively cheaper nutrition has attracted researchers leading to development of specific genotypes for pulse, fodder and silage through breeding. Even though the crop has lost the race for popular pulses due to less palatability and anti-nutritional factors, improved methods of processing, availability of drought-tolerant, better yielding, insect resistant genotypes make this a better alternative to popular pulses due to relatively low cost of production. Research to improve agronomical values via breeding and genetic engineering approach are imperative under unpredictable climatic conditions. Efforts are necessary to popularize this crop by enhancing palatability and acceptance via better processing methods to tide over shortage of pulses due to ever increasing population and reducing cultivable land.

Adaptability of hyacinth bean to diverse climates and soils and higher and better yields under stress conditions than popular pulse crops can be exploited to feed the burgeoning population as well as livestock under harsher environmental conditions.

Bangalore University, Central College,
Department of Biochemistry, Bengaluru, India
(devaraj@bub.ernet.in)

Origin, domestication and global dispersal of *Lablab purpureus* (L.) Sweet (Fabaceae): Current understanding

by Brigitte L. MAASS

Abstract: *Lablab purpureus* is one of the most diverse domesticated legume species regarding various attributes and multiple uses. Both domestication syndrome and founder effect are evident. Due to the occurrence of wild plants only in eastern and southern Africa, these areas are likely centers of origin, with Ethiopia as one of the potential centers of domestication. Pathways of prehistoric dispersal within Africa are unrevealed, while archaeological finds date to before 2,000 BC in India. The Indian subcontinent constitutes a center of secondary diversity. Lablab reached the Americas early during Columbian exchange. Modern global dispersal is strongly constrained to a couple of commercially available forage cultivars leading to narrow genetic diversity.

Key words: botanical exchanges, center of origin, crop domestication, *Lablab purpureus*, secondary center of diversity

Introduction

Lablab purpureus (L.) Sweet, hyacinth bean or hyacinth bean, is one of the most diverse domesticated legume species. Lablab has multiple uses as pulse, vegetable, livestock feed, green manure, ornamental or medicinal herb, also reflected in ample morpho-agronomic diversity (10, 16, 18). Despite the significant worldwide germplasm collection of about 3,000 accessions (16), the diversity of hyacinth bean is not comprehended in the context of origin, domestication and global dispersal. This paper reviews our current understanding, considering morphological, anatomical, physiological, biochemical, molecular, archaeobotanical and historical evidence.

Georg-August University of Göttingen, Göttingen, Germany (Brigitte.Maass@yahoo.com)

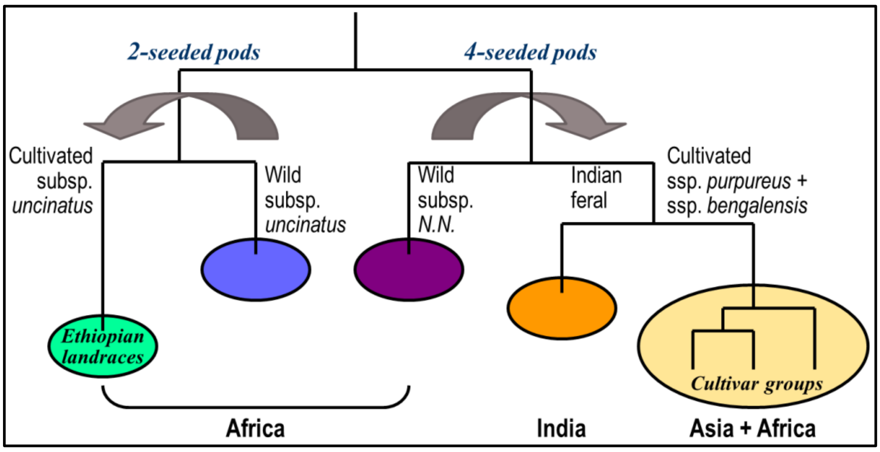

Figure 1. Proposed relationships of two wild African subtaxa of *Lablab purpureus* with feral escapes from India and cultigens worldwide, reflecting two domestication events (modified from 13); *N.N. - nomen nominandum* , taxonomic identity uncertain

Patterns of diversity and domestication

Lablab Adans. is acknowledged as a monotypic genus, closely related to *Dolichos* L. In his revision, Verdcourt combined all wild morphological variants under subsp. *uncinatus* Verdc., recognizing only var. *rhomboïdeus* (Schinz) Verdc. as a separate wild variant (25). Yet, both pod morphology and molecular diversity are conspicuously distinct between wild 2-seeded and 4-seeded types (13, 15, 21). Crossing cultivated with wild 4-seeded types was uncomplicated (18), (Venkatesha 2012, cited in 2), while 2-seeded wild types have probably not been tested. Supported by molecular markers (13, 21), a 2-seeded cultigen with typical pod shape is only known from Ethiopia generating the hypothesis that two domestication events occurred. Other cultigens like ssp. *bengalensis* are genetically inconspicuous (Fig. 1).

Domestication. Alike other legumes, the domestication syndrome is evident in numerous changes from wild to domesticated plants (Table 1). These refer to differences in morphological, anatomical, physiological and biochemical seed attributes when comparing wild with cultivated and semi-domesticated accessions (14). During domestication, the use type has possibly influenced selecting large-seeded variants for grain types as opposed to vegetable types (14), for which pod size and shape were key traits. Immense pod shape diverseness in vegetable or ornamental types exists, for example, in Bangladesh (10). Further seed changes in dormancy and germination took place from wild to cultivated plants (14).

Few other studies compared agriculturally important traits between wild plants and domesticates (Table 1). Wild hyacinth bean is indeterminate. In the past, plant habit differentiation between indeterminate climbers (garden) and bushy (field) cultigens even reflected use-type dissimilarities in taxonomic designation. Ingredients with anti-nutritional effects have lately been characterized on broader germplasm sets. Wide ranges of tannins, trypsin inhibitor activity (TIA) and cyanogenic potential (HCNp) exist; whereas wild accessions had a considerably broader range in HCNp than cultivated ones, it was similar for TIA (9).

Table 1. Characteristic plant modifications in *Lablab purpureus* providing evidence for the domestication syndrome

Attribute*	Wild	Domesticated	Reference
Seed			
Seed mass (g 1000^{-1} seed)	60-150	200-1000	(10, 14)
Seed shape	Similar; relatively flat	Very diverse; round, flat, elongated, spherical	(10, 14)
Seed colour	Similar: greyish-brown and mottled throughout	Very diverse: white, cream, greenish, tan, red-brown, dark brown, black; sometimes mottled	(14)
Tannin contents (%)	4-8	0-8	(14)
Trypsin inhibitor units in FM (mg^{-1})	10-38	14-41	(9)
Cyanogenic potential in FM (μmol^{-1})	2-15	1-7	(9)
Hardseededness (at day 10, %)	3-48	0-8	(14)
Pods			
Fresh pod length (cm)	2-6	4-17	(10, 18)
Fresh pod width (mm)	17-22	15-43	(10, 18)
Number of seeds per pod	2-4	1-7	(10, 18)
Pod colour	Green, purple	Green, purple, very light green	(10, 18)
Plant			
Flower colour	Purple	Purple, violet, white	(10, 18)
Growth habit	Indeterminate	Indeterminate / climber, determinate / bushy	(10, 18)
Maturity type (number of days to flowering)	Intermediate to very late (83-200)	Early to very late (54-220)	(10, 18)
Molecular markers			
RAPD - diversity	Wide	Narrow	(12, 23)
AFLP - diversity	Wide	Narrow to intermediate	(15, 24)
SSR - diversity	Wide	Narrow	(26)

*FM - fresh matter, AFLP - Amplified Fragment Length Polymorphism, RAPD - Random Amplified Polymorphic DNA, SSR - Simple Sequence Repeat markers

Like other domesticated crops, hyacinth bean shows a 'founder effect' by extensive phenotypic variability with concurrent narrow genetic variability (Table 1), especially in South Asian germplasm, while higher genetic diversity exists in Africa (15, 16, 24).

Centers of diversity and domestication

The origin of hyacinth bean is highly likely eastern and southern Africa, the only continent of natural occurrence (25). All revised wild herbarium specimens and germplasm accessions originate from eastern and southern Africa (Fig. 2). Some inconspicuous, seemingly wild accessions from India (18), collected by I. A. Staples in 1984 were reconsidered escapes from early attempts of domestication, based on morphological and molecular evidence (13). Recent publications about purported wild hyacinth bean from India (11, 22) are clearly based on taxonomic misidentification referring to published images that show seeds of *Phaseolus lunatus* L. (D. G. Debouck, pers. comm.).

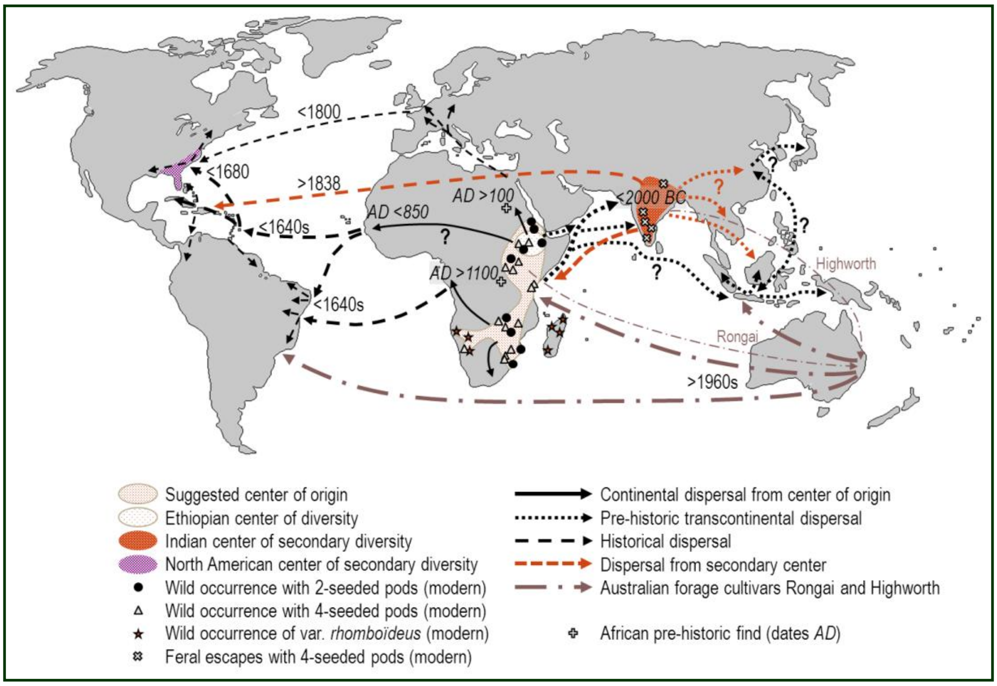

Figure 2. African origin and global dispersal of *Lablab purpureus* derived from diverse sources (3, 6, 8, 13, 14, 15) and S. Ramme and B. L. Maass (unpublished data); basic world map from 2009 (www.outline-world-map.com)

A center of hyacinth bean domestication cannot yet be derived from the scanty data available. However, Ethiopia is highly likely among the candidate areas. Alike several crops of African origin, hyacinth bean was found in archaeological sites in India millennia before archaeological finds in Africa (1). There is little evidence, though, to prove the presumption that hyacinth bean has been trans-domesticated in India, certainly constituting a center of secondary diversity; yet, the feral escapes from India are intermediate between wild African accessions and the cultigens (Fig. 1) (13). Another, much smaller secondary center of diversity might have developed in North America due to the ornamental use (Fig. 2).

Global dispersal

Prehistoric distribution in Africa. There are no archaeological finds of hyacinth bean cultigens in Africa, except for Qasr Ibrim in Egyptian Nubia AD 100-400 (4) and Nguri cave in Rwanda AD 1100 (8). As evidence lacks, it is challenging to devise a map of dispersal within Africa in general and pathways from eastern to central and West Africa in particular (Fig. 2). Following Blench's arguments for its usual companion crops, sorghum (*Sorghum bicolor* (L.) Moench) and millet (*Pennisetum glaucum* (L.) R. Br.) (1), it is postulated that hyacinth bean was transported via ancient trade networks by mobile pastoralist societies along the Sahelian region of domestication. Fuller (5) suggests its cultivation in West Africa from at least AD 850. Latest, by the beginning of the transatlantic slave trade in the early 17th century, hyacinth bean was grown both in Senegambia and Angola (3).

Prehistoric dispersal out of Africa - The Monsoon exchange. Lablab is so widely distributed in the Indian subcontinent and beyond in East and Southeast Asia that early sources suggest an Indian origin. Although ample archaeological evidence (Table 2) would support this, the distribution of wild plants would not. It is now commonly accepted that hyacinth bean, together with various other crops of African origin (1), was transferred to India on the Sabaean Lane. The direct transfer of hyacinth bean by small-scale coastal and maritime societies is suggested because archaeological evidence lacks from the Arabian Peninsula, despite its traditional cultivation in Yemen and Oman (6). First crop introductions to India must have taken place before 2000 BC (Table 2).

Table 2. The earliest archaeological finds of *Lablab purpureus* cultigens in Africa and South Asia

Region/country	Site	Period	Dates	Reference
Africa				
Egypt	Qasr Ibrim	Late Meroitic Nubia	AD 100-400	(4)
Rwanda	Nguri cave	Iron Age	ca. AD 1100*	(8)
Asia (India)				
Eastern Harappan/ Upper Ganges	Mahorana	Pre-Harappan/Bara	?2200-1900 BC	(5)
	Sanghol	Late Harappan		(5, 6)
	Harappa	Late Harappan		(6)
Middle Ganges	Taradih (Bihar)	Chalcolithic		(6)
North Deccan	Daimabad	Early Chalcolithic	1500-1200 BC	(5, 6)
	Inamgaon	Early Chalcolithic	1700-900 BC	(5, 6)
	Apegaon	Late Chalcolithic	ca. 1200 BC	(5, 6)
	TuljapurGarhi	Late Chalcolithic	1500-1200 BC	(5, 6)
	Adam	Iron Age		(6)
	Bhagimohari	Iron Age	800-400 BC	(5, 6)
	Bhokardan	Iron Age		(6)
South Deccan	Budihal	Southern Neolithic III		(6)
	Sanganakallu	Southern Neolithic III	1800-1200 BC	(5, 6)
	Sannarachamma Hill (Sanganakallu)	Megalithic	1400-1100 BC*	(7)
	Hiregudda	Southern Neolithic	1500-1300 BC*	(7)
	Hallur	Southern Neolithic III	> 1800 BC	(5, 6)
	Hallur	Southern Neolithic	1600-1400 BC*	(7)
	Veerapuram	Iron Age	1st millennium BC	(5, 6)

*calibrated

Numerous finds from archaeological sites provide evidence that its introduction to India must have occurred from West to East (5).

Dates and terrestrial or maritime dispersal routes beyond the Indian subcontinent are unidentified. Traditional use is known from Southeast Asia, China and Japan (16), and its distribution goes as far as Melanesia (1). In absence of archaeological evidence, molecular data can shed light on geographical relationships. Accessions from Myanmar, Thailand, Japan, the Philippines and Indonesia (23) or China (26) characterized by molecular markers were inconspicuously blended with those from Africa and the Indian subcontinent; this hints to onward-dispersal of cultigens from India (Fig. 2). Then again, undated reintroductions contributed new diversity to eastern and southern Africa (1).

The Columbian exchange and beyond. After the conquest of the Americas, hyacinth bean was transported to Brazil and the Caribbean on the Middle Passage from West Africa and possibly Angola (Fig. 2), where it was among the victuals for slave ships and so reached the Americas in historic times (3). In the 17th century, African slaves cultivated hyacinth bean among their food crops in northeastern Brazil, several Caribbean islands and the Province of Carolina, to where planters from Barbados introduced it. When migrating to the Caribbean after slave abolishment by the British since 1838 (19), Indian indentured labourers probably carried hyacinth bean among their familiar food items.

Modern distribution. In agricultural statistics, hyacinth bean is worldwide recognized as a 'minor crop', usually pooled with 'other beans' regardless of its local or regional significance. Knowledge on modern cultivation, production and spread of particular hyacinth bean cultivars is, consequently, imprecise. The Kikuyu tribe in eastern Africa holds hyacinth bean in high esteem, especially for traditional ceremonies (17). Under colonial rule in Kenya, however, farmers were forced to give up their local 'njahe' bean to produce common beans (*Phaseolus vulgaris* L.) for export (20). This resulted in decreasing production areas and volume together with declining genetic diversity used.

In India and Bangladesh, improved commercial cultivars are available (16); yet, their distribution beyond national borders is unknown. Lablab used to be widespread in China and Southeast Asian countries (16). More than vegetable or forage, today hyacinth bean is regarded an ornamental plant in North America. Cultivars Rongai and Highworth, released forage varieties in Australia, dominate the seed sector elsewhere (Fig. 2). This has led to undue genetic uniformity of a very diverse species (16).

Conclusions

Strikingly little is known of a legume that appears to have played a role on three continents in the past. The lack of archaeological finds in Africa creates a challenge for reconstructing the prehistoric and historic past; even trans-domestication in India and reintroduction as cultigen to Africa should be considered. To elucidate patterns of diversity from which crop dispersal might be derived, a broader spectrum of disciplines needs to be considered; for example, linguistics has been largely ignored. Attributes typical for domesticates need to be investigated and compared between wild plants and cultigens (e.g., physiology, biochemistry). Future molecular studies should integrate the core collection (15, 18) to generate a comprehensive picture of diversity patterns. There is ample scope for further studies to unravel relations between African and Asian hyacinth bean in particular.

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References

(1) Blench R (2003) The movement of cultivated plants between Africa and India in prehistory. In: Neumann K, Butler EA, Kahlheber S (eds) Food, Fuel and Fields: Progress in African Archaeobotany. Africa Praehistorica 15. Heinrich-Barth-Institut, Köln, 273-292

(2) Bohra A, Jha UC, Kishor PK, Pandey S, Singh NP (2014) Genomics and molecular breeding in lesser explored pulse crops: current trends and future opportunities. Biotechnol Adv 32:1410-1428

(3) Carney JA, Rosomoff RN (2009) In the shadow of slavery: Africa's botanical legacy in the Atlantic world. University of California Press, Berkeley

(4) Clapham AJ, Rowley-Conwy PA (2007) New discoveries at Qasr Ibrim, Lower Nubia. In: Clappers RTJ (ed) Fields of Change: Progress in African Archaeobotany. Barkhuis and Groningen University Library, Groningen, 157-164

(5) Fuller DQ (2003) African crops in prehistoric South Asia: A critical review. In: Neumann K, Butler EA, Kahlheber S (eds) Food, Fuel and Fields: Progress in African Archaeobotany. Africa Praehistorica 15. Heinrich-Barth-Institut, Köln, 239-271

(6) Fuller DQ, Boivin N (2009) Crops, cattle and commensals across the Indian Ocean. Current and Potential Archaeobiological Evidence. Etudes Ocean Indien 42-43:13-46

(7) Fuller DQ, Boivin N, Korisettar R (2007) Dating the Neolithic of South India: new radiometric evidence for key economic, social and ritual transformations. Antiq 81:755-778

(8) Giblin JD, Fuller DQ (2011) First and second millennium AD agriculture in Rwanda: archaeobotanical finds and radiocarbon dates from seven sites. Veget Hist Archaeobot 20:253-265

(9) Guretzki S, Papenbrock J (2014) Characterization of *Lablab purpureus* regarding drought tolerance, Trypsin Inhibitor activity and Cyanogenic potential for selection in breeding programmes. J Agron Crop Sci 200:24-35

(10) Islam MT (2008) Morpho-agronomic diversity of hyacinth bean (*Lablab purpureus* (L.) Sweet) accessions from Bangladesh. Plant Genet Resour Newsl 156:72-77

(11) Janarthanan S, Suresh P, Radke G, Morgan TD, Oppert B (2008) Arcelins from an Indian wild pulse, *Lablab purpureus*, and insecticidal activity in storage pests. J Agric Food Chem 56:1676-1682

(12) Liu CJ (1996) Genetic diversity and relationships among *Lablab purpureus* genotypes evaluated using RAPD markers. Euphytica 90:115-119

(13) Maass BL, Tefera Tolera (2008) Relative molecular similarity in wild *Lablab purpureus* from India underlines the crop's African center of origin. Abstract Booklet, Harlan II International Symposium *Biodiversity in Agriculture: Domestication, Evolution, and Sustainability*, Davis, USA, 14-18 September 2008, 25

(14) Maass BL, Usongo MF (2007) Changes in seed characteristics during the domestication of the hyacinth bean (*Lablab purpureus* (L.) Sweet: Papilionoideae). Crop Pasture Sci 58:9-19

(15) Maass BL, Jamnadass RH, Hanson J, Pengelly BC (2005) Determining sources of diversity in cultivated and wild *Lablab purpureus* related to provenance of germplasm using amplified fragment length polymorphism (AFLP). Genet Resour Crop Evol 52:683-695

(16) Maass BL, Knox MR, Venkatesha SC, Tefera TA, Ramme S, Pengelly BC (2010) *Lablab purpureus* - a crop lost for Africa? Trop Plant Biol 3:123-135

(17) Maundu PM, Ngugi GW, Kabuye CHS (1999) Traditional food plants of Kenya. National Museums of Kenya, English Press, Nairobi

(18) Pengelly BC, Maass BL (2001) *Lablab purpureus* (L.) Sweet - diversity, potential use and determination of a core collection of this multi-purpose tropical legume. Genet Resour Crop Evol 48:261-272

(19) Rangan H, Carney J, Denham T (2012) Environmental history of botanical exchanges in the Indian Ocean World. Environ Hist 18:311-342

(20) Robertson CC (1997) Black, white, and red all over: Beans, women, and agricultural imperialism in twentieth-century Kenya. Agric Hist 71:259-299

(21) Robotham O, Chapman M (2016) Population genetic analysis of hyacinth bean (*Lablab purpureus* (L.) Sweet, Leguminosae) indicates an East African origin and variation in drought tolerance. Genet Resour Crop Evol (in press) DOI 10.1007/s10722-015-0339-y

(22) Sakthivelkumar S, Velayutham V, Karuppiah H, Arumugam M, Janarthanan S (2014) Analysis on the arcelin expression in bruchid pest resistant wild pulses using real time RT-qPCR. Indian J Exp Biol 52:1195-1200

(23) Sultana N, Ozaki Y, Okubo H (2000) The use of RAPD markers in hyacinth bean (*Lablab purpureus* (L.) Sweet) phylogeny. Bull Inst Trop Agric Kyushu Univ 23:45-51

(24) Venkatesha SC, Ganapathy KN, Byre Gowda M, Ramanjini Gowda PH, Mahadevu P, Girish G, Ajay BC (2013) Variability and genetic structure among hyacinth bean collections of India and their relationship with exotic accessions. Vegetos 26:121-130

(25) Verdcourt B (1970) *Lablab* Adans. Studies in the Leguminosae-Papilionoideae III. Kew Bull 24:409-411

(26) Wang ML, Morris JB, Barkley NA, Dean RE, Jenkins TM, Pederson GA (2007) Evaluation of genetic diversity of the USDA *Lablab purpureus* germplasm collection using simple sequence repeat markers. J Hortic Sci Biotechnol 82:571-578

Some aspects of biodiversity, applied genetics and agronomy in hyacinth bean (*Lablab purpureus*) research

by Vojislav MIHAILOVIĆ[1], Aleksandar MIKIĆ[1]*, Marina ĆERAN[1], Branko ĆUPINA[2], Vuk ĐORĐEVIĆ[1], Ana MARJANOVIĆ-JEROMELA[1], Sanja MIKIĆ[1], Vesna PERIĆ[3], Aleksandra SAVIĆ[1], Mirjana SREBRIĆ[3], Sreten TERZIĆ[1], Mirjana VASIĆ[1], Sanja VASILJEVIĆ[1] and Svetlana VUJIĆ[2]

Abstract:. Our intention was to give a very rough draft of 1) our contemporary knowledge on various aspects of the hyacinth bean (*Lablab purpureus* (L.) Sweet) biodiversity, 2) most important aspects of breeding this crop for forage, grain and biomass yield and ornamental purposes and 3) innovative approaches in its agronomy, such as intercropping with other legumes.
Key words: biomass, breeding, forage, genetic resources, grain, hyacinth bean, intercropping, *Lablab purpureus*, ornamentals

Introduction

Hyacinth bean (*Lablab purpureus* (L.) Sweet) is a well-known warm season annual legume, widely cultivated in many tropical and semi-tropical regions, such as Sub-Saharan Africa and the Indian subcontinent (7), as well as in numerous transitional climates towards the more moderate zones.

The genus *Lablab* Adans belongs to the sub-tribe *Phaseolinae* Bronn, the tribe *Phaseoleae* (Bronn) DC and the legume sub-family *Faboideae* Rudd. This genus is monospecific, with hyacinth bean as its only member and comprising three sub-species, namely:

1) subsp. *bengalensis* (Jacq.) Verdc. (syn. *Dolichos benghalensis* Jacq.);
2) subsp. *purpureus* (syn. *Dolichos hyacinth bean* L., *Dolichos purpureus* L., *Lablab leucocarpos* Savi, *Lablab niger* Medik. and *Lablab vulgaris* Savi);
3) subsp. *uncinatus* Verdc.

[1]Institute of Field and Vegetable Crops, Novi Sad, Serbia (aleksandar.mikic@ifvcns.ns.ac.rs)
[2]University of Novi Sad, Faculty of Agriculture, Department of Field and Vegetable Crops, Novi Sad, Serbia
[3]Maize Research Institute Zemun Polje, Belgrade, Serbia

Table 1. The structure of the hyacinth bean accessions in the portal GENESYS according to their country of origin (9)

Country of origin	Number of accessions	Country of origin	Number of accessions	Country of origin	Number of accessions
Angola	9	Indonesia	18	Rwanda	1
Argentina	3	Iran	1	Senegal	4
Australia	33	Israel	1	Serbia	16
Bangladesh	161	Italy	3	South Africa	18
Bhutan	4	Kenya	6	Spain	17
Bolivia	1	Korea, North	3	Sudan	6
Brazil	7	Laos	11	Swaziland	1
Cambodia	7	Lebanon	1	Taiwan	6
China	15	Madagascar	3	Tanzania	5
Colombia	7	Malawi	7	Thailand	81
Congo, DR	2	Malaysia	7	Togo	27
Cuba	2	Maldives	1	Tunisia	1
Denmark	1	Mali	1	Uganda	5
Ecuador	7	Mozambique	1	UK	1
Egypt	1	Myanmar	12	USA	4
Ethiopia	38	Nepal	12	USSR	7
Georgia	1	Nigeria	7	Uzbekistan	1
Germany	1	Oman	6	Vietnam	3
Guatemala	5	Pakistan	3	Zambia	9
Honduras	2	Peru	22	Zimbabwe	15
Hungary	6	Philippines	41	Total	1,345
India	64	Portugal	1		

Despite economic significance of hyacinth bean, rather little is known on the current status of its genetics resources in comparison to other annual legume crops. By this reason, we dared to venture and give a very rough draft of our contemporary knowledge on the hyacinth bean biodiversity and its various aspects.

Genetic resources

GENESYS. As a global portal to information about Plant Genetic Resources for Food and Agriculture, GENESYS represents a gateway from which germplasm accessions from diverse genebanks around the world can be easily found and ordered (9). It is the result of collaboration of Diversity International, on behalf of System-wide Genetic Resources Programme of the Consultative Group on International Agricultural Research (CGIAR), the Global Crop Diversity Trust and the Secretariat of the International Treaty on the Plant Genetic Resources for Food and Agriculture. Its databases list nearly 1,350 hyacinth bean accessions originating from more than 60 countries from all the continents (Table 1).

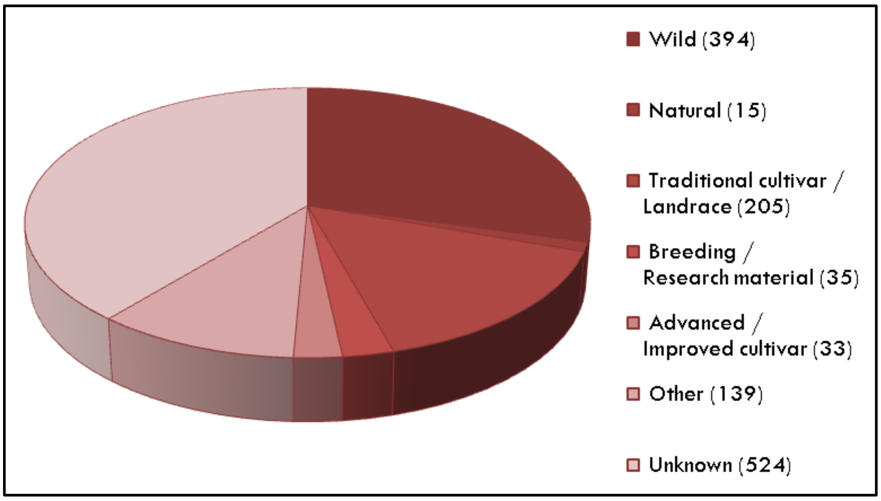

Figure 1. The structure of the hyacinth bean accessions in the portal GENESYS according to their status (9)

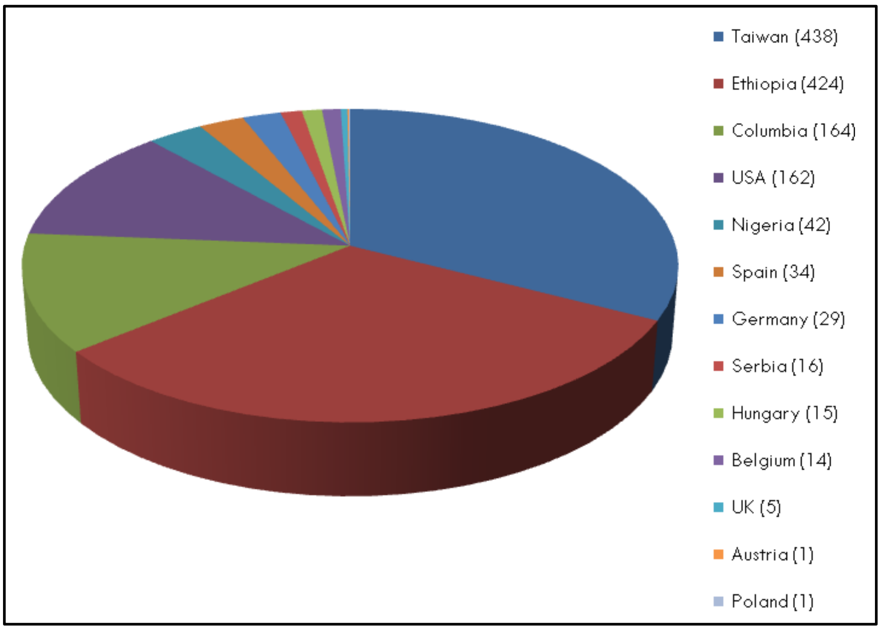

Figure 2. The structure of the hyacinth bean accessions in the portal GENESYS according to holding country (9)

Geographic origin. In a way, the structure of the hyacinth bean in GENESYS according to the country of origin provides a nice insight into history and current status of this crop. On one side, there is more than 320 accessions originated in a vast territorial continuum from India, via Bangladesh and Myanmar to Thailand, while, on the other side, Ethiopia and the sub-Saharan African countries are home to more than 130 accessions. This fits nicely into a suggested model of a two-step domestication of hyacinth bean, with Ethiopia as its centre of origin and primary growing, while India and Southeast Asia are the place of its secondary and definite place of cultivation (12).

According to some rather certain estimations, the worldwide hyacinth bean germplasm collection may contain 3,000 accessions. Thus, a detailed overview of numerous hyacinth bean accessions not covered by GENESYS is still missing, especially of those stored at the Bangladesh Agricultural Research Institute (BARI) and in China (23).

Status. The structure of the hyacinth bean accessions according to their status, as covered by GENESYS, demonstrates a remarkable proportion of wild ones and traditional cultivars and landraces, 394 and 205, respectively (Fig. 1). Such structure may be considered desirable for breeding purposes, since if offers a wealthy genepool of diverse desirable traits, in the same way like in many other annual legumes (16). On the other hand, a small number of both breeding and research material on one side and advanced and improved cultivars on another side, 35 and 33, respectively, shows a much slower rate of the applied genetic research in hyacinth bean in comparison to pigeonpea (*Cajanus cajan* (L.) Huth) and akin warm-season field legume crops. It also represents another reminder of the need for enhancing hyacinth bean research specifically answering the needs of African cropping systems (11). Numerous accessions of other (139) and, especially, unknown (524) status are also a significant resource of economically significant traits and characteristics in modern hyacinth bean improvement programmes.

Collections. With, unfortunately, hardly accessible data on the accessions preserved in several institutions in Bangladesh and China, the portal GENESYS provides an insight into a structure of the hyacinth bean collections in individual countries and their genebanks (Fig. 2). Again, the fact that Taiwan and Ethopia, with 438 and 424 accessions, respectively, are home to extensive hyacinth bean collections is another indicator of this crop's prominent role in the local agricultures of South Asia and Africa (21). The collections kept in Columbia comprise a large number of the hyacinth bean accessions introduced to the New World, while those in USA are important for their multidimensionally important structure and applied research.

Characterisation. The terms *characterisation* and *evaluation* are often either used as synonyms or are attributed different meanings. From the viewpoint of genetic resources, characterisation is as a description of the traits of non-metric and qualitative nature, controlled by one or few genes and almost at all not depending on environment. In a conventional sense, it is usually aimed at recording various traits related to plant anatomy and morphology (23).

Among these, there are those such as:

- bushy or vining growing habit,
- stem colour and determined / intermimined stem growth,
- leaf colour, shape, size and indentation,
- flower colour and inflorescence shape,
- pod position, shape and colour and
- seed colour and size.

Characterising anatomical and morphological traits in hyacinth bean is one of the basic procedures in pre-breeding. Molecular characterisation is aimed at casting more light onto the genomic and biochemical traits and has a distinctive development and protocols than those for morphology (6, 26).

Evaluation. Although frequently regarded as a synonym of the term *characterisation*, evaluation, from a more precise viewpoint of those who deal with plant genetic resources, may be defined as describing the characteristics that are usually of metric and quantitative nature, are controlled by many genes and are under a strong impact of climate and various organisms (24). Basically, evaluation covers the following:

- photoperiod response and length of growing season,
- timespan of flowering and seed maturity,
- yield of forage, grain, straw, aboveground and belowground biomass,
- yield of crude and digestible protein, oil and other nutrients and anti-nutritional factors,
- response to diverse forms of abiotic and biotic stress and
- agroeconomic parameters.

Evaluation is often the last step in completing a holistic overview and assesment of the potential of any accession in applied research.

Breeding for yield, quality and... ...Beauty

Forage yield. Developing hyacinth bean cultivars primarily for forage production (Fig. 3) requires a careful evaluation of the parental genotypes for hybridisation, emphasizing forage yield components, such as time span between sowing and full flowering, number of stems, lateral branches, internodes and photo-synthetically active leaves per plant (14). A peculiar significance is present in reliable seed yield per plant and per area unit, since it is essential for a market future of any novel cultivar. In the genotypes rather sensitive to photoperiod, like Royes and NI 470, high forage yield is annulled by inability to produce seed (Table 2).

Table 2. Results of a ten-year (2004-2013) evaluation of some economically important characteristics of the hyacinth bean collection of the Institute of Field and Vegetable Crops in Novi Sad

Accession name	Forage dry matter yield (t ha^{-1})	Forage crude protein yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Grain crude protein yield (kg ha^{-1})	Aboveground biomass nitrogen yield (kg ha^{-1})
ICPL 88020	1.8	405	719	180	65
Hunt	9.5	2138	930	233	342
Quantum	6.1	1373	1756	439	220
Quest	10.1	2273	2053	513	364
Royes	9.5	2138	0	0	342
NI 470	12.9	2903	0	0	464
MV 001	5.4	1215	1345	336	194
Novi Sad 1	4.9	1103	1123	281	176
Novi Sad 2	4.8	1080	1345	336	173
Novi Sad 3	5.3	1193	978	245	191
Beograd 1	5.2	1170	1078	270	187
Đurđevo 1	6.0	1350	1212	303	216
CAJ 012	9.4	2115	2210	553	338
Deep Purple	8.4	1890	2524	631	302
Pink Floyd	6.7	1508	1973	493	241
Purple Haze	9.9	2228	1492	373	356
$LSD_{0.05}$	2.9	653	155	39	104
$LSD_{0.01}$	4.0	900	200	50	144

Figure 3. *Purple Haze*, a hyacinth bean line for forage production in temperate regions, developed at the Institute of Field and Vegetable Crops in Novi Sad, Serbia

Figure 4. ***Deep Purple*****, a hyacinth bean line for immature pod and both immature and dry grain production in temperate regions, developed at the Institute of Field and Vegetable Crops in Novi Sad, Serbia**

Grain yield. An ideotype of a hyacinth bean cultivar targeting satisfactory and stable grain yield in any environment should comprise a neutral photoperiodical reaction and a prominent earliness combined with uniform and concurrent pod and grain maturity (Fig. 4). Among other characteristics are timespan from sowing to harvest, stem length, number of fertile nodes, pods and grains per plant and thousand grain mass (13).

Forage and grain quality. Hyacinth bean is rich in crude protein in both forage and grain dry matter, with the yields that may surpass 2100 kg ha^{-1} and even 400 kg ha^{-1} or 500 kg ha^{-1}, respectively (Table 2).

Green manure. If cut in full flowering and timely incorporated into the soil, the hyacinth bean aboveground biomass represent a high quality source of nitrogen, with a potential of more than 350 kg ha^{-1} of gradually releasing nitrogen (Table 2), with a long-term positive effect on subsequent crops and decreased or excluded need for mineral fertilisers.

Ornamental purposes. Hyacinth bean is one of the most beautiful cultivated legume species (15) and it is no wonder that there are breeding programmes aimed at developing cultivars solely for this use, informally called *beauty yield* (Fig. 5). In this case, one of the most important characteristics is prolonged flowering and increased presence of aromatic compounds in the nectaries.

Figure 5. ***Pink Floyd*****, an ornamental hyacinth bean line, developed at the Institute of Field and Vegetable Crops in Novi Sad, equally suitable for growing in village house gardens and sun-exposed terraces of city buildings**

Intercropping hyacinth bean with cereals, brassicas and other annual legumes

Intercropping is usually regarded as a practice of simultaneously cultivating at least two crops in the same field (27), without necessarily sowing or harvesting them together. It is one of the oldest cropping systems, especially by the first farmers in the world, in West Asia, ten millennia ago, where several initially domesticated plant species were sown and used together, prevalently in human diets (1). Intercropping has always been a part of diverse cropping systems worldwide, especially in Europe, with temperate annual legumes and cereals. However, this was significantly reduced by 'fossilising' agriculture with synthetic fertilisers and pesticides (10).

Today, annual legumes are intercropped in cold, temperate and warm climates, mostly with cereals (2, 20, 22, 25) and sporadically with brassicas (3). Intercropping annual legumes with perennial legumes for forage or with each other for both forage and grain production is a relatively novel agricultural practice and with extremely scarce available literature (4).

Why intercropping legumes with each other? Indeed, such an idea may cause an instinctive reaction of an unnecessary saturation of a field with two too similar species in so many ways. However, exactly in the fact that both intercrop components are more protein-rich than cereals, brassicas or some other crops is the point of proposing this novel practice. One of its concepts suggests that two legume species, if grown together, will surely produce forage dry matter with at least their average value of crude protein content, by all means higher in comparison to the traditional mixtures (8). A possibility of mutually negative influence, such as allelopathy, must not be neglected (18).

Establishing intercropping principles. The aforementioned issues had begun to be carefully and gradually formulated and, during the past decade, were finally articulated jointly by the Institute of Field and Vegetable Crops, the Faculty of Agriculture of the University of Novi Sad and the Maize Research Institute Zemun Polje in the form of the schemes developed specifically for intercropping annual legumes with each other, as well as with various cereal and brassica crops (Fig. 6). There have been defined four fundamental postulates (4, 18):

1) The components have to have the same time of sowing;

2) They need to have similar growing habit, such as stem length and/or stand height;

3) The components also have to be characterised with concurrent growth and development, regardless of the cultivating purpose, and thus being in an optimal stage either for cutting for forage or harvesting for grain production;

4) One component, referred to as a supporting crop, has to have a good standing ability, while another is susceptible to lodging and regarded as supported crop.

Determining intercrop groups and agronomic parameters. Following these rules, intercropping annual legumes with cereals, brassicas and other annual legumes was assessed in a series of field trials within three main groups:

1) Autumn- and spring-sown 'tall' cool season annual legume crops with poor standing ability, such as pea (*Pisum sativum* L.) and Hungarian (*Vicia pannonica* Crantz), common (*V. sativa* L.) and hairy (*V. villosa* Roth) vetches were intercropped with common wheat (*Triticum aestivum* L.), durum wheat (*Triticum durum* Desf.), barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.) and triticale (× *Triticosecale* Wittm. ex A. Camus.);

2) Autumn- and spring-sown 'short' cool season annual legume crops, where afila-leafed pea was a supporting crop for lentil (*Lens culinaris* L.), normal- and acacia-leafed pea, fenugreek (*Trigonella foenum-graecum* L.) and bitter vetch (*V. ervilia* (L.) Willd.);

3) Warm-season annual legume crops, where the lodging-suceptible hyacinth bean (*Lablab purpureus* (L.) Sweet) and several *Vigna* species were intercropped with sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.), rapeseed (*Brassica napus* L. var. *napus*), white mustard (*Sinapis alba* L.), pigeon pea (*Cajanus cajan* (L.) Huth.; Fig. 7),

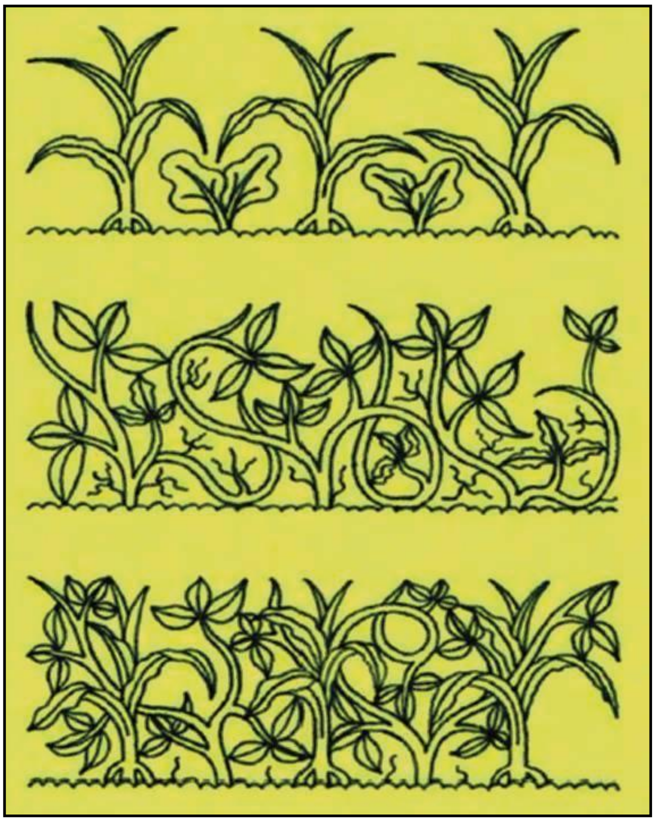

Figure 6. Some aspects of intercropping hyacinth bean: (top row) cereals, such as maize, have an excellent standing ability, but are easily infested by weeds, like in brassicas, such as rapeseed, or lodging-resistant legumes, such as soya bean; (middle row) hyacinth bean efficiently fights weeds, but heavily lodges, losing a great amount of protein-rich lower leaves and decreasing its photosynthetic efficiency; (bottom row) intercropping is beneficial for both, since weeds are suppressed and physiologically active leaves in hyacinth bean are preserved (18)

Figure 7. Intercropping hyacinth bean with pigeon pea forage production, Zemun Polje, northern Balkans, late July 2009

Figure 8. Intercropping hyacinth bean with soya bean for forage production, Zemun Polje, northern Balkans, late July 2009

Table 3. Forage dry matter yield (t ha^{-1}) and its land equivalent ratio (LER) in the intercrops of hyacinth bean and several spring-sown cereals, brassicas and annual legumes with good standing ability; average for two locations in northern Balkans, namely Rimski Šančevi and Zemun Polje, from 2009 to 2012 (unpublished data)

Supported crop	Supporting crop	Supported crop forage dry matter yield	Supporting crop forage dry matter yield	Total forage dry matter yield	LER
-	Maize	0.0	6.7	6.7	-
-	Sorghum	0.0	6.5	6.5	-
-	Rapeseed	0.0	3.4	3.4	-
-	White mustard	0.0	2.3	2.3	-
-	Pigeon pea	0.0	7.9	7.9	-
-	Soya bean	0.0	8.2	8.2	-
-	White lupin	0.0	6.4	6.4	-
Hyacinth bean	-	7.6	0.0	7.6	-
Hyacinth bean	Sorghum	4.3	4.2	8.5	1.21
Hyacinth bean	Maize	4.5	3.9	8.4	1.17
Hyacinth bean	Rapeseed	2.9	3.1	6.0	1.29
Hyacinth bean	White mustard	3.1	2.7	5.8	1.58
Hyacinth bean	Pigeon pea	4.3	4.6	8.9	1.15
Hyacinth bean	Soya bean	4.4	4.3	8.7	1.10
Hyacinth bean	White lupin	5.5	2.8	8.3	1.16
LSD$_{0.05}$			0.5		0.07

soya bean (*Glycine max* (L.) Merr.; Fig. 8) and white lupin (*Lupinus albus* L.).

Each intercrop component participated with 50% of its usual number of viable seeds per area unit. In other words, ordinary sowing rates of every intercrop component were strictly reduced by half, since doing the opposite, that is, sowing both intercrops at their usual full rates is unnecessarily excessive, with an insignificantly higher yield, and economically unjustified practice, since double seed costs. On the other side, our recommendation preserves the calculated sowing costs and may be an attractive model for the farmers worldwide as both feasible and economically reliable and attractive (8).

Hyacinth bean with cereals. The overall performance of intercropping hyacinth bean with warm-season cereals, such as sorghum and maize, may be characterised as rather well, with the average four-year forage dry matter yield 8.5 t ha^{-1} and 8.4 t ha^{-1}, respectively (Table 3). It proved more productive in comparison to the intercrops of maize with most *Vigna* species (20). Intercropping hyacinth bean with sorghum and maize represents an abundant and quality source of protein-rich feed, in the form of either forage dry matter or silage. A full compatibility in the time of sowing between hyacinth bean and sorghum or maize is another important advantage for introducing this practice into a wider forage production.

Hyacinth bean with brassicas. Since a shorter growing season of rapeseed and white mustard, their intercrops with hyacinth bean have lower forage dry matter yields in comparison to cereals or annual legumes (Table 3; 17). For this reason, such mixtures may be recommended mainly as a simple, cheap and fast solution easily fitting into majority of cropping systems.

Hyacinth bean with legumes. All three intercrops of hyacinth bean and other warm season annual legumes produced higher long-term average forage dry matter yields than their sole crops and in the previously conducted trials (5, 19). The land equivalent ratio values higher than 1 (Table 3) also justifies their reliability. This intercropping scheme may be perspective and requires more knowledge on forage quality, physiological parameters and undeground microbiological aspects.

Conclusions

A rather vast and still undersufficiently used genepool is the main tool in improving the hyacinth breeding and developing novel cultivars, adaptive to contrasting environments and suitable to be cultivated for various purposes, either as sole crops or in mixtures with cereals, brassicas and other annual legumes.

Verily, still much available and still much to do!

Acknowledgements

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References

(1) Abbo S, Lev-Yadun S, Gopher A (2010) Agricultural origins: Centers and noncenters; A Near Eastern reappraisal. Crit Rev Plant Sci 29 5:317-328

(2) Bedoussac L, Justes E (2010) The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. Plant Soil 330:19-35

(3) Cortés-Mora FA, Piva G, Jamont M, Fustec J (2010) Niche separation and nitrogen transfer in Brassica-legume intercrops. Ratar Povrt 47:581-586

(4) Ćupina B, Mikić A, Stoddard FL, Krstić Đ, Justes E, Bedoussac L, Fustec J, Pejić B (2011) Mutual legume intercropping for forage production in temperate regions. In: Lichtfouse E (ed) Sustainable Agriculture Reviewes 7, Springer Science+Business Media, Dordrecht, 347-365

(5) Ćupina B, Mikić A, Đorđević V, Perić V, Srebrić M, Mihailović V, Krstić Đ, Antanasović S (2013) Intercropping soya bean with other annual legumes for forage production. Legum Perspect 1:47

(6) Devaraj VR, Manjunatha NH (1999) Purification and characterization of a proteinase inhibitor from field bean, *Dolichos hyacinth bean perpureus* L. Journal Protein Chem 18:47-54

(7) D'sousa MR (2012) Biochemical characterization of abiotic stress response in *Dolichos hyacinth bean*. PhD Thesis. Bangalore University, Bangalore

(8) Duc G, Agrama H, Bao S, Berger J, Bourion V, De Ron AM, Gowda CLL, Mikić A, Millot D, Singh KB, Tullu A, Vandenberg A, Vaz Patto MC, Warkentin TD, Zong X (2015) Breeding annual grain legumes for sustainable agriculture: New methods to approach complex traits and target new cultivar ideotypes. Crit Rev Plant Sci 34:381-411

(9) GENESYS (2013-2015) *Lablab purpureus*. Bioversity International / Global Crop Diversity Trust / Secretariat of the International Treaty on the Plant Genetic Resources for Food and Agriculture. https://www.genesys-pgr.org

(10) Hauggaard-Nielsen H, Peoples MB, Jensen ES (2011) Faba bean in cropping systems. Grain Legum 56:32-33

(11) Maass BL, Knox MR, Venkatesha SC, Tefera TA, Ramme S, Pengelly BC (2010) *Lablab purpureus* - a crop lost for Africa? Trop Plant Biol 3:123-135

(12) Maass BL, Robotham O, Chapman MA (2016) Evidence for two domestication events of hyacinth bean (*Lablab purpureus* (L.) Sweet): a comparative analysis of population genetic data. Genet Resour Crop Evol (in press) DOI: 10.1007/s10722-016-0431-y

(13) Mihailović V, Mikić A, Vasiljević S, Milić D, Vasić M, Ćupina B (2005) Preliminary results of growing tropical and subtropical grain legumes in the Northern Balkans. Proceedings, 1st International Edible Legume Conference in conjunction with the IVth World Cowpea Congress (Papers), Durban, South Africa, 17-21 April 2005, 288-297

(14) Mihailović V, Mikić A, Vasiljević S, Milić D, Ćupina B, Krstić Đ, Ilić O (2006) Tropical legumes for forage. Grassl Sci Eur 11:306-308

(15) Mikić A (2015) All legumes are beautiful, but some legumes are more beautiful than others. Legum Perspect 8:26-27

(16) Mikić A, Mihailović V (2014) Significance of genetic resources of cool season annual legumes. II. Neglected and underutilised crops. Ratar Povrt 51:127-144

(17) Mikić A, Ćupina B, Mihailović V, Marjanović-Jeromela A, Antanasović S, Krstić Đ, Katanski S, Milošević B (2013) Intercropping spring-grown brassicas and legumes for forage production. Crucif Newsl 32:14-16

(18) Mikić A, Ćupina B, Rubiales D, Mihailović V, Šarūnaitė L, Fustec J, Antanasović S, Krstić Đ, Bedoussac L, Zorić L, Đorđević V, Perić V, Srebrić M (2015) Models, developments, and perspectives of mutual legume intercropping. Adv Agron 130:337-419

(19) Mikić A, Mihailović V, Vujić S, Ćupina B, Đorđević V, Tomičić M, Perić V (2015) Intercropping some warm season annual forage legumes with each other in temperate regions. Legum Groat Crop 2015:3:49-55

(20) Mikić S, Mikić A, Nastasić A, Mihailović V, Stojaković M, Katanski S, Mitrović B, Stanisavljević D (2013) *Amaizing* legumes: Aboveground biomass yield and quality in intercropping maize (*Zea mays*) with *Vigna* species. Legum Groat Crop 2016:2:143-149

(21) Murphy AM, Colucci PE (1999) A tropical forage solution to poor quality ruminant diets: A review of *Lablab purpureus*. Livest Res Rural Dev 11:2:16

(22) Ngongoni NT, Mwale M, Mapiye C, Moyo MT, Hamudikuwanda H, Titterton T (2007) Evaluation of cereal-legume intercropped forages for smallholder dairy production in Zimbabwe. Livest Res Rural Dev 19:129

(23) Pengelly BC, Maass BL (2001) *Lablab purpureus* (L.) Sweet - diversity, potential use and determination of a core collection of this multi-purpose tropical legume. Genet Resour Crop Evol 48:261-272

(24) Rai N, Singh PK, Verma A, Lal H, Yadav DS, Rai M (2008) Multivariate characterization of Indian bean [*Lablab purpureus* (L.) Sweet] genotypes. Indian J Plant Genet Resour 21:47-50

(25) Šarūnaitė L, Deveikytė I, Arlauskienė A, Kadžiulienė Ž, Maikštėnienė S (2013) Pea and spring cereal intercropping systems: Advantages and suppression of broad-leaved weeds. Pol J Environ Stud 22:541-551

(26) Wang ML, Morris JB, Barkley NA, Dean RE, Jenkins TM, Pederson GA (2007) Evaluation of genetic diversity of the USDA *Lablab purpureus* germplasm collection using simple sequence repeat markers. J Hortic Sci Biotechnol 82:571-578

(27) Willey R (1979) Intercropping - Its importance and research needs. 1. Competition and yield advantages. Field Crop Abstr 32:1-10

Morphological and molecular characterization of hyacinth bean (*Lablab purpureus* (L.) Sweet) accessions in Kenya

by Miriam G. KINYUA[1]*, Grace N. KISIRKOI[2], Anne W. MUIGAI[2], Grace KAMOTHO[3] and Eliezer KAMAU

Abstract: Lablab or hyacinth bean (*Lablab purpureus*) is a bean species which grows like a vine and produces seeds of variety of colours and beautiful fragrant purple or white flowers which attract insect and bird pollinators. It is a high grain-yielding, nitrogen fixing, dual purpose legume that improves soil fertility and some varieties can survive a dry spell. Lablab is grown in Eastern, Coast, Central and some Rift Valley parts of Kenya. It was important to characterize existing germplasm of hyacinth bean in Kenya to form an inventory as well as for preservation of diversity. Lablab accessions were assayed using 22 SSR markers, out of which 7 amplified and 5 were polymorphic. Accessions that visually withstood aphids (genotypes 12038 and 12230) recorded a high genetic distance of 0.750 between the aphid-susceptible, fast maturing DL002, showing suitability for gene mapping. Induced mutations of segregating hyacinth bean accessions increased genetic variability. Significant genetic distance was observed between the parent of the mutants and the mutants, demonstrating increased genetic variability hence increased gene pool for propagation of desired traits. This information is invaluable for introgression of aphid-resistance genes into hyacinth bean varieties.
Key words: genetic diversity, *Lablab purpureus*, polymorphic, SSR markers

[1]University of Eldoret, Eldoret, Kenya (mgkinyua@africaonline.co.ke)
[2]Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya
[3]Karatina University, Karatina, Kenya
[4]Kenya Agricultural and Livestock Research Organisation, Thika, Kenya

Characterization of aphid resistance

In the quest for plants with desirable traits, mutation induction techniques have been proven to be helpful sources of new genes as they increase genetic variability (1). Diversity in Kenyan hyacinth bean populations has been reported to be low (5, 8), necessitating the search for more diversity. This can only be achieved effectively if the existing diversity is first assessed and documented. Aphid resistance to Cow Pea Aphid (CPA) in cowpea (*Vigna unguiculata* (L.) Walp.) and groundnuts (*Arachis hypogaea* L.) has been developed before through mutation (5, 11). A core set is suggested for evaluation across target production environments and years to identify widely/specifically adapted and stable accessions to foster enhanced access and use of hyacinth bean germplasm (14). To develop the collection, the diverse germplasm need to be assembled and characterised.

Morphological traits assay of mutant accessions

The diversity of hyacinth bean germplasm developed through mutation techniques was assessed using morphological and molecular methods. An irradiated population at M3 was grown in the field at Thika, Kenya and morphological characters determined using the AVRDC descriptors. In the study, the mutant accession M24 was seen to be more resistant to aphid infestation than its parent DL002 (data not shown). This signifies a remarkable shift in genetic loci of coding regions of aphid resistance genes caused by induced mutation by gamma irradiation. This observation is in line with previous studies in which varieties resistant to the CPA were developed through mutation induction techniques (11).

SSR markers assay of selected mutant hyacinth bean accessions

Genetic diversity is the variety of alleles and genes that are present in a population. These alleles are reflected in morphological, physiological, and behavioural differences between individuals and whole populations (4). Physical isolation of accessions, individuals, and populations is an important influencing factor of genetic diversity (12). Human development of plants and animals also greatly influences genetic diversity (2). High genetic diversity between genotypes would allow for selection among them for CPA resistance or tolerance genes. It is also possible to carry on with mapping for such populations. Karuri (7) found that morphological characters could not reliably classify genotypes of sweet potatoes (*Ipomoea batatas* (L.) Lam.) based on resistance to sweet potato virus disease and dry matter content after using 6 SSR primers to further characterize 89 morphologically characterized germplasm. It would, therefore, require application of more strategies in identification of appropriate germplasm for improvement. The increase in genetic distance between the parent of the mutant accessions (DL002) and the mutant accessions (genotypes M24, M25, M15 and M31) which ranges from 0.500 to 1 in this study, indicated that gamma irradiation had a significant impact on genetic variability.

Genetic distance is a reflection of ancestral gene flow between the accessions and it provides an estimate of the time that has passed since the populations began existing as a cohesive unit (12). The genetic distance between the parent DL002 and its M_2 progeny M15 was 1.000, which is the highest showing that these two mutant progenies of DL002 became genetically different based on the loci assayed by the specific SSR markers under study following induced mutation by gamma irradiation. This is in line with Arabi, (1) who found that induced mutation resulted in increased genetic variability.

Microsatellite markers are locus-specific and co-dominant (12). Typically, single locus is amplified resulting in one or two bands depending on the homozygous or hetero-zygous states in diploid organisms (16). Allelic polymorphism at SSR locus is caused mainly by a variable number of tandem repeats (2). These SSRs are quite useful because they are abundant, short, and easy to amplify, are evenly distributed in the genome, have high levels of variability, and allow ease of assessing size variation by PCR with pairs of flanking primers (12).

Materials and method for molecular characterisation

Young leaves from the planted seedlings of hyacinth bean accessions from the Gene Bank of Kenya and collections from Lablab growing areas were harvested. The DNA was extracted by a modified CTAB method, using 22 microsatellite primers in total and with 7 of them for amplifying the genomic DNAs from the accessions. Eleven accessions were selected from previous morphological characterization of genebank accessions and segregating mutant accessions in M_2 generation.

Microsatellite marker assays

From 22 selected, seven SSR markers of the hyacinth bean accessions U10419, BMD 46, PVAG004, BQ481672, CP5, CP6, and CP7 (Table 1, Fig. 1) were amplified and all but CP5 and CP7 were polymorphic.

Polymorphism is a reflection of DNA variation (3, 10, 12) and its visualization is enabled by electrophoresis-based methods. Monomorphism indicates a lack of variation at a specific DNA locus at the point where the primer under study annealed and amplified (4). Polymorphism may uncover DNA variation at more than one locus (3, 12), depicted by multiple bands on genotype lanes after electrophoresis as evidenced by primers BMD 46, PVAG004 and CP6.

Table 1. SSR primers used in molecular characterization of hyacinth bean accessions

DNA name	Forward primer	Reverse primer	Species*	Reference
U10419	TCCCACGATCTGTTTGAGC	CTGCATTAGTTTTTGTTTAGATTG	*P. vulgaris*	Gowda 2010
BQ481672	ATTTTTGGTGTGCTTTCGTTTAT	TCCGTGGCTTGCTGATTAG	*P. vulgaris*	Gowda 2010
CP5	AGCTCCTCATCAGTGGGATG	CATTGCCACCTCTTCTAGGG	*Vigna sp.*	Gowda 2010
CP6	GGGGGAGAGAGAGAGAGAGAGA	TTCTCCCCCTATGTGGACCT	*Vigna sp*	Gowda 2010
CP7	GAGGAGGAGGAGGATCTGACA	CTTCTGCAGGCTTGTGGTTC	*Vigna sp*	Gowda 2010
PVAG004	TTGATGACGTGGATGCATTGC	AAAGGGCTAGGGAGAGTAAGTTGG	*P. vulgaris*	Shivachi 2010
BMD46	GGCTGACAACAACTCTGCAC	CTGGCATAGGTTGCTCCTTC	*P. vulgaris*	Shivachi 2010

**P. vulgaris - Phaseolus vulgaris* L., common bean

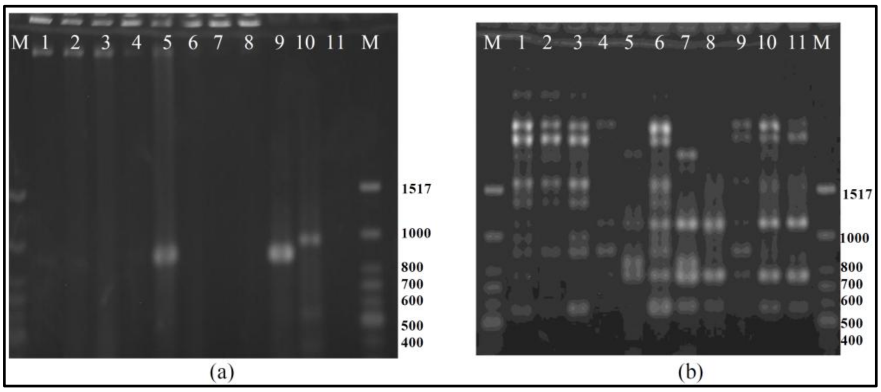

Figure 1. Gel picture indicating polymorphism revealed by the cowpea primer CP 5 (a) and the common bean primer BMD 46 (b); lanes labelled 1-11 contain DNA from plant genotypes 1-11 (from left to right); these lanes are flanked by 100bp DNA ladder on lane marker (M) manufactured by New England BioLabs®; key: 1-12038, 2-12230, 3-11716, 4-11735, 5-11736, 6-M24, 7-M25, 8-DL002, 9-M15, 10-M31, 11-11723

The genetic distance between M31 and 11723 was 0.000, implying that they were completely similar with respect to the SSR markers employed (data not shown). The bootstrap value of these genotypes (M31 and 11723) was the highest (56%) and the only significant one (> 50%) showing that these genotypes were significantly similar. Accessions 11736 and 12038, 11736 and M31, 11736 and 11723; and M15 and DL002 all had a genetic distance of 1.000 implying that they are entirely different genotypes. This observation is in line with a past study which used SSR markers to characterize Kenyan sweet potato genotypes for resistance to sweet potato virus disease (SPVD) and high dry matter content by Karuri *et al.* (7). In that sweet potato study, the phylogenetic tree clustered 89 genotypes into 2 clusters and 5 sub-clusters within which otherwise morphologically different accessions were classified in the same sub-cluster. In our hyacinth bean study, the phylogenetic tree clustered the tested genotypes into 2 main clusters (Fig. 2). The accessions from Taita Taveta, 12038, 12230 and 11735 each classified into different sub-clusters, even though they were collected from the same location. This is indicative of genetic dissimilarity among the tested genotypes from Taita Taveta. The resistant ones 12038 and 12230 were classified under the same tree sub-cluster on the phylogenetic tree suggesting their genetic relatedness.

From the phylogenetic tree generated using the data obtained through assays by polymorphic SSR markers, the co-mmercialized fast maturing but susceptible DL002 was found significantly different from 12038 and 12230, the two resistant ones (Fig. 3). This observation singles DL002 out as a potentially suitable parent for gene mapping to identify aphid resistance genes. Recent molecular-based studies on hyacinth bean improvement in India on local and exotic germplasm faced limitations due to lack of molecular markers developed specifically for this plant, hence the use of markers developed from genetically related legumes such as common beans and *Vigna* species (3). This was the approach adopted by the present study and 32% of the primers used amplified with 23% being polymorphic indicating DNA sequence similarities between these legumes and hyacinth bean. The primers used in the study were from related but more studied legumes such as common bean, cowpea and soybean (*Glycine max* (L.) Merr.) the most informative in terms of PIC being from *P. vulgaris* and *V. unguiculata*. The difference in species of the soybean aphid, *Aphis glycines* Matsumura, and the cowpea aphid, *Aphis craccivora* C. L. Koch may have contributed to the differences in loci conferring aphid resistance. Marker CP6 uncovered more alleles in the accessions of Kenyan origin than in the accessions of Indian origin. The SSR marker BMD 46 was the most informative giving a PIC of 0.8 and revealing gene diversity of 0.83 between the 11 selected genotypes for molecular characterisation (Table 2). It was followed closely by PVAG004 with a PIC of 0.76 and revealing 0.79 gene diversity. CP6, BQ 481 and U10419 had a PIC of 0.48, 0.32 and 0.25; and revealing gene diversity of 0.56, 0.40 and 0.30 respectively between the 11 genotypes.

The amplification and polymorphism of these SSR primers derived from *P. vulgaris* SSR markers indicates a similarity in the genome at the loci that amplified and will be helpful towards the development of the hyacinth bean genetic linkage map.

The maximum genetic distance value of 1.000 implies that the two populations with this genetic distance share no alleles at any loci. This is in line with observation made by Arabi (1), that in germplasm where genes conferring traits of interest have not been found, mutation induction techniques are valuable in heightening the genetic variability.

Table 2. Polymorphism, diversity, and frequency revealed by five markers in 11 hyacinth bean accessions

Marker	Major allele frequency	Sample size	Allele number	Genetic diversity	PIC
BMD46	0.27	11	7	0.83	0.80
BQ481	0.73	11	2	0.40	0.32
PVAG004	0.27	11	6	0.79	0.76
CP6	0.55	11	3	0.56	0.48
U10419	0.82	11	2	0.30	0.25
Mean	0.53	11	4	0.58	0.52

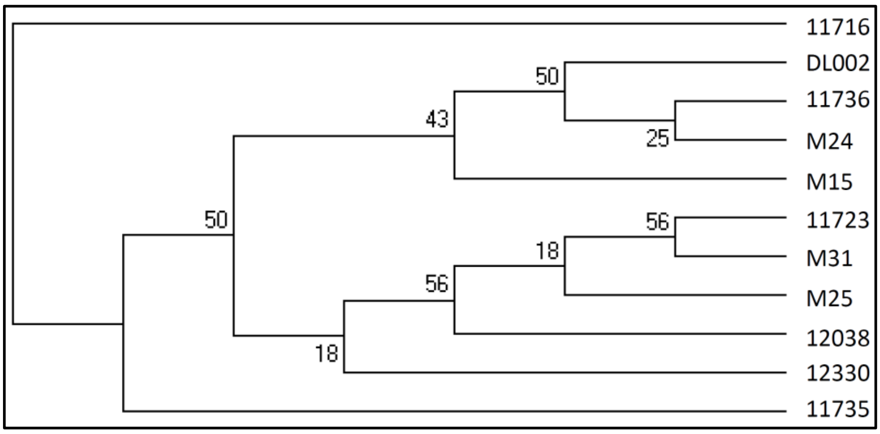

Figure 2. Phylogenetic tree showing hyacinth bean accessions selected for SSR characterization; origin of accessions: 11716-Kwale, DL002-Mutant parent, 11736-Kilifi, M24-Mutant, M15-Mutant, 11723-Nairobi, M31-Mutant, M25-Mutant, 12038-Taita Taveta, 12330-Taita Taveta, and 11735-Taita Taveta

Conclusion

The SSR markers used were able to indicate diversity of the accessions of hyacinth bean tested. Information from this study can be used to select lines for improvement purposes.

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References

(1) Arabi M (2004) Durable resistance to net blotch and agronomic performance in some barley mutants. J Genet Breed 58:225-232

(2) Freyre R, Skroch P, Geffroy V, Adam-Blondon A, Shirmohamadali A, Johnson W, Llaca V, Nodari R, Pereira P, Tsai S, Tohme J, Dron M, Nienhuis J, Vallejos C, Gepts P (1998) Towards an integrated linkage map of common bean for development of a core map and alignment of RFLP maps. Theor Appl Genet 97:847-856

(3) Gowda B (2009) Genetic enhancement of Dolichos bean through integration of conventional breeding and molecular approaches. University of Agricultural Sciences, Bangalore

(4) Innes J (2004) Molecular marker techniques for crop improvement. In: Course Manual, 4-63

(5) Kamau EM, Kinyua M, Kiplagat O, Gohole L (2011) Gamma radio sensitivity determination for hyacinth bean (*Lablab purpureus*) bean. Plant Mut Rep 2:3

(6) Kamotho GM, Kinyua MG, Muasya R (2015) Evaluation of performance of hyacinth bean (*Lablab purpureus* (L.) Sweet) under different agro-ecological environments in Kenya. Res J J Agric 2:9:1-11

(7) Karuri H, Ateka M, Amata R, Nyende B, Muigai A (2009) Morphological markers cannot reliably identify and classify sweet potato genotypes based on resistance to sweet potato virus disease and dry matter content. J Appl Biosci 15:820-828

(8) Kimani EN, Wachira FN, Kinyua MG (2012) Molecular diversity of Kenyan hyacinth bean (*Lablab purpureus* (L.) Sweet) accessions using amplified fragment length polymorphism markers. Am J Plant Sci 3:313-321

(9) Kinyua M, Orwa D, Kimani E, Kamotho G (2008) Survey of hyacinth bean (*Lablab purpureus*) production systems, utilization, marketing and the collection and characterization of germplasm in Kenya. Proceedings, International Dolichos Meeting, Arusha, Tanzania, 8 March 2008

(10) Kisirkoi GN (2012) Morphological and simple sequence repeat marker characterization of *Lablab purpureus* accessions for aphid resistance. MSc Thesis. Jomo Kenyatta University of Agriculture and Technology, Juja

(11) Odeigah PGC, Osanyinpeju AO, Myers GO (1998) Induced mutations in cowpea, *Vigna unguiculata* (Leguminosae). Rev Biol Trop 46:579-586

(12) Register J (2001) Using molecular markers in plant genetics research, unlocking genetic potential for increased productivity. Mol Marker 5:1-7

(13) Shivachi A, Kinyua MG, Kiplagat KO, Kimurto PK (2012) Cooking time and sensory evaluation of selected dolichos (*Lablab purpureus*) Genotype. Afr J Food Sci Technol 3

(14) Vaijayanthi PV, Ramesh S, Byre M, Gowda Mohan Rao A, Kerth CM (2015) Development of core sets of hyacinth bean (*Lablab purpureus* L. Sweet) germplasm. J Crop Improv 29:405-419

(15) Wang D, Shi J, Carlson S, Cregan P, Ward R, Diers B (2003) A low-cost, high-throughput polyacrylamide gel electrophoresis system for genotyping with microsatellite DNA markers. Crop Sci 43:1828-1832

(16) Wang D, Clarice M, Difonzo C, Zhang G, Liu M, Yang Z (2010) Markers for aphid resistance germplasm in soybean plants. U.S. Patent No. 8, 227, 662. U.S. Patent and Trademark Office, Washington

Hyacinth bean (*Lablab purpureus*): An adept adaptor to adverse environments

by V. Rangaiah DEVARAJ[1]* and Myrene R. D'SOUZA[2]

Abstract: Survival and distribution of plants under diverse climatic conditions, including high temperature, salinity, and drought are determined by their genetic and biochemical ability to respond to environmental cues and adapt to newer conditions. Lablab (*Lablab purpureus*) has remarkable physiological and morphological traits to adapt to a range of abiotic stresses. Its robust antioxidant system comprising of antioxidants, antioxidant enzymes, various osmoprotectants and transporters have jointly contributed to remarkable tolerance to drought, salinity and high temperature. Biochemical basis of this tolerance in terms of markers of oxidative stress and/or tolerance is reviewed herein.

Key words: antioxidant enzymes, anti-oxidants, drought, high temperature stress, hyacinth bean, oxidative stress, salinity, tolerance

Figure 1. The hyacinth bean variety HA-4: (left) in the stages of flowering and fruiting; (right) seeds

Introduction

Droughts, extremes of temperature and salinity stress are major causes of agricultural productivity losses. Many wild and cultivated plants are endowed with remarkable genetic resource to cope up with these adverse physical environmental conditions. These genes associated with stress tolerance help to alter the physiology of the plants under stressful conditions, albeit temporarily, up to a certain tolerable levels. Abiotic stresses such as drought, salinity, and high temperature in plants induce oxidative stress due to production of reactive oxygen species (ROS) beyond the scavenging capacity of the plants (6, 14). However, plants resistant to these stresses have evolved battery of antioxidants, antioxidant enzymes, and other components to safeguard the cellular macromolecules against oxidative damages, and maintain cellular homeostasis (8, 9). Over the last two decades, the physiology of stress response or tolerance has been extensively investigated in wide variety of crop plants. A good number of genes encoding components of antioxidant system, ion transport, and metabolism have been tested in transgenic crops (15, 16, 17). Despite partial success, the major limiting factor appears to be multigenic aspect of stress physiology/tolerance (11). Recently, functional genomic studies have identified more candidate genes associated with stress tolerance, which may throw more light on the stress tolerance physiology (7, 13, 18).

Results

Hyacinth bean, *Lablab purpureus* L., has emerged as an ideal crop in rain deficient and low fertile areas due to its proven ability to survive under relatively harsh environments (12, 19). Traditional knowledge of its drought tolerance was tested in 10-days old seedlings of an authentic genotype HA-4 (Fig. 1) for 8 days after withholding water (2). Although stress caused apparent growth reduction, elevated levels of oxidative stress markers, H_2O_2, glutathione, malon-dialdehyde, proline, ascorbic acid, total phenols, and total soluble sugars indicated physiological alterations contributing to stress tolerance (Table 1). While antioxidant enzymes, peroxidase (POX), and glutathione reductase (GR) were elevated, catalase (CAT) declined with time. Further, metabolic enzymes β-amylase and acid phosphatase activities were enhanced in both leaves and roots. The plant showed ability to rehydrate and grow upon re-watering (Fig. 2), and levels of antioxidant components correlated with drought tolerance of the plant (2). Salinity stress in the hyacinth bean HA-4 cultivar in 10-days old seedlings (100 mM NaCl - 500 mM NaCl) over 72 h also resulted in similar physical changes and physiological parameters such as antioxidants and enzymes (1). Particularly, antioxidant enzymes, POX and GR activities, and CAT changed in concentration and time dependent manner in leaves. Metabolic enzymes β-amylase and acid phosphatase changed in contrasting manner, with elevated amylase and decreased phosphatase. Hyacinth bean showed reasonable tolerance up to 300 mM NaCl, with better values in leaves than roots (1).

[1]Bangalore University, Central College, Department of Biochemistry, Bengaluru, India (devaraj@bub.ernet.in)
[2]Mount Carmel College, Department of Chemistry, Bangalore, India

Table 1. Levels of stress markers in hyacinth bean under drought and salinity stress (1, 2)

Parameter	Drought (8 DAS)		Salinity (300 mM 72 h)	
	Control	Stress	Control	Stress
H_2O_2 (μg g^{-1} FWt)	109.73 ± 9.8	194.5 ± 9.1	8.61 ± 0.4	32.9 ± 1.7
GSH (μg g^{-1} FWt)	373.4 ± 5.1	461.3 ± 3.8	26.1 ± 4.8	150.9 ± 9.3
Ascorbate (μg g^{-1} FWt)	42.44 ± 4.0	59.73 ± 2.6	121.4 ± 7.7	278.0 ± 14.6
Proline (μg g^{-1} FWt)	601.0 ± 12.2	983.3 ± 8.3	0.71 ± 0.1	1.21 ± 0.08
MDA (mmol g^{-1} FWt)	5.29 ± 0.49	9.38 ± 0.61	7.88 ± 0.8	16.10 ± 0.8
Total soluble sugars (μg g^{-1} FWt)	11.67 ± 0.47	20.13 ± 0.38	20.77 ± 1.4	19.67 ± 0.7
Total phenols (μg g^{-1} FWt)	2.07 ± 0.23	4.55 ± 0.31	2.12 ± 0.06	2.63 ± 0.01

Figure 2. Effect of drought on hyacinth bean plants: (left) 6 DAS; (right) 5 days after recovery

Effect of high temperature (40 °C for 5 h) and salinity stress (100 mM) in hyacinth bean acclimatized at 35 °C for 2 h and non acclimatized seedlings was studied in 5-day old seedlings. Stress/tolerance indicators were quantified under stress and after 3-days of recovery. While physical parameters RWC and dry weight declined under stress, antioxidants GSH, ASC, and osmolytes, proline and total soluble sugars were elevated under direct stressing as well as stressing after acclimation. Similar pattern was observed for antioxidant enzymes, GR and POX, and metabolic enzymes invertase and β-amylase. The results indicated that heat acclimation improved performance against heat stress, but not against salt stress (3).

Discussion

As salinity and drought cause osmotic stress, response of hyacinth bean to these stresses therefore are similar, although the overall response to drought is more complex than ionic and osmotic homeostasis observed for salinity. Dehydration stress-induced ROS generation occurs via electron transport reactions in mitochondria and chloroplasts. ASC and GSH are key components of nonenzymatic antioxidant system in hyacinth bean contributing to scavenging of ROS (1, 2). Parallel elevation of these two antioxidants under drought, salinity, as well as high temperature stress suggests efficient operation of GSH-ASC cycle. Tolerance to dehydration is partly due to overproduction of osmolytes, proline and soluble sugars (10). Synthesis of proline bears a direct correlation with carbohydrate levels. The observed elevation of TSS in hyacinth bean indicated the prevalence of such a correlation. Elevated levels of TSS are important for energy production, stabilization of cellular membranes, maintenance of turgor, and signaling, which altogether accounts for tolerance to dehydration stress. Phenols and polyamines also contributed to tolerance in hyacinth bean. While phenols protect the cells from potential oxidative damage and increase the stability of cell membrane, polyamines are known to prevent water loss by inducing calcium mediated closure of K^+ inward rectifier channels. Elevated levels of spermidine under drought and protective effect of exogenous spermidine substantiated this fact (4, 5).

Antioxidant enzymes are key players in positive adaptation of the plant to abiotic stress (14). H_2O_2 produced in hyacinth bean under abiotic stress is effectively detoxified by APX and POX. An elevated level of GR activity is suggested to provide the reductant (reduced ASC) necessary for POX to reduce H_2O_2 under drought stress. Although many plants employ CAT for H_2O_2 reduction, hyacinth bean preferentially employs POX. This apart, enzymes like polyphenol oxidase (PPO) and β-amylase, and invertase have considerable role in abiotic stress tolerance in hyacinth bean (2).

Conclusion and future prospects

From the apparent stress response indicators evaluated under abiotic stresses mentioned above, it is concluded that hyacinth bean is a versatile crop adaptable to diverse climatic conditions. This adaptation is due to the battery of genes coding for components of redox homeostasis. Although few stress-specific gene functions have been characterized, functional genomic studies have indicated greater genetic resource to cope with variety of stress. Genome wide analysis and/or sequencing of the genome of hyacinth bean would throw more light on specific players at molecular level.

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References

(1) D'souza MR, Devaraj VR (2010) Biochemical responses of hyacinth bean (*Lablab purpureus*) to salinity stress. Acta Physiol Plant 32:341-353

(2) D'souza MR, Devaraj VR (2011) Specific and non-specific responses of hyacinth bean (*Dolichos hyacinth bean*) to drought stress. Indian J Biotechnol 10:130-139

(3) D'souza MR, Devaraj VR (2013) Induction of thermotolerance through heat acclimation in hyacinth bean (*Dolichos hyacinth bean*) Afr J Biotechnol 12:5695-5704

(4) D'souza MR, Devaraj VR (2015) Pre-treatment with spermidine reverses inhibitory effects of salt stress in hyacinth bean (*Lablab purpureus*). J Chem Pharm Res 7:504-509

(5) D'souza MR, Kokila S, Devaraj VR (2014) Polyamine levels in leaves of hyacinth bean (*Lablab purpureus*) and their relation to drought-tolerance. World Appl Sci J 32:2398-2402

(6) Foyer CH, Noctor G (2005) Oxidant and antioxidant signalling in plants: a re-evaluation of the concept of oxidative stress in a physiological context. Plant Cell Environ 28:1056-1071

(7) Golldack D, Li C, Mohan H, Probst N (2014) Tolerance to drought and salt stress in plants: Unraveling the signaling networks. Front Plant Sci 5:151

(8) Hasanuzzaman M, Nahar K, Gill SS, Fujita M (2013) Drought stress responses in plants, oxidative stress, and antioxidant defense In: Tuteja N, Gill SS (eds) Climate Change and Plant Abiotic Stress Tolerance. Wiley-Blackwell, 209-250

(9) Hussain K Farrukh Nisar M, Abdul Majeed, Nawaz K, Hayat Bhatti K, Shahid Afghan S, Aamir Shahazad A, Zia-ul-Hussnian S (2010) What molecular mechanism is adapted by plants during salt stress tolerance. Afr J Biotechnol 9:416-422

(10) Khan MS, Ahmad D, Adil Khan M (2015) Utilization of genes encoding osmoprotectants in transgenic plants for enhanced abiotic stress tolerance. Electron J Biotechnol 18:257-266

(11) Kikuchi A, Huynh HD, Endo T, Watanabe K (2015) Review of recent transgenic studies on abiotic stress tolerance and future molecular breeding in potato. Breed Sci 65:85-102

(12) Maass BL, Angessa TT, Ramme S (2010) Lablab purpureus - A crop lost for Africa? Trop Plant Biol 3:123-135

(13) Mickelbart MV, Hasegawa PM, Bailey-Serres J (2015) Genetic mechanisms of abiotic stress tolerance that translate to crop yield stability. Nat Rev Genet 16:237-251

(14) Miller G, Suzuki N, Ciftci-Yilmaz S, Mittler R (2010) Reactive oxygen species homeostasis and signalling during drought and salinity stresses. Plant Cell Environ 33:453-467

(15) Mittler R, Blumwald E (2010) Genetic engineering for modern agriculture: challenges and perspectives. Annu Rev Plant Biol 61:443-462

(16) Munns R (2005) Genes and salt tolerance: Bringing them together. New Phytol 167: 645-663

(17) Qin F, Shinozaki K, Yamaguchi-Shinozaki K (2011) Achievements and challenges in understanding plant abiotic stress responses and tolerance. Plant Cell Physiol 52:1569-1582

(18) Prasch CM, Sonnewald U (2015) Signaling events in plants: Stress factors in combination change the picture. Environ Exp Bot 114:4-14

(19) Yao L-M, Wang B, Cheng L-J, Wu T-L (2013) Identification of key drought stress-related genes in the hyacinth bean. PLoS ONE 8:e58108

Observations on pests and diseases in *Lablab purpureus* in Nigerian northern Guinea savanna

by Sylvester U. EWANSIHA[1]*, Shirley A. TARAWALI[2] and Uchechukwu F. CHIEZEY[3]

Abstract: Many pests and diseases seem to affect hyacinth bean (*Lablab purpureus*). The objective was to identify the various pests and diseases that affect hyacinth bean and measure the severity of disease damage. Various insect pests including *Ootheca mutabilis*, *Podagrica uniforma*, *Monolepta goldingi*, *Lema cephalotes*, *Nematocerus acerbus* and *Anoplocnemis curvipes,* fungal diseases including *Colletotrichum* spp., *Curvularia* spp., *Rhizoctonia* spp. and *Helminthosporium* spp., and a parasitic plant, *Cassytha filiformis*, were found on hyacinth bean. With regular use of insecticides and fungicides, severity ranged from nil to moderate. Plant growth, biomass, pod and seed yield were all affected. These variables had negative and significant relationship with disease severity. It was clear that pests and diseases can constitute a serious setback to the production of hyacinth bean but cultural practices with moderate use of pesticides may be able to reduce the problem.

Key words: cultural control, disease, insect pest, hyacinth bean, pesticide

Lablab (*Lablab purpureus* (L.) Sweet) is a multipurpose crop used for food, feed, soil improvement, soil protection and weed control. It was one of the several candidate herbaceous legumes evaluated at the International Institute of Tropical Agriculture (IITA) and International Livestock Research Institute (ILRI) in Nigeria, for soil improvement, weed control and crop-livestock production potentials (3, 4, 5). During the period of evaluation a complex of pests and diseases were observed on hyacinth bean that necessitated the use of insecticides and fungicides both in the wet and dry seasons. This paper reports the observations made on the pests and disease encountered during this study.

Forty six accessions of hyacinth bean were evaluated at the research field of the Institute for Agricultural Research (IAR), Samaru, Zaria in the northern Guinea savanna of Nigeria to identify accessions with the potential to contribute to grain or forage production and those with the potential for multiple uses (4). Insect pests and diseases affected the hyacinth bean plants right from the planted seeds through the emerging seedlings and vegetative stage to podding. Young millipedes attacked planted seeds and seedlings. Plant samples suspected to have fungal disease were taken to the IAR pathology laboratory for diagnosis. The insect samples collected at 4 weeks after planting and insect larvae at 18 weeks after planting were also sent for diagnosis.

Table 1. Disease severity in *Lablab purpureus* accessions grown at Samaru in the northern Guinea savanna of Nigeria

Accession	8 WAP†	12 WAP	Accession	8 WAP†	12 WAP
BARSDI	4	9	PI 387994	21	15
Grif12293	4	0	PI 388003	20	13
Grif1246	13	4	PI 388012	19	14
Grif969	27	30	PI 388013	16	8
Standard1	13	9	PI 388017	22	20
ILRI 4612	13	6	PI 388018	25	25
ILRI 6930	0	9	PI 388019	32	15
ILRI 7279	8	4	PI 392369	23	9
ILRI 730	9	9	PI 401553	28	15
ILRI 7403	14	0	PI 416699	13	10
NAPRI2	13	0	PI 439586	19	24
PI 164302	13	0	PI 509114	15	9
PI 164772	19	15	PI 532170	13	13
PI 183451	13	23	PI 542609	13	10
PI 195851	20	17	PI 555670	19	12
PI 284802	25	23	PI 596358	28	23
PI 288466	21	16	Standard 2	20	9
PI 288467	22	20	NAPRI3	9	10
PI 322531	23	12	TLN13	10	9
PI 337534	15	9	TLN29	9	0
PI 338341	17	15	TLN6	9	0
PI 345608	36	26	TLN7	4	0
PI 346440	15	15	TLN9	13	0
Mean	16	12	Mean	16	12
SE	5.5	5.0	SE	5.5	5.0

†Values are given in arcsine; WAP: weeks after planting

[1]University of Benin, Faculty of Agriculture, Department of Crop Science, Benin City, Nigeria (sylvester.ewansiha@uniben.edu)
[2]International Livestock Research Institute, Nairobi, Kenya
[3]Ahmadu Bello University, Institute for Agricultural Research, Department of Agronomy, Zaria, Nigeria

Figure 1. Insect damage to the leaves of *Lablab purpureus*, accession PI 532172, in Samaru, the northern Guinea savannah of Nigeria)

Foliage insects included *Ootheca mutabilis* (Sahlb.), *O. bifrons* (Labois.), *Podagrica uniforma* (Jac.), *Monolepta goldingi* (Bryant), *M. nigeriae* (Bryant), *Lema cephalotes* (Lac.) and leaf miners. *Nematocerus acerbus* (Faust) and *Silidieus apicalis* (Waterh.) on stems were identified. Pod-sucking insects observed included *Anoplocnemis curvipes* (F.) and *Cletus notatus* (Thunberg). Larvae of *Helicoverpa armigera* (Hübner) at different stages were found eating the pods. Aphids were observed on whole plants and were common in both wet and dry seasons.

Fungal diseases identified were those caused by *Colletotrichum* spp., *Curvularia* spp., *Rhizoctonia* spp. and *Helminthosporium* spp. Disease severity was recorded at 8 and 12 weeks after planting, prior to spraying with fungicides each time. It was measured by scoring on the scale 0, 5, 10, 25, 75, 100 and this represented the extent of damage on affected plant parts recorded along two middle rows of a plot of four rows with each row separated by 75 cm. Most damage (above 25% severity) was observed for PI 345608, PI 388019, PI 596358, PI 401553, Grif 969, PI 388018 and PI 284802 at each time (Table 1). At 8 weeks after planting, one accession (ILRI 6930) had no disease incidence and eight accessions had less than 10% disease severity. At 12 weeks after planting, unaffected accessions increased to eight while 13 accessions had less than 10% disease severity. The remaining accessions had between 10 and 24% disease severity. This indicates that some level of control was achieved with fungicide use. A particular accession, PI 532170, was noted for being highly susceptible to attack by insect pests both on the pods and leaves (Fig. 1). This accession has been described as good for vegetable use (5).

A parasitic weed, *Cassytha filiformis* (L.) was also observed growing on hyacinth bean plants.

It was observed that severe damage on pods is possible from the pod-eating and pod-sucking insects that caused pod filling to fail after attack. In Australia, soil, leaf, pod, and flower insect pests have proved very serious (7). While pod boring insects are troublesome on hyacinth bean plants (8), in India, pod boring larvae are the most serious pests of hyacinth bean, reducing the crop both in quantity and quality (6). The seedling emergence failure due to rotten seeds and disease damage found in plots where portions of the experimental field retained more water is an indication that waterlogging had a major influence on disease severity. Some authors (1, 6, 2, 9) have reported that hyacinth bean is highly susceptible to waterlogging or wet soils. The inverse relationship recorded between disease severity and plant growth as well as biomass production (Table 2) may be due to the dense growth of the hyacinth bean plants which encouraged more moisture to be retained over a longer period. With plant growth affected, pod and seed production suffered some yield reduction especially that the fungal diseases also directly affected pods. *Colletotrichum* spp. (anthracnose) and *Curvularia* spp. caused the greatest damage. In India, *Colletotrichum lindemuthianum* (Sacc. & Magnus) Briosi & Cavara is reported to have potential to cause serious crop losses (6). In a worldwide survey involving the diseases of hyacinth bean, *C. lindemuthianum*, *Curvularia lunata* (Wakker) Boedijn and *Helminthosporium hyacinth beanis* Sawada & Katsuki were reported (2).

Table 2. Correlation coefficients between descriptor pairs for observed attributes in *Lablab purpureus* accessions

Attribute†	Emergence (%) at 2 weeks after planting	Establishment (%) at 6 weeks after planting	Days to flowering	Soil cover at flowering	Canopy height at flowering	Shoot dry matter at flowering	Pod number plant^{-1}	Seed yield plant^{-1}
DS 8 WAP	0.19*	0.17*	-.22*	-.26*	-.28*	-.25*	-0.14	-0.13
DS 12 WAP	0.19*	0.20*	-.30*	-.32*	-.31*	-.33**	-.19*	-.24*

†DS: disease severity; WAP: weeks after planting; *significant at 5% level; **significant at 1% level

It is therefore necessary to study the level of economic importance of these diseases in this ecozone. Among the insect pests observed, *Ootheca mutabilis* and *Helicoverpa armigera* were the most common. It would be worthwhile to conduct research into the losses that might be suffered from these major insect pests.

Our experience seems to indicate that hyacinth bean production may not be without the use of pesticides. The many use of chemicals (insecticide and fungicide) in this study including pre-plant application of Lorsban (chlorpyrifos; o, o-diethyl o- (3,5,6-trichloro-2-pyridinyl) phosporothioate) to control millipedes and spray application of Sherpa plus at 2-week intervals during the dry season to control aphids, is not without its implication for the farmer in terms of cost, availability and use, which may be somewhat discouraging. But it is thought that good cultural practices will reduce pest problems.

For example, hyacinth bean production should be carried out on well-drained soils to avoid excess soil moisture, which induces fungal diseases. To avoid excess moisture within plant canopy while maintaining good seed and biomass yields, research to determine appropriate planting time, plant population and spacing is necessary. Flowering time may have implications for the insect pests vis a vis the time cowpea in the same production area has flowers. For instance, insect pests for hyacinth bean may be more severe if the hyacinth bean plants are the last to flower after cowpea because both crops have similar insect pest complex.

It may be concluded that pests can constitute a serious setback to the production of hyacinth bean in the agroecological zone but cultural practices with use of pesticides may be able to reduce the problem when well employed.

References

(1) Cassidy GJ (1975) Lablab bean for autumn grazing. Qld Agric J 101:37-40

(2) Duke JA, Kretschmer AE Jr, Reed CF, Weder JKP (1981) *Lablab purpureus* (L.) Sweet. In: Duke JA (ed) Handbook of Legumes of World Economic Importance. Plenum Press, New York,102-106

(3) Ewansiha SU, Chiezey UF, Tarawali SA, Iwuafor ENO (2007) Potential of *Lablab purpureus* accessions for crop-livestock production in the West African savanna. J Agric Sci 145:229-238

(4) Ewansiha SU, Chiezey UF, Tarawali SA, Iwuafor ENO (2007) Morpho-phenological variation in *Lablab purpureus*. Trop Grassl 41:277-284

(5) Ewansiha SU, Tarawali SA, Odunze AC, Iwuafor ENO (2008) Potential contribution of hyacinth bean residues to maize production in moist savanna of West Africa. J Sustain Agric 32:393-406

(6) Kay DE (1979) Crop and Product Digest 3 - Food Legumes. Tropical Products Institute, London

(7) NAS (1979) Lablab bean. In: Tropical Legumes: Resources for the Future. National Academy of Sciences, Washington, 59-67

(8) Shivashankar G, Kulkarni RS (1989) *Lablab purpureus* (L.) Swe*et*. In: van der Maesen LJG, Somaatmadja S (eds) Plant Resources of South-East Asia 1. Pulses. Pudoc / Prosea, Wageningen, 48-50

(9) Skerman PJ, Cameron DG, Riveros F (1988) *Lablab purpureus* (L.) Sweet. In: Skerman PJ (ed) Tropical Forage Legumes. Food and Agricultural Organization of the United Nations, Rome, 311-319

Breeding for pest resistance in hyacinth bean in Kenya

by Miriam G. KINYUA[1]*, Eliezer M. KAMAU[2], Grace N. KISIRKOI[3] and Oliver KIPLAGAT[1]

Abstract: Pests are one of the major constraints to agricultural production in Kenya. Insect pests attack crops during all stages of growth, from seedling to storage while bruchids attack at maturity and during storage. The need to strategize for integrated pest management (IPM) options for the underutilized crops like hyacinth bean is therefore of importance. This study was initiated to determine effect of pests in hyacinth bean in Kenya. Experiments were carried out in field in 4 sites. Controlled infestation of aphids and Bruchids was carried out in the lab at Thika, Kenya. Germplasm from geneback of Kenya and two check varieties D1002 and Njoro were tested. Eleven accessions were found to be moderately resistant to CPA and 2 accessions gave indication of resistance to bruchids. Bruchids and cow pea aphid were found to be major pests of hyacinth bean. Existing resistance can be used for breeding.

Key words: bruchids, cow pea aphid, integrated pest management, *Lablab purpureus*

Introduction

The major pests recorded in hyacinth bean (Lablab purpureus (L.) Sweet) include bruchids (*Callosobruchus* spp), cow pea aphid (*Aphis craccivora* Koch) (CPA) and other aphids, pod borers (*Maruca testulalis* Fabricius *Helicoverpa armigera* Hübner, *Adsura atknsoni* Moore), leaf beetle (*Ceretoma ruficormis* Olivier), hyacinth bean bug (*Copotosoma cribraria* Fabricius), mylabris beetle (*Mylabris pustulata* Thunberg) and mites (*Eutetranychus orientalis* Klein).

These pests are known to have negative impact on yield and crop quality. In Kenya, hyacinth bean production system is still underdeveloped with majority of the farmers relying on natural control. This has contributed to the low grain yield of less than 0.5 t ha experienced at the farmer's field, with two pests being widespread in the country (3). Biological and cultural control methods have a limited application among the small scale farmers who cannot afford costly pesticides, or even don't know how to use them. Host plant resistance (HPR) is a better option and the use of resistant varieties in pest management offers the farmers the advantage of genetically incorporated insect control for just the cost of seed alone. HPR also works synergistically with other control methods. The need to understand hyacinth bean insect resistance in Kenya is therefore important.

Materials and methods

Germplasm resources for insect resistance in Kenya. There are very few improved hyacinth bean varieties in Kenya. Varieties Dl002 and Dl009 were released by KALRO more than two decades ago. However, the gene bank of Kenya (GBK) contains a sizeable collection of 343 germplasm which include landraces and introduced hyacinth bean accessions. Kinyua et al., (3) reported a wide genetic diversity between the landraces in different production areas.

A preliminary morphological characterization of some of the collections in the genebank suggested a wide genetic variability. The variation noted include stem pigmentation, intensity of leaf hair, leaf colour, growth habit, maturity period, flower colour and yield parameters among others. The existing diversity provides a potential source of resistance to insect pests and other important traits needed to improve the existing varieties. These accessions were used in the screening

Screening for insect resistance. Screening was carried out in the field under the natural field infestation and in screen houses under artificial infestation.

Aphids

CPA is considered as one of the most important pest (6) of hyacinth bean in Asia and Africa (Fig .1). It's widely distributed in all the hyacinth bean growing areas in Kenya (3). CPA causes injury by feeding on the plant stems, petioles of seedlings, pods and flowers thereby weakening the host plant severely. Significant yield losses of between 20%-35% attributed to CPA on hyacinth bean have been reported in Asia (1). Even though the potential damage of CPA to hyacinth bean in Kenya is not documented, it is quite substantial (308). Resistance to CPA in some leguminous crops has been identified (5). However, before the inception of hyacinth bean crop improvement project in Kenya in 2007, there was no published literature on a search for resistance to CPA in hyacinth bean.

Figure 1. Cow pea aphid infestation on leaves and flowers of hyacinth bean

[1]University of Eldoret, Eldoret, Kenya (mgkinyua@africaonline.co.ke)
[2]Kenya Agricultural and Livestock Research Organisation, Thika, Kenya
[3]Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Figure 2. (above, left) Insect proof screen house at KALRO Thika; (above, right) screening hyacinth bean for cowpea aphid resistance (CPA) resistance in a screenhouse at different growth stages; (below, left) artificial infestation of CPA using camel brush; (below right) aphid proof cage used for rearing CPA colonies

Test materials and methods. Planting of the seeds was done at different dates so as to synchronize the attainment of the three growth stages simultaneously (Fig. 2, above, left, and above, right). This allowed the test plants at different stages of growth to be evaluated simultaneously. The aphids were transferred to young (two trifoliate leaves stage) plants of a susceptible hyacinth bean accession Njoro using a camel brush (Fig. 2, below, left). The plants were kept in a small aphid proof cage (2 m long, 1 m wide, 0.5 m high) (Fig. 2, below, right). The cage was maintained in a green house at a temperature between 25 °C and 27 °C. The plants were infested by placing the nymphs on the young topmost growing shoots of the test plants. The aphids were left to multiply and move between the plants. Accessions with mean damage scores of 1 - 3.0 were rated resistant, 3.1 - 5.5 moderately resistant, 5.6 - 6.5 moderately susceptible and 6.5 - 9.0 very susceptible, respectively. A damage score of 3.0 was considered to be resistant on the basis of our observation that hyacinth bean accessions with scores of less than 3.0 never showed any plant damage symptoms.

CPA plant damage. The screenhouse experiment showed that the accessions and growth stage interacted significantly suggesting that the responses of the accessions to CPA damage at various growth stages were different. None of the accessions evaluated at 14 DAS growth stage was resistant (damage score < 3.0) to CPA (Table 1). Only accession 012192 was rated as moderately resistant (score range 3.1 - 5.5) to CPA at this stage. When infested at 40 DAS, 11 accessions were moderately resistant, 10 moderately susceptible while the rest were very susceptible. None of the accessions evaluated at 70 DAS was resistant to CPA but 13 accessions were classified as moderately resistant. The mean plant damage scores were lower when plants were infested at 40 DAS and 70 DAS than at 14 DAS. Although most accessions changed their rankings in the 3 growth stages, accessions 012192, 012212 and 012021 were less variable and were consistently the lowest.

Table 1. Mean damage scores in the 6th week* for 11 selected hyacinth bean accessions infested with CPA at three plant growth stages

Accession	Growth stage at infestation (DAS)			Accession	Growth stage at infestation (DAS)		
	14	40	70		14	40	70
010814	9.00	8.00	6.33	011800	7.33	5.33	5.33
012192	5.33	5.33	5.00	011719	7.66	5.00	5.00
010841	7.00	6.00	6.00	011019	8.33	7.66	6.33
DL002	8.66	5.66	6.33	012187	7.33	7.66	6.00
Njoro	7.66	8.33	7.33	Mean	7.2	6.2	5.8
011803	6.00	5.66	5.66	*LSD*		1.55	
027029	7.33	8.00	6.33	*SE*		0.55	

*1= no visual damage; 9 = severely stunted or dead plants

The screenhouse study showed that there was no accession with high resistance (damage score < 3.0) to CPA at any of the growth stages while, the field evaluation identified two accessions (012038 and 012230) to be resistant to aphid (data not shown). Screening for resistance in the field under natural infestation is beneficial because it represents the actual pest and crops dynamics experienced in the farmers farms. However, due to the many uncontrolled factors that affect resistance in the field, it is usually hard to determine whether the resistance is due to the genetic factors in the host plant or due to environmental variation. In screen house evaluation, the environment and the initial aphid population are controlled. Therefore, the variation in reaction to aphid damage recorded amongst the test plants can be attributed to the genetic differences in the accessions. Such genetic variation is of great importance to the breeding program because it represents the factors that can be transferred to the next generation.

There were a few accessions were found to be moderately resistant (damage score 3.1 - 5.5) especially at later growth stages under the screen house evaluation (Table 1). The need to have parents with high resistance to aphids is key to successful development and adoption of improved hyacinth bean varieties. There is therefore need to continue with searching for the CPA resistance genes in other hyacinth bean collections not covered in these two studies.

Bruchids

Little information is available on resistance to bruchids in hyacinth bean. In Kenya, no documented information on studies of bruchids resistance is available despite the fact that the pest is of economic importance to hyacinth bean.

Maintenance of bruchids cultures in the laboratory. The bruchids culture used in this study was collected from a hyacinth bean infested seeds in a storehouse at KALRO-HRI, Thika. Twenty bruchids adult were collected and placed in a 0.5 liter glass bottle jar containing 0.5 kg of seeds of a hyacinth bean variety susceptible to bruchids. The jar was covered with muslin cloth, which allowed adequate ventilation but prevented insects from escaping. The insects were allowed to oviposit for 10 days, after which they were discarded, and their progeny used to form

Figure 3. Insect rearing incubator with controlled temperature and humidity

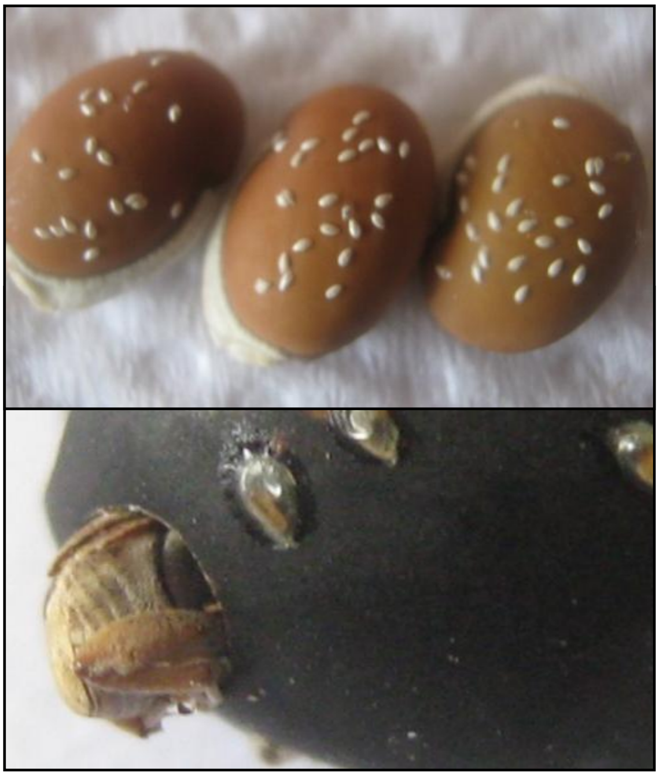

Figure 4. (above) bruchids eggs on hyacinth bean seeds; (below) bruchids adult emerging from hyacinth bean seed

the F_1 generation of the laboratory population. This population was maintained by regularly replacing the infested grain with fresh seeds.

Bruchids infestation. In the first preliminary screening activity 22 accessions were evaluated. A no-choice test was conducted in the laboratory by infesting hyacinth bean samples in plastic containers with bruchids using the method described by Kananji (2). The experiment was conducted in an insect rearing incubator with 25 °C - 27 °C and over 60% humidity (Fig. 3). After 10 days, number of eggs laid (Fig. 4, above) was estimated using a magnifying lens, and adults were removed. In cases where no eggs were visible, samples were re-inoculated with new adults.

Emerging F_1 adults from each sample was counted daily (Fig. 4, below). Data was collected for the total number of F_1 adults emerging after inoculation, number of days for first adult emergence (DAE) and number of days for 50% of total F_1 adults emerged (median time).

The number of eggs laid on the three seeds infested with five 1-3 days old adult bruchids varied between 5 and 38 with a mean of 21 (Table 2). The least no of eggs were recorded on accessions 12003, 12028 and 12022 with 5, 10 and 13 eggs respectively. The number of F_1 adults emerging ëfrom the laid eggs ranged from 2 to 28 with accession 12022 having the least. An ideal resistant accession is the one that has none or very few F_1 emergings. This would indicate that the eggs laid on the accessions could not complete the whole life cycle in the seed. The larvae of bruchids are inhibited from developing to maturity by either the presence of some biochemical compounds or physical barriers such as hard seed coat or rough seed texture. In this study accession 12022, 12028, 12003 and 12167 had the least number of F_1 emerging. The combination of low F_1 emergencies and long time to emerge gives us more indicators that 12028, 12022 and 12167 might be having some resistance. However, more experiments need to be carried out before concluding with certainty the presence of resistance.

Table 2. The mean number of eggs and time taken for F_1 adults to emerge from 4 selected hyacinth bean accessions infested with bruchids

Accession	Mean number of eggs laid	Mean number of adults emerged	Mean days to First emergence	Mean days to 50% emergence
12167	15	5	29	40
12003	5	5	31	32
12022	13	2	44	44
12028	10	3	44	44

Conclusion

Cow pea aphid and bruchid were shown to be major pests of hyacinth bean in Kenya. Breeding for resistance to these pests would be the best and most economical control measure for small scale farmers.

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References

(1) Ahmed KU, Rahman MM, Alam MZ, Ahmed SU (2004) Methods of pest control and direct yield loss assessment of country bean (*Dolichos hyacinth bean*) at farmers' field condition: A survey finding. Pak J Biol Sci 7:287-291

(2) Kananji GA (2007) A study of bruchids resistance and its inheritance in Malawian dry bean germplasm. PhD Thesis. University of KwaZulu-Natal

(3) Kinyua MG, Orwa D, Kimani E, Kamotho G (2008) Survey of hyacinth bean *(Lablab purpureus)* production systems, utilization, marketing and the collection and characterization of germplasm in Kenya. Proceedings, International Dolichos Meeting, Arusha, Tanzania, 8 March 2008,

(4) Kisirkoi GN (2010) Characterization of *Lablab purpureus* using morphological and simple sequence repeat markers for aphid resistance. MSc Thesis. Jomo Kenyatta University of Agriculture andTechnology

(5) Laamari M, Khelfa L, Coeur d'Acier A (2008) Resistance source to cowpeas aphid in broad beans Algerian landrace collection. Afr J Biotechnol 7:2486-2490

(6) Rekha S, Mallapur CP (2007) Abundance and seasonability of sucking pests of hyacinth bean. Karnataka J Agric Sci 20:397-398

Hyacinth bean (*Lablab purpureus* (L.) Sweet): A hidden treasure of useful phytochemicals

by Mohd NAEEM[1]*, M. Masroor A. KHAN[1] and Moin UDDIN[2]

Abstract: A number of medicinal legumes have great potential as nutraceuticals because of their healing properties. Vegetarian population in India consumes large amounts of legumes, particularly, vegetable beans, in their diet where they serve as a good sources of proteins. Among them, hyacinth bean (*Lablab purpureus* L.) has great potential as medicinal legume and is reported to be a multipurpose crop. It contains several secondary metabolites that can be used as nutraceuticals or pharmaceuticals. The present article covers the active constituents, nutritional components, pharmacological actions and therapeutic uses of this crop.

Key words: *Lablab purpureus* L., nutraceuticals; medicinal use, seed-protein; tyrosinase enzyme

Introduction

Hyacinth bean (*Lablab purpureus* L.) is a herbaceous, erect and perennial or annual herb (Fig. 1), often grown as an annual crop (19). It originated in India and was introduced to Africa from Southeast Asia during the 8th century (5). Hyacinth bean is known by different names, viz. *Bonavist bean*, *Egyptian kidney bean*, *Lablab bean* and *Indian butter bean*; it is locally known as *Sem.*

Figure 1. A potted hyacinth bean plant

The beans are naturally rich in carbohydrates, proteins, fats, and fibers as well as in minerals including calcium, phosphorus and iron. A multi-purpose crop used for food, forage, soil improvement, soil protection, and weed control (15), is also known for its use as a green manure, carrying edible young pods, dried seeds, leaves and flowers (14). Hyacinth bean has great potential as medicinal legume. It constitutes an important source of therapeutic agents used in the modern as well as in traditional systems of medicine (14).

Active constituents

Hyacinth bean contains a variety of useful compounds including, alkaloids, flavonoids, tannins, saponins, phenols, carotenoids, glycosides and diterpenes. Keeping its high medicinal value in mind, the performance of five hyacinth bean accessions of different origins (16), namely, EC-497617 (Australia), EC-497616 (China), EC-497615 (Egypt), EC-497619 (Iran), and EC-497618 (Kenya) were evaluated; the accessions were received from the USDA, ARS, Plant Genetic Resources Conservation Unit, Griffin, GA, USA. The seed protein content of all accessions varied from 24.70% to 25.06%. The carbohydrate content varied between 50.83% and 53.16% across all the accessions tested. Among all, the accession EC-497619 showed the highest tyrosinase activity in the seeds (Fig. 2).

Nutritional components

Hyacinth bean is good sources of protein, carbohydrates, fiber and minerals (calcium, magnesium, zinc, and manganese). The dried seeds contain: moisture, 8.0%; fibre, 10.5%; fat, 1.3%; carbohydrate, 51.3%, protein, 20% - 28 %; phosphorus, 307 mg $100g^{-1}$; potassium, 198.6 mg $100g^{-1}$; calcium, 191.1 mg $100g^{-1}$; sodium, 8.0 mg $100g^{-1}$ and magnesium, 43.8 mg $100g^{-1}$ (19). It is a good source of the amino acid, lysine leucine and tyrosine.

Therapeutic uses

The seeds of hyacinth bean are used as laxative, diuretic, anthelmintic, anti-spasmodic, aphrodisiac, anaphrodisiac, digestive, carminative, febrifuge and stomachic (6). Hyacinth bean is also used in the treatment of cholera, vomiting, diarrhea, leucorrhoea, gonorrhea, edema, alcohol intoxication and globefish poisoning. Myo-inositol, a useful carbohydrate found in

[1]Aligarh Muslim University, Department of Botany, Plant Physiology Section, Aligarh, India (naeemgaur@gmail.com, naeem_phd@yahoo.co..in)
[2]Aligarh Muslim University, Women's College, Botany Section, Aligarh, India

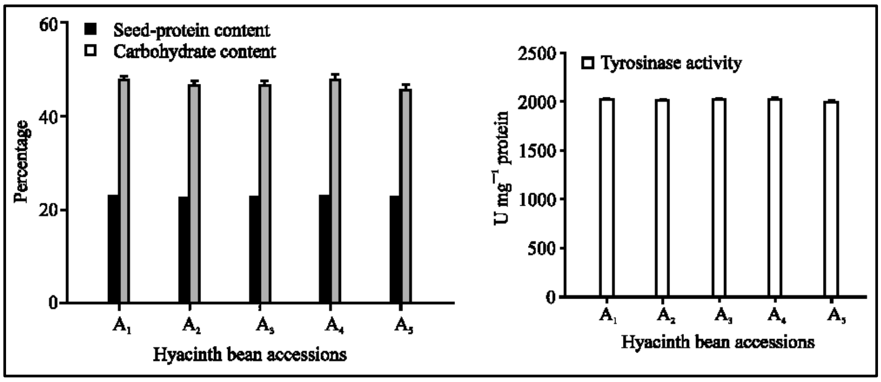

Figure 2. Variation in seed-protein, carbohydrate, and tyrosinase activity of hyacinth bean accessions analyzed at 150 DAS; A1 - EC-497617 (Australia), A2 - EC-497616 (China), A3 - EC-497615 (Egypt), A4 - EC-497619 (Iran), and A5 - EC-497618; error bars (┬) LASD at 5% level (8)

hyacinth bean seed is claimed to be useful for treating panic disorders (11). Hyacinth bean fiber, is known to prevent cancer, diabetes, heart disease and obesity (11). Flavonoid kievitone, and genistein, respectively, have been reported to fight breast cancer (3) and prevent cancer (9), and the latter has been suggested as a chemo-therapeutic and/or chemopreventive agent for head and neck cancer (12). Hyacinth bean contains tyrosinase (polyphenol oxi-dase), which has potential for the treatment of hypertension in humans (11). However, it is not yet being used to its full potential.

Pharmacological actions

Antimicrobial activity. The n-Hexane and chloroform extracts of hyacinth bean exhibited significant antimicrobial and antifungal activities against *Bacillus subtilis* (Ehrenberg) Cohn, *Staphylococcus aureus* Rosenbach, *Pseudomonas aeruginosa* (Schröter) Migula, *Escherichia coli* (Migula) Castellani & Chalmers and *Candida albicans* (C. P. Robin) Berkhout (1).

Anti-inflammatory / Antioxidant / Cytotoxicity activity. Momin et al., (4) evaluated *in vitro* anti-inflammatory, antioxidant, and cytotoxic properties of methanol extracts of two Bangladesh hyacinth bean pods, 'white' and 'purple'. Their results showed that both had significant anti-inflammatory activity; both the strains were potential source of natural antioxidants. 'White' exhibited concentration dependent potential cytotoxicity.

Antidiabetic activity. A study investigating the anti-diabetic effects of Indian beans showed a low glycaemic response both *in vitro* and *in vivo*. A low post-prandial glucose response and the slow starch digestibility suggested that they could be ideal foods for diabetics (13). In another study, Kante and Reddy (10) evaluated the antidiabetic activity of a methanolic extract of hyacinth bean seeds in STZ-Nicotimamide induced diabetic model. Their results showed dose-dependent reduction of blood glucose, total cholesterol, and triglycerides. Using glibenclamide as standard drug, Balekari et al. (2) evaluated the anti-hyperglycemic activity of hyacinth bean and reported that it lowered the blood glucose, serum lipids and liver enzymes in diabetic rats. The group also reported anti-hyperlipedimic activity of methanolic extract of hyacinth bean.

Antibacterial, antifungal and antiviral activity. The seeds of hyacinth bean contain lectin, which has significant antimicrobial activity on different bacterial strains (*Vibrio mimicus* Davis et al., *Staphylococcus aureus, Bacillus sereus* Frankland & Frankland, *Salmonella typhi, Shigella dysentery* (Shiga) Castellani & Chalmers, etc.). It has also showed significant haemagglutination activity and moderate anti-oxidant property as well (10).

Fakhoury and Woloshuk (7) isolated and characterized a 36-kDa protein from hyacinth bean that inhibited α-amylase and the growth of *Aspergillus flavus* Link. Also, an antifungal protein (dolichin) was modified in the hyacinth bean seeds. The protein exhibited antifungal activity against *Fusarium oxysporum* Schlecht. emend. Snyder & Hansen, *Rhizoctonia solani* J.G. Kühn and *Coprinus comatus* (O.F.Müll.) Pers. (17). Dolichin purified from the seeds of hyacinth bean was also capable of inhibiting HIV reverse transcriptase and α- and β-glucosidases, which are glycohydrolases implicated in HIV infection (20).

Analgesic activity. Proma et al. (18) have suggested that methanolic extract of hyacinth bean aerial parts could be used for relieving pain and hence, this medicinal legume has analgesic potential.

Conclusions

Hyacinth bean bears numerous and important therapeutic compounds for potential use in alternative systems of medicine. Tyrosinase, a copper containing enzyme from Lablab catalyses formation of quinones using phenols and polyphenols has potential for the treatment of hypertension in humans. Hyacinth flavonoids, viz. kievitone and genistein, can be used as chemotherapeutic and / or chemopreventive agents. Besides, seed of this medicinal legume is an important source of proteins, carbohydrates and minerals. In fact, hyacinth bean has the potential as a quality and nutritious vegetable for Indian vegetarian population.

Future prospectives

This medicinal legume is used as a potent source of nutraceuticals and pharmaceuticals. Identification and characterization of hidden useful phytochemicals and their biosafety evaluation is expected to add value to the crop. Specific pharmacological actions of each phytochemicals, genetic variability of the crop in terms of the phytochemicals need further evaluation.

References

(1) Alhasan SA, Aranha O, Sarkar FH (2001) Genistein elicits pleiotropic molecular effects on head and neck cancer cells. Clin Cancer Res 7:4174-4181

(2) Balekari U, Reedy CS, Krishnaveni K (2013) Antihyperglycemic and antihyperlipidemic activities of *Dolichos hyacinth bean* seed extract on streptozotocin - nicotinamide induced diabetic Rats. Proceedings, International Conference and Exhibition on Pharmacognosy, Phytochemistry & Natural Products, Hyderabad, India, 21-23 October 2013, 2-4

(3) Beckstrom-Sternberg SM, Duke JA (1994) The Phytochemical Database, http://ars-genome.cornell.edu/cgi-bin/WebAce/webace?db=phytochemdb

(4) Dahake AP, Joshi AB, Patel KM (2009) Antimicrobial investigation of different extracts of *Dolichos hyacinth bean*s. Res J Pharmacogn Phytochem 1:125-129

(5) Deka RK, Sarkar CR (1990) Nutrient composition and anti-nutritional factors of *Dolichos hyacinth bean* L. seeds. Food Chem 38:239-246

(6) El-Siddig OOA, El-Tinay AH, Alla, AWHA, Elkhalifa AEO (2002) Proximate composition, minerals, tannins, *in vitro* protein digestibility and effect of cooking on protein fractions of hyacinth bean (*Dolichos hyacinth bean*). J Food Sci Technol 39:111-115

(7) Fakhoury AM, Woloshuk CP (2001) Inhibition of growth of *Aspergillus flavus* and fungal alpha-amylases by a lectin-like protein from *Lablab purpureus*. Mol Plant Microb Interact 14:955-961

(8) Fatima S, Kapoor R (2006) *In vivo* and *in vitro* glycemic effects of certain legumes. J Food Sci Technol 43:263-266

(9) Hoffman R (1995) Potent inhibition of breast cancer cell lines by the isoflavonoid Kievitone: comparison with genistein. Biochem Biophys. Res Commun 211:600-606

(10) Kante K, Reddy CS (2013) Anti diabetic activity of *Dolichos hyacinth bean* (seeds) in Streptozotocin- Nicotinamide induced diabetic rats. Hygeia J Drug Med 5:32-40

(11) Kirtikar KR, Basu BD (1995) Indian Medicinal Plants I. Sri Satguru Publications, New Delhi

(12) Kobayashi T, Nakata T, Kuzumaki T (2002) Effect of flavonoids on cell cycle progression in prostate cancer cells. Cancer Lett 176:17-23

(13) Momin MAM, Habib MR, Hasan MR, Nayeem J, Uddin N, Rana MS (2012) Anti-inflammatory, antioxidant and cytotoxicity potential of methanolic extract of two Bangladeshi bean *Lablab purpureus* (L.) sweet white and purple. Int J Pharm Sci Res 3:776-781

(14) Morris JB (2003) Bio-functional legumes with nutraceutical, pharmaceutical, and industrial uses. Econ Bot 57:254-261

(15) Murphy AM, Colucci PE (1999) A tropical forage solution to poor quality ruminant diets: a review of *Lablab purpureus*. Livest Res Rural Dev 11:2:16

(16) Naeem M, Khan MMA, Morris JB (2009) Agrobotanical attributes, nitrogen-fixation, enzyme activities, photosynthesis, nutraceuticals of *Lablab purpureus* L. - a bio-functional medicinal legume. Am J Plant Physiol 4:58-69

(17) Priya S, Jenifer S (2014) Antibacterial activity of leaf and flower extract of *Lablab purpureus* against clinical isolates of *Staphylococcus aureus*. Res Rev J Drug Des Discov 1:5-7

(18) Proma JJ, Faruque MO, Rahman S, Bashar ABMA, Rahmatullah M (2014) Analgesic potential and phytochemical screening of *Lablab purpureus* aerial parts. World J Pharm Pharm Sci 3:165-173

(19) Purseglove JW (1974) Tropical Crops: Dicotyledons. Longman, London

(20) Ye XY, Wang HX, Ng TB (2000) Dolichin, a new chitinase-like antifungal protein isolated from field beans (*Dolichos hyacinth bean*). Biochem Biophys Res Commun 269:155-159

Relative performance of hyacinth bean and other herbaceous legumes in Nigerian rainforest zone

by Sunday A. OGEDEGBE, Sylvester U. EWANSIHA* and Ehizogie J. FALODUN

Abstract: Herbaceous legumes provide multiple uses in crop-livestock systems. The objective of this research was to ascertain the performance of 6 herbaceous legumes in the rain forest region of Nigeria. The highest yielding legumes in terms of fresh biomass were *Mucuna pruriens* (5.06 t ha^{-1}) and *Lablab purpureus* (3.21 t ha^{-1}) whereas *Centrosema pascourum* and *Pueraria phaseoloides,* had the lowest yields (0.24 t ha^{-1} and 0.41 t ha^{-1}, respectively). Because of quick growth and high biomass, mucuna and hyacinth bean can be introduced into the farming system of the rainforest zone in Nigeria, one as a cover crop and the other as both cover and feed crop.

Key words: biomass, herbaceous legume, hyacinth bean, leaf:stem ratio, soil cover

Increased use of herbaceous legumes in the tropics is inevitable because of scarcity and high cost of mineral fertilizers and serious protein deficiency among human and animal populations (3). In Nigeria, some herbaceous legumes were screened in the northern Guinea savannah (6), southern Guinea savannah (1) and derived savannah (4). However, little or no screening of herbaceous legumes has been carried out in the humid rainforest zone where soils are highly weathered, leached and prone to erosion. This research was carried out to evaluate the performance of 6 herbaceous legumes in the humid rainforest region of Nigeria with a view of recommending the most promising ones for soil protection and feed.

University of Benin, Department of Crop Science, Benin City, Nigeria
(sylvester.ewansiha@uniben.edu)

The experiment was conducted at the Teaching and Research Farm of the University of Benin, Benin City, Nigeria. Six herbaceous legumes, namely *Centrosema pascuorum* Mart. ex Benth., *Lablab purpureus* (L.) Sweet (Fig. 1 and Fig. 2) - cultivar ILRI 4612, *Mucuna pruriens* (L.) DC, *Peuraria phaseoloides* (Roxb.) Benth., *Stylosanthes hamata* (L.) Taub. and *Vigna unguiculata* (L.) Walp.- cultivar Sampea 14, were evaluated in a Randomized Complete Block Design with four replications. A plot measured 3 m × 5 m and had four rows each separated by 75 cm. Seeds were treated with 3 g of Apron Star (20 % w/w thiamethoxam, 20 % w/w metalaxyl-M, 2 % w/w difenoconazole of active ingredient) per kg before sowing, to protect them from soil-borne pests and diseases. Seeds were sown at a spacing of 75 cm × 30 cm on flat seedbeds. Manual weeding was done to keep the field weed-free. Attributes measured at 8 weeks after sowing were soil cover, leaf:stem ratio, and fresh biomass. The data collected were subjected to Analysis of Variance (ANOVA) using the Statistical Analysis System software (8). Means were separated using LSD at a 5% level of significance.

Legumes differed in their performance (Table 1). *Lablab purpureus, Mucuna pruriens* and *Vigna unguiculata* had the highest soil cover (5.0 score). Fresh biomass was highest in *Mucuna pruriens* followed by *Lablab purpureus*. This may be due to their quick growth and suggests that both legumes can provide soil protection, biomass for green manure or fodder for livestock (7, 5) early in the growing season. *Centrosema pascuorum* and *Pueraria phaseoloides* had very low yields because they usually exhibit slow establishment and growth rate in the year of sowing. Leaf:stem ratio did not differ between *Pueraria phaseoloides* and *Stylosanthes hamata*; it was however, higher for these legumes than the others. Although *Pueraria phaseoloides* was less productive but its high leaf:stem ratio may mean more palatable leafy fodder for ruminants' nutrition. However, the low leaf:stem ratio of *Mucuna pruriens*, *Lablab purpureus* and *Centrosema pascuorum* seems to suggest that these legumes should be utilized within 8 weeks of sowing when stems had not become woody.

Table 1. Soil cover and yield of herbaceous legumes at 8 weeks after sowing

Legume	Soil cover (m^2 m^{-2})	Leaf : stem ratio	Fresh biomass (t ha^{-1})
Centrosema pascuorum	3.0	0.5	0.24
Lablab purpureus	5.0	0.5	3.21
Mucuna pruriens	5.0	0.5	5.06
Pueraria phaseoloides	3.0	1.1	0.41
Stylosanthes hamata	4.0	0.9	1.07
Vigna unguiculata	5.0	0.6	1.76
Mean	4.2	0.7	2.0
$LSD_{0.05}$	0.36	0.33	1.68

Figure 1. Young hyacinth bean plants two weeks after emerging (© Tecomate)

Figure 2. A hyacinth bean field for herbage production (photo by Kendrick Cox, © DPI & F)

It may be concluded that *Lablab purpureus*, together with *Mucuna pruriens*, have a great potential for early use in the growing season. The ways to incorporate both crops into the existing farming systems of the region need to be explored more thoroughly in the future.

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References

(1) Abayomi YA, Fadayomi O, Babatola JO, Tian G (2001) Evaluation of selected legume cover crops for biomass production, dry season survival and soil fertility improvement in a moist savanna location in Nigeria. Afr Crop Sci J 9:615-627

(2) Bhattacharya B (2009) Advanced Principles and Practices of Agronomy. Kalyani Publishers, New Delhi

(3) Hoveland CS (1986) Understanding legume crops. Understanding Technology Series. Volunteers in Technical Assistance, Virginia

(4) Muhr L, Tarawali SA, Peters M, Schultze-Kraft R (1999) Nutrient import and export by forage legumes and their rotational effects on subsequent maize. Trop Grassl 33:245-256

(5) Jones JB (2003) Agronomic Handbook: Management of Crops, Soils and Their Fertility. CRC Press, New York

(6) Odunze AC, Tarawali SA, De Haan NC, Akoveguon E, Amadji AF, Schultze-Kraft R, Bawa GS (2004) Forage legumes for soil productivity enhancement and quality fodder production. Food Agric Environ 2:201-209

(7) Otsyina RM, von Kaufmann RR, Mohamed Saleem MA, Suleimann H (1987) Manual on fodder bank establishment and management Sub-humid zone programme, International Livestock Centre for Africa. ILCA Press, Addis-Ababa

(8) SAS (2002) Statistical Analysis System. Guides for personal computers. Version 9.0. SAS Institute Inc., Cary

Relative yields of dual-purpose hyacinth bean and cowpea when intercropped with maize

by Sylvester U. EWANSIHA[1]*, Sunday A. OGEDEGBE[1] and Uchechukwu F. CHIEZEY[2]

Abstract: Intercropping is a way to intensify agriculture. The objective was to compare the yields of dual-purpose hyacinth bean and cowpea intercropped with maize. Our recent study showed that in sole crop and in intercrop, grain yields of hyacinth bean were 21.3% and 29.8% lower respectively, than those of cowpea. Fodder yields of hyacinth bean were however, higher than for cowpea in both sole (84.4%) and intercrop (59.6%). Averaged across cropping systems, hyacinth bean had a grain yield of 610.1 kg ha^{-1} and cowpea 818.1 kg ha^{-1}; hyacinth bean had a fodder yield of 3005.6 kg ha^{-1} and cowpea 1760.7 kg ha^{-1}. Therefore, in crop-livestock systems, dual-purpose cowpea will furnish more grains for humans while dual-purpose hyacinth bean will provide more fodder for animals.

Key words: cowpea, fodder yield, grain yield, intercrop, hyacinth bean

Intercropping is a way to intensify land use because more crops are grown together on the same piece of land relative to growing the staple crop as a sole crop. Intercropping is practised because it often gives higher total yields and greater economic and monetary returns than the same crops grown sole. The practice also lowers risks and minimizes losses due to pests and diseases and losses due to adverse environmental conditions (6, 8, 9). Other advantages include labour complementarity, provision of more balanced human diet and efficient utilization of resources by plants of different heights, rooting systems, and nutrient requirements (9, 11, 12).

In particular, intercropping maize (*Zea mays* L.) with cowpea (*Vigna unguiculata* (L.) Walp.) has been observed to increase gross yield per unit area (4) with additional yield advantages accruing in maize under improved management (2). In addition, cereal/cowpea intercrops were observed to promote higher productivity when maize was the cereal component than when the cereal component was either millet (*Panicum miliaceum* L.) or sorghum (*Sorghum bicolor* (L.) Moench) (1).

Cowpea and hyacinth bean (*Lablab purpureus* (L.) Sweet) are dual-purpose legumes used for food, feed and improvement of soil fertility (3, 5). While cowpea is an important component of the traditional farming systems especially in the savanna region of West Africa, hyacinth bean being an underutilized crop has not yet gained widespread popularity. Even though hyacinth bean has potential to make significant contributions to the farming systems of the region (3), its incorporation into the system by way of intercropping it with the major cereal crops has not been tested. The objective of our study was to evaluate the yielding ability of hyacinth bean *vis-à-vis* that of cowpea when grown together with maize.

The experiment was conducted in 2010 and 2011 cropping seasons, at the research farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Samaru, Zaria in the northern Guinea savanna zone of Nigeria. Two dual-purpose cultivars of both hyacinth bean (ILRI 4612 and NAPRI 2) and cowpea (IT89KD-288 and IT99K-241-2) were evaluated under early and late maturing maize cultivars (TZE COMP. 5-W and TZL COMP. 1 SYN). The legume seeds of hyacinth bean or cowpea were sown in the same row with the maize component six weeks after the sowing of maize. Grain and fodder yields were measured and the land equivalent ratio (LER) was calculated as a simple indicator of the biological efficiency of the intercrop system (7, 10).

Averaged across the sole crop and intercrop systems, the two hyacinth bean cultivars had similar grain yields; the two cowpea cultivars also had similar grain yields, but the grain yields of cowpea were significantly higher than those of hyacinth bean. This may be so due to higher harvest index in cowpea. Intercrop reduced grain yield by 57.7% in hyacinth bean and by 52.6% in cowpea (Fig. 1).

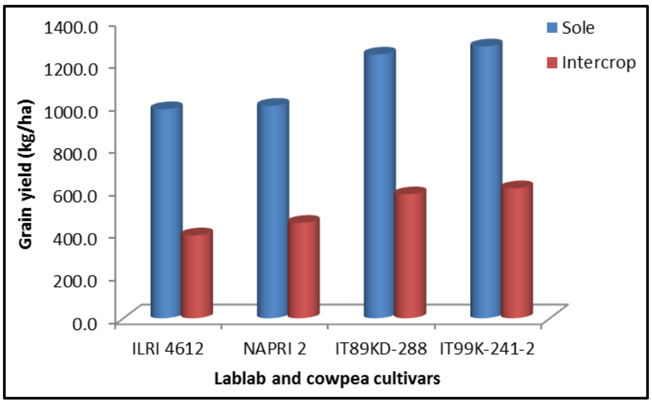

Figure 1. Grain yield of dual-purpose hyacinth bean and cowpea cultivars grown sole and when intercropped with maize

[1]University of Benin, Faculty of Agriculture, Department of Crop Science, Benin City, Nigeria (sylvester.ewansiha@uniben.edu)
[2]Ahmadu Bello University, Institute for Agricultural Research, Department of Agronomy, Zaria, Nigeria

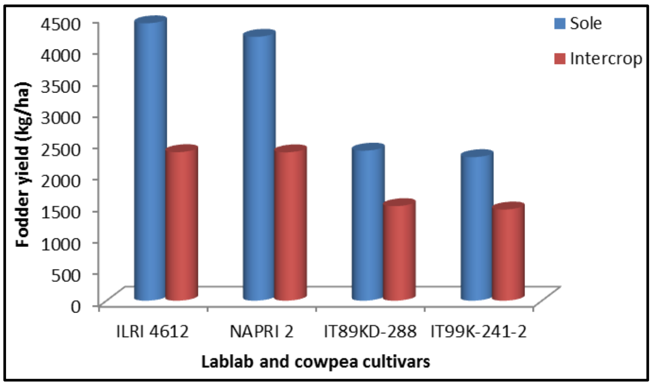

Figure 2. Fodder yield of dual-purpose hyacinth bean and cowpea cultivars grown sole and when intercropped with maize

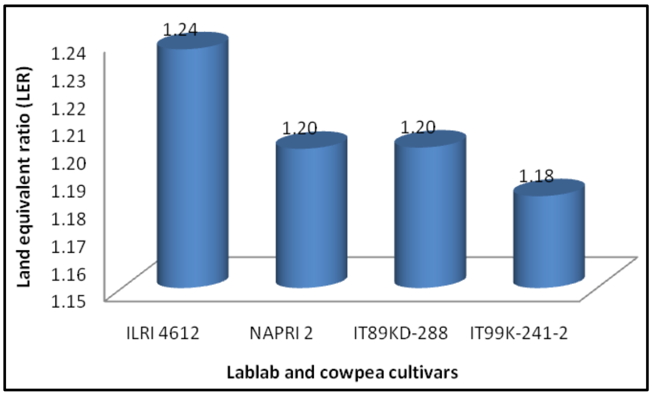

Figure 3. Land equivalent ratio (LER) of dual-purpose hyacinth bean and cowpea cultivars

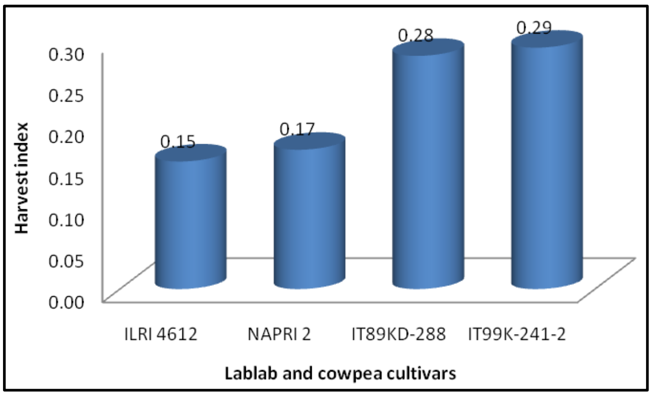

Figure 4. Harvest index of dual-purpose hyacinth bean and cowpea cultivars

The grain yield of cowpea in intercrop was 29.8% higher than that of hyacinth bean which was not significant ($p > 0.05$). Fodder yields of hyacinth bean were significantly higher than those of the cowpea cultivars. Lablab-maize intercrop reduced hyacinth bean fodder yield by 45.1% while cowpea-maize intercrop reduced cowpea fodder yield by 36.7% (Fig. 2). The fodder yield of hyacinth bean in intercrop was 59.9% higher than that of cowpea and the difference was significant ($p < 0.05$). Intercrop cowpea and hyacinth bean were more efficient than their sole crops (LER = 1.18 for IT99K-241-2 to 1.24 for ILRI 4612; Fig. 3). Lablab was slightly more biologically efficient than cowpea (LER = 1.22 vs. 1.19), probably because of better soil cover and use of environmental resources.

The higher grain yield and lower fodder yield of cowpea and the lower grain yield and higher fodder yield of hyacinth bean may be due to the fact that cowpea had a higher harvest index (Fig. 4). These results assure that dual-purpose cowpea will furnish more grains for humans, whereas, dual-purpose hyacinth bean will provide more fodder for animals. In addition, hyacinth bean can be included into the traditional cropping systems of the region. However, it will be worthwhile to test the low and slower growing cultivars of hyacinth bean with less biomass together with the high and faster growing cultivars with more biomass to determine the better suited cultivars in intercrop with cereals.

References

(1) Ajeigbe HA, Oseni TO, Singh BB (2006) Effect of planting pattern, crop variety and insecticide on the productivity of cowpea-cereal systems in northern Guinea savanna of Nigeria. J Food Agric Environ 4:145-150
(2) Baker EFI (1974) Mixed cropping with cereals - a system for improvement. Proceedings, International Workshop on Farming Systems, Hyderabad, India, 18-21 November 1974, 287-301
(3) Ewansiha SU, Chiezey UF, Tarawali SA, Iwuafor ENO (2007) Potential of *Lablab purpureus* accessions for crop-livestock production in the West African savanna. J Agric Sci 145:229-238
(4) IITA (1983) Annual Report. International Institute of Tropical Agriculture, Ibadan
(5) IITA (2009) Crops. Nigeria. International Institute of Tropical Agriculture, Ibadan, http://www.iita.org
(6) Kurata T (1986) A study on farming system in USSA. Q J Agric Ecol 26:179-205
(7) Mead R, Willey RW (1980) The concept of a land equivalent ratio and advantages in yields from intercropping. Exp Agric 16:217-228
(8) Ofori F, Stern WR (1987) Cereal-legume intercropping systems. Adv Agron 41:41-49
(9) Okigbo BN, Greenland DJ (1976) Intercropping systems in tropical Africa. In: Papendick RI, Sanchez A, Triplett GB (eds) Multiple Cropping. American Society for Agronomy, Madison, 63-101
(10) Vandermeer JH (1990) Intercropping. In: Carroll CR, Vandermeer JH, Rosset PM (eds) Agroecology. McGraw-Hill, New York, 481-516
(11) Willey RW (1979) Intercropping-its importance and research needs. Part 1. Competition and yield advantages. Field Crop Abstr 32:1-10
(12) Willey RW, Osiru DSO (1972) Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. J Agric Sci 79:517-529

Economic importance of hyacinth bean (*Lablab purpureus* L.): An Indian perspective

by V. Rangaiah DEVARAJ

Abstract: Pulses in traditional kitchens have served as symbols of culture and are pointers to evolution of food habits and agricultural practices. Domesticated wild plants have graduated to the elite pulses category due to ease of production, modern agricultural practices, economic benefits and preferences of consumers and livestock. These selections have pushed some of the legumes to oblivion in spite of their proven nutritional and economic values. Hyacinth bean (*Lablab purpureus*) is one such minor pulse with greater potential to provide cheaper source of quality protein and essential nutrients for poor and high protein fodder for livestock. This brief review is aimed at providing an economic perspective of the plant in tropics and subtropics under projected uncertain weather conditions.

Key words: agricultural economics, hyacinth bean, *Lablab purpureus*, nutritional values

Introduction

Globalization initiated by expansion of commerce and trade have led to extensive urbanization and altered social behaviors. Quest for better life and economic sources have driven rural communities towards towns and cities and forced them to emulate urban life style and food habits. With these altered priorities of native communities, their choice of crops has been shifted to market driven commercial crops offering greater economic benefits with lesser inputs. In the process, some of the conserved crops which saved generations of humans under unfavorable climatic conditions have been relegated to one of the least preferred crops.

Hyacinth bean (*Lablab purpureus* (L.) Sweet) was a quintessential crop in the tropics, especially in South Asia and African countries. To cite a personal account and folk-accounts from the Indian State of Karnataka, it was a matter of pride to possess stocks of hyacinth bean seeds, while hyacinth bean curry used to be a main item in the feast served at important social events such as marriages and other local celebrations. Over a period of 50 years, the menu in rural marriage parties has made over to suite the urban preference. A glance through this issue of *Legume Perspectives* would highlight the robustness of hyacinth bean to adapt to diverse climatic conditions and its agronomical and nutritional values (11, 7). This rapid altered preference is due to availability of more productive grain legumes such as common bean (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata* (L.) Walp.), chickpea (*Cicer arietinum* L.), pigeon pea (*Cajanus cajan* (L.) Huth), which have been extensively researched and improved for greater yields and other qualities (6).

Projected global population of 9.3 billion to 12.3 billion, concentrating in Africa and Asia by 2030, is expected to increase food production by 2 to 4 fold (5). With higher yield gaps in pulses in arid regions (4), reliance on increasing productivity of major grain legumes alone may not be the only strategy to feed the population since most grain legumes commercialized to date underperform during drought, which is expected to be frequent. Drought resistant multipurpose hyacinth bean could be a choice of pulses to be promoted to contribute to inclusive agricultural growth. This may open new markets and strengthen value chain in marketing, storage, transport, quality control.

Commercial value of hyacinth bean can be visualized from the accounts of its sustained cultivation over centuries in the south Indian states of Karnataka, Tamilnaadu, and Andhra Pradesh. Although authentic figures of volumes of business are not available, the impact of hyacinth bean on vegetable market for four months from November to March is remarkable. With the release of photo-insensitive short-season varieties (2), green pods of hyacinth bean (*avarekai*) as vegetable are available throughout the year (Table 1).

Table 1. A selection of the online pricelist of a regional cooperative marketing organization in the Indian districts of Bangalore Urban, Bangalore Rural, Kolar, Ramanagar and Chikkaballapura (http://www.hopcoms.kar.nic.in)

Item name	Price	Item name	Price	Item name	Price
Amla	57.00	Mango Raw	60.00	Raddish	29.00
Avarekai	40.00	Menthya Greens	40.00	Raddish Red	80.00
Baby corn	17.00	Mint Leaves	36.00	Sham gadde	55.00
Baby corn cleaned	83.00	Mushroom Button	200.00	Snake Gourd	23.00
Beans	43.00	Palak Greens	31.00	Sponge Gourd	25.00
Beet Root	20.00	Peas Delhi	80.00	Spring Onion	42.00
Bitter Gourd	27.00	Peas local	116.00	Spring Onion (Cleaned)	59.00
Bottle Gourd	24.00	Peas seeds	287.00	Sweet corn	40.00
Brinjal (R)	17.00	Potato (M)	29.00	Sweet corn seeds	23.00

[1]Bangalore University, Central College, Department of Biochemistry, Bengaluru, India (devaraj@bub.ernet.in)

Fig. 1 Customers thronging for skinned hyacinth bean seeds at a local market

Fig. 2 Different products of hyacinth bean displayed in a fair (http://gallery.oneindia.com)

Despite extensive urban food habits, hyacinth bean is favorite among locals for its aroma, and nutritional values, as exemplified by the annual fairs of hyacinth bean festival and its products amounting to a rough estimated transaction of 300,000 USD over a period of 15 days in central Bangalore, benefitting hundreds of local farmers (Fig. 1 and Fig. 2). The Karnataka state accounts for 90% of hyacinth bean production in India with annual production ranging between 700,000 t and 800,000 t from 85,000 hectares (2). Compared to dry seed market (http://krishimaratavahini.kar.nic.in/), the seasonal market for green pods and skinned seeds is lucrative due to local delicacies which have been traditionally conserved and improved upon to attract customers. A reasonably good number of business establishments, which buy the products from the farmers for domestic market and export, are engaged in hyacinth bean trade (http://gallery.oneindia.com). Apart from grain and vegetable market, purple-flowered hyacinth bean is gaining popularity in cut-flower market, albeit without any guaranteed longevity. Another area where hyacinth bean is being recognized for its economic potential is utility as a good source of nutraceuticals (8).

Major concerns of the consumers of hyacinth bean, such as anti-nutritional factors and palatability factors, are monitored by improved processing and cooking practices (10). The problem of flatulence while feeding livestock can be overcome by mixed foraging (9). At this juncture, the research must be directed towards improvement of palatability and attractiveness of hyacinth bean, so as to attract the consumers from non-traditional areas.

Considering the afore mentioned facts, albeit without authentic statistical figures, in changing conditions of irregular rain pattern and dwindling ground water, hyacinth bean has potential to be a beneficial resource for poor farmers, providing them with improved, health-safe food and economic income in arid regions.

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References

(1) Akpapunam M (1996) Hyacinth bean (*Lablab purpureus* L., Sweet). In: Nwokolo E, Smartt J (eds) Legumes and Oil Seeds in Nutrition. Chapman & Hall, London, 103-108

(2) Byre Gowda M (2013) Genetic enhancement of hyacinth bean through integration of conventional breeding and molecular approaches. In: Dolichos Bean, *Lablab purpureus* (L.) Sweet. University of Agricultural Sciences, Bangalore

(3) Devaraj VR, D'souza MR (2016) Dolichos hyacinth bean (Hyacinth bean): An adept adaptor to adverse environments. Legume Perspectives 13:21-23

(4) FAOSTAT (2016) Food and Agriculture Organization of United Nations, Rome

(5) Gerland P, Raftery AE, Ševčíková H, Li N, Gu D, Spoorenberg T, Alkema L, Fosdick BK, Chunn J, Lalic N, Bay G, Buettner T, Heilig GK, Wilmoth J (2014) World population stabilization unlikely this century. Sci 346:234-237

(6) Maass BL, Knox MR, Venkatesha SC, Tefera TA, Ramme S, Pengelly BC (2010) *Lablab purpureus* - a crop lost for Africa? Trop Plant Biol 3:123-135

(7) Maass BL, Robotham O, Chapman MA (2016) Evidence for two domestication events of hyacinth bean (*Lablab purpureus* (L.) Sweet): a comparative analysis of population genetic data. Genet Resour Crop Evol (in press) DOI 10.1007/s10722-016-0431-y

(8) Morris JB (2003) Bio-functional legumes with nutraceutical, pharmaceutical, and industrial uses. Econ Bot 57:254-261

(9) Murphy AM, Colucci PE (1999) A tropical forage solution to poor quality ruminant diets: a review of *Lablab purpureus*. Livest Res Rural Dev 11:2:16

(10) Soetan KO, Oyewole OE (2007) The need for adequate processing to reduce the antinutritional factors in plants used as human foods and animal feeds: A review. Afr J Food Sci 3:223-232

Origin of some scientific and popular names designating hyacinth bean (*Lablab purpureus*)

by Aleksandar MIKIĆ[1]* and Vesna PERIĆ[2]

Abstract: This brief overview attempts to assess the origin and diversity of several scientific and popular names denoting hyacinth bean (*Lablab purpureus*). The Linnean name *Dolichos* is a derivation of the Ancient Greek δολιχὸς, meaning *long* and having a descriptive nature. Sweet's genus *Lablab* might owe its ultimate origin to the Proto-Indo-European **lab-*, **leb-*, **lob*, that, via Ancient Greek λοβός (*pod*), the Georgian *lobio* and the Armenian *lobi* (both *faba bean*), was borrowed by Arabic and became *lablāb* (*hyacinth bean*). The oldest attested Proto-Dravidian root, denoting precisely *Lablab purpureus*, is **ávarai*, producing numerous modern descendants with the preserved original meaning.

Key words: crop origin, etymology, historical linguistics, hyacinth bean, *Lablab purpureus*, lexicology

To Brigitte, with admiration.

Overture

Hyacinth bean (*Lablab purpureus* (L.) Sweet) is regarded as one of the significant annual legume crops globally, especially in diverse subtropical and tropical regions across the world. Like other grain legumes, it is used mainly in animal feeding, in the form of fresh forage, hay, forage meal, grain and straw, grazing and browsing, and for human consumption, as fresh leaves, immature pods, immature grains and mature grains (11). Hyacinth bean is also considered an ornamental plant and it is no wonder that its name is derived from *jacinth*, a variety of zircon, used as a gem stone (14).

[1]Institute of Field and Vegetable Crops, Novi Sad, Serbia (aleksandar.mikic@ifvcns.ns.ac.rs)
[2]Maize Research Institute Zemun Polje, Belgrade, Serbia

Apart from *hyacinth bean*, the English names for this legume include *Australian pea*, *bonavist bean*, *bonavist pea*, *bonavista bean*, *butter bean*, *hyacinth bean*, *dolique hyacinth bean*, *Egyptian kidney bean*, *field bean*, *Indian bean*, *hyacinth bean* or simply *batao/batau*, *hyacinth bean*, *papaya bean*, *poor-man's bean*, *seim bean*, *Tonga bean* (21, 25). As may be seen, they denote rather diverse terms, such as the country from which hyacinth bean was introduced, a visual resemblance to some specific object, local name and, as in the case of *poor-man's bean*, a kind of confirmation of its low-input production and an essential contribution to the diets of human population in certain regions.

Origin and domestication

For a long time, it has been debated if hyacinth bean had originated and had been domesticated in Africa or India. During the past decade, a complex analysis of more than 100 accessions of different geographic origin and using amplified fragment length polymorphism (AFLP) markers suggested that hyacinth bean could originate in Africa and, via early domesticated escapes, became a more advanced crop in India (5, 10; Fig. 1).

In another complex analysis of various morphological, anatomical, physiological, and nutritional seed characteristics of hyacinth bean accessions of diverse status, it was assessed that the wild ones usually had small, brownish and mottled seeds, a thicker seed coat, larger proportions of hard seeds, non-uniform germination and higher proportion of tannin and nitrogen in the seed dry matter (9). These important results are similar to those obtained in other grain legumes and point out that the process of domesticating hyacinth bean basically required improving all the listed characteristics, as it was confirmed in the semi- and fully cultivated accessions examined in the same analysis.

A need of merging archaeobotanical and genetic researches with historical linguistics has been pointed out recently (4, 8).

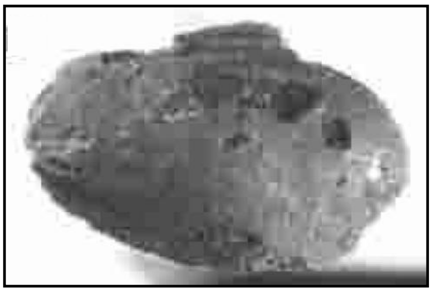

Figure 1. A charred seed of hyacinth bean with partial preservation of strophiole/hilum, Southern Neolithic site of Sanganakallu, southern India, mid- to late 2nd millennium BC (5; © 2006 Association for Environmental Archaeology)

Dolichos

The name *dolichos* was first introduced into plant taxonomy by Carl Linnaeus (7), in order to denote a genus, today still named *Dolichos* L., belonging to the tribe Phaseoleae (Bronn) DC., and comprising about 60 species of herbaceous plants and shrubs. The first scientific name of hyacinth bean was *Dolichos hyacinth bean* L. and is still in use by numerous researchers as the most frequent synonym of *L. purpureus*.

Linnaeus often used either Ancient Greek or common Latin names to designate both plant and animal genera and species. Thus, in the case of hyacinth bean, it is the Ancient Greek adjective δολιχὸς, denoting 'long' and obviously having a descriptive nature, that served as a source for naming the genus, since it comprises many species with vining stems, including hyacinth bean. This Ancient Greek word is derived from the same Proto-Indo-European root **dl̥h*$_{1}$*g*^{h}*ós*, being also 'long', together with the Avestan *darəya*, the Hittite *daluki*, the Latin *longus*, the Proto-Germanic **langaz*, the Proto-Slavic **dlŭgŭ* and the Sanskrit दीर्घ (*dirgha*), all with the identical basic meaning (6, 22).

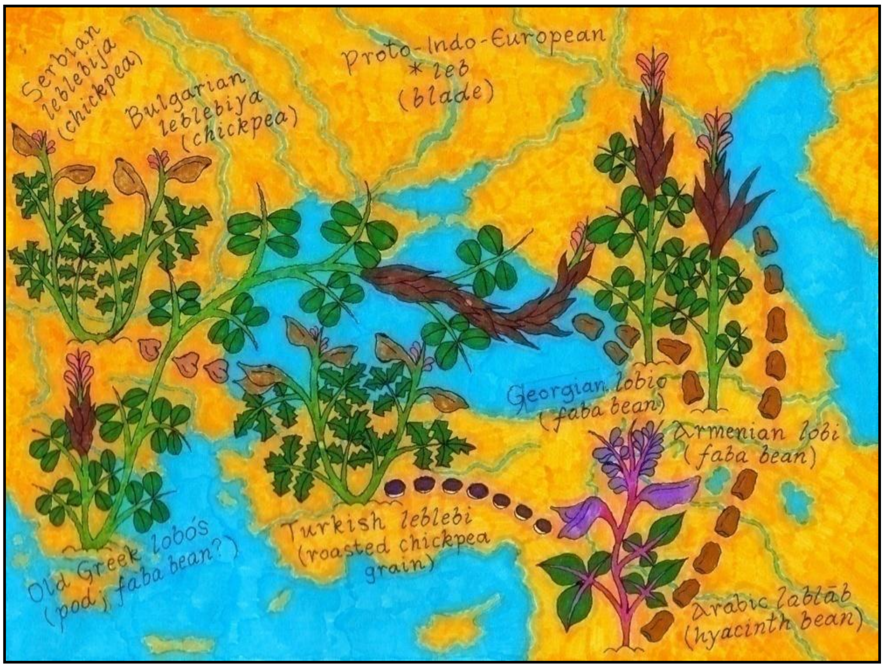

Figure 2. One of the possible origins of the word *hyacinth bean,* its evolution and further development: **leb-* > *lobós* > *lobio* > *lobi* > *lablāb* > *leblebi* > *leblebija* and *leblebiya*

Lablab

The initial taxonomic status of hyacinth bean was changed by Robert Sweet, an English botanist, horticulturist and ornithologist, who excluded it from the genus *Dolichos* and placed it into a novel genus *Lablab* Sweet, as its only species (24).

The origin and evolution of the word *hyacinth bean* is still not clarified to a sufficient extent. What is definite is that it is used to denote hyacinth bean in the modern Arabic, Persian and Turkish languages, with لبلاب the words لبلاب (*lablāb*), لبلب (*hyacinth bean*) and *hyacinth bean*, respectively (21). We shall take liberty to suggest one of the hypothetical paths of the history of the word *hyacinth bean* in the following paragraph.

The very beginning may lay in the Proto-Indo-European root **lāb-*, **leb-*, **lĕb-*, **lŏb-*, meaning *blade* and also denoting something hanging down loosely (18, 20). (Fig. 2) This tongue, the forefather of all modern Indo-European ethnolinguistic groups, such as Balto-Slavic, Celtic, Germanic, Hellenic or Italic, is supposed to be spoken in the Pontic-Caspian steppe, from 4,000 BC to 3,000 BC (2, 3, 15). Both quoted meanings could also have been descriptively associated with legume pods, since the Proto-Indo-Europeans are proved to be 'green-fingered' growers of grain legumes (16).

The only attested descendant of the said Proto-Indo-European root is found in the Ancient Greek language, generally placed between 9th and 6th centuries BC. It is the word λοβός, designating pod and, perhaps, other similar fruits in the form of elongated seed envelopes, such as husks, and having a potential link with the Latin *legūmen*, meaning *pod* (18, 20).

During 6th and 5th centuries BC, Milesian Greek colonised a region in the Black Sea coastal region in the Southern Caucasus, then known as Colchis and today being a part of Georgia. It is highly probable that the Greeks exported the word λοβός to the local population, where it became ლობიო (*lobio*) and have been denoting faba bean (*Vicia faba* L.) until today. It is curious that and still unexplained why this and all the other names for this crop in Georgian and other Kartvelian languages are, in fact, borrowings from diverse neighbouring languages, although faba bean had been cultivated in the Northern Caucasus and Asia Minor from Neolithic times (12). Whatever, it also seems that the Greek λοβός was further transferred to Armenian, where, under the name of լոբի (*lobi*), it also denotes faba bean (13).

We can only continue to speculate by postulating that the word was spread down south and came into a contact with the Semitic languages, especially Arabic, then spoken mostly in the sothern parts of the Arabian Peninsula and with much less numerous communities living in the Near East. There, the root **lāb-* could easily become associated with hyacinth bean, that had already begun its widespread eastwards (8). A phenomenon of duplicating essentially one-syllabic words, such as *lob-* and shifting one vowel into another, such as *o* to *a*, is quite common and often met in historical linguistic research (11): in our case, borrowing the root *lob-* into old or Classical Arabic, either from Armenian or from the Greek population, then inhabiting Asia Minor, eventually led to the well-known *lablāb*. From Arabic, this word could have been exported into Persian at some still non-assessed time. What is attested is that the Arabic *lablab* was borrowed into Turkish (19), most likely after the first Seljuks' invasions of Baghdad and Asia Minor.

The borrowed word, now in the form of the Turkish *hyacinth bean*, kept on developing. On the basis of a claim that the Turks in their new homeland did not grow hyacinth bean, either on a significant scale or at all, it passed through one more transformation. It became *leblebi* and, along with some other words, began to denote chickpea (*Cicer arietinum* L.) and, especially, its roasted grain. This should not be surprising, since chickpea has been present in Asia Minor almost ten millennia already, as one of the very first domesticated crops in the world (13).

Along with the Ottoman Turkish conquests of the territories in Europe and the introduction of their culture to the local peoples, there also came their rich cuisine art. Thus, the Turkish *leblebi* was imported by some Slavic languages in the Balkan Peninsula, such as the Bulgarian *leblebiya* and the Macedonian and Serbian *leblebija*, also with a primary meaning of *roasted chickpea grain* and, sometimes, referring to the chickpea crop itself. In this way, we may say that the word responsible for the scientific name *Lablab* made a full circle over two millennia and returned to the point from which it had begun its long odyssey.

This already complex theory will become even more intriguing if we add that the Ancient Greek λοβός had an independent evolution and that it, via λέβινθοι, produced the modern ρεβιθιά, denoting chickpea (20), as well as that the modern Russian word designating hyacinth bean is *lobiya*: let us hope that time will reveal more on this topic.

Table 1. Evolution of the Proto-Dravidian root **ávarai*, denoting hyacinth bean and with a preserved basic meaning in all its direct and indirect descending languages (23)

Proto-language	Transitional languages			Modern languages	Modern words
Proto-Dravidian *ávarai	Proto-Southern *avarai	Proto-Tamil-Kannada	Proto-Kannada-Badaga	Kannada	*amare, avare, ãvare, avari*
			Proto-Tamil	Malayalam	*amara, amarakka, avara, avarakka*
				Tamil	*avarai*
			Proto-Nilgiri *avîrä	Kota	*avr*
				Toda	*efïr*
		Proto-Tulu		Tulu	*abadhè, abarè, avadhè, ăvadhè, avarè*

Local names in India

Regarding the overlap between the attested times of, on one side, the domestication of hyacinth bean in India (8), and, on another side, the Indus Valley Civilisation, lasting roughly from 3,300 BC to 1,300 BC, it may be assumed that the Dravidian peoples were responsible for introducing this crop in the human diets and its wide-scale cultivation on the territory of modern India. This is rather similar to the case of pigeonpea (*Cajanus cajan* (L.). Huth.), another important Indian grain legume (17).

Proto-Dravidian is the supposed ancestor of all numerous extinct and living Dravidian languages. Some linguists estimate that it was spoken during 4th millennium BC, as well as that it began to split into three main branches about 1,000 years later (1).

So far, there have been attested three Dravidian roots primarily and solely relating to hyacinth bean (23).

The first one is the Proto-Dravidian **ávarai*, which was directly descended only by the Proto-Southern language and eventually brought forth the words denoting hyacinth bean in numerous members of this branch of the Dravidian ethnolinguistic family, such as Kannada, Malayalam or Tamil, just to mention those with a large number of speakers (Table 1).

The other two are the Proto-South **moc-ai*, giving the Malayalam *mocca* and the Tamil *moccai*, while another is the Proto-Telugu **cikkudh-*, surviving in the form of the modern Telugu *cikkudhu* (23).

Among the Indo-Aryan languages, stemming from the Proto-Indo-European, it may be noteworthy to quote the Hindi *sem* and the Sanskrit **राजशिम्बी** (*rājaśimbi*), literally meaning *royal legume*: a beautiful way, we do believe, to end this survey, that will hopefully at least a bit contribute to future multidisciplinary efforts on the topic of grain legume domestication.

Acknowledgements

The projects TR-31024 and TR-31068 of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

(1) Andronov MS (2003) A Comparative Grammar of the Dravidian Languages. Harrassowitz Verlag, Wiesbaden
(2) Anthony DW (2007) The Horse, the Wheel, and Language: How Bronze-Age Riders from the Eurasian Steppes Shaped the Modern World. Princeton University Press, New Jersey
(3) Balter M, Gibbons A (2015) Indo-European languages tied to herders. Sci 347:814-815
(4) Diamond J, Bellwood P (2003) Farmers and their languages: The first expansions. Sci 300:597-603
(5) Fuller DQ, Harvey EL (2006) The archaeobotany of Indian pulses: identification, processing and evidence for cultivation. Environ Archaeol 11:219-246
(6) Liddell HG, Scott R, Jones HS, McKenzie R (1940) A Greek–English Lexicon, Volume 2. Clarendon Press, Oxford
(7) Linnaeus C (1753) Species plantarum :exhibentes plantas rite cognitas, ad genera relatas, cum differentiis specificis, nominibus trivialibus, synonymis selectis, locis natalibus, secundum systema sexuale digestas, I-II. Impensis Laurentii Salvii, Stockholm
(8) Maass B (2016) Origin, domestication and global dispersal of *Lablab purpureus* (L.) Sweet (Fabaceae): Current understanding. Legum Perspect 13:5-8
(9) Maass BL, Usongo MF (2007) Changes in seed characteristics during the domestication of the hyacinth bean (*Lablab purpureus* (L.) Sweet: Papilionoideae). Crop Pasture Sci 58:9-19
(10) Maass BL, Jamnadass RH, Hanson J, Pengelly BC (2005) Determining sources of diversity in cultivated and wild Lablab purpureus related to provenance of germplasm by using amplified fragment length polymorphism. Genet Resour Crop Evol 52:683-695
(11) Mihailović V, Mikić A, Vasić M, Ćupina B, Đurić B, Duc G, Stoddard FL, Hauptvogel P (2010) Neglected legume crops of Serbia - Faba bean (*Vicia faba*). Ratar Povrt 47:27-32
(12) Mikić A (2011) Words denoting faba bean (*Vicia faba*) in European languages. Ratar Povrt 48:233-238
(13) Mikić A (2012) Origin of the words denoting some of the most ancient Old World pulse crops and their diversity in modern European languages. PLoS ONE 7:e44512
(14) Mikić A (2015) All legumes are beautiful, but some legumes are more beautiful than others. Legum Perspect 8:26-27
(15) Mikić A (2015) Fragmenta excerpti de *Thesauri Leguminosarum*: Three of the world's first domesticated plants in the Indo-European languages of Europe. Ratar Povrt 52:44-51
(16) Mikić A (2015) Indo-European languages might also be tied to farmers. Sci 347:814-815 http://comments.sciencemag.org/content/10.1126/science.347.6224.814
(17) Mikić A (2016) The most ancient words relating to pigeonpea (*Cajanus cajan*). Legum Perspect 11:52-53
(18) Nikolayev SL (2012) Indo-European Etymology. The Tower of Babel, an International Etymological Database Project, http://starling.rinet.ru
(19) Nişanyan S (2002) Sözlerin Soyağaci: Çağdaş Türkçenin Etimolojik Sözlüğü. Adam yay, Istanbul
(20) Pokorny J (1959) Indogermanisches Etymologisches Wörterbuch 1. Francke, Bern
(21) Porcher MH (2000) Sorting *Lablab* names. In: Porcher MH (ed) Multilingual Multiscript Plant Name Database. The University of Melbourne, Melbourne
(22) Ringe D (2006) From Proto-Indo-European to Proto-Germanic. Oxford University Press, Oxford
(23) Starostin G (2006) Dravidian Etymology. the Tower of Babel, an International Etymological Database Project, http://starling.rinet.ru
(24) Sweet R (1826) Sweet's Hortus Britannicus: Or a Catalogue of Plants Cultivated in the Gardens of Great Britain. James Ridgeway, London
(25) White R (2015) *Lablab purpureus*. In: White R (ed) International Legume Database & Information Service World Database of Legumes. University of Cardiff, Cardiff

The genetics and breeding of *Lablab purpureus* (L.) Sweet (syn. *Dolichos lablab* L., *Lablab niger* Medik)

Author: Avinashat Chuntapursat

Publisher: University of Natal, Pietermaritzburg

Year: 1995

OCLC number: 890335729

http://www.worldcat.org/title/genetics-and-breeding-of-lablab-purpureus-l-sweet-syn-dolichos-lablab-l-lablab-niger-medik-a-literature-review/oclc/890335729

Standardization of Maize (*Zea mays* L.) + Field Bean (*Dolichos lablab* L.) Intercropping System in Southern Transitional Zone of Karnataka

Author: R. Kumar Mohan

Publisher: University of Agricultural Sciences, Gandhi Krishi Vignana Kendra

Year: 2011

OCLC number: 794256976

127 pages

Web page: http://www.worldcat.org/title/standardization-of-maize-zea-mays-l-field-bean-dolichos-lablab-l-intercropping-system-in-southern-transitional-zone-of-karnataka/oclc/794256976

Development and Validation of Core Collections of Dolichos Bean (*Lablab purpureus* L. Sweet) Germplasm

Author: P. V, Vaijayanthi

Publisher: University of Agricultural Sciences, Gandhi Krishi Vignana Kendra

Year: 2013

OCLC number: 898008474

244 pages

Web page: http://www.worldcat.org/title/development-and-validation-of-core-collections-of-dolichos-bean-lablab-purpureus-l-sweet-germplasm/oclc/898008474

Second International Legume Society Conference (ILS2) *2016: Legumes for a Sustainable World*

Tróia, Portugal, 12-14 October 2016

http://www.itqb.unl.pt/meetings-and-courses/legumes-for-a-sustainable-world/welcome#content

The International Legume Society and the Instituto de Tecnologia Química e Biológica of the Universidade Nova de Lisboa cordially invite you to join us at the Second International Legume Society Conference, scheduled from 12-14 October, 2016 at Tróia resort, in the vicinity of Lisbon, Portugal.

In a world urgently requiring more sustainable agriculture, food security and healthier diets the demand for legume crops is on the rise. This growth is fostered by the increasing need for plant protein and for sound agricultural practices that are more adaptable and environmentally sensitive. Food, feed, fiber and even fuel are all products that come from legumes – plants that grow with low nitrogen inputs and in harsh environmental conditions. The Second Legume Society Conference will be held during 2016 - the United Nations' International Year of Pulses. The goals of this UN International Year include: the encouragement of connections throughout the food chain that would better utilize pulse based proteins; increase global production of pulses; better utilization of crop rotations; and to address challenges in the trade of pulses.

The conference will address the following themes: Legume Quality and Nutrition; Farming Systems/Agronomy; Abiotic and Biotic Stress Responses and Breeding; Legume Genetic Resources; and New "Omics" Resources for Legumes. The health and environment benefits, as well as, the marketing of legumes will be transversal topics throughout the conference. Special attention will be given to foster the interaction of researchers and research programs with different stakeholders including farmers and farmer associations, seed/feed and food industries, and consumers. For this, the conference will also be the site of the Final Meeting of the EU-FP7 ABSTRESS project, the Annual Meeting of EU-FP7 LEGATO project; and final dissemination events of EU-FP7-ERANets MEDILEG and REFORMA. The results and conclusions from these four important research programs will be shared with conference attendees.

Please join us in beautiful Tróia, Portugal from 12-14 October, 2016! Plan now to include the Second ILS Conference in your busy agenda. Kindly share this information with any colleagues dealing with legumes.

Diego Rubiales, on behalf of the Scientific Committee
Pedro Fevereiro, Carlota Vaz Patto and Susana Araújo, on behalf of the Organizing Committee

Local Organizers

The Instituto de Tecnologia Química e Biológica António Xavier (ITQB NOVA) is responsible for organising the Conference, in cooperation with the International Legume Society. The official language of the Conference is be the English.

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Venue

The conference will be held in Tróia in the vicinity of Lisbon, Portugal. Tróia is a beautiful sand peninsula dividing the Sado River from the Atlantic Ocean.

The nearest airport is the Lisbon International Airport, about 50 Km away. Shuttles will be made available from and to Lisbon International Airport.

During the period of Roman occupation, date from the 1st century to the 6th century AD, Tróia was an island of Sado delta, called Ácala Island.

The Sado Estuary Nature Reserve, where dolphins swim, and the Serra da Arrábida Natural Park, where a full developed Mediterranean forest can be seen, are two of the main natural attractions nearby Tróia peninsula.

The Tróia Golf Championship Course is considered the best course in Portugal in the categories of difficulty and variety. It also stands in 20th place in the list of the best golf courses in Europe drawn up by the Golf World magazine.

FINAL PROGRAM

October 10th-11th 2016

Satellite events (registration needed)
*10th-11th October **Ascochyta 2016 Workshop** (program in http://www.ascochyta2016.aweb.net.au/)*
*11th October 09:00-18:00h **LEGATO project meeting** (partners only)*
*11th October 09:00-18:00h **EUROLEGUME project meeting** (partners only)*
*11th October 09:00-18:00h **ABSTRESS project meeting** (partners only)*

October 11th 2016

18:00-20:00 ILS2 Conference Registration

October 12th 2016

08:00-12:00 Registration (cont.)
09:00-09:15 Welcome address

09:15-10:30 Session 1, plenary: Legumes value chain: market requirements and economic impact
Chaired by Eduardo Rosa (UTAD, Portugal) and Adrian Charlton (FERA, UK)

09:15-09:45 Key lecture: Hakan Bahceci: Forging a New Future for Pulses: Addressing research challenges with the momentum of the UN International Year of Pulses
09:45-10:00 P. Iannetta: Main-streaming pulses: exploring local solutions to supply chain limitations
10:00-10:15 F. Muel: Would the protein fraction be the future of oil and grain legume crops by 2030?
10:15-10:30 G. Dubois: Legume future from European Union perspective: Horizon 2020, EIP-AGRI and CAP

10:30-11:00 Coffee break

11:00-12:00 Session 2, plenary: Legumes and environment
Chaired by Richard Thompson (INRA, France) and Diego Rubiales (CSIC, Spain)

11:00-11:30 Key lecture: Marie-Hélène Jeuffroy: Validating the environmental benefits of legumes requires a territorial approach
11:30-11:45 B. Cupina: Environmental impact of introducing legumes into cropping system
11:45-12:00 C. Watson: Sustainable management of grass-white clover leys in ley-arable farming systems

12:00-13:00 Poster viewing

13:00-14:30 Lunch

14:30-16:00 Parallel sessions

Session 3, parallel: Beneficial legume-microbe interactions
Chaired by Carmen Bianco (Univ. Bari, Italy) and Pedro Fevereiro (ITQB, Portugal)

14:30-15:00 Key lecture: Jens Stougaard: Receptor mediated signaling in legume symbiosis
15:00-15:10 J. Keller: Symbiotic genes expression in a context of nitrogen-fixing symbiotic specificity in *Lupinus*
15:10-15:20 M. Vosatka: Beneficial microbes associated with legumes
15:20-15:30 V. Bourion: Partner choice in a core collection of pea inoculated by a mix of five Rhizobium strains
15:30-15:40 M. Lepetit: Improving adaptation of legume-rhizobium symbiosis to the soil environment
15:40-16:00 General discussion on beneficial legume-microbe interactions

Session 4, parallel: Genetic resources
Chaired by Hari Upadhyaya (ICRISAT) and Rodomiro Ortiz (SLU, Sweeden)

14:30-15:00 Key lecture: Noel Ellis: Where are we after 150 years of legume genetics?
15:00-15:10 E. von Wettberg: Using collections of wild relatives of chickpea to understand domestication
15:10-15:20 M. Carvalho: Characterizing the genetic diversity of cowpea accessions using a high-density SNP
15:20-15:30 K. Fischer: LupiBreed - Valorisation of novel genetic variability in narrow-leafed lupin
15:30-15:40 M. Nelson: Domestic bliss? Causes and consequences of a modern era domestication event
15:40-16:00 General discussion on genetic resources

16:00-16:30 Coffee break and Poster viewing

16:30-17:30 Parallel sessions

Session 5, parallel: Legumes value chain: market requirements and economic impact (cont.)
Chaired by Frédéric Muel (Terres Inovia, France) and Pete Iannetta (JHI, UK)

16:30-16:40 L. Bedoussac: Evaluating cereal-legume intercrops towards sole crops
16:40-16:50 M. Magrini: Escaping from grain-legume socio-technical system lock-in
16:50-17:00 A. Bentaibi: Analysis of social and organizational aspects of food legumes chain
17:00-17:10 D. Lemken: The re-innovation of mixed cropping - who cares? - Trial Willingness
17:10-17:30 General discussion on Legumes value chain

Session 6, parallel: Root diseases
Chaired by Julie Pasche (North Dakota St. Univ., USA)

16:30-16:40 L. Gentzbittel: Quantitative response of *M. truncatula* to verticillium wilt
16:40-16:50 M.-L. Pilet-Nayel: Genetics of pea resistance to *Aphanomyces euteiches* in the genomics era
16:50-17:00 C. Coyne: Progress on understanding genetic resistance to Fusarium root rot in pea
17:00-17:10 S. Chatterton: Molecular quantification of pathogenic *Fusarium* spp. in soil to predict pea root rot risk
17:10-17:30 General discussion on rot diseases

17:30-18:30 Poster session 1: Slots of flash presentations (3 min + 2 min questions) from selected posters (topics of the day)
Chaired by Alessio Cimmino (Univ. Naples, Italy) and Georg Carlsson (SLU, Sweeden)

A. Seabra Pinto: Do consumers' value the new use of legumes?
C. Ghoulam: Intercropping legume-cereals is a system to value legume-rhizobia symbiosis
J. Fustec: Synergy between crop diversity and earthworm community improve crop yields
C. Lotti: A novel source of genetic diversity in cultivated chickpea as revealed by GBS and genotyping
M. G. Tobar-Pinon: Genetic diversity of the Gautemalan climbing bean collection
M. Ruland: Temporal and regional development of lentil populations by natural selection on-farm
A. Moussart: Effect of pea sowing date on aphanomyces root rot development and yield losses
A. Lesné: Construction and evaluation of Near-Isogenic Lines for resistance to *Aphanomyces euteiches* in pea
R. Tollenaere: Nested Association Mapping for resistance to *Aphanomyces* in *M. truncatula*
C. Bianco: The auxin indole-3-acetic acid (IAA) is more than a plant hormone

20:45 Third International Legume Football Cup

October 13th 2016

8:30-10:00 Session 7, plenary: Legumes in food and feed and other alternative uses
Chaired by Maria Carlota Vaz Patto (ITQB, Portugal) and Ambuj B. Jha (Univ. Saskatchewan, Canada)

08:30-09:00 Key lecture: Frédéric Marsolais: Using beans with novel protein compositions for nutritional improvement
09:00-09:15 M. Bronze: The hidden phenolic content of faba beans
09:15-09:30 J.C. Jimenez-Lopez: Use of narrow-leafed lupin b-conglutin proteins in human food to tackle diabetes
09:30-09:45 C. Domoney: Genetic diversity in pea and its impact on strategies for seed quality improvement
09:45-10:00 A.F. Monnet: Understanding the structuring of wheat-legume cakes to promote product innovation

10:00-10:30 Coffee break and Poster viewing

10:30-12:00 Session 8, plenary: Frontiers in legume genetics and genomics
Chaired by Roberto Papa (Univ. Le Marche, Italy) and Marta Santalla (CSIC, Spain)

10:30-11:00 Key lecture: Judith Burstin: Towards the genome sequence of pea: a tribute to Mendel
11:00-11:15 P. Wan: Genome sequencing of *Vigna angularis* provides insight into high starch and low fat.
11:15-11:30 P. Annicchiarico: Genotyping-by-sequencing and its exploitation in forage and grain legume breeding
11:30-11:45 S. Kaur: Application of historical data from Australian lentil breeding program in genomic selection
11:45-12:00 G. Boutet: WGGBS in pea without reference genome and data assembly

12:00-13:00 Poster session 2: Slots of 3 min flash presentations (+ 2 min questions) from selected posters (topics of the day)
Chaired by Nuno Almeida (ITQB, Portugal) and Sara Fondevilla (CSIC, Spain)

E. Collado: Pea straw: an advantageous co-product in dairy goat diets
C. Arribas-Martinez: Nutritional and nutraceutical characterization of extruded gluten-free snacks
M. Książkiewicz: Genes involved in flowering time regulation in white lupin
R.V. Penmetsa: Mendel's enduring legacy: orthologs of two of his seven factors in multiple current day crop legumes
R. Papa: Bean Adapt: The genomics of adaptation during crop expansion in common bean
A. Sarkar: The *Lathyrus sativus* genome project
H. Bobille: Effect of soil water deficit on amino acid exudation in *Pisum sativum* roots
C. Le May: Plant disease complex: antagonism and synergism between pathogens
A. Cimmino: Necrotrophic effectors produced by fungal pathogens of legume crops
A. Quillévéré-Hamard: Genetic and phenotypic diversity of pea isolates of *Aphanomyces euteiches* in France
L. Aguirrezabal: Modelling the effect of assimilate availability on seed weight and composition in soybean

13:00-14:30 Lunch

14:30-16:00 Parallel sessions

Session 9, parallel: Legumes in food and feed and other alternative uses (cont.)
Chaired by Ruta Galoburda (Latvia Univ. of Agriculture, Latvia) and Tom Warkentin (Univ. Saskatchewan, Canada)

14:30-14:40 E. Tormo: A meta-analysis to assess the effect of fine grinding, dehulling and pelleting
14:40-14:50 E. Mecha: Protein quality of different Portuguese varieties of common bean
14:50-15:00 L. Proskina: Economic factors of using the legumes in broiler chickens feeding
15:00-15:10 M.C. Serrano: Tocopherols and carotenoids diversity in a chickpea germplasm
15:10-15:20 A. Clemente: Bowman-Birk inhibitors from legumes and mammalian gut health
15:20-15:30 A.B. Jha: Evaluation of a pea genome wide association study panel for folate profiles by UPLC-MS/MS
15:30-16:00 General discussion on Legumes in food and feed and other uses

Session 10, parallel: Frontiers in legume genetics and genomics (cont.)
Chaired by Bernadette Julier (INRA, France) and Kevin McPhee (North Dakota State Univ. USA)

14:30-14:40 C. Le Signor: A protein quantity loci approach combined with a genome-wide association study
14:40-14:50 M.C. Vaz Patto: Using genomics to decipher the grain legumes quality riddle
14:50-15:00 A.M. Torres: Strategies and advances to identify candidate genes for low vicine-convicine in faba bean
15:00-15:10 M. Santalla: Homologues of Arabidopsis genes involved in photoperiod response in common bean
15:10-15:20 P. Smykal: Wild pea *P. fulvum* and *P. elatius* chromosome segment substitution lines in cultivated pea
15:20-15:30 A. Campa: Delimiting the physical positions of anthracnose resistance clusters
15:30-16:00 General discussion on frontiers in genetics and genomics

16:00-16:30 Coffee break and Poster viewing

16:30-17:45 Parallel sessions

Session 11, parallel: Frontiers in plant and crop physiology
Chaired by Christophe Salon (INRA, France) and Luis Aguirrezabal (CONICET, Argentina)

16:30-17:00 Key lecture: Phil Mullineaux: The identification of novel genes controlling plant-environment interactions
17:00-17:10 J. Vorster: Drought-induced transcriptome changes in soybean crown nodules
17:10-17:20 R. Metzner: In vivo monitoring of the development of legume roots, nodules and pods
17:20-17:30 G. Louarn: A common shoot developmental framework for perennial legume species
17:30-17:45 General discussion on frontiers in plant and crop physiology

Session 12 parallel: Integrated pest and disease management
Chaired by Jenny Davidson (PIRSA-SARDI, Australia) and Christophe Le May (INRA, France)

16:30- 17:00 Key lecture: Seid Kemal: Integrated disease and insect pest management pest and in cool-season food legumes
17:00-17:10 A. Baranger: PISOM: Ideotypes, Systems, Surveys of pea and faba bean Main diseases
17:10-17:20 Y. Mehmood: The Australian *Ascochyta rabiei* population structure
17:20-17:30 W. Chen: Chickpea damping-off caused by metalaxyl resistant Pythium in the US Pacific Northwest
17:30-17:45 General discussion on integrated pest and disease management

17:45-19:00 ILS General Assembly

20:45 Third International Legume Football Cup

October 14th 2016

8:30-10:00 Session 13 plenary: Frontiers in legume breeding
Chaired by Wolfgang Link (Georg-August-University, Germany) and Gerard Duc (INRA, France)

08:30-09:00 Key lecture: Scott Jackson: Contribution of epigenetic variation to improvement
09:00-09:15 B. Julier: QTL detection for forage biomass of alfalfa in mixture with a forage grass
09:15-09:30 A. Charlton: Improving the resistance of legume crops to combined abiotic and biotic stress
09:30-09:45 M. Pazos: Integrated platform for rapid genetic gain in temperate grain legumes and wild *Cicer* species
09:45-10:00 A. Sarker: Broadening the genetic base of lentil

10:00-10:30 Coffee break and Poster viewing

10:30-12:00 Session 14, plenary: Frontiers in legume agronomy
Chaired by Erik S. Jensen (SLU, Sweden) and Susana Araujo (ITQB, Portugal)

10:30-11:00 Key lecture: Eric Justes: Synthesis on the effects of grain legume insertion and cereal-grain legume intercrops in low input cropping systems in Southern France
11:00-11:15 E. Pelzer: Design and assessment of legume-based cropping systems with stakeholders in Europe
11:15-11:30 C. Porqueddu: Performance of legume-based annual forage crops in three Mediterranean regions

11:30-11:45 A. Lingner: Legume-based mixed cropping systems may have higher water use efficiency
11:45-12:00 G. Carlsson: Participatory development of grain legume-cereal intercrops for enhanced productivity

12:00-13:00 Poster session 3: Slots of 3 min flash presentations (+ 2 min questions) from selected posters (topics of the day)
Chaired by Sofia Duque (ITQB, Portugal) and Angel M. Villegas-Fernández (CSIC, Spain)

L. Wiesel: Starter fertilisers: Do they influence rhizobial populations in vining pea fields?
R. Bowness: Evaluation of agronomic practices on production of Clearfield red lentil in Alberta, Canada
R. Seljåsen: Nitrogen availability from peas and faba beans as pre-crops to broccoli followed by lettuce
J. Rebola Lichtenberg: Biomass production in mixed short-rotation woody cropping of *Populus* hybrids and *Robinia*
M. Ćeran: Discovering genetic signatures of selection in the elite soybean germplasm
J. Aper: Flower abscission rates of early-maturing soybean varieties
C. Holdt: Genetic studies of winter hardiness in pea
A. Scegura: Marker-assisted backcross selection of virus resistance in pea
J. J. Ferreira: Genetic resistance to powdery mildew in common bean
M. Pérez-de-la-Vega: RNA-seq analysis of gene expression in lentils in response to *Ascochyta lentis* infection
V. Vernoud: A transcriptomic approach identifies candidate genes for drought tolerance in pea

14:30-16:00 Parallel sessions

Session 15, parallel: Frontiers in legume breeding (cont.)
Chaired by Paolo Annicchiarico (CREA, Italy)

14:30-14:40 B. Taran: Genomic prediction for seed size in chickpea
14:40-14:50 L. Brünjes: Faba bean lines differ in their contribution as pollen donor to cross-fertilized seed
14:50-15:00 L. Pecetti: Assessing and overcoming genetic trade-offs in breeding grazing-tolerant alfalfa
15:00-15:10 T. Warkentin: Enhancing the nutritional quality of field pea
15:10-15:20 B. Rewald: Machine learning approaches for root trait determination and differentiation of cultivars
15:20-15:30 R. Madhavan-Nair: An International network to improve mungbean breeding and production
15:30-16:00 General discussion on frontiers in legume breeding

Session 16, parallel: Advances in legume agronomy (cont.)
Chaired by Fred Stoddard (Univ. Helsinki, Finland) and Claudio Porqueddu (CNR, Italy)

14:30-14:40 G. Corre-Hellou: Ecosystem services provided by legumes and exploited by stakeholders 14:40-14:50 G. Maé: Quantification of nitrogen fluxes and explanatory plant traits
14:50-15:00 N. Carton: Cereals as companion crops in cereal-grain legume intercrops: case of lupin 15:00-15:10 E. Journet: Intercropping lentil with spring wheat in organic farming
15:10-15:20 S. Guy: Diversification of USA dryland cropping systems using autumn-sown winter pea 15:20-15:30 J. Streit: Quantitative analysis of the root distribution in a faba bean-wheat intercropping system
15:30-16:00 General discussion on advances in legume agronomy

16:00-16:30 Coffee break and Poster viewing

Session 17, parallel: Legumes and environment (cont.)
Chaired by Christine Watson (SRUC, UK)

16:30-16:40 E.S. Jensen: Soil nitrogen fertility and nitrogen acquisition in faba bean
16:40-16:50 D. Savvas: Impact of organic practices on growth, yield, greenhouse gas emissions
16:50-17:00 K. McPhee: Effect of simulated hail treatment on yield loss in chickpea
17:00-17:10 V. Verret: Meta-analysis of the effects of legume companion plants
17:10-17:20 S. Mediene: A tool integrating knowledge to select legume species for oilseed rape intercropping
17:20-17:30 V. Sánchez-Navarro: Nitrous oxide and methane fluxes from a cowpea-broccoli crop rotation
17:30-18:00 General discussion on Legumes and environment

Session 18, parallel: Resistance to biotic and abiotic stresses
Chaired by Weidong Chen (USDA-ARS, USA) and Laurent Gentzbittel (CNRS, France)

16:30-16:40 M. Dickinson: Exploring metabolic changes in legumes exposed to combined biotic and abiotic stress
16:40-16:50 K. Toyoda: The role of plant cell wall in resistance and susceptibility to pathogenic pathogen
16:50-17:00 J.M. Osorno: Detecting tolerant germplasm and QTLS associated with flooding stress in dry bean
17:00-17:10 S. Beji: Genome-Wide association mapping of frost tolerance in *Pisum sativum*
17:10-17:20 B. Ruge-Wehling: Marker-assisted breeding strategies for anthracnose resistance in lupin
17:20-17:30 D. Rubiales: Use of wild relatives in pea breeding for disease resistance
17:30-18:00 General discussion on resistance to biotic and abiotic stresses

18:00-19:00 Concluding session
Poster and oral presentation awards
ILS Honorary member's awards

20:00 Farewell Dinner

October 15th 2016 (satellite events)

08:00-12:00 ***REFORMA project meeting*** *(partners only)*

08:00-12:00 ***IYP Research Strategy write shop*** *(by invitation)*

19th Symposium of the European Grassland Federation
Alghero, Italy, 7-10 May 2017
http://www.egf2017.org/

European Association for Research on Plant Breeding (EUCARPIA) Genetic Resources section meeting
Montpellier, France, 8-11 May 2017
http://www.eucarpia.org/activities/meetings.html

10th World Soybean Research Conference and 17th Biennial Conference on the Molecular and Cellular Biology of Soybean
Savannah, USA, 10-15 September 2017
http:// www.wsrc10.net

European Association for Research on Plant Breeding (EUCARPIA)
Joint meeting of Fodder Crops and Amenity Grasses Section and Protein Crops Working Group
Vilnius, Lithuania, 11-14 September 2017
http://www.eucarpia.org/activities/meetings.html

8th International Conference on Legume Genetics and Genomics
Siófok, Hungary, 18-22 September 2017
http://iclgg2017.hu

Dr. Jean Picard

The first President of AEP, Jean Picard (1924-2016), passed away in April 2016.

He was among the founding members of the European Association for Grain Legume Research (L'Association Européenne de recherche sur les Protéagineux, AEP). Jean was elected as the first President at the initial AEP conference in Angers, France, in 1992.

As a geneticist and plant breeder of faba bean and red clover, he had a long career at INRA-Dijon, France, 1986. Jean has been involved in numerous European projects, in ICARDA working groups and in the forage research community.

Since his retirement, Jean was living in his home village at Neuvy-Pailloux, a charming village of the Champagne berrichonne, France, taking care of his garden and bees.

Dr. Jean Picard, evaluating red clover trials in his professionally active years as a geneticist and plant breeder at INRA Dijon, France

We send a message of condolences to Jean's family and reserve a thought for all that he generously built for the legume research community that continues today in our various networks.

International Legume Society

Legume Perspectives is an international peer-reviewed journal aiming to interest and inform a worldwide multidisciplinary readership on the most diverse aspects of various research topics and use of all kinds of legume plants and crops.

The scope of *Legume Perspectives* comprises a vast number of disciplines, including biodiversity, plant evolution, crop history, genetics, genomics, breeding, human nutrition, animal feeding, non-food uses, health, agroecology, beneficial legume-microorganism interactions, agronomy, abiotic and biotic stresses, agroeconomy, sociology, scientometrics and networking.

The issues of *Legume Perspectives* are usually thematic and devoted to specific legume species or crop, research topic or some other issue. They are defined by the Editorial Board, led by the Editor-in-Chief with the help from Assistant Editors, who select and invite one or more Managing Editors for each issue. Having accepted the invitation, the Managing Editor agrees with the Editorial Board the details, such as the deadline for collecting the articles and a list of the tentative contributors, from whom he, according to his own and free choice, solicit the articles fitting into the defined theme of an issue.

There is a possibility that every member of the global legume research community, with a preference of the International Legume Society members or established authorities in their field of interest, may apply to the Editorial Board to be a Managing Editor and suggest a theme for his issue, done simply by contacting the Editor-in-Chief by e-mail, with a clearly presented idea, structure and authors of the potential issue.

The articles published in *Legume Perspectives* are usually concise, clear and up-to-date reviews on the topic solicited by the Managing Editor from each author. Managing Editor is solely responsible for collecting the articles from the authors, anonymous peer-review, communicating with the Technical Editor and providing the authors with the proofs of their manuscript prior to the publication.

Legume Perspectives prefers a clear, simple and comprehensive writing style that would make its articles interesting and useful for both academic and amateur audience.

Legume Perspectives welcomes either longer (900-1,100 words + up to 3 tables, figures or photos + up to 10 references) or shorter (400-500 words + 1 table, figure, photograph or drawing + up to 4 references) manuscripts. The Editor-in-Chief, depending on the opinion of the Managing Editor, may allow any variation in length or structure, from case to case.

The manuscripts for *Legume Perspectives* should be prepared in Microsoft Office Word, using Times New Roman font, 12 points size and single spacing. Please provide each manuscript with a 100-word abstract and 4-6 key words listed alphabetically. The references should follow the style of the published papers in this issue, be given in full and listed alphabetically. The tables may be incorporated in the manuscript, while figures, photographs or drawings should be submitted separately as jpg files with a resolution of at least 300 dpi. The authors whose native language is not English are strongly advised to have their manuscripts checked by a native English speaker prior to submission.

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