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

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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.

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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).

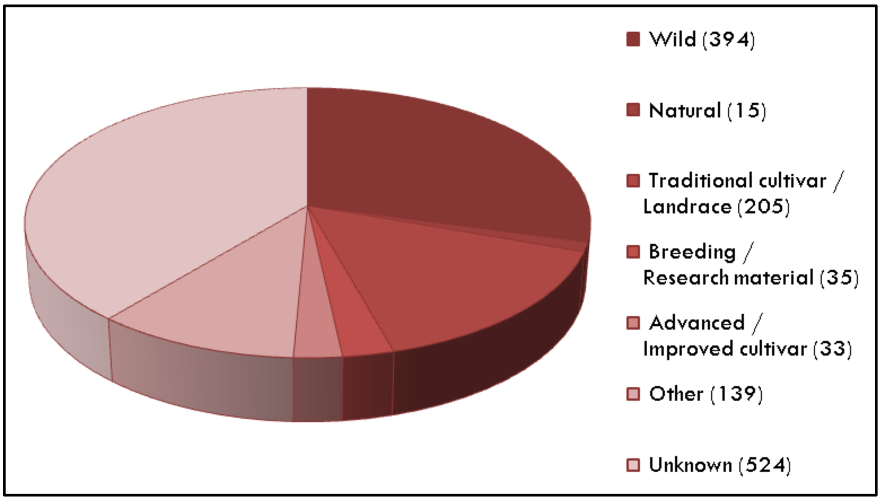

Figure 1. The structure of the hyacinth bean accessions in the portal GENESYS according to their status (9)

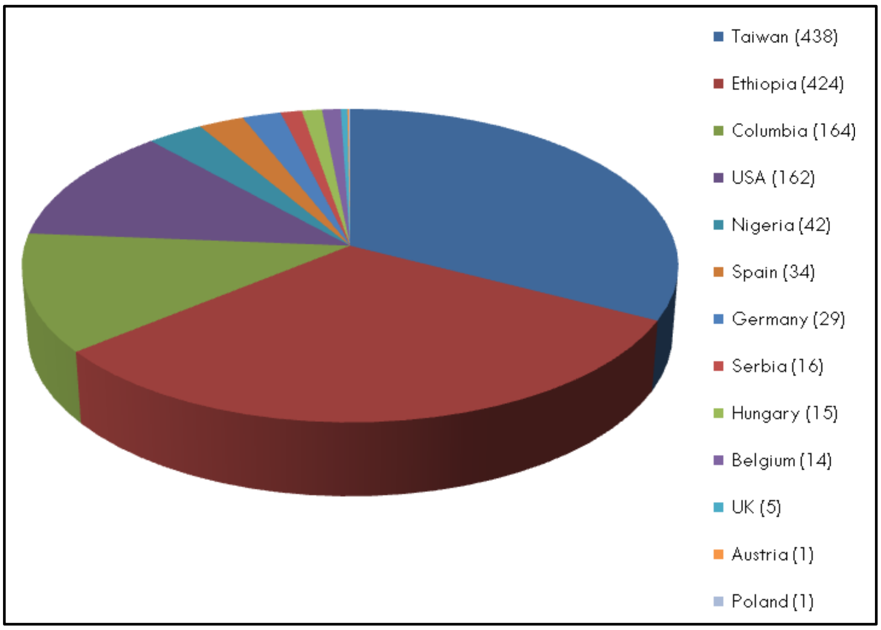

Figure 2. The structure of the hyacinth bean accessions in the portal GENESYS according to holding country (9)

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 / indermimined 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),

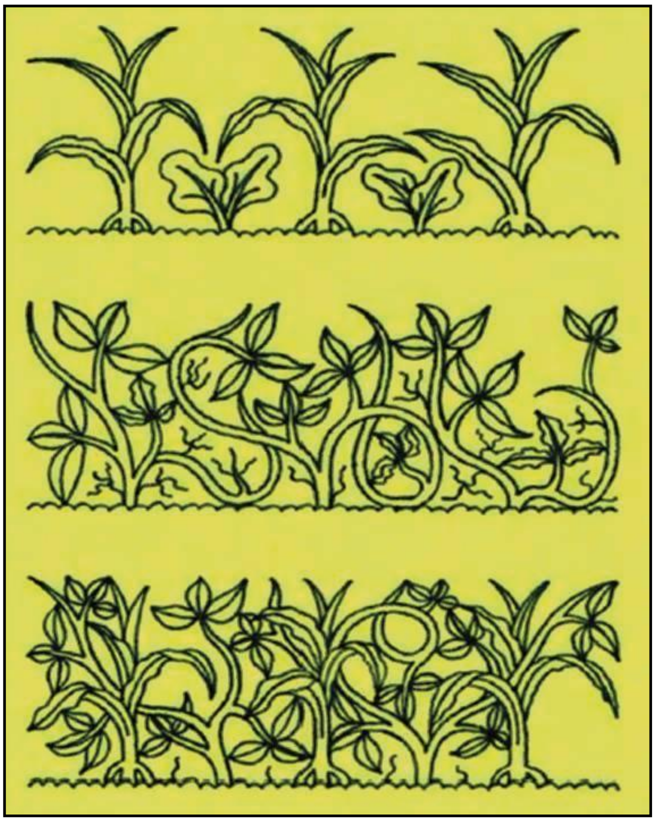

Figure 6. Some aspects of intercropping hyacinth bean: (top row) cereals, such as maize, have an excellent standing ability, but are easily infested by weeds, like in brassicas, such as rapeseed, or lodging-resistant legumes, such as soya bean; (middle row) hyacinth bean efficiently fights weeds, but 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

The projects TR-31016, TR-31022, TR-31024, TR-31025, TR-31066, TR-31068 and TR-31073 of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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