ASSESSMENT OF PHENOTYPIC DIVERSITY OF KENYAN DOLICHOS BEAN (LABLAB PURPUREUS L. SWEET) GERMPLASM BASED ON MORPHOLOGICAL MARKERS

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ABSTRACT

In Kenya, lack of phenotypic diversity assessment of Lablab has hindered its improvement. It is common to find that morphologically similar cultivars do not bear the same name while cultivars bearing the same name may not be identical morphologically. The aim of this study was to clear the ambiguity that exists in differentiating between the various phenotypes of Lablab. The morphological method is the oldest and considered the first step in description and classification of germplasms. Forty five accessions of Lablab collected from farmers' fields in Rift Valley, Eastern, Coast and Central regions of Kenya were planted at Kenya Agricultural and Livestock Research Organization, Njoro farm. A descriptor from Asian Vegetable Research Development Center was used as a guide. Results on means separation showed a high level of variability in quantitative traits and a low level of variability in qualitative traits. Eigen vectors derived from principal component analysis indicated that seed yield per plant, number of pods per plant, plant height and days to 90% mature pods contributed highly to total diversity in Lablab. In conclusion, Lablab germplasm grown in Kenya is morphologically diverse in quantitative traits where different genotypes are distinctly dissimilar.

Keywords: Lablab, Morphological, diversity, Kenya

Introduction

In Kenya Lablab, is also known as "njahe" among the Kikuyu, "chabi" among the Meru, Embu and Mbeere, "mbumbu" among the Kamba and Taita, "elikeri" among the Kisiis and "chemakikosor" among the Kalenjini (Kamotho *et al*., 2015). Several other communities who grow and utilize the crop in Kenya albeit in a limited amount have adopted the name "njahe". The diversity of names among different communities in Kenya demonstrates the popularity of this crop. In Kenya, Lablab is grown from near sea level at the coastal region (Lamu), through

the dry areas of Esatern Kenya (Mwingi, Machakos, Embu, Mbeere) and Riftvalley region (Nakuru) to the foot of Mount Kenya, largely in Meru, Nyeri, Murang'a and Kiambu counties. Although Lablab is a minor crop in many areas where it is grown, in Lamu county it is a major crop mainly grown as an intercrop with maize where it has effectively replaced common beans both in the field and diet (Kinyua and Kiplagat, 2012).

In Kenya, Lablab is utilized as food. Schippers, (2000) noted that the Kikuyu people in Kenya traditionally consume Lablab during wedding ceremonies. In general, the Meru, Kamba, Mbeere and Kikuyu communities use it in stews and local dishes such as "Githeri" and "Mokimo". As food, the grains are the most preferred and are presented in a variety of recipes ranging from mixtures with other food stuffs such as potatoes, bananas and various vegetables to exclusive "Njahe" stew. However, leaves and young pods are also fried and used as vegetables especially during the dry season (Kamotho *et al.,* 2010, Kinyua and Kiplagat, 2012).

Some farmers use it as a livestock feed where the whole crop is cut at the base. In areas where it is grown, it fetches higher returns per unit quantity as compared to maize and beans (Kamotho *et al*., 2010; Kinyua and Kiplagat, 2012). The main growers of Lablab in Kenya are small scale farmers who either grow it as intercrop or pure stand (Kamotho *et al*., 2010; Kinyua and Kiplagat, 2012). In some areas such as Mbeere, Embu, Mwingi, Machakos and Murang'a counties, Lablab plays a major role in soil fertility improvement strategies as it is included in the rotation programme or is intercropped with maize where it forms a good soil cover (Kamotho *et al*., 2010; Kinyua and Kiplagat, 2012). In such cases, the biennial varieties such as DL1002 and DL1009 are planted. These are known to smother the weeds by the thick canopies they form thereby reducing the number of times the main crop is weeded.

Furthermore, with its deep tap root, Lablab is not only drought hardy, but is able to bring minerals, otherwise not available for annual crops, from the depths to the topsoil (Cook *et al.,* 2005; FAO, 2012). As a legume, the crop is known to provide biological nitrogen fixation which is a process of natural action of converting atmospheric nitrogen into forms available for the plant-soil system which improves productivity in an inexpensive, environmentally friendly manner. This "natural fertilizer" enables small landholders to improve the soil without incurring costs (McDonald *et al*., 2001). Despite the importance of Lablab in Kenya, low yields are obtained from the crop.

Morphological characterization is the first step that should be done before more profound biochemical or molecular studies are carried out (Hoogendijk & Williams, 2001; Hedrick, 2005). Morphological characterization is traditionally the most common method used and many different crops have been studied (González *et al.*, 2002). Some of the most important

advantages of using morphological characterization are that they are simple to identify and do not need specialized labour, published descriptor lists are readily obtainable for most major crop species, it can be carried out *in situ*, is relatively low-cost and easy to perform. However, morphological estimations are more dependent on environment and are more subjective than other measurements (Li *et al.,* 2011). Morphological variability depends on a limited number of genes, and may not access much of the potential variability for the agronomic traits present in a crop (Boder *et al.,* 2006). The use of morphological and agronomic traits is a standard way of assessing genetic variation for many species, especially under-researched crops (Azam-Ali *et al.,* 2001). Although molecular characterization is increasingly being used, morphological characterization continues to be a useful component that enhances the power of molecular methods. Morphological characterizations criteria are thus important and some main characteristics that can be used as references in Lablab bean breeding programmes or in marketing are needed.

2. MATERIALS AND METHODS

2.1 Seed Acquisition and Planting

Seeds of forty five (45) accessions of *Lablab purpureus* were obtained from Rift Valley, Eastern, Coast and Central provinces of Kenya. Among them, twenty nine (29) were brown and sixteen were black (Table 1). Seeds were planted on plots of 2.25m x 1.8m at spacing of 90cm x 75cm in Kenya Agricultural and Livestock Research Organization (KALRO), Nakuru-Njoro farm. Randomized complete block design (RCBD) was used and each bock was replicated three times.

Table 1 Dolichos bean accessions and places of collection

Accession	Place Collected	Seed Testa Colour
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	Lamu	Brown
14, 15, 16	Machakos-Kalama	Dark- Brown
17, 18, 19, 20	Machakos-Kathiani	Dark- Brown
21	Machakos-Yatta	Black
22, 23	Murang'a-Makuyu	Black
24, 25, 26, 27	Thika-Kakuzi	Black

28	Thika-Municipality	Black
29, 30	Mbeere-Siakago	Brown
31	Meru-Abothoguchi	Black
32	Meru-Mihiriga Mieru	Black
33, 34, 35	Nakuru-Lare	Black
36	Nakuru-Bahati	Black
37, 38	Naivasha-Maragushu	Black
39, 40, 41, 44, 45	Mwingi-Central	Brown
42, 43	Mwingi-Migwani	Brown

2.2 Data Collection

Data were taken on the qualitative and quantitative vegetative characters as indicated in Table 2. A descriptor from Asian Vegetable Research Development Center (AVRDC) was used as a guide for morphological characterization. Overall, twenty six characters were considered.

Table 2: Descriptor for agro-morphological traits used in characterization of the 45 accessions of Lablab bean

Trait	Description
Emerging cotyledon color	1=white, 2=green, 3=purple
Hypocotyl color	1=green, 2=purple
Vein color of fully developed primary leaves (on inner face)	1=green, 2=purple
Plant height	In centimeters, from cotyledon scar to tip of plant on 10 randomly selected mature plants
Leaflet length and width, measured on the terminal leaflet of third trifoliate leaf from pulvinus to leaf tip	3=5-7, 5=9-11, 7=13-15 10 randomly selected mature plants
Leaflet width, measured on the terminal leaflet of third trifoliate leaf on the widest part of leaf	3=2-6, 5=7-10, 7=11-15 10 randomly selected mature plants
Growth habit	1=determinate bush, 2=intermediate semi-climber 3=indeterminate climber, 4=others

Days to maturity	Days from emergence to stage when 90% of pods are ripe
Days to flowering	From emergence to stage when 50% of plants have begun to flower
Colour of flower kill	1=greenish, 2=tinged (pink or purple)
Colour of flower standard (upper part of inner side)	1=white, 3=light pink, 5=deep pink, 7=violet
Raceme length	In centimeters, one raceme from each of 10 plants at pod filling period; if determinate type, one terminal raceme; if indeterminate type, one lateral raceme- 6th from apex
Duration of flowering	From first flowers to stage where 50% of plants have finished flowering
Pod length	In centimeters, average of 10 randomly chose mature pods. If pods are curved, measure straight line from base to tip of pods
Pod width	In centimeters, of the largest width from 10 randomly chosen mature pods
Pod colour (of mature pods)	1=light green 2=green 3=green with purple suture 4=purple
Number of seeds per pod	Average from 10 randomly chosen ripe pods
Number of pods per raceme	Average of 10 randomly chosen racemes
Number of racemes per plant	Average of 10 randomly chosen 3 mature plants
Number of pods per plant	Average of 10 randomly chosen 3 mature plants when 90% of pods are ripe
Cotyledon colour (of ripe seeds)	1=white, 2=green, 3=brown, 4=purple
Seed length	In millimeters, average of 10 ripe seeds chosen at random
Seed width	In millimeters, average of 10 ripe seeds chosen at random In millimeters, average of 10 ripe seeds chosen at random
Seed weight	Weight of 100 seeds in milligrams, moisture content of 12-14%
Seed yield	Weight of all seeds harvested from 3 randomly chosen plants
Seed germination	Days taken for 90% shoot emergence in field

3. RESULTS

3.1 Dolichos bean agro-morphological traits

Agro-morphological traits considered in this study were emerging cotyledon color, hypocotyl color, vein colour, testa colour, growth habit, hypocotyl length, plant height, leaf width, leaf length, raceme length, pod length, pod width, seed length, seed width, days to seed germination in the field, days to 50% flowering, duration of flowering, colour of flower kill, colour of flower standard, pod colour, days to 90% mature pods, number of pods per raceme, number of racemes per plant, number of nodes per raceme, number of pods per raceme, number of pods per plant, number of seeds per pod, 100 seed weight and seed yield per plant.

3.2 Lablab bean diversity for emerging cotyledon colour, hypocotyl colour, vein colour and growth habit

Out of the 45 accessions of Lablab bean collected, 57.8% had green colour of emerging cotyledon while 42.2% had purple colour. Forty eight point nine percent (48.9%) had green hypocotyl colour while 51.1% had purple colour. All Lablab bean accessions that had green emerging cotyledon colour had also a green vein colour (48.9%) while Lablab bean accessions that had purple emerging cotyledon colour had a purple vein colour (51.1%), Fig.1.
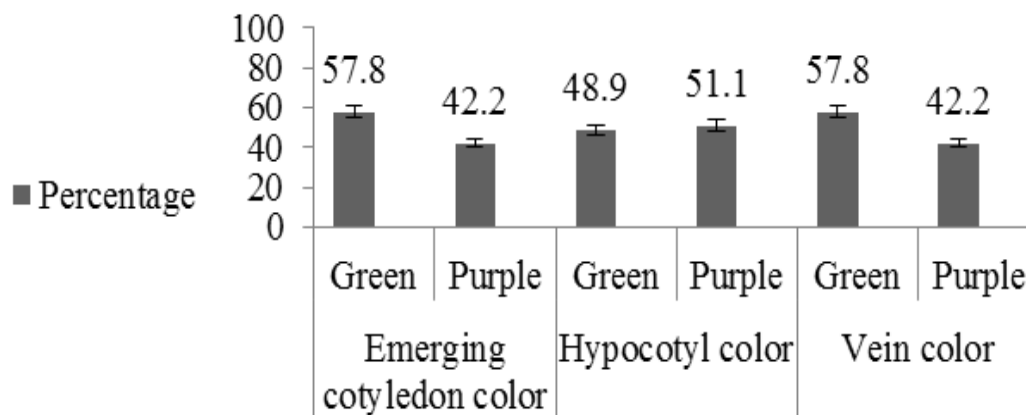

Fig. 1 Lablab bean diversity for emerging cotyledon colour, hypocotyl colour and main vein colour.

Figure 2a, shows that the forty five Lablab bean accessions used in this study could be grouped into one of the three growth habit categories, that is, determinate bush, indeterminate climber and intermediate semi-climber. Out of the 45 collected accessions, 31.1% were determinate bush, 20% were indeterminate climber while 48.9% were intermediate semi-climber. Figure 2b, shows that Lablab bean considered in the study had three seed testa colour variations, that is, black (35.5%), brown (48.9%) and dark brown (15.6%).

(a)

(b)
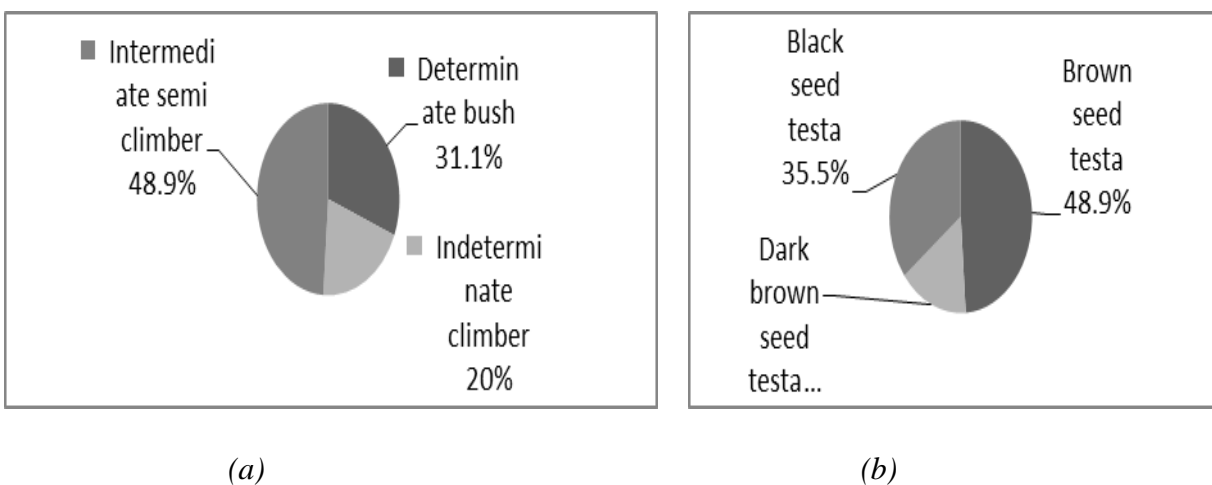
Fig. 2 Lablab bean diversity for (a) growth habit and (b) colour of seed testa

3.3 Dolichos bean diversity for colour of flower kill, colour of flower standard and pod colour

Figure 3 indicates that out of the forty five accessions of Lablab bean studied, 48.8% had greenish colour of flower kill, 35.6% had tinged purple colour while 15.6% had tinged pink colour. The 45 Lablab bean accessions depicted three colours of flower standard, that is, white (48.8%), purple (35.6%) and light pink (15.6%). Figure 3 indicates that the forty five accessions of Lablab bean considered in the study could be grouped into two pod colours, that is, green pod colour that comprised of 64.4% and green with purple sature pods that were 35.6%.

(a)

(b)

(c)
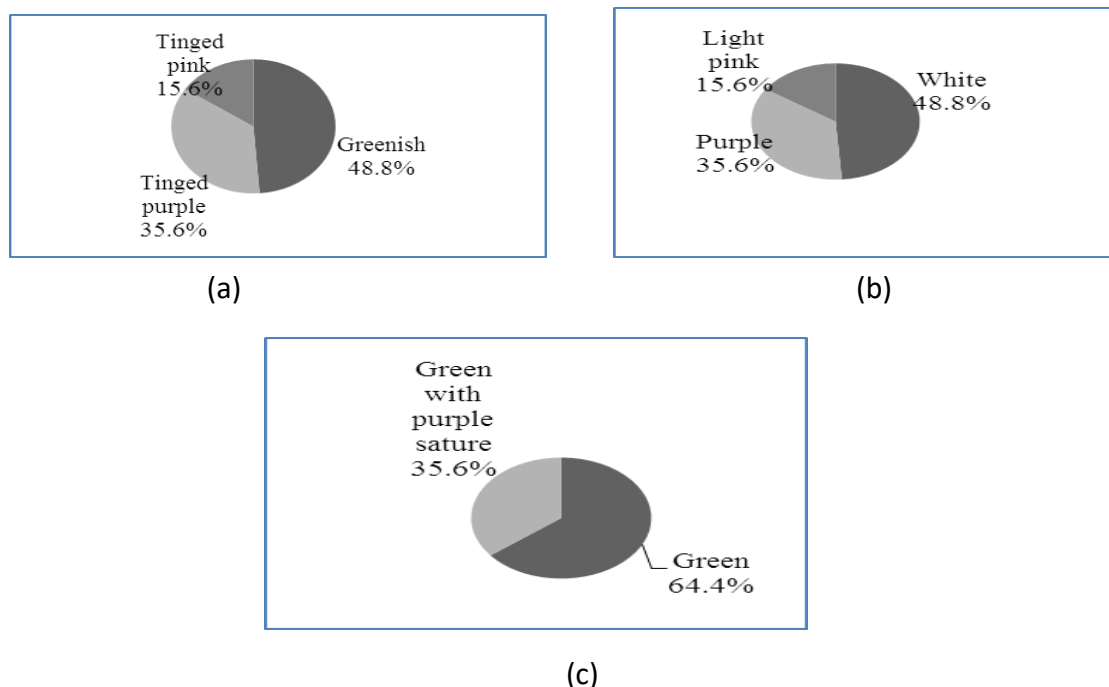
Fig. 3 **Proportion of Lablab bean accessions for (a) colour of flower kill (b) colour of flower standard and (c) pod colour.**

3.4 Lablab bean diversity for yield and yield associated characters

Table 3 indicates that Lablab bean accessions varied significantly in days to 50% flowering, duration to flowering, days to maturity and number of racemes per plant. In general, accessions differed in number of seeds per pod. Nevertheless, accessions collected from Lamu and Mwingi were not significantly different while accessions collected from Thika, Meru and Nakuru were also not significantly different in number of seeds per pod. Lablab bean accessions collected from different regions were significantly different in number of pods per plant. There was clear categorization of Lablab bean accessions on 100 seed weight according to regions of collection. Accessions collected from same region were not significantly different in seed yield per plant but differed significantly with accessions collected from other regions.

Table 3 Means of nine quantitative reproductive traits of the forty-five Lablab bean accessions

Accession code	DaF	DuF	DaM	PR	RP	SP	PP	100 SW	SY
1	88.7a	16.1a	123.3a	8.8a	11.2a	3.63a	122.9a	24.5a	138.1a
2	88.7a	16.2a	123.3a	8.8a	11.1a	3.60a	122.9a	24.5a	138.2a
3	88.8a	16.3a	123.7a	8.7a	11.2a	3.57a	123.1a	24.6a	138.1a
4	88.7a	16.1a	123.3a	8.7a	11.1a	3.58a	123.2a	24.5a	138.0a
5	88.7a	16.3a	123.1a	8.8a	11.2a	3.60a	122.9a	24.6a	138.1a
6	88.6a	16.2a	123.3a	8.7a	11.1a	3.57a	123.0a	24.5a	138.2a
7	88.7a	16.3a	123.7a	8.8a	11.1a	3.60a	123.1a	24.5a	138.2a
8	88.8a	16.1a	123.4a	8.7a	11.2a	3.58a	123.3a	24.6a	138.1a
9	88.7a	16.2a	123.3a	8.8a	11.1a	3.57a	122.8a	24.5a	138.1a
10	88.8a	16.3a	123.7a	8.7a	11.2a	3.60a	122.9a	24.5a	138.0a
11	88.7a	16.1a	123.4a	8.6a	11.1a	3.57a	123.2a	24.6a	138.0a
12	88.6a	16.3a	123.3a	8.7a	11.2a	3.61a	123.0a	24.5a	138.1a
13	88.7a	16.2a	123.3a	8.7a	11.1a	3.60a	123.1a	24.6a	138.2a
14	121.3b	35.3b	192.6b	5.6b	9.8b	3.87b	65.8b	23.0b	63.2b
15	121.7b	35.7b	192.7b	5.6b	9.7b	3.85b	65.9b	23.1b	63.1b
16	121.3b	35.3b	192.5b	5.7b	9.8b	3.87b	65.8b	23.0b	63.2b
17	121.7b	35.3b	192.3b	5.6b	9.7b	3.47c	65.9b	23.1b	63.1b
18	121.3b	35.7b	192.1b	5.4b	9.8b	3.46c	60.3c	23.1b	56.0c
19	121.7b	35.3b	192.3bb	5.5b	9.7b	3.47c	60.6c	23.0b	56.1c
20	121.7b	35.7b	192.7b	5.7b	9.8b	3.47c	60.3c	23.1b	56.0c
21	93.6c	16.5a	126.3c	6.6c	10.6c	3.83b	89.7d	22.0c	75.1d
22	98.7d	25.6c	152.3d	9.6d	13.3d	4.11d	135.7e	32.5d	188.1e
23	98.5d	25.7c	152.8d	9.7d	13.3d	4.11d	135.4e	32.6d	188.0e
24	98.3d	25.1c	152.7d	10.9e	13.4d	4.18d	146.4f	29.3e	181.2e
25	98.7d	25.3c	152.8d	10.8e	13.4d	4.20d	146.7f	29.4e	181.3e
26	98.3d	25.7c	152.7d	10.9e	13.2d	4.19d	146.9f	29.3e	181.2e
27	98.7d	25.2c	152.8d	10.8e	13.1d	4.19d	146.7f	28.4e	181.2e

28	98.7d	25.3c	152.7e	10.9e	13.1d	4.20d	146.4f	29.4e	181.3e
29	102.4e	25.6c	158.3e	9.5f	12.6e	3.88b	125.4g	28.6f	173.7f
30	102.7e	25.7c	158.7e	9.4f	12.6e	3.87b	125.6g	28.7f	173.8f
31	102.4e	25.2c	158.3e	10.7g	13.1d	4.16d	146.4f	29.3e	181.3e
32	102.5e	25.3c	158.3e	10.8g	13.1d	4.20d	146.3f	29.4e	181.4e
33	113.7f	31.1d	172.7f	10.1h	12.6e	4.10d	133.8h	29.3e	153.6f
34	113.4f	31.3d	173.3f	10.2h	12.5e	4.12d	133.6h	29.4e	153.7f
35	113.7f	31.1d	172.7f	10.2h	12.6e	4.13d	133.4h	29.3e	153.6f
36	91.3g	16.3a	125.7c	12.1i	13.4d	4.17d	162.6i	29.8g	203.5g
37	121.3b	44.7e	197.3g	4.7j	5.4f	2.83e	34.4j	19.7h	23.1h
38	121.2b	44.6e	196.7g	4.8j	5.4f	2.87e	34.5j	19.6h	23.0h
39	103.3e	27.7f	126.3c	9.2k	12.4f	3.60a	128.6k	27.7i	119.2i
40	103.1e	27.3f	125.7c	9.1k	12.3f	3.59a	128.5k	27.8i	119.2i
41	103.3e	27.6f	126.3c	9.2k	12.4f	3.60a	128.4k	27.7i	119.1i
42	103.2e	27.7f	126.6c	9.1k	12.3f	3.63a	128..5k	27.8i	119.2i
43	103.1e	27.5f	126.3c	9.1k	12.4f	3.62a	128.6k	27.7i	119.1i
44	103.2e	27.4f	126.5c	9.2k	12.3f	3.62a	128.4k	27.8i	119.2i
45	103.3e	27.7f	126.3c	9.1k	12.4f	3.63a	128..5k	27.8i	119.1i
Range	**36.0**	**31.0**	**66.0**	**7.4**	**6.87**	**1.4**	**128.4**	**13.0**	**180.5**
Min	**88.0**	**15.0**	**123.0**	**4.7**	**5.43**	**2.8**	**34.3**	**19.6**	**23.0**
Max	**124.0**	**46.0**	**189.0**	**12.1**	**13.30**	**4.2**	**162.7**	**32.6**	**203.5**
Grand mean	**102.5**	**26.16**	**143.45**	**8.67**	**11.31**	**3.72**	**115.37**	**26.22**	**129.54**
LSD (0.05)	**0.943**	**0.936**	**0.947**	**0.138**	**0.315**	**0.115**	**0.512**	**0.141**	**0.554**
CV%	**0.6**	**2.2**	**0.4**	**1.00**	**1.7**	**1.9**	**0.3**	**0.3**	**0.1**

KEY: Means with similar letters are not significantly different at $p \leq 0.05$. DaF=Days to 50% flowering, DuF=Duration of flowering, DM=Days to maturity, PR=Number of pods per raceme, RP=Number of racemes per plant, SP=Number of seeds per pod, PP=Number of pods per plant, 100 SW=100 seed weight, SY=Seed yield

3.5 Lablab bean diversity for vegetative and seed characters

Table 4 shows that Lablab bean accessions considered in this study differed significantly in days taken to germination in the field. Germination in this case was considered as shoot emergence. Data was taken when each accession had 90% of seedlings having emerged. Lablab bean

accessions were significantly different in plant height, leaf length and leaf width. Generally, there were no significant differences in pod width and seed width among accessions.

Table 4 Means of nine vegetative quantitative traits of the forty-five Lablab bean accessions

Acc. Code	DG	PH	LL	LW	RL	NR	HL	PL	PW	SL	SW
1	14.3a	157.7a	9.2a	8.7a	32.9a	11.8a	3.8a	5.3a	2.2a	1.1a	0.8a
2	14.3a	160.3a	9.3a	8.6a	33.4a	11.6a	3.7a	5.3a	2.2a	1.1a	0.8a
3	14.7a	157.1a	9.1a	8.5a	33.0a	11.7a	3.8a	5.3a	2.2a	1.1a	0.8a
4	14.3a	159.2a	9.3a	8.6a	33.2a	11.6a	3.8a	5.3a	2.1a	1.1a	0.8a
5	14.3a	161.1a	9.2a	8.6a	33.2a	11.8a	3.9a	5.4a	2.2a	1.1a	0.8a
6	14.7a	156.3a	9.1a	8.5a	33.1a	11.5a	3.8a	5.3a	2.1a	1.1a	0.8a
7	14.3a	156.1a	9.2a	8.6a	33.4a	11.3a	3.7a	5.3a	2.2a	1.1a	0.8a
8	14.7a	160.0a	9.3a	8.7a	33.3a	11.6a	3.8a	5.3a	2.2a	1.1a	0.8a
9	14.3a	158.5a	9.1a	8.5a	33.1a	11.7a	3.7a	5.4a	2.2a	1.1a	0.8a
10	14.7a	159.7a	9.3a	8.6a	32.9a	11.4a	3.8a	5.4a	2.2a	1.1a	0.8a
11	14.3a	160.4a	9.1a	8.7a	33.2a	11.5a	3.7a	5.3a	2.2a	1.1a	0.8a
12	14.3a	160.0a	9.1a	8.6a	33.3a	11.6a	3.7a	5.3a	2.1a	1.1a	0.8a
13	14.7a	159.4a	9.2a	8.5a	33.2a	11.4a	3.8a	5.4a	2.1a	1.1a	0.8a
14	17.7b	351.1b	13.1b	11.5b	44.2b	9.6b	4.6b	4.6b	2.2a	1.1a	0.8a
15	17.5b	350.6b	12.9b	11.6b	44.1b	9.2b	4.7b	4.5b	2.2a	1.1a	0.8a
16	17.7b	348.8b	13.1b	11.6b	44.3b	9.7b	4.7b	4.6b	2.1a	1.1a	0.8a
17	17.4b	349.6b	12.9b	11.5b	44.0b	9.3b	4.6b	4.5b	2.2a	1.1a	0.8a
18	17.7b	347.3b	12.9b	11.4b	43.7b	9.7b	4.7b	4.4c	2.1a	1.1a	0.8a
19	17.5b	348.2b	13.0b	11.5b	43.8b	9.1b	4.6b	4.3c	2.2a	1.1a	0.8a
20	17.7b	349.7b	12.9b	11.5b	43.8b	9.3b	4.7b	4.4c	2.2a	1.1a	0.8a
21	14.3a	159.1a	9.2a	8.5a	32.8a	11.7a	3.9a	4.3d	2.2a	1.0b	0.7b
22	12.3c	225.7d	11.6d	9.3c	32.9a	11.2a	4.4c	5.5e	2.3ab	1.2c	0.9c
23	12.7c	222.3d	11.7d	9.3c	33.2a	11.3a	4.3c	5.6e	2.3ab	1.2c	0.9c
24	12.3c	222.0d	11.8d	9.2c	32.9a	12.6c	4.2c	5.6e	2.2a	1.1a	0.8a
25	12.0c	224.9d	11.8d	9.2c	33.0a	12.5c	4.3c	5.5e	2.2a	1.1a	0.8a

26	12.7c	222.3d	11.7d	9.1c	33.3a	12.5c	4.4c	5.5e	2.2a	1.1a	0.8a
27	12.3c	224.5d	11.9d	9.2c	33.2a	12.6c	4.2c	5.5e	2.1a	1.1a	0.8a
28	12.3c	224.8d	11.8d	9.1c	32.8a	12.7c	4.3c	5.5e	2.2a	1.1a	0.8a
29	14.3a	272.7e	12.6e	10.2d	29.8c	11.9a	4.7d	5.2f	2.2a	1.1a	0.8a
30	14.7a	273.2e	12.7eb	10.3d	29.6c	11.8a	4.6d	5.1f	2.1a	1.1a	0.8a
31	12.7c	273.3e	12.7eb	10.1d	32.9a	12.4c	4.5d	5.5e	2.2a	1.1a	0.8a
32	12.3c	271.4e	12.6e	10.3d	33.0a	12.3c	4.4d	5.6e	2.2a	1.1a	0.8a
33	12.3c	336.3f	12.8eb	10.2d	36.7d	12.5c	4.5d	5.2f	2.1a	1.1a	0.8a
34	12.3c	335.9f	12.7eb	10.2d	37.0d	12.4c	4.5d	5.1f	2.2a	1.1a	0.8a
35	12.0c	337.8f	12.8eb	10.1d	37.3d	12.4c	4.4d	5.2f	2.2a	1.1a	0.8a
36	11.7d	122.7g	12.7eb	10.2d	33.2a	13.8d	4.2e	5.5e	2.1a	1.1a	0.8a
37	17.7b	374.7h	12.3g	11.1e	25.3e	6.1e	4.8f	4.2g	1.9c	0.8d	0.7b
38	17.7b	374.6h	12.3g	11.2e	25.2e	6.2e	4.9f	4.1g	1.8c	0.8d	0.7b
39	14.0a	205.5i	12.7eb	11.5b	29.8c	10.6f	4.4d	4.9h	2.2a	1.0b	0.8a
40	14.3a	203.6i	12.8eb	11.6b	30.3c	10.7f	4.5d	4.8h	2.2a	1.0b	0.8a
41	14.0a	202.1i	12.9b	11.5b	30.4c	10.5f	4.4d	4.9h	2.1a	1.0b	0.8a
42	14.3a	200.6i	12.7eb	11.5b	29.8c	10.7f	4.5d	4.8h	2.1a	1.0b	0.8a
43	14.3a	201.8i	12.8eb	11.6b	30.1c	10.4f	4.5d	4.9h	2.2a	1.0b	0.8a
44	14.3a	201.6i	12.9b	11.4b	30.2c	10.6f	4.4d	4.9h	2.2a	1.0b	0.8a
45	14.0a	202.2i	12.8eb	11.5b	30.3c	10.5f	4.5d	4.8h	2.2a	1.0b	0.8a
Range	**6.0**	**252.0**	**4.0**	**3.1**	**19.1**	**7.7**	**1.2**	**1.3**	**0.5**	**0.4**	**0.2**
Min	**11.67**	**122.7**	**9.1**	**8.5**	**25.2**	**6.1**	**3.7**	**4.3**	**1.8**	**0.8**	**0.7**
Max	**17.67**	**374.7**	**13.1**	**11.6**	**44.3**	**13.8**	**4.9**	**5.6**	**2.3**	**1.2**	**0.9**
Grand mean	**14.36**	**236.59**	**11.51**	**9.96**	**33.94**	**11.05**	**4.31**	**5.16**	**2.18**	**1.10**	**0.80**
LSD (0.05)	**0.963**	**4.427**	**0.275**	**0.233**	**0.871**	**0.752**	**0.276**	**0.120**	**0.111**	**0.095**	**0.087**
CV%	**4.1**	**1.2**	**1.5**	**1.3**	**1.6**	**1.8**	**2.7**	**1.4**	**3.1**	**5.3**	**5.8**

KEY: Means with similar letters are not significantly different at $p \leq 0.05$. DG=Days to germination, PH=Plant height, LL=Leaf length, LW=Leaf width, RL=Raceme length, PL=Pod length, PW=Pod width, SL=Seed length, SW=Seed width.

3.6 Correlation analysis of yield and yield associated characters

A Pearson product-moment correlation was run to determine the relationship between the various agro-morphological components for seed yield and yield associated characters. Table 5 indicates that there was a significant positive correlation between most seed yield per plant and yield associated traits.

Table 5 Correlation matrix on yield and yield related characteristics

	DaF	DuF	DaM	PR	RP	PP	SP	100 SW	SY
DaF	1								
DuF	0.933**	1							
DaM	0.902**	0.833**	1						
PR	-0.607**	-0.433**	-0.540**	1					
RP	-0.568**	-0.515**	-0.457**	0.848**	1				
PP	-0.715**	-0.580**	-0.599**	0.973**	0.901**	1			
SP	-0.199*	-0.243**	-0.027	0.604**	0.774**	0.641**	1		
100SW	-0.236**	-0.113	-0.220*	0.853**	0.767**	0.788**	0.667**	1	
SY	-0.501	-0.374**	-0.359**	0.950**	0.873**	0.937**	0.741**	0.912**	1

KEY: **. Correlation is significant at the 0.01 level *. Correlation is significant at the 0.05 level, DaF= Days to flowering, DuF= Duration of flowering, DaM=Days to mature pods, PR=Pods per raceme, RP=Racemes per plant, PP=Pods per plant, SP=Seeds per pod, SW= 100 seed weight, SY= Seed yield

3.7 Cluster analysis on reproductive quantitative traits

The taxonomic dissimilarity matrix of reproductive quantitative traits for the 45 Lablab bean genotypes was employed for cluster analysis and dendrogram was constructed (Figure 4) using GenStat version 12. The 45 accessions were largely divided into two clusters, A and B at similarity coefficient 0.84. Cluster A comprised of 9 accessions and cluster B had 36 accessions. Cluster A was further divided into two sub-clusters A1, and A2 at similarity coefficient 0.93. Sub-cluster A2 subdivided further into A2a and A2b at similarity coefficient 0.99 to separate accessions collected from Machakos-Kalama (14, 15, 16, 17) in A2a, with accessions collected from Machakos-Kathiani (17, 18, 19, 20) in A2b. Similarly, cluster B was further divided in sub-clusters B1 and B2 at similarity coefficient 0.935. Sub-cluster B2 further subdivided into two

sub-clusters (a, and b) at similarity coefficient 0.95. Generally, accessions with similar traits were grouped together irrespective of localities of collection in the larger clusters but with further subdivisions, several accessions grouped according to places of collection.

Cluster A comprised of accessions collected from Machakos-Kalama (14, 15, 16 and 17), Machakos-Kathiani (18, 19 and 20) and Naivasha (37 and 38). The Naivasha accessions had small sized seeds that had a black seed testa and produced purple flowers. They were the poorest performers for most traits considered in this study but had the highest plant height. They took long to germinate and mature and had the least yield per plant. Dolichos bean accessions collected from Machakos (Kalama and Kathiani) had distinct pink flowers and dark brown seed testa. They took relatively long to mature and had low yield per plant (Table 3) compared to other accessions and were second poorest performers in the reproductive quantitative traits considered in this study. Cluster B1 was composed of one accession, 36, collected from Nakuru-Bahati. This accession had a black seed testa and purple flowers. It was the best performer in most of the traits evaluated. It recorded the highest yields per plant and it ranked second in time to germinate and maturity period. Cluster B2 was the largest with 35 accessions of Lablab bean collected from Lamu (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13), Machakos-Yatta (21), Maragwa (22 and 23), Thika (24,25,26,27 and 28), Mbeere (29 and 30), Meru (31 and 32), Nakuru-Lare (33, 34 and 35) and Mwingi (39, 40, 41, 42, 43, 44 and 45). Accessions collected from Lamu, Mbeere and Mwingi had brown seed testa and white flowers. Accessions collected from Machakos-Yatta, Murang'a, Thika, Meru and Nakuru-Lare had black seed testa and purple flowers. Accessions in this cluster performed above average in all traits under evaluation. This cluster further sub-divided into two, B2a and B2b.

Sub-cluster B2a was composed of accessions collected from Machakos-Yatta, Murang'a (22 and 23), Thika (24, 25, 26, 27 and 28), Mbeere (29 and 30), Meru (31 and 32), Nakuru-Lare (33, 34 and 35) and Mwingi (39, 40, 41, 42, 43, 44 and 45). Sub-cluster B2b was comprised of accessions collected from Lamu (1,2,3,4,5,6,7,8,9,10,11,12 and 13). Of the two sub-clusters, B2a accessions were better performers in most traits as indicated in Table 3 but sub-cluster B2b had the shortest germination and maturity period. Sub-cluster B2a further divided into two distinct groups (I) and (II) at dissimilarity coefficient of 0.96 (Fig. 4). Sub-cluster B2a (I) was composed of accessions 21, (collected from Machakos-Yatta), 33, 34, 35 (collected from Nakuru-Lare), 22, 23 (collected from Murang'a), 24, 25, 26, 27, 28 (collected from Thika), 31, 32 (collected from Meru) and 29, 30 (collected from Mbeere). Sub-cluster B2a (II) was composed of accessions 39, 40 41, 42, 43, 44 and 45 (collected from Mwingi).

Table 6 Cluster distribution of the 45 Lablab bean accessions based on reproductive quantitative traits.

Cluster	Sub-cluster	Similarity coefficient	Number of entries	Accessions in cluster
A		0.84	9	14, 15, 16, 17, 18, 19, 20, 37, 38
	1	0.93	2	37, 38
	2	0.93	7	14, 15, 16, 17, 18, 19, 20
	2a	0.99	3	18, 19, 20
	2b	0.99	4	14, 15, 16, 17
B		0.84	36	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44, 45
	1	0.935	1	36
	2	0.935	35	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 39, 40, 41, 42, 43, 44, 45
	2a	0.95	22	21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 39, 40, 41, 42, 43, 44, 45
	2b	0.95	13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
	2aI	0.96	15	21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35
	2aII		7	39, 40, 41, 42, 43, 44, 45
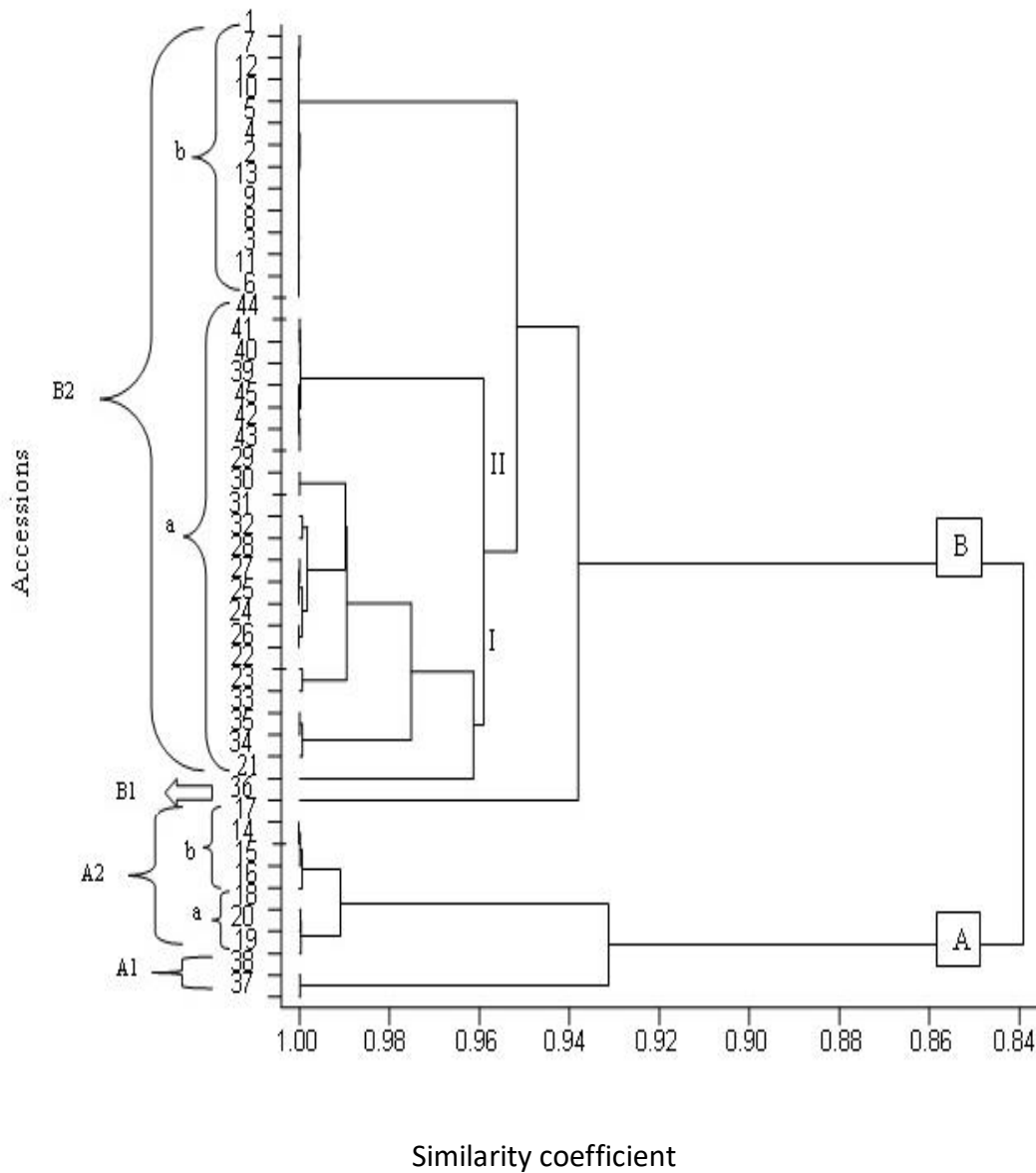
Fig.4 Dendrogram showing relatedness of Lablab bean accessions based on reproductive quantitative traits

3.8 Principal component analysis (PCA) of Lablab bean reproductive traits

Four principal component (PC) axes made a substantial contribution to the total variation of the forty five Lablab bean accessions considered in this study. The first two PC axes described

98.67% of the total variation for the traits evaluated (Table 7). The first Eigen vector explained 85.23% of the total variation while the second described 13.44%. Three traits, that is, seed yield per plant, days to 90% ripe pods and plant height loaded PC1 and PC2 while days to 50% flowering, duration of flowering and days to 90% ripe pods contributed to variation in PC3. Two traits (seed yield per plant and pods per plant) that contributed greatly to PC1 re-featured in PC4.

Table 7 Eigen vectors and percentage variance of Lablab bean reproductive morphological traits

	Principal Component Axes			
	PC1	PC2	PC3	PC4
Eigen value	4.67	0.74	0.04	0.02
(%) variance per PC axis	85.23	13.44	0.78	0.47
% cummulative variance across PC axes	85.23	98.67	99.45	99.92
	Eigen vector loadings for the traits			
Days to 50% Flowering	-0.15	0.30	0.68	-0.02
Days to 90% ripe pods	-0.28	0.86	-0.33	0.22
Duration of flowering (days)	-0.09	0.19	0.54	-0.27
Pods per raceme	0.03	0.01	0.08	0.03
Pods per plant	0.53	0.05	0.26	0.79
Racemes per plant	0.03	0.02	0.02	0.06
Seed yield per plant	0.78	0.35	-0.11	-0.49
100 seed weight(g)	0.04	0.06	0.23	-0.12

Days to germination	0.01	-0.03	0.06	0.54
Leaf length	0.01	0.01	-0.06	-0.83
Plant height	0.92	0.39	-0.02	0.02
Pod length	0.00	0.01	0.02	0.09
Pod width	0.00	0.00	0.00	0.01
Raceme length	0.03	0.00	1.00	-0.08

Note: Eigen vectors greater than or equal to 0.2 were considered to contribute highly to the loading of each PC-axis.

DISCUSSION

4.1 Lablab bean diversity for agro-morphological traits

Germplasm characterization is an important component of breeding programmes for an effective and efficient management and utilization of plant genetic resources (Singh *et al.,* 2012). Morphological markers have been used for assessment of relationships among plant genotypes and for estimating genetic diversity among germplasm lines (Rai *et al*., 2010). Lablab bean accessions studied exhibited a wide variability in certain morphological traits and narrow variability in other traits. Lablab bean accessions varied significantly in days to 50% flowering, days to maturity, seed yield, number of racemes per plant, raceme length, pod length, number of pods per plant and 100 seed weight. Accessions exhibited little variability in pod width, seed length, seed width, growth habit, hypocotyl colour, flower colour and seed testa colour.

4.2 Corelation of yield and other agro-morphological traits

A basic knowledge of interrelationship of certain plant characters with yield and correlation among themselves is an important topic for breeder to improve a complex character such as yield. Yield is an important and complex trait difficult to manipulate for crop improvement (Shi *et al.,* 2009). However, traits such as seed number per plant, pods number per plant and 100 seeds weight could be correlated to other characters (Ozier, 2012). This will then allow an indirect selection of yield based on those characters. Seed yield is a final product of several components determined at different growth stages (Savitha *et al*., 2008). In a study to evaluate eight cowpea varieties in Nigeria, Agbogidi & Egho, (2012) found strong association between plant height, leaf area and grain yield. Jonah *et al*., (2010), reported high positive correlation between seed yield per hectare and pod yield per plant, seed yield per hectare and seed yield per

plant and between seed yield per plant and plant height in 12 accesions of bambra groundnuts fom Nigeria. In this study, important characters for seed yield per plant were pods per raceme, pods per plant, racemes per plant, 100 seed weight, pod length, seed length and seeds per pod. Similar findings were also reported in pigeon pea (Bhadru *et al.,* 2010). In this study, seed yield per plant was negatively correlated with days to 50% flowering and days to 90% mature pods.

4.3 Cluster analysis

Although cluster analysis grouped the 45 Lablab accessions used in this study into two distinct clusters with sub-clusters per each group, the accessions were found to differ significantly in one or more individual traits. Clustering was irrespective of localities of collection where genotypes collected from one locality also fell into other separate clusters. The present study agrees with findings in other studies that accessions collected from the same geographic region were distributed among different clusters (Sultana *et al*., 2010; Tariqul, 2010). Exchange of seed for planting among the farming community, genetic drift, natural and artificial selection could be responsible for diversity observed in genotypes collected from same regions. Adaptive gene complexes evolve in plant populations restricted to small geographic areas or subjected to identical environmental pressures. These gene complexes are conserved by genetic linkages or stringent natural or human selection (Tariqul, 2010).

4.4 Principal component analysis

Principal component analysis showed that the first two principal components PC1 and PC2 with a proportion of 85.23% and 13.44% respectively contributed more to the total variation of Lablab bean. According to Chahal & Gosal, (2002) characters with largest absolute values closer to unity within the first principal component influence the clustering more than those with absolute values closer to zero. Therefore, differentiation of the genotypes into different clusters was because of a cumulative effect of a number of characters rather than the contribution of specific few characters. Characters having higher value in the first principal component (PC1) were seed yield per plant, pods per plant and plant height. These had more contribution to the total diversity and were responsible for the differentiation of clusters.

CONCLUSION

Morphological markers used in this study indicate that Lablab bean accessions studied exhibited a wide variability in morphological traits such as days to germination, plant height, leaf length, raceme length, days to flowering, duration of flowering, days to maturity, number of pods per plant, 100 seed weight and seed yield per plant. However, accessions had little variability in morphological traits such as growth habit, colour of main vein, hypocotyl colour, pod width, seed width, and colour of seed testa where Lablab bean accessions used in the study

could be grouped into two or three categories. Twelve accessions (22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32 and 36) displayed high potential for yield and yield associated characters and could be selected for utilization in Lablab bean improvement programmes in Kenya.

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