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Morphological screening and farmers' acceptability of selected lablab bean (lablab purpureus) accessions in Moshi district, Tanzania

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MORPHOLOGICAL SCREENING AND FARMERS' ACCEPTABILITY OF SELECTED LABLAB BEAN (*Lablab purpureus*) ACCESSIONS IN MOSHI DISTRICT, TANZANIA

Kissa Chawe

A dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

A set of 41 lablab bean accessions were evaluated based on morphological characteristics and farmers' participatory selection was performed based on agronomic and sensory traits. An experimental plot was laid down in augmented block design where accessions collected from different gene bank were sown at spacing of 75 cm x 40 cm. Descriptive and multivariate analysis based on 21 quantitative traits revealed high coefficient of variation (CVs) in secondary branches, seed yield, and pods per plant. Principle component analysis (PCA) showed that first 6PCs contributed to 83.3% of the total variation. Days to maturity had significant correlation with days to podding (0.855) and flowering (0.821). Seed yield per plant had strong association with pods per plant (0.793). Cluster analysis based on Un-weighted Pair Group Method Average (UPGMA) grouped 41 accessions into 7 clusters based on traits kinship. Cluster II, VI and VII are genetically different from other clusters. Farmers selected ten best accessions, D163, D137, D88 D27, D85, D155, D7, D159, D151 and D140. The selection criteria perceived were diseases and pest resistance, pod per plant, earliness, bulk leaves, high yield, seed colour, seed size, drought tolerance, plant height and growth type. Farmers' preferred traits; high yielding, better taste, earliness and short cooking time need to be incorporated in bean breeding programs. In sensory evaluation, panelists chose accessions D137, D85 and D88 due to good sensory potential for home consumption. This study recommends accessions D137, D163, D85, D208 and D88 for further evaluation on different locations for developing lablab varieties in Tanzania.

DECLARATION

I, Kissa Chawe do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that the presented dissertation is my own original work and where there is work of others I acknowledge and include the references.

_____ _____

Kissa Chawe **Date**

(Master's candidate)

The above declaration is confirmed;

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Dr. Pavithravani B. Venkataramana **Date**

Name and signature of supervisor 1

_____ _____

Prof. Patrick A. Ndakidemi **Date**

Name and signature of supervisor 2

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CERTIFICATION

The undersigned certify that they have read the dissertation titled "Morphological Screening and Farmers' Acceptability of Selected Lablab Bean (*Lablab purpureus*) Accessions in Moshi District, Tanzania" and recommend for examination in fulfilment of the requirements for the degree of Master's in Life Sciences of The Nelson Mandela African Institution of Science and Technology.

_____ _____

Dr. Pavithravani B. Venkataramana **Date**

Name and signature of supervisor 1

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Prof. Patrick A. Ndakidemi **Date**

Name and signature of supervisor 2

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DEDICATION

This work is dedicated to my dearest parents Godfrey Salatiel Chawe and Agnes Meja Mpalala, my lovely daughter Lorraine Calvin Nguku.

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LIST OF ABREVIATION AND SYMBOLS

Al	Aluminium
g	Gram
mg	Milligram
Mn	Manganese
%	Percentage
GI	Glycaemic index
PVS	Participatory Variety Selection
NM-AIST	Nelson Mandela African Institution of Science and Technology
NBPGR	National Bureau Plant Genetic Resources
AVRDC	Asian Vegetable Research and Development Center
TPRI	Tropical Pesticides Research Institute
N	Nitrogen
GHGS	Greenhouse gases
CH_4	Methane gas
N_2O	Nitrous oxide
CO_2	Carbon dioxide
APKL	Africa Plantation Kilimanjaro Limited
SARI	Selian Agricultural Research Institute
CV	Coefficient of Variation
PCA	Principle Component Analysis
UPGMA	Un-weighted Pair Group Average
AHC	Agglomerative Hierarchical Clustering analysis

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Lablab bean (*Lablab purpureus* L. Sweet) is a prehistoric crop widely grown in the tropics and subtropics mostly in mixed crop-livestock systems (Kimani *et al.*, 2012). It is broadly distributed and domesticated in Africa, the Indian subcontinent and Southeast Asia as a grain legume and vegetable (Maass *et al.*, 2005). In Africa, the lablab bean is mostly grown and adapted in Kenya (Machakos, Kitui, Makueni, Mwingi, and Tharaka-Nithi, Laikipia district, Transzoia along rift valley), Tanzania (Arusha, Manyara, Kilimanjaro, Mbeya, Dodoma, Tanga and Morogoro) and Ethiopia as a pulse crop (Ngailo *et al.*, 2001; Kamotho *et al.*, 2016). Lablab bean has multiple uses including food for human beings, fodder for livestock and improvement of soil fertility through biological fixation of atmospheric nitrogen (Pengelly *et al.*, 2003). Despite its wide distribution and potentials in Tanzania, it is still underutilized and considered as an orphan crop (Varshney *et al.*, 2009; Maass *et al.*, 2010).

Lablab crop is a self-pollinated, herbaceous perennial with 2n=22 number of chromosomes, photoperiod sensitive and belong to family Fabaceae (Byregowda *et al.*, 2015). However, Gnanesh *et al.* (2006) reported that 6 to 10 % of the lablab beans are cross-pollinated as a result of the frequent movement of insects such as flower beetles and butterfly. It is climbing with a vigorous taproot and occurs as bushy, semi-erect and exhibits typical prostate growth habit with alternate and trifoliate leaves (Valenzuela and Smith, 2002; Guretzki and Papenbrock, 2014). Lablab beans have many outstanding qualities including tolerant to heat, drought and can also thrive in deep sands to heavy clays soil due to their excellent botanical features (Groteluschen, 2014).

A large portion of the African population considers common bean as a substantial grain legume as staple food. However, the major abiotic and abiotic production constraints such as susceptibility to diseases and pests and sensitivity to drought, heat, macronutrients deficient and toxic levels of Aluminium (Al) and Manganese (Mn) in the soil reduce productivity and contributing to food insecurity, malnutrition and poverty for both countryside and town dwellers (Kimani *et al.*, 2012). Therefore, the exploitation of lablab cultivars to replace the sensitive legumes that is currently in use is essential to increase production and productivity for both food self-sufficient and poverty alleviation. This is due to the fact that lablab can

tolerate harsh environmental conditions relative to other commonly preferred legumes (Robotham and Chapman, 2017). However, in the most African regions the average production of lablab beans are unknown particularly in Tanzania (Ngailo *et al*., 2003). In Kenya, the demand for lablab is increasing rapidly thus breeders put more effort on improving and developing new varieties. Based on nutrition aspects, lablab beans have high protein content (21-38%), carbohydrate with low glycaemic index (GI), fibres, and rich in minerals, vitamins, carotenoids and polyphenols which are essential for well-being of the people and livestock (Foyer *et al*., 2016). With the comparison of other grain legumes, the beans have moderately balanced amino acid and iron content of 6-7% and 155 mg/100 g dry weight, respectively. Thus it is proposed to complement heavy staples diets and fight against malnutrition to the poor resource community where there is nutrients deficit (Chau *et al.*, 1998; Maundu *et al.*, 1999).

The characterization of this crop has significant impacts on the breeding program due to the fact that any variation detected are vital in the improvement and development of superior variety for food production and productivity, research development, farmer's welfare, poverty eradication and sustainability of food security. However, the potential of lablab crop for sustainable crop improvement and food sufficiency has been described by conventional and modern plant breeding settings (Pengelly and Maass, 2001; Kamotho *et al.*, 2016). The morphological screening of lablab legume are crucial to the breeding program (Ayisi *et al.*, 2004). The selection process of the superior accessions includes identification of a plant which has desired forms of expression for a group of morphological characteristics. However, the growing of lablab bean has significant physio-morphological variation among the genotypes which are vastly influenced by the interaction of the genotype and environmental attributes such as soil properties, temperature, altitude and rainfall patterns as well as management practices involved (Rahman *et al.*, 1985; Islam *et al.*, 2002; Maass and Usongo, 2007). Both non and semi-domesticated accessions of lablab grain legume have a wide variation in plant structure, flowering time, maturity time, harvesting time, pod and seed characteristics (Ewansiha *et al.*, 2007). Therefore there is a need of screening the wild and landraces lablab cultivars based on morphological aspects to increase the diversity of the crop. These tools aim to identify the variations among landraces and wild species which are essential for crop improvement in breeding activities.

Currently, farmers' participation and on-station types of research and field demonstrations has widely been put into action to improve crop productivity taking into consideration of the agronomic, and morphological tools (Pengelly *et al.*, 2003; AbdAllah *et al.*, 2015). The aims of introducing Participatory Variety Selection (PVS) approach into a variety development program are to increase the dissemination, diffusion and adoption rate of released varieties as result increase varieties portfolio available in the locality. This in turn increases the pool of crop diversity through seed exchange, farmers saved seed and community based seed (Mulatu and Belete, 2001). Subsequently, farmers are involved in developmental process starting from initial stages of production to provide wide room of selecting the crop or accession of their interest (Bucheyeki and Mmbaga, 2013). Farmer's criteria in breeding and selection of appropriate varieties usually are based on two categories including agronomic and sensory characteristics. Therefore, integration of farmers' knowledge and selection criteria and modification of breeders' criteria have great impact in plant breeding program and development (Rahman *et al.*, 2015).

Therefore, these methods help breeders and agronomists to understand which varieties perform better on-farm or on station and are preferred by farmers. Furthermore, information obtained during sensory and agronomic evaluation paves the way to the identification of farmers' preferable criteria of introduced lablab accessions that have great opportunity in the improvement of this crop and is the key determinant of predicting the adoption and utilization of introduced accessions. This study aims at screening the morphology and agronomic characters and to assess farmer's acceptability of selected lablab bean (*Lablab purpureus*) accessions for proper utilization of germplasms while providing the way for more research and spanning the gap between farmers and researchers for research development.

1.2 Statement of the Problem and Justification

Despite their nutritional and economic qualities, lablab beans are underutilized compared with other legumes such as common bean (*Phaseolus vulgaris*), soybean (*Glycine max*), garden pea (*Pisum sativum*), pigeon pea (*Cajanus cajan*), mung bean (*Vigna radiata*) and groundnut (*Arachis hypogaea*), Bambara nut (*Vigna subterranean*) in Tanzania (Ngailo *et al*., 2003). This may possibly be due to lack of improved lablab varieties which compels farmers to settle for local genotypes with poor productivity. Nevertheless, the average production of lablab beans is not well known since the crop has been neglected in research and development studies towards human consumption as a result limit the understanding of its

agro-morphological diversity and utilization (Tefera, 2006). However, in Tanzania the studies to evaluate the genetic diversity of the lablab accession as domesticated crop have not been reported.

The newly introduced forty 40 lablab beans accessions to be studied have been imported by NM-AIST from different gene banks in the world encompassing NBPGR, India and Australian pastures gene bank, AVRDC, Taiwan, Eastern and Southern Africa, and TPRI, ECHO, and local cultivar from the nearby market, Tanzania. To better understand their performance, there is a need of screening the lablab beans for morphological traits and understand the genetic diversity as well as to assess farmers' preference and acceptability of the introduced accessions for future seed production and improvement of this crop. The characterization and evaluation will provide a rapid, reliable and efficient means of information for proper utilization of germplasms, which make a long run to identify the suitable variety. In this study, different accessions of lablab bean were compared to determine the potential genotypes with superior traits that would suite to the local production environment and farmer's demand. However, farmer's involvement is key determinants to the successful utilization and adoption of introduced accessions in any locality.

1.3 Objectives of the Study

1.3.1 Overall Objective

The overall objectives of this study is to screen the lablab bean accessions for morphological traits and assess the farmer's acceptability of selected lablab accessions in order to obtain the genotypes with superior characters for future crop improvement.

1.3.2 Specific Objectives

The specific objectives of the proposed study were to:

(i) Morphological characterization of lablab bean accessions
(ii) Assess the farmers' agronomic preference of the selected lablab bean accessions.
(iii) Evaluate the sensory preference of selected best 10 accessions based on agronomic assessment.

1.4 Research Hypothesis

There is no difference among lablab bean accessions based on morphological features and the farmers' acceptability of the lablab is not based on agronomic characters and sensory attributes.

1.5 Significance of the Study

The characterization and evaluation will provide a rapid, reliable and efficient means of information for proper utilization of germplasm to identify the suitable accessions with superior traits that would suite to the local production environment and farmer's demand. Moreover, the superior performing accessions could be used as the parental material in the future crop improvement programme. In addition, involvement of farmers in this study will increase awareness on the importance, accessibility, adaptation and utilization of this crop as source of food and income. This study could open the new insight for breeders in improving and developing lablab variety that suit the farmers growing environment and satisfies their needs which can speed up the adoption rate and utilization of this crop in the future.

1.6 Research Framework

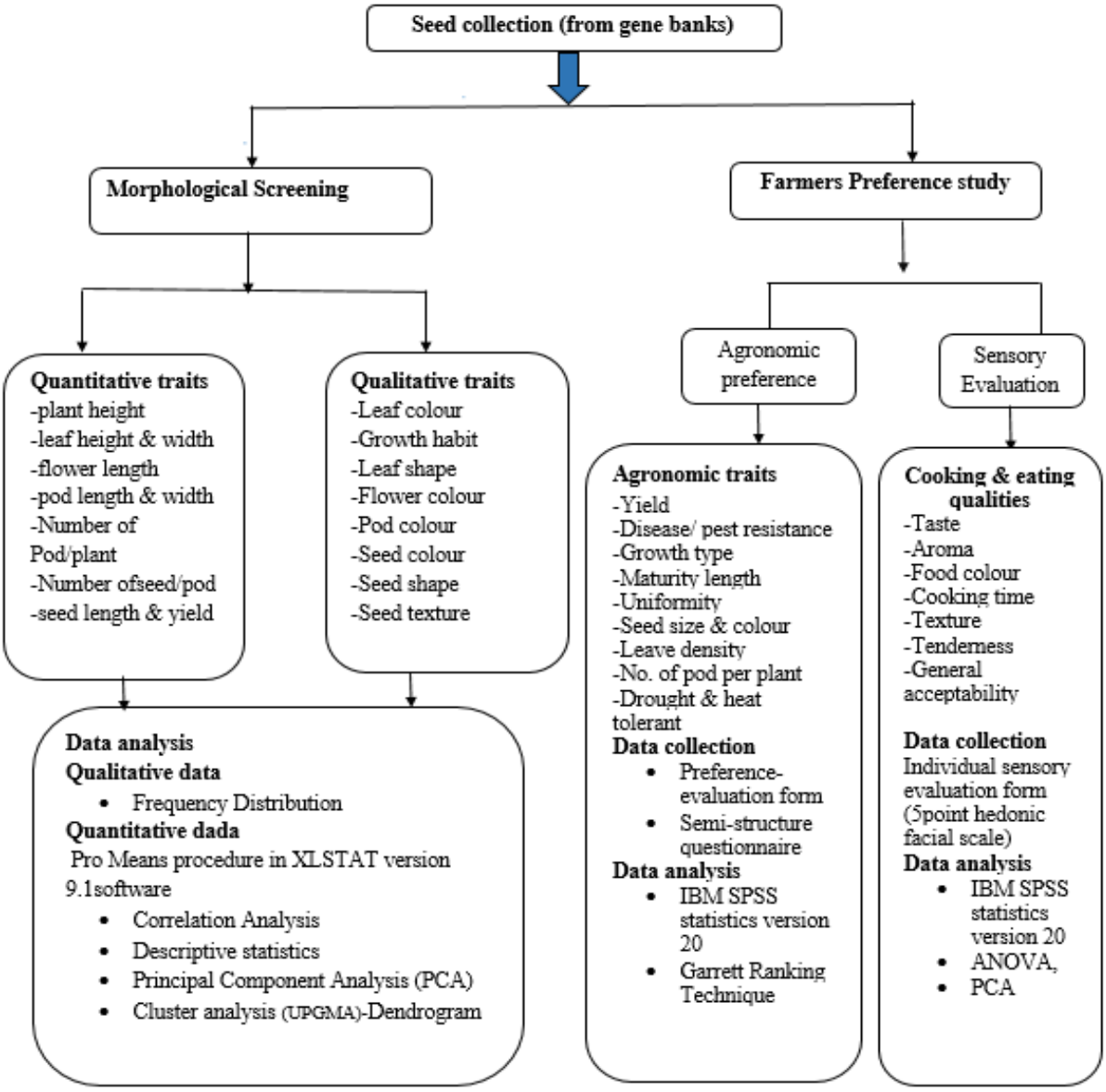


Figure 1: A conceptual participatory variety selection model for breeding and selection of variety

CHAPTER TWO

LITERATURE REVIEW

2.1 Morphological Characterization of Lablab Bean Accessions

The morphological traits of lablab legume are crucial to the breeding program (Ayisi *et al.*, 2004). The process of selecting the superior accessions includes identification of a plant which has desired forms of expression for a group of characteristics (Bèye and Wopereis, 2014). The fresh and dry seed colour, length, width, shape, texture, odour and dry seed yield per plant are the traits preferred by breeders, farmers and consumers. The crop is herbaceous perennial, climbing with a vigorous taproot and occurs as bushy, semi-erect and exhibits type of prostrate growth habit with alternate and trifoliate leaves (Valenzuela and Smith, 2002). The physio-morphological traits vary among accessions which are vastly influenced by the interaction of the genotype and environmental attributes such as soil properties, temperature, altitude and rainfall patterns (Maass and Usongo, 2007). The semi-domesticated accessions of lablab grain legume have a wide variation in plant structure, flowering time, maturity time, harvesting time, pod and seed characteristics (Ewansiha *et al.*, 2007). The shape of leaves differ from one accession to another and some are round, ovate, ovate lanceolate, lanceolate and linear lanceolate (Byregowda *et al.,* 2015). The plant parts such as pods, flowers and seeds vary considerably in colour, size and forms (Maass and Usongo, 2007). Pod length varies from 4 cm to 10 cm, smooth, flat, pointed, and contains 2 to 4 seeds (Valenzuela and Smith, 2002). The flowers develop in clusters on raceme bearing inflorescence in the angle between the leaf and the main stem (Byregowda *et al.*, 2015). Floral parts such as standard petal colour, wing and keel petal colour are white, purple, pink, cream or light yellow (Islam *et al.,* 2010). The number of raceme per plant, raceme length and position as well as number of nodes per raceme vary with the type of accession. Days to 50% flowering from the date of sowing vary considerably resulting into differences in physiological maturity of the pods (Ewansiha *et al.*, 2007; Whitbread *et al.*, 2011). Accessions vary in maturity duration with some exhibiting early maturity, intermediate maturity, or late and extreme late maturity from the first harvesting date (Whitbread *et al.,* 2011).

Qualitative and quantitative characters of pods and seeds of lablab beans vary in colour, size and shape. Days to 50% pod formation vary among accessions, some are characterized by early and others with late podding (Byregowda *et al.,* 2015). The fresh pod colour of lablab bean accessions vary from white, cream, green, green with purple suture, purple, dark purple

and red while at physiological maturity, pod colour are tan and brown (Islam *et al.*, 2010). The fresh pod curvature, pubescence, fragrance, constriction and attachment vary with the type of accession. The number of fresh pod per plant, length and width determine the number of seeds formed in an individual fresh pod and the fresh weight of pods. This variation might be due to alterations in number of flower buds in a raceme, number of racemes in an individual plant, nodes in a raceme, number of buds in a node, number of pods per raceme and tendency of flower dropping in the genotypes (Islam *et al*., 2010). Pengelly and Maass (2001) found variation in pod length and width which ranged from 2.5 to 14.0 cm and l.6 to 3.2 cm, respectively, among 249 genotypes. The fresh and dry seeds can be white, green, cream, purple, brown, black speckled red or brown and plain red. The seed length varies from 6.3 to 15.6 mm in most genotypes (81.8%) (Islam *et al*., 2010). The seeds of the wild cultivars are greyish brown in colour and relatively small in size (Maass and Usongo, 2007). Harvesting of dry pods containing the seeds is usually done any time since they do not shatter (Maundu *et al*., 1999). The average mature seed yields depend largely on variety, cropping systems, cropping history of an area, environmental conditions and the management practices employed (Whitbread *et al*., 2011). In mixed cropping system, the average yield of lablab beans is reported to be 0.5 t ha^{-1} while in sole cropping the highest yields are averaged to between 1-3t ha^{-1} (Murphy and Colucci, 1999; Akter *et al.*, 2018)

Characterization of lablab genotypes or cultivars based on the morphology and physiology is important in order to obtain the preliminary information required for breeding activities. The knowledge of plant breeding and agronomy for the lablab bean is still very scarce in potentially suited areas for its cultivation. Furthermore, the variations in morphological and physiological characters among accessions of lablab beans are crucial as a starting point of selecting suitable breeding lines for sustainable crop improvement, variety development and future seed production and multiplication.

2.2 The Potential of Lablab Beans as a Grain Legume

Lablab bean is one of the few grain legumes in the family Fabaceae that have multiple functions. These include: food for human beings, feed for animals and beneficiates for improvement of soil fertility and health through fixation of atmospheric nitrogen, increase soil organic matter, enhance microbial activities and reduce soil erosion, temperature and retain soil moisture when cultivated as a crop cover in the mixed farming (Abayomi *et al.*, 2001; McDonald *et al.*, 2001; Khoury *et al.*, 2014).

2.2.1 Nutritional and Pharmaceutical Aspects of Lablab Bean

Nutritionally, the lablab beans contain protein, carbohydrate with low glycaemic index (GI), fibre, minerals, vitamins, carotenoids and polyphenols (Foyer *et al*., 2016). The beans also have moderately balanced amino acids with high lysine content (6-7%), thus it is proposed to complement heavy staples diets and fight against malnutrition (Chau *et al*., 1998). They are the potential sources of iron among legumes (155 mg/100 g dry weight) (Maundu *et al*.,1999). With the comparison of other grain legumes, lablab bean produces high crude protein in grain and leaves of 20 to 28% and 21 to 38%, respectively while the crude protein in grain of common bean (20.9-22.1%), garden pea (17-20%), pigeon pea (20-22%), mung bean (24.3%), bambara nut (16-25%) and chick pea (17-22%) (Tharanathan and Mahadevamma, 2003; Mkandawire, 2007; Jukanti *et al.*, 2012; Bouchenak and Lamri-Senhadji, 2013; Hayat *et al.*, 2014; AbdAllah *et al.*, 2015). In backing food industry, the food additive like protein isolates used are extracted from lablab beans for cake quality improvement (Subagio and Morita, 2008).

Lablab beans are sometimes used as medicines, nutraceuticals, and pharmaceuticals (Morris, 1999). The grains also contain phytochemicals such as amino acids, lauric acid and flavonoids which can be used for hyperlipidaemia, as an antimicrobial agent, appetite suppressant and as medicine for treating of osteoporosis, hypertension, and pancreatic cancer (Morris, 1999; Morris, 2009).

2.2.2 Improvement of Soil Health and Fertility for Food Production Sustainability

Despite their nutritional qualities and economic contributions, lablab beans improve soil health and fertility for food production in the field conditions (Grotelüschen *et al*., 2014). This is due to the fact that it has ability of fixing nitrogen from the atmosphere to ammonia through biological association with nitrogen-fixing bacteria (rhizobia) thereby benefiting the component non N_2-fixing crop when are cultivated in mixtures or a subsequent crop in the same field (Varshney *et al.*, 2009; Foyer *et al.*, 2016; Massawe *et al.*, 2016). The crop is characterized by a deep-reaching taproot system which provides access to macro and/or micro elements and water in deeper soil layers. The extensive root system increase cycling and susceptibility of rock-associated metallic nutrients for crop uptake including calcium, magnesium, potassium, iron, manganese, sulphur, zinc, copper, and phosphorus (Thomas, 1995; Rao, 1998; Schultze-Kraft *et al.*, 2018). The decomposition of lablab residues from leaves, stems and roots increases the availability of nitrogen and phosphorus, organic matter

contents and humus for plants uptake and beneficial soil microorganisms and lowers the bulk density of the soil (Massawe *et al.*, 2016; Stagnari *et al.*, 2017). The extensive root system together with densely packed leaves improve the physical soil properties by increasing water holding capacity and reduce run-off through ground cover (Wortmann *et al.*, 2000; AbdAllah *et al.*, 2015).

Intercropping and rotations system of grain legumes with cereals often increases productivity and the quality of the component crops in the mixed or mono-cropping system (Ojiem *et al.*, 2014; Dwivedi *et al.*, 2015). However, in intercropping systems, the monetary return and losses compensation for farming community are higher compared with mono-cropping system (Langat *et al.*, 2006; Matusso *et al.*, 2014).

2.2.3 Lablab Crops as Feed for Livestock Production and Income Generation

Wellbeing and economic status of pastoralist society are rapidly increasing due to availability of livestock products and increase in demand (Pengelly *et al.*, 2003). However in resource poor farmers, livestock feeds are the major challenge in livestock keeping. Lablab is a useful fodder and hay for livestock during the dry season, supplementing likely shortages of animal feed in subsistence settings. This keeps on sustaining live weight of the animals and increase milk production on one part as well as human welfare due to access to high quality livestock products on the other (Pengelly *et al*., 2004). Irrespective of the cropping system, lablab cultivated sole or intercropped with cereals still provides better quality feed for livestock (Stagnari *et al.*, 2017). During dry seasons, the leaves may be harvested as fodder or companion crop with cereals or mixed with cereal silage to enrich nutritional value while increasing feed palatability (Robotham and Chapman, 2017). Lablab leaves are a good source of animal feed providing crude protein (12%), fibres and dry matter digestibility (Murphy, 1999). It produces more dry mass during drought and can yield the total biomass of 2.5 tons per acre (Valenzuela and Smith, 2002).

Lablab retains some green growth during drought seasons and, therefore, becomes a potentially grazed feed by cattle, sheep, pigs and goats (Murphy and Colucci, 1999; Serdeczny *et al*., 2017; Kimani *et al*., 2012). Indirectly, healthier animals also provide manure, which increase soil organic matter, improve texture and structure of the soil that is aggregation, microbial activities in soils, and moisture retention (Gebru, 2016; Schiere *et al*., 2002). Products from raised animals generate income for smallholders in under developed countries which improves the economic status of the households (Pengelly *et al*., 2004).

Therefore, the importance of lablab as a fodder crop has to be explored under smallholders' settings in areas where such contribution has not been tested for awareness and suitability, acceptability and adoption by the community as well as its need for further sensitization across gender equity.

2.2.4 Lablab Beans as Potential Crop for Climate Change Impact Resilient

Most regions around the globe have been identified to be vulnerable to the impacts of climate variability (Innocent *et al.*, 2017). The IPPC (2014) states that the key driver of climate change is the increase in anthropogenic greenhouse gases (GHGs) emissions, mainly carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). This vulnerability has great impact on food production and is likely to jeopardize a basket of food security and may increase poverty and malnutrition among poor resource holders. More than 21 of 36 African countries worldwide accounting to 58%, are food insecure due to the variation the climate and weather of an area (Toulmin, 2009). Weather extremes and climate variability such as uneven distribution of rain, persistence of short rains, temperature change, severe and prolonged flood and drought, loss of arable land due to desertification and soil erosion shift agricultural calendar to unpredictable way affecting overall food productivity (Ewansiha *et al.*, 2007; Lema *et al.*, 2014; Innocent *et al.*, 2017; Serdeczny *et al.*, 2017). Subsistence agriculture is mostly rain-fed which is susceptible to the impact associated with climate change (Lema *et al.*, 2014; Serdeczny *et al.*, 2017). A large portion of smallholder and poor farmers in Sub-Saharan Africa (SSA) are dependent on food crops, which are sensitive to the impacts associated with climate change (Asseng *et al.*, 2011). Climate change aggravates the existing environmental degradation in Africa, intimidating the rich diversity of plant and animal species (Seimon *et al.*, 2011). Unpredictable temperatures and precipitation rates increase the risks of insects and diseases, which are among the major constraints of crop production (Oxfam, 2012; Deressa, 2014; Serdeczny *et al.*, 2017). Prolonged droughts have negative impacts on the natural resources such as biodiversity and water resource, food security, human health and animal production (Oxfam, 2012; Serdeczny *et al.*, 2017).

Lablab bean is more tolerant to drought in relation to other grain legumes such as common bean (*Phaseolus vulgaris)* and cowpea (*Vigna unguiculata*) (Ayisi *et al.*, 2004; Robotham and Chapman, 2017) dedicating this legume for household food self-sufficiency and poverty reduction (Ayisi *et al.*, 2004; Maass *et al.*, 2010). This crop has many outstanding growing qualities compared with other members of leguminaceae family, which can resilient the

effects associated with climate change including unfavourable temperature and uneven distribution of rains (Maass *et al.*, 2010; Robotham and Chapman, 2017). Lablab bean grows well in diverse environments as it is adaptable to a wide range of rainfall (200 to 2500 mm), temperature (18 to 30^{o} C) and altitudes 1800 meters from sea level (Murphy and Colucci, 1999; Ewansiha *et al.*, 2007; Schultze-Kraft *et al.*, 2018). It can thrive on relatively acidic to the alkaline soil of low fertility and high aluminium toxicity due to its rooting system, morphology and mode of proliferation (Morris, 2009; Zhang *et al.*, 2013; Guretzki and Papenbrock, 2014). Lablab beans are a perennial grain legume with an extensive root system which penetrates deep below the soil for water, and nutrients uptake (Schultze-Kraft *et al.*, 2018). It proliferates throughout growing circle thus produces flowers and seeds for many months, and remains green even when the weather becomes dry and cool that can endure in different climatic conditions (Groteluschen, 2014). Some species of lablab beans are used as cover crops because of dense green leaves with spreading or bushy growth habit. They retain soil moisture, maintain soil structure and reduce water surface runoff as well as modification of soil temperature (Groteluschen, 2014). Subsequently, the demand for heat and drought-tolerant crops with high nutritional value such as lablab bean for different climatic conditions to replace vulnerably susceptible leguminous crops is a viable option for food and nutritional security and poverty eradication across sub-Saharan Africa (Foyer *et al.*, 2016).

Therefore, different strategies should be implemented to improve sustainable productivity of lablab crop in relation to the impact of climatic variability whilst improving the nutritional status of human and animals. One among the best options would be screening of lablab germplasms adaptable to production constraints such as fluctuating temperatures causing drought or increase in heating effect, infestation and damage by insect pests, diseases, floods, and soil salinity. Due to increase in population density and declining arable land, adoption of multiple cropping systems such as crop rotation and intercropping of lablab beans with other staple crops like cereals would diversify systems productivity intensification. Interactions of environmental (agro-ecologies), genetics (varieties/cultivars), and cropping systems (sole, mixtures, rotations) are pertinent to be well evaluated and demonstrated for outreach.

2.3 Involvement of Farmers' Knowledge and Preferences in Breeding for Sustainable Crop Development and Household Food Security

Breeding and selection criteria of appropriate varieties includes farmers' perceptions and preferences through Participatory Variety Selection (PVS) (Joshi and Witcombe, 2002;

Witcombe *et al.*, 2005). This approach can be successfully done by using mother trials (on-station) and/or baby trials (on-farm) to integrate the criteria of both farmers and breeders in early stages of variety development (vom Brocke *et al.*, 2010). Baby trials are managed by farmers using their commonly employed management techniques. Farmers ideas are collected such that the practice allows information to be shortened as numbers or ratings, as well as in lists of farmers' comments about the varieties (Paris *et al.*, 2011). In mother trials, the groups of farmers are invited at different growth stages and development of the crop including land preparation, sowing, realization of 50% flowering, 50% podding, maturity stage, harvesting and appropriate storage measures. The PVS requires that the farmer evaluates the trial randomly and participate in ranking the varieties using a simple technique of preference score (PS) (Virk *et al.*, 2006). The aims of introducing PVS into a variety development program is to increase the rate of adoption to the products.

Farmer's criteria in breeding and selection usually are based on two categories including agronomic and sensory characteristics**.** The agronomic criteria which are preferred by farmers during selection of newly introduced accessions include; large seed size, early maturity, high yielding, disease resistance, insect-pest resistance, bulk leaves and drought tolerant (Joshi and Witcombe, 1996). Furthermore, farmers and growers essentially need plants that can adapt the growing conditions of their local production environment and which could suite the employed cultivation practices (Rahman *et al.*, 2015). In the heterogeneity of rain-fed environments involvement of farmers, especially women in variety development has shown successes in previous studies (Bucheyeki and Mmbaga, 2013; Goa and Ashamo, 2017). The sensory attributes vary considerably with the product type and gender (Angessa *et al.*, 2008). These characteristics are basically preferred by consumers to be related to good taste, food colour, tenderness, texture, cooking time and quality of the product (Watts *et al.*, 1989). Sensory analysis involve trained and untrained personnel in using senses of sight, smell, taste and touch to measure and identify differences among similar food products using standard scale (Watts *et al.*, 1989; Meilgaard *et al.*, 1999). The criteria considered by farmers to accept or reject the crop depends on the crop type, environmental conditions, gender and economic status (vom Brocke *et al.*, 2010). In this approach, the opinions of women farmers, poor farmers and farmers from minority ethnic and social groups are highly considered. The social goal of this approach is to stimulate gender equity in resources and agricultural knowledge accessibility (Paris *et al.*, 2011).

Quantification of farmers' selection criteria and modification of breeders' criteria have great impact in plant breeding program development (Rahman *et al.*, 2015). Subsequently, farmers are involved in developmental process starting from initial stages of production to provide wide room of selecting the crop or accession of their interest (Bucheyeki and Mmbaga, 2013). Therefore, these methods help breeders and agronomists to understand which varieties perform better on-farm and are preferred by farmers. In addition, PVS enhances early adoption, distribution and utilization of new accessions in the locality. This in turn increases the pool of crop diversity through seed exchange, farmers saved seed and community based seed (Mulatu and Belete, 2001).

Therefore, integration of farmers knowledge and criteria using their overall preference scores with the breeder's criteria during cultivars selection from accessions results into development of varieties that suit farmer's needs, fit their local production environment and fulfil customer's satisfaction. Furthermore, information obtained during sensory and agronomic evaluation paves the way to the identification of farmers' preferable criteria of introduced lablab accessions that have great opportunity in the enhancement of this crop and is the major determinant of predicting the adoption of introduced accessions.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Site

The experiment was conducted at Kahawa estate of Africa Plantation Kilimanjaro Limited (APKL) in Moshi Rural, Kilimanjaro, Tanzania. The experimental site was located at latitude $3^0 13' 59.59'' S$ and longitude $37^0\ 20'\ 35'' E$ with elevation of 888 meters above sea level. The soil originated from volcanic ash and characterized by low levels of total nitrogen and available phosphorus. The monthly average of the total rainfall (mm) and temperature range (^0C) during growing season were recorded and are presented in Fig. 2

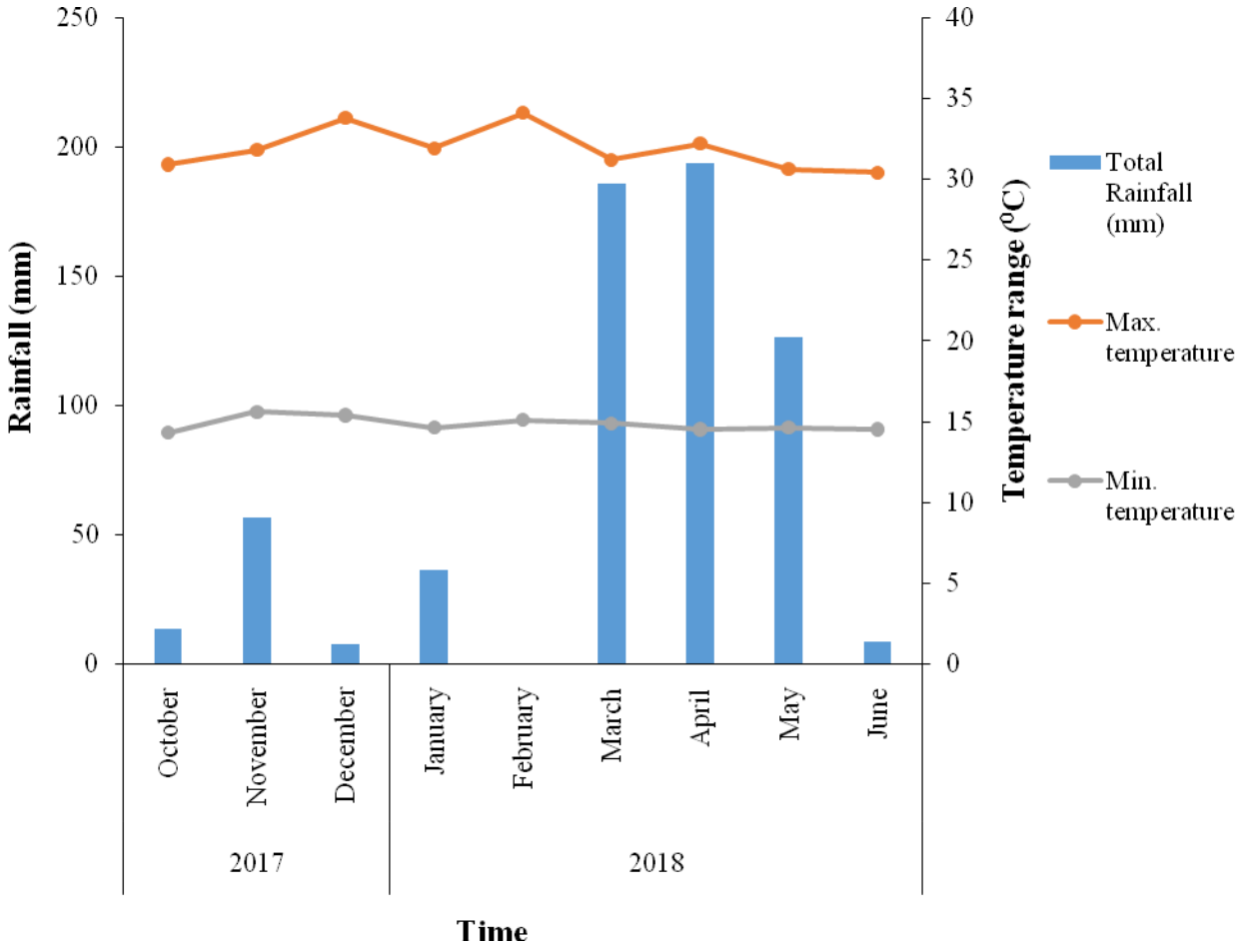


Figure 2: Monthly average of rainfall and temperature range during growing period

3.2 The Experimental Materials

A total of forty one (41) lablab bean accessions were imported from National Bureau of Plant Genetic Resources (NPGR), India, Australian pastures gene bank, Australia, The world vegetable center (AVRDC), Taiwan and Eastern and Southern Africa, Tropical Pesticides Research Institute (TPRI), Niel (ECHO) and local market, Tanzania (Table 2). One improved variety (HA4) was imported from NPGR, India and one local cultivar (Katumani) purchased from nearby market in Tanzania were used as checks in this study. The imported accessions were selected for its uniformity in term of colour, shape and good physical appearance. The selection criteria of improved and local cultivars as control were: (a) HA4 possessing determinate growth habit and photoperiodic insensitive to create heterogeneity in the field. (Tb) Katumani was used in the study for comparison purpose as it has been used by farmers.

3.3 Site Selection

The selection criteria of the study site was first based on general overview of the crop legume diversity, crop history, general understanding and awareness of farmers about the crop. The second criterion was irrigation system since most of lablab accessions are late maturing therefore the planting time was to be done during off-season. Third, criterion used was the nature of the study where the main objective was to screen the morphology of different lablab accessions which is highly influenced by environmental factors such as rainfall distribution and temperature therefore the site was selected due to the availability of instruments used to measure the weather elements.

Table 1: Origin and Gene banks of 41 lablab beans accessions used in the study

S/N	Origin country	Gene bank	Plant ID	No. of
1.	Thailand	AVRDC, Taiwan	VI039775	D1
2.	Thailand	AVRDC, Taiwan	VI039881	D7
3.	Thailand	AVRDC, Taiwan	VI039940	D10
4.	Lao People's Democratic	AVRDC, Taiwan	VI047210	D26
5.	Lao People's Democratic	AVRDC, Taiwan	VI047240	D27
6.	Tanzania	AVRDC, Eastern and Southern	RVI01124	D95
7.	Tanzania	AVRDC, Eastern and Southern	RVI02477	D107
8.	Australia	AVRDC, Eastern and Southern	RVI01114	D85
9.	Unknown	AVRDC, Eastern and Southern	RVI01117	D88
10.	Denmark	Australian Pastures Gene bank,	50360	D112
11.	India	Australian Pastures Gene bank,	50454	D135
12.	India	Australian Pastures Gene bank,	50461	D137
13.	Ethiopia	Australian Pastures Gene bank,	50307	D140
14.	Ethiopia	Australian Pastures Gene bank,	50333	D149
15.	Ethiopia	Australian Pastures Gene bank,	50335	D151
16.	Tanzania	Local market	Unknown	Katum
17.	Tanzania	TPRI, Tanzania	TZA10	D155
18.	Tanzania	TPRI, Tanzania	TZA 5485	D159
19.	Tanzania	SARI, Tanzania	Ngwara	D163
20.	Ethiopia	Niel (ECHO, Tanzania)	PI195851	D164
21.	Columbia	Niel (ECHO, Tanzania)	CIAT 22759	D165
22.	Kenya	Niel (ECHO, Tanzania)	DL 1002	D168
23.	India	NBPGR, India	IC330414	D190
24.	India	NBPGR, India	IC344081	D203
25.	India	NBPGR, India	IC340282	D192
26.	India	NBPGR, India	IC344070	D195
27.	India	NBPGR, India	IC344075	D199
28.	India	NBPGR, India	IC344076	D200
29.	India	NBPGR, India	IC344077	D201
30.	India	NBPGR, India	IC345464	D204
31.	India	NBPGR, India	IC349766	D207
32.	India	NBPGR, India	IC349785	D208
33.	India	NBPGR, India	IC361155	D210
34.	India	NBPGR, India	IC369566	D211
35.	India	NBPGR, India	IC373248	D217
36.	India	NBPGR, India	IC375857	D220
37.	India	NBPGR, India	IC381553	D222
38.	India	NBPGR, India	IC383067	D223
39.	India	NBPGR, India	IC383069	D225
40.	India	NBPGR, India	IC344072	D196
41.	India	NBPGR, India	Unknown	HA4

3.4 Experimental Design and Layout

3.4.1 Morphological Characterization

The experiment was laid down in augmented block design where (39) accessions and two checks namely Katumani and HA4 were randomly assigned in three blocks using statistics tool from the website. The design produced three blocks with total of 51 rows. Whereas each block had 17 rows which accommodated 13 accessions and 2 checks in 2 replication per block. The field was prepared by slashing and uprooting the existing vegetation and ploughing was done by using hand hoe. The ridges at spacing of 75 cm were prepared to facilitate water flow during irrigation. Each row of 4 m accommodated a total of 10 seeds per accession at spacing of 40 cm. One seed per hole of each genotype was sown into ridge in the experimental plot.

The crop was sown on 17 November, 2017 and harvested from May to August, 2018 based on the maturity rate of accessions. The maximum temperature during the growing period ranged from 36.9 °C in February to 30.5 °C in June, 2018 and the minimum temperature was 14 °C in all months of cultivation. The mean maximum and minimum temperature ranged between 34.1 and 14.3 ^{0}C, respectively. During the growing season the average precipitation was 117.28 mm, of which March, April and May, 2018 received high amount of rain (185.7 mm, 193.5 mm and 126.3 mm), respectively. While December, 2017 received an average of 7.4 mm. The soil of the experimental plot originated from volcanic ash and characterise by low levels of total nitrogen and available phosphorus (Funakawa *et al.*, 2012; Kihara *et al.*, 2017). The recommended agronomic management practices such as irrigation, insect pest control, fertilization, weeding and staking were followed to raise the good crop stand.

3.4.2 Farmers Participatory Variety Selection (PVS)

(i) Sampling Procedure

The participatory variety selection was done at experimental site. Moshi rural was purposively selected as representative because it is agriculturally potential area and traditionally it was one among the area where lablab beans were cultivated previously in Tanzania. A stratified random sampling procedure was used to randomly select six villages. Boro, Karanga, Kindikati, Shirimatunda, Sambarai and Kirima were selected. Five farmers were selected from each village to capture the inherent variability within the district. A total of thirty (30) farmers were randomly selected based on their farming experiences of lablab

beans production and assessed through the semi-structured survey. The composition of 30 respondents was such that 16 female and 14 male were involved in this survey to evaluate this trial objectively and effectively.

(ii) Experimental Design

A total of thirty (30) questionnaires and (6) checklists were prepared for evaluation of farmers' preferences on lablab beans cultivars (Appendix 1 and 2). Thirty (30) farmers from lablab consuming population were invited four times at different stage of crop growth and operations. This included planting time, vegetative phase, flowering phase and maturity phase. A group of five participants identified ten criteria jointly for ranking. Three hundred (300) paper ballots of different colour were prepared for evaluation process. Ten (10) ballots of different colors were given to each participants, where red colour represent (female) and green colour represent (male). Farmers were allowed to rank the accessions based on their preferred traits and uses. A scale of 1–10 was used to choose preferred accessions based on their traits of interest as follows: 1= extreme preferred and 10= not preferred. The participants were allowed to go through the field trials freely to "vote" for the best accessions by depositing paper ballots in an envelope in front of each row of accession. The votes were counted and the highest total number was first classified. The participants were requested to observe the ten accessions that received the highest number of votes and explain why they liked the selected accessions.

3.4.3 Sensory Evaluation of Ten Lablab Bean Accessions

Ten (10) most farmers preferred lablab accessions selected during field assessment were used for sensory evaluation. Lablab bean samples (250 g) of each accession was washed and cooked according to common cooking method practiced by farmer. Initially, 1 litre of water was used for each sample and more water was added according to the ability of the grain to absorb water and cooking time. A label consisting of code number, colour of the sample before and after cooking, cooking time, volume of the sample before and after cooking was placed with the corresponding sample. Each cooked sample was served into similar 10 disposable plates. Each sample was randomly labeled with 3 digit to avoid biasness. Thirty (30) panelists were recruited based on awareness to this crop, oral health status, interests, and use of scales. The participants in this trial were aged between 15 and 57 years and were previous consumers of lablab beans.

Each participant was given a food sample, bottle of water, spoon and individual evaluation sheet ready for the ranking. Each panelist was given the bottle of water to rinse their mouth after tasting each sample to avoid residual taste contamination before tasting the next sample and was requested to evaluate each food sample based on the sensory attributes provided in the individual sensory evaluation sheet which are taste, texture, food colour, tenderness and cooking time (Appendix 3). Acceptance testing was conducted according to Santa Cruz *et al.* (2002) using a 5-point hedonic scale (5 = like extremely, 1 = dislike extremely) to assess the consumers' acceptance of the food sample. Consumers were asked to express their overall acceptance of the product and their acceptance of the sensory attributes. During evaluation the panelist was requested to write number 1 - 5 to the appropriate box according to the named sensory attributes using the provided scale. The reasons for selecting the most-preferred sample based on characteristics of their choice were noted. Each sample was evaluated based on individual perception and acceptability.

3.5 Experimental Crop Management

3.5.1 Irrigation

Fallow irrigation was used where the water are allowed to pass through the ridges. Irrigation was done before planting to ensure the excess soil moisture followed by seeding. The experimental plot was irrigated until the seeds germinated and the crops established. Thereafter, irrigation was done four times per month except in December, 2017 and February, 2018 where the rate was increased to eight times per month due to the fact that the daily temperature was very high resulting into increasing soil temperature and evaporation.

3.5.2 Fertilizer Application

The knapsack sprayer was used to spray the crop. The foliar fertilizer (booster) was applied 3 times throughout the growing circle at the rate of 30 ml per 16 L to facilitate leaves and flowers proliferation. However, the application was done depending on the physical appearance of the crop. At 16 weeks, 5 g of urea fertilizer per hole was top dressed to soil for plant uptake. The aim was to reduce yellowing due to excessive leaching of the nutrients and to boost the growth of the leaf and to facilitate flowering reformation after droppings which caused by heavy rains and low nitrogen this was observed in March, 2018.

3.5.3 Weeding

Weeding was done in three different time depending on the population of weeds in the experimental plot. In week four (4) and six (6) after planting the population of broad leaf weeds was higher because the lablab leaf canopy was not well developed therefore the weeding was done by using hand hoe. In week ten (10) and above the weeds population reduced due to suppressive ability of the lablab, large leaf canopy, spreading and climbing growth habit.

3.5.4 Roughing

Roughing was done by using hand where unwanted plants which deviated from the rest (off-type) were removed from each row of the experimental plot.

3.5.5 Staking

By 6^{th} week, all crops which possessed an indeterminate growth habit were supported by a stake for climbing and the plants were lopped by using sisal rope to support climbing and to avoid overlapping of plant from one row to another.

3.5.6 Diseases and Insect Pests Control

The diseases and insect pests such as pod borer *(Maruca testulalis*), aphids, grasshopper, stink bugs (*Coptasoma eribraria*), leaf miner, thrips (*Megalurothrips sjostedti*), stem borer, pod sucking bud (*Hemiptera spp*), bacterial leaf spot and wilting were identified. The broad spectrum insecticides such as cyclone 505 EC, duduba 450 EC, thiovin and ascoris 48 EC at 30ml/16L of water were used to control aphids, thrips, white fly, stem borer and pod borer.

3.6 Data Collection

3.6.1 Germination Percentage

The date of planting was recorded and the germination data was recorded when trifoliate leaves were observed. The data were collected by visual and counting observation method where the number of plant seedlings in each row was counted and recorded.

3.6.2 Morphological Characterization

Qualitative and quantitative data was collected from five competitive plants in each row where the observations were taken in five replicate at randomly from each plant. Data was collected and recorded as per Byregowda *et al.* (2015) descriptor characterization sheet of

lablab beans with modification Table 3. The data was collected and recorded at different plant growth stage including; vegetative phase, inflorescence or flowering phase, podding phase and seed phase.

(i) Vegetative Phase

At vegetative phase both the qualitative and quantitative data were observed and recorded. The qualitative data included emerging cotyledon colour, hypocotyl colour, stem pigmentation, leaf vein colour, leave colour, leaf hairiness, leaf shape, growth habit, primary branches, and secondary branches and branch orientation. All data regarding the colour were observed from 6 week after planting by using standard plant colour chat which helped to determine the colour of the plant tissue. The leaf hairiness was observed by using the waltex 8X magnifier to quantify the concentration and length of pubescence on the inner surface of the leaf. Thereafter, visual observation were followed on the leaf shape, growth habit, and stem pigmentation the data were recorded as per given scale. On other hand, different instrument such as ruler, tape measure, sisal rope were used to determine the length and width of the leaf, leaf let length and plant height.

(ii) Inflorescence or Flowering Phase

At flowering phase both the qualitative and quantitative data were observed and recorded. Fourteen characters were observed from five middle plant out of ten planted crop with different scale. These included the following; days to first flowering, days to 50% flowering, flower bud length and width, petal colour (standard, wing and keel), number of flower bud/ raceme, number of raceme per plant, raceme length, peduncle length, raceme position, number of node per raceme and number of bud per node. The flower bud and petal colour were determined by using the standard plant colour chat where the width and length of the bud, raceme length, and peduncle length were measured in centimeter (cm) by using ruler.

(iii) Podding Phase

At podding phase a total of fifteen characters were observed from five middle plant out of ten planted crop with different scale. The selected plants were marked with the corresponding characters to avoid misinterpretation of the findings. The qualitative data observed were fresh pod curvature, fresh pod pubescence, fresh pod fragrance, fresh pod oil composition, fresh pod constriction, fresh pod colour, fresh pod attachment, and pod colour at physiological maturity. The intensity of fresh pod fragrance and oil composition were determined by using

the sense of smell and touch respectively. Fresh pod pubescence was observed on the fully expanded immature pods. However, the quantitative data observed were days to first podding, days to 50% podding, fresh pod beak length, fresh pod length and width, number of fresh pod per plant, number of locules per fresh pod, number of seed per fresh pod and days to maturity. The fresh pod beak length, fresh pod length and width of the crop were measured by string and ruler.

(iv) Seed Characteristics

Fifteen seed characteristics were observed and recorded as per descriptor characterization sheet of lablab beans. The dry and fresh seed colour, fresh and dry seed helium colour were observed by placing the plant colour chart along with the randomly selected seeds per accession. The seed shape and dry seed texture were visually quantified. The quantitative seed characteristics such as fresh seed length and width, dry seed thickness, and dry seed length and width were measured by using graph paper. The average of 100 seeds were chosen at randomly per accession and weighed in gram (g) using weigh balance.

Table 2: Descriptor characterization sheet of lablab beans

S/N	Descriptor	Scale/state
1	**Vegetative**	
1.1	Emerging cotyledon colour	1 = White, 2 = Green, 3 = Purple
1.2	Hypocotyl colour	1 = Green, 2 = Purple
1.3	Stem pigmentation	0 = No pigment, 3 = Localized to nodes, 5 = Extensive, 7 = solid
1.4	Leaf vein colour	1 = Green, 2 = Purple
1.5	Leaf colour	1 = Pale green, 3 = Green, 5 = Dark green, 7 = Purple, 9 = Dark Purple
1.6	Leaf hairiness	0 = Glabrous, 3 = Low pubescent, 5 = Moderately pubescent, 7 = Highly pubescent
1.7	Leaflet length	Measured on the terminal leaflet of third trifoliate leaf from pulvinus to leaf tip from 5 plants (cm).
1.8	Leaf shape	1 = Round, 3 = Ovate, 5= Ovate- lanceolate, 7 = Lanceolate, 9 = Liner –lanceolate
1.9	Growth habit	1= Determinate, 2= Semi determinate, 3= Indeterminate, 4= Others
1.10	Primary branches	Average from 5 randomly chosen plants
1.11	Secondary branches	Average from 5 randomly chosen plants
1.12	Branch orientation	3 = Short and erect lateral branches 5 = Branches tending to be perpendicular to main stem, medium in length 7= First lateral branches long and spreading over ground
1.13	Plant height	Measured on 5 random matured plants form cotyledon scar to tip (cm).
2	**Inflorescence**	
2.1	Days to 50 % flowering	Days from sowing to 50 % of the plant produce flower
2.2	Flower bud colour	1= white, 2 = Cream, 3 =Light Yellow , 4 =Pink, 5 = Purple
2.3	Standard petal colour	1= white, 2 = Cream, 3 =Light Yellow , 4 =Pink, 5 = Purple
2.4	Wing petal colour	1= white, 2 = Cream, 3 =Light Yellow , 4 =Pink, 5 = Purple
2.5	Keel petal colour	1= white, 2 = Cream, 3 =Light Yellow , 4 =Pink, 5 = Purple
2.6	Number of racemes/ plant	Average of 5 randomly chosen plants
2.7	Raceme length	Average of 5 randomly chosen plants (cm)
2.8	Raceme position/ emergence	3 = Within foliage, 5 = Intermediate, 7 =complete emergence from leaf canopy

Table 2 (continue)

S/N	Descriptor	Scale/state
3	**Fruit**	
3.1	Fresh pod curvature	0 = Straight, 3 = Slightly curved, 5 = Curved
3.2	Fresh pod pubescence	0 = Glabrous, 3 = Moderately pubescent , 5- Pubescent
3.3	Fresh pod fragrance	0 = Absent, 1 = Low, 2= Medium, 3 = high
3.5	Fresh pod oil composition	0 = Absent, 1 = Low, 3= Medium, 5 = high
3.6	Fresh pod length	Average of 5 randomly chosen pods (cm)
3.7	Fresh pod width	Average of 5 randomly chosen pods (cm)
3.8	Fresh pod constriction	0= No constriction, 3= Slightly constricted, 5= constricted
3.9	Fresh pod colour	1 = White, 2 = Cream, 3 = Green, 4 = Green with purple suture, 5= Purple, 6= Dark Purple, 7 = Red
3.10	Fresh pod attachment	1 = Erect, 2 = Intermediate, 3 = Pendant
3.11	Number of fresh pods/plant	Average number of pods from 10 randomly chosen plants
3.12	Number of locules/ fresh pod	Average of 5 randomly chosen pods
3.13	Number of seeds/fresh pod	Average of 5 randomly chosen pods
3.14	Days to 50% podding	Days from 50 % of the plant produce pods
3.15	Pod color at physiological maturity	3= Tan, 5=Brown, 7=others (specify)
3.16	Days to maturity	Days taken for physiological maturity of pods
4	**Seed**	
4.1	Fresh seed colour	1 = Green, 2 = Cream, 3= Purple, 4 = Brown, 5 = Black
4.2	Fresh seed hilum colour	1 = White, 2= Tan, 3= Others (specify)
4.3	Fresh seed shape	1 = Round, 2= Oval, 3 = Flat, 4 = Other (specify)
4.4	Dry seed colour	1 = White, 2= Green, 3= Cream, 3= Purple, 5 = Brown, 6= Black
4.5	Dry seed hilum colour	1 = White, 2= Tan, 3= Others (specify)
4.6	Dry seed length	Average of 5 seeds chosen at random (mm)
4.7	Dry seed width	Average of 5 seeds chosen at random (mm)
4.8	Dry seed thickness	Average of 5 seeds chosen at random (mm)
4.9	Dry seed shape	1 = Round, 2 = Oval, 3 = Flat, 4 = Others (specify)

Table 2 (continue)

S/N	Descriptor	Scale/state
4	**Seed**	
4.10	Dry 100 seed weight	Average weight of 100 seeds chosen at random (g)
4.11	Dry seed texture	3= Smooth, 5 = moderately ridged, 7 = markedly ridged
4.12	Dry seed yield /plant	Average of 5 plants chose

3.6.3 Farmer's Acceptability of Lablab Beans Accession

(i) Agronomic Preferences

Primary data was collected by using semi-structured questionnaire and checklist through both formal and informal surveys. Local agricultural extension staff and contact personnel facilitated the survey by creating a good relationship with local people, mobilizing farmers for discussion and providing list of farmers to be sampled for the formal surveys. A questionnaire designed had two sections including demographic and general cropping and production information. This approach enables self-explanatory of individual farmer regarding the crop. While the group interview, the checklist was structured to collect farmer's preferences for lablab bean and factors for its abandonment. Throughout the process, a facilitator guided the activity, while enumerators focused on taking notes.

(ii) Sensory Evaluation

The individual perception and preference or acceptance of food products were collected using individual sensory evaluation sheet. Each panelist was given a sheet to evaluate the sensory attributes of cooked lablab beans. The form given consist of the date, name of respondent, gender, panel number and code numbers of each sample. The attributes collected were farmers' perception to food colour, taste, tenderness, aroma, texture, and cooking time of the different accessions.

3.7 Data Analysis

3.7.1 Quantitative Data

Population means of all plant parameter from 39 accessions and two checks were used for statistical analysis. The standard deviation, range, coefficient of variation (CV %) were determined using the XLSTAT software version 9.1. The multivariate analysis including

Pearson correlation coefficient was estimated to study similarities among the accessions. Principal Component Analysis (PCA) and Cluster analysis using the Un-weighted Pair Group Method of Average (UPGMA) were used to generate dendrogram to reveal the morpho-genetic relationship among accessions. The first two principal components (PCs) were utilized to view a graphical illustration called scatter plots to show extent of divergence among the accessions.

3.7.2 Farmer's Acceptability

(i) Agronomic Evaluation

The collected qualitative and quantitative data from the semi-structured questionnaires and checklists were classified, coded and analyzed using Microsoft Excel and IBM SPSS statistics version 20 software. The Pearson correlation coefficient was used to assess the future association of key determinants for the adoption and use of lablab beans. The data was subjected to simple tabular analysis and the results were compared, contrasted and interpreted according to the study's objectives.

Garrett Ranking technique was used to analyze the farmers' selection criteria and preferred traits for crop readopting, reutilization of the different cultivars of Lablab bean in the study area. Also to identify the farmers most preferred traits to be incorporated in the future lablab beans breeding. The technique ranks the set of parameters as perceived by the representative respondents based on certain criteria. According to Garrett (1969) the order of merit assigned by the respondents was converted into percentage position by using the formula as follows:

$$Percent\ position = \frac{100(Rij - 0.5)}{Nj}$$

Where,

Rij =the rank given for i^{th} traits by j^{th} individual;

Nj = the number of traits ranked by the j^{th} individual.

By referring the Garrett's ranking conversion table **(**Appendix 4), the per-cent position of each rank calculated was converted into Garrett score. Then, for each factor the scores of various respondents were added and the Garrett mean score was estimated. The factor with the highest mean score was considered to be the most important factor.

(ii) Sensory Evaluation

The numerical scores for each sample are tabulated and analyzed by using XLSTAT-MX software version 9.1 for Windows. A one-way analysis of variance (ANOVA) was performed on consumer overall liking scores considering consumer and sample as sources of variation. Consumers' ratings were averaged and significant difference in mean degree of liking score between the cooked lablab samples with respect to the six sensory attributes was evaluated. The means separation for each treatment (accession) were done by post hoc pair wise test (Turkeys Honest Significant Difference) at ($p < 0.05$) for each of the 10 samples (n=30).

Principal components analysis (PCA) was performed to determine the main sources of systematic variation between variables in a data set. Consumer scores for overall liking were subjected to PCA on the correlation matrix of consumer individual liking data. Agglomerative Hierarchical Clustering Analysis using ward's method was used to segment the consumers. The results were presented in tabular and graphical forms.

CHAPTER FOUR

RESULTS AND DISCUSSION

This study characterized the morphological traits of 41 selected lablab bean accessions and assessed the farmer's or consumer's acceptability of newly introduced accessions in their locality. The level of acceptability was highly dependent on the morphological, agronomic characteristics and the good sensory attributes such as plant height, seed size, growth habits, and number of pod per plant, seed colour, seed yield, leaf density, food color, texture, taste, tenderness, aroma, cooking time.

4.1 Morphological Characterization

4.1.1 Qualitative Characteristics

(i) Vegetative Traits

The vegetative characteristics of lablab beans were evaluated for 10 most important traits (Table 3). Results indicated that the white colour (61.0%) of emerging cotyledon was dominant over green (22.0%) and purple (17.0%). The hypocotyl colour was mostly green (63.4%) with only 15 accessions showed purple (36.6%) hypocotyl. The largest number of accessions (30 out of 41) had green vein colour (73.2%), while 11 accessions (26.8%) were purple in colour. Similar findings were also found by (Sultana *et al.*, 2002), and reported that only green and purple vein colours among 107 hyacinth bean accessions was observed. Above 50% of 41 accessions had no stem pigmentation while 19.5% was localized into the nodes, 22.0% was almost solid and only 2% for accession D223 was extensive in stem pigmentation. Leaf colour intensity varied as pale green, green or dark green and purple. Leaf colour intensity varied from pale green, green or dark green to purple. Green leaf colour (65.8%) showed the dominant state over other colours like dark green (17.1%), purple (9.8%) and pale green (7.3%) among the accessions. The leaves of accessions D207, D223 and D200 were found to be pale in colour while D217, D7, D208 and D1 was purple. However, none of accession had dark purple colour. Similar result was devoted by Islam *et al.* (2010) who found that leaf colour varied from pale green, green to dark green. In respect to leaf hairiness, 56.1%, 19.5%, 14.6% and 9.8% of the total accessions were glabrous, low pubescence, moderately pubescence and highly pubescent (D199, D26, D112 and D95), respectively. Three different leaf shapes were identified in this study of which 51.2% genotypes were

round, 36.6% ovate, and 12.2% of accessions D196, D204, D192, D220 and D211 were ovate lanceolate while none of them had lanceolate and linear lanceolate.

The branch orientations were grouped into three categories where short and erect lateral branches were found in 13 accessions (31.7%), 11 (26.8%) accessions had branches perpendicular to the main stem, medium in length and 17 (41.5%) had first lateral branches long and spreading over the ground. Growth habit varied among accessions based on the types where indeterminate (56.1%) was dominated the field over semi-determinate (31.7%), spreading type (9.8%) for accessions D199, D26, D155 and D211 and determinate growth types (2.4%) for accession HA4. This result is in agreement with the results portrayed by Vaijayanthi *et al.* (2015). High frequencies of indeterminate followed by semi-determinate types of accessions were anticipated as most of lablab landraces or wild species possessing climbing habit and are photosensitive (Prasad *et al.*, 2015). The lowest frequencies of determinant type pave the way to germplasm utilization for yield and yield attributes. This is due to its ability of accelerating and synchronizing flowering and reduced period of pod production leading to uniformity in pod maturity and stable harvest index (Kwak *et al.*, 2012).

Therefore, breeding this crop to obtain genotypes with determinant growth type and photo-insensitive which are gaining popularity among the farmers are essential for food security and poverty alleviation.

Table 3: Frequency distribution (%) of vegetative characteristics of the studied accessions

Traits	Level	Number of accession	Frequency (%)
Emerging cotyledon colour	1. White	25	61
	2. Green	9	22
	3. Purple	7	17
Hypocotyl colour	1. Green	26	63.4
	2. Purple	15	36.6
Stem pigmentation	0. No pigmentation	23	56.1
	3. Localized to node	8	19.5
	5. Extensive	1	2.4
	7. Almost solid	9	22
Leaf vein colour	1. Green	30	73.2
	2. Purple	11	26.8
Leaf colour	1. Pale green	3	7.3
	3. Green	27	65.8
	5. Dark green	7	17.1
	7. Purple	4	9.8
	9. Dark purple	0	0
Leaf hairiness	0. Glabrous	23	56.1
	3. Low pubescent	8	19.5
	5. Moderately pubescent	6	14.6
	7. Highly pubescent	4	9.8
Leaf shape	1. Round	21	51.2
	3. Ovate	15	36.6
	5. Ovate lanceolate	5	12.2
	7. Lanceolate	0	0
	9. Linear lanceolate	0	0
Growth habit	1. Determinate	1	2.4
	2. Semi determinate	13	31.7
	3. Indeterminate	23	56.1
	4. Spreading	4	9.8
Branch orientation	3. Short and erect lateral branches	13	31.7
	5. Branches tend to be perpendicular to main stem, medium in length	11	26.8
	7. First lateral branches long and spreading over ground	17	41.5

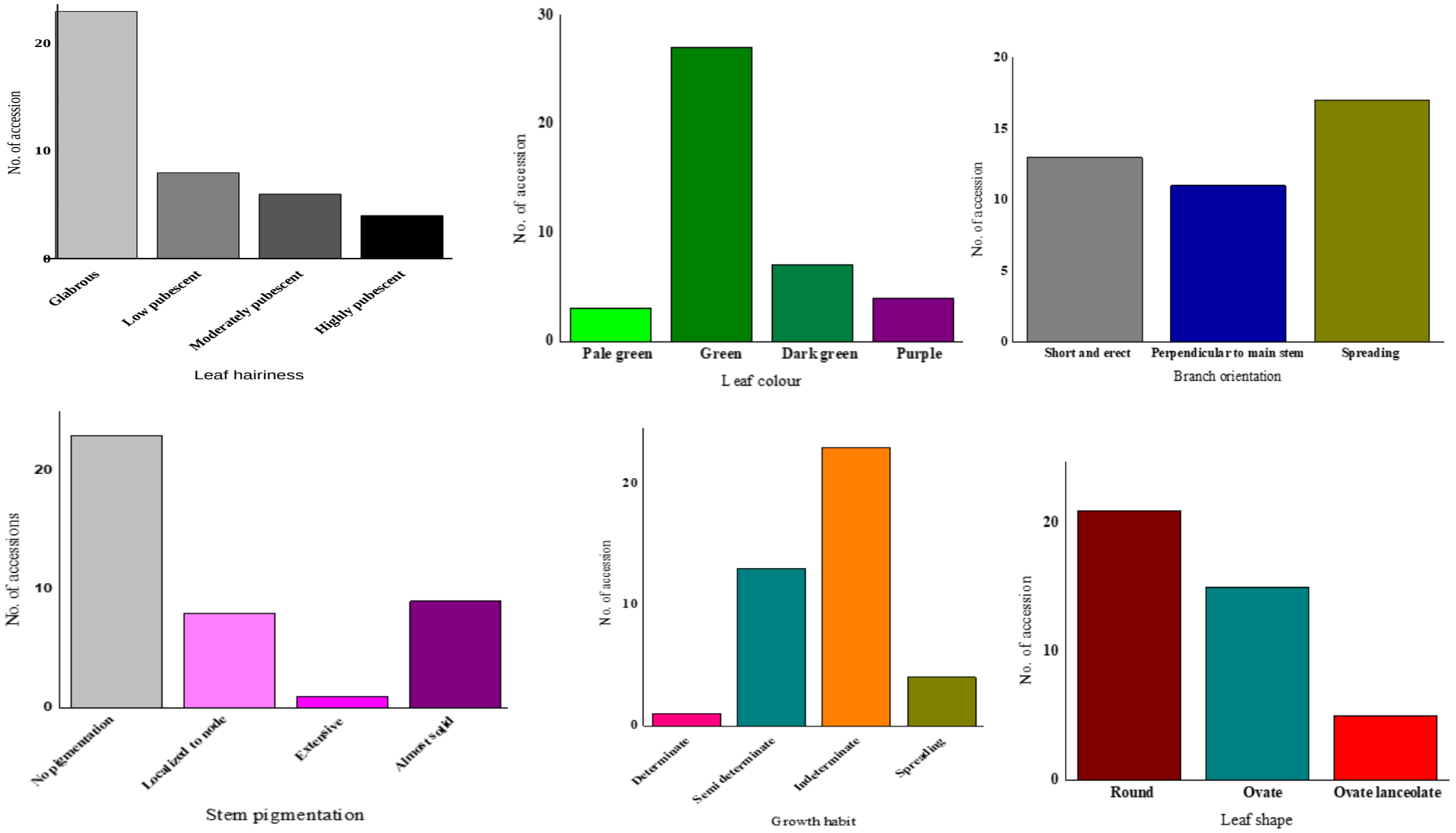


Figure 3: Frequency distribution of vegetative traits

(ii) Inflorescence Traits

Different inflorescence characteristics of lablab bean accessions are presented in Table 4. The study revealed that purple flower bud colour was dominant (46.3%) over light yellow (34.1%) and cream (19.5%) colours none of them had white and pink colour. White (43.9%), purple (29.3%), pink (17.1%), cream (9.8%) standard petal colours were widely distributed throughout the experimental units. In addition, accessions D26, D222, D204 and D140 were significant different from others while none had light yellow petal colour. Similar findings have been reported by Maass *et al.* (2005). The flower colour has a direct reflection to the seed colour (Pandey *et al.*, 2011). In the present study, most of black or mottled black and purple seeds produced pink or purple flowers while the cream or white or brown seeds produced white, cream or yellow flowers. Ewansiha *et al.* (2007) reported that 46 accessions of *Lablab purpureus* with purple flowers produced black seeds. In respect to wing petal colour, pink (17.1%) and cream (14.6%) were less than the purple colour (29.3%) and the significant dominant colour was white (39.0%). The contribution of white and cream keel petal colour was 78.0% and 17.1%, respectively. The significant divergence was observed in accessions D1 and D165 with pink and purple keel petal colour, respectively. Results also indicated that 87.8% of accessions possessed intermediate raceme position over 12.2% (D135, D107, D225, D192 and D149) which were completely emerged from the leaf canopy.

Plate 1: Morphological variation of flower bud and standard petal colour

Table 4: Frequency distribution (%) of inflorescence traits

Traits	Level	Number of accession	Frequency (%)
Flower bud colour	1. White	0	0
	2. Cream	8	19.5
	3. Light yellow	14	34.1
	4. Pink	0	0
	5. Purple	19	46.3
Standard petal colour	1. White	18	43.9
	2. Cream	4	9.8
	3. Light yellow	0	0
	4. Pink	7	17.1
	5. Purple	12	29.3
Wing petal colour	1. White	16	39
	2. Cream	6	14.6
	3. Light yellow	0	0
	4. Pink	7	17.1
	5. Purple	12	29.3
Keel petal colour	1. White	32	78
	2. Cream	7	17.1
	3. Light yellow	0	0
	4. Pink	1	2.4
	5. Purple	1	2.4
Raceme position	3. Within foliage	0	0
	5. Intermediate	36	87.8
	7. Complete emergence from leaf canopy	5	12.2

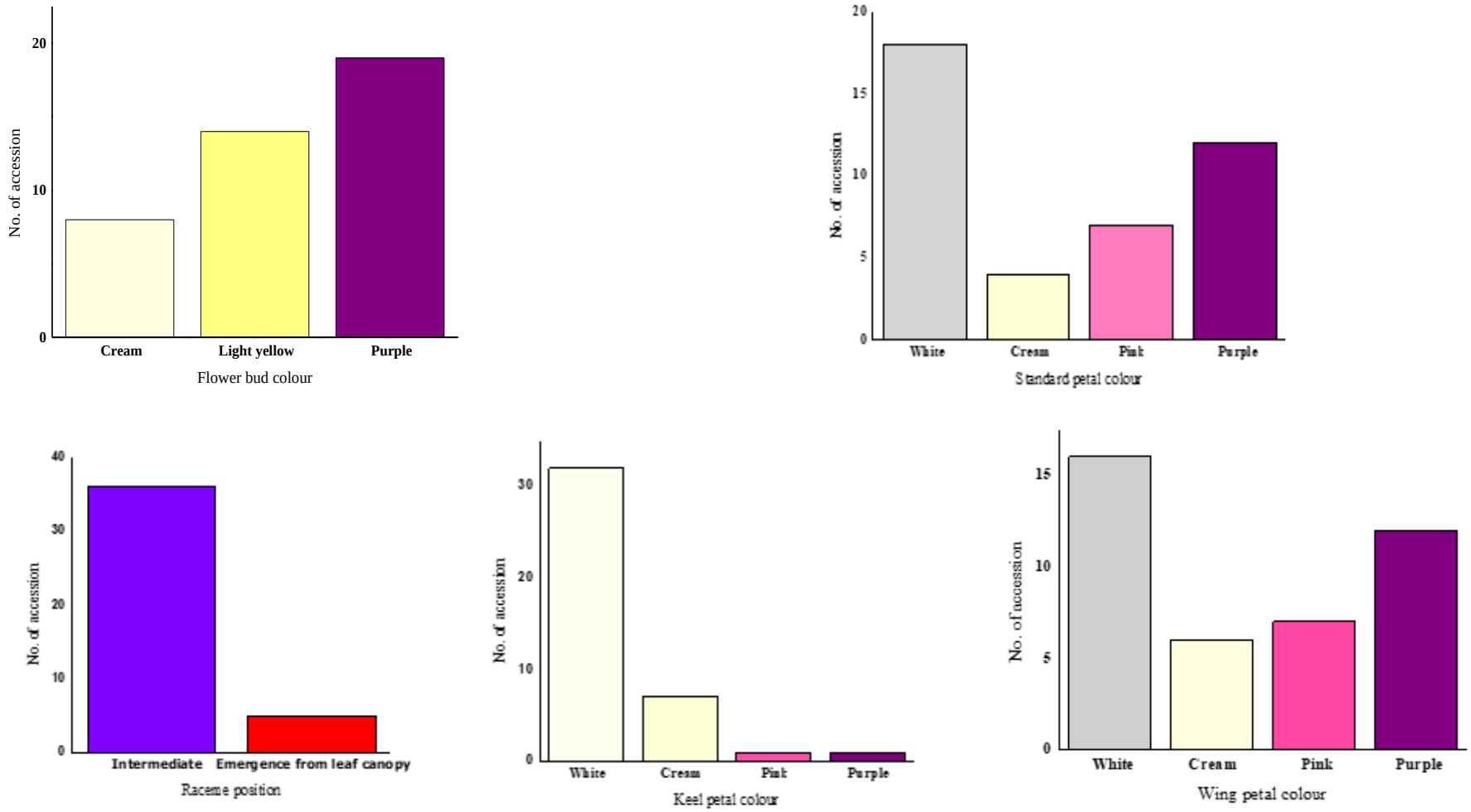


Figure 4: Frequency distribution of lablab accessions based on inflorescence traits

(iii) Pod Traits

Most of the accessions (63.4%) had straight pod structure (Table. 5). The pubescence was highly observed in 16 accessions (39.0%) followed by glabrous (36.6%) and moderately pubescent (24.4%). The intensity of fresh pod fragrance and oil composition varied considerably due to the nature and types of accessions. In this regard, 48.8% and 61.0% of total accessions had no fragrance or oil composition, respectively. Small number of accessions possessed medium level of pod fragrance and oil composition while 22.0% and 19.5% had higher levels of fragrance and oil composition, respectively. Similar observation is shown in Vaijayanthi *et al.* (2015) whose findings are 46.14%, 32.25%, 18.06% and 3.55% of the accessions with high, moderate, low and absence of fragrance, respectively. According to Fernandes and Nagendrappa (1979) there was strong relationship between pod fragrance and oil composition since the fragrance has been attributed to oily exudates. The pod constriction varied depending on the species and form. No constriction, slightly constricted and constricted characteristics were observed in 8 (19.5%), 24 (58.5%) and 9 (22.0%) accessions, respectively. Vaijayanthi *et al.* (2015) reported that 51.39% of the accessions were slight constricted, 25.62% and 22.99% of the accessions were constricted and absence of constrictions, respectively.

The present study also revealed that the least number of accessions (5) including Katumani, D27, D192 and D140 had pods with light green colours. While about 51.2% of accessions were green in colour. In addition, 17.1% produced pods with green colour but purple sutured. It was also found that 9.8% had cream pods while 4.9% had pods with dark purple (D203, D208) and cream colour with purple suture (D223, D217).This study depicts different colours of pods at physiological maturity ranging from tan (65.9%) to brown (19.5%) while cream was observed in accessions D201, D200, D190 and purplish in D1, D208, and D203 were 7.3% each. The overall pod attachments of accessions were erect (43.9%) and intermediate (36.6%) while the remaining (19.5%) was pendant in position.

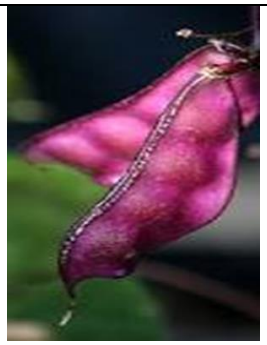
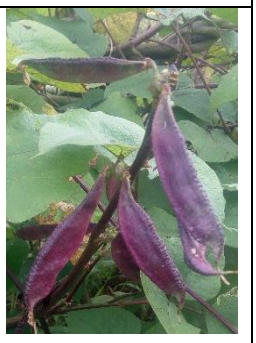
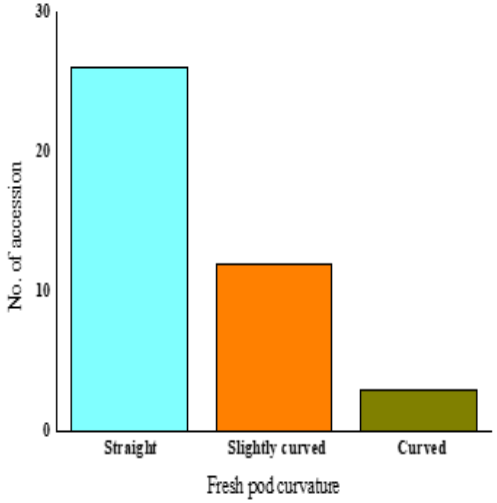
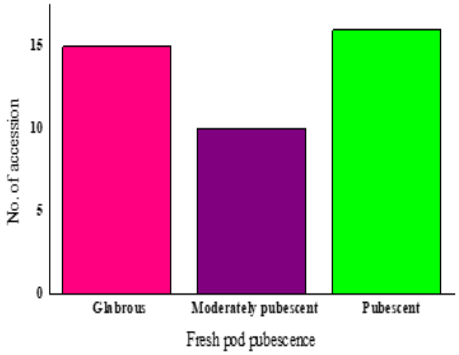
			
a) green fresh pod	b) purple fresh pod	c) cream with purple suture	d) No pod constriction
			
e) Green with purple suture	f) Erect attachment	h) Fresh pod pubescence	i) Pedant attachment

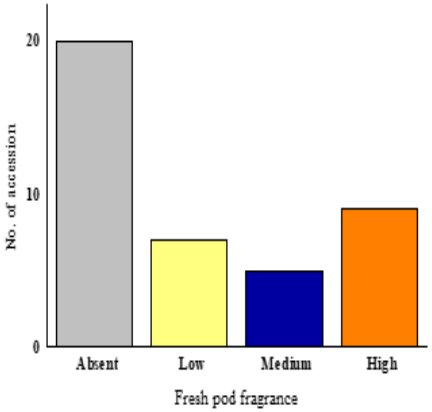
Plate 2: Morphological variation of pod characteristics in the field

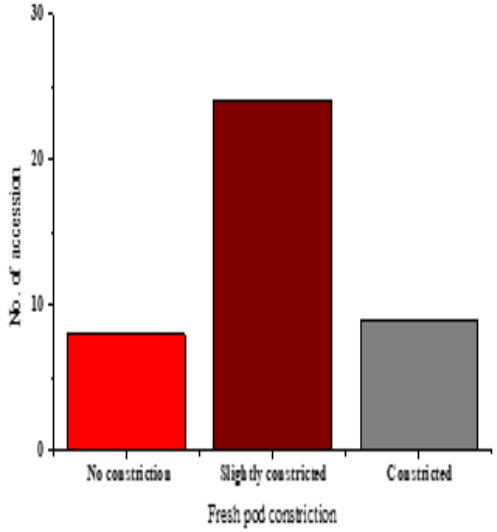
Table 5: Frequency distribution (%) of pod characteristics

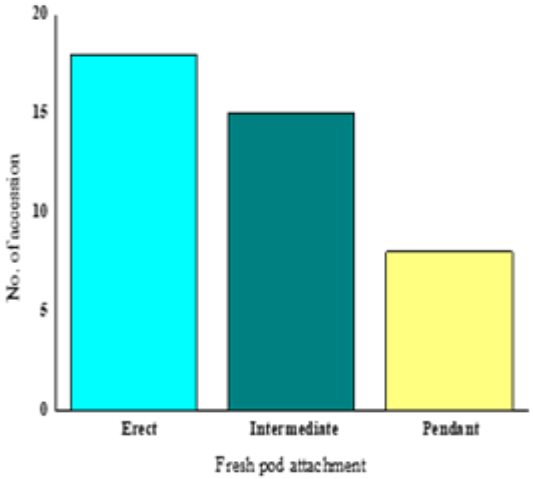
Traits	Level	Number of accession	Frequency (%)
Fresh pod curvature	0. Straight	26	63.4
	3. Slightly curved	12	29.3
	5. Curved	3	7.3
Fresh pod pubescence	0. Glabrous	15	36.6
	3. Moderately pubescent	10	24.4
	5. Pubescent	16	39
Fresh pod fragrance	0. Absent	20	48.8
	1. Low	7	17.1
	2. Medium	5	12.2
	3. High	9	22
Fresh pod constriction	0. No constriction	8	19.5
	3. Slightly constricted	24	58.5
	5. Constricted	9	22
Fresh pod colour	1. White	0	0
	2. Cream	4	9.8
	3. Green	21	51.2
	4. Green with purple suture	7	17.1
	5. Purple	0	0
	6. Dark purple	2	4.9
	7. Light green	5	12.2
	8. Cream with purple suture	2	4.9
Fresh pod attachment	1. Erect	18	43.9
	2. Intermediate	15	36.6
	3. Pendant	8	19.5
Pod colour at physiological maturity	3. Tan	27	65.9
	5. Brown	8	19.5
	7. Cream	3	7.3
	8. Purplish	3	7.3
Pod oil composition	0. Absent	25	61
	1. Low	6	14.6
	3. Medium	2	4.9
	5. High	8	19.5

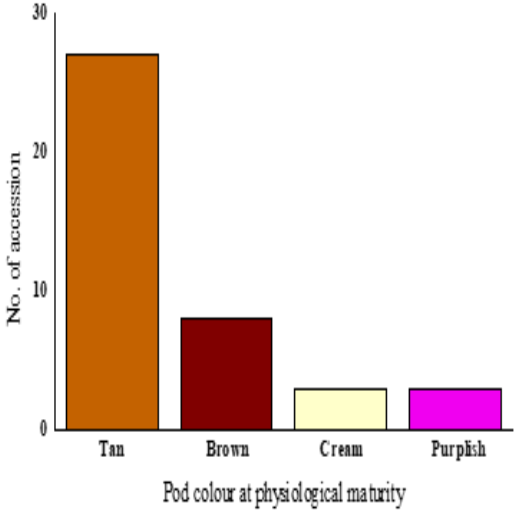

No. of accession
30
20
10
0
Straight
Slightly curved
Curved
Fresh pod curvature


No. of accession
15
10
5
0
Glabrous
Moderately pubescent
Pubescent
Fresh pod pubescence


No. of accession
20
10
0
Absent
Low
Medium
High
Fresh pod fragrance


No. of accession
30
20
10
0
No constriction
Slightly constricted
Constricted
Fresh pod constriction


No. of accession
20
15
10
5
0
Erect
Intermediate
Pendant
Fresh pod attachment


No. of accession
30
20
10
0
Tan
Brown
Cream
Purplish
Pod colour at physiological maturity

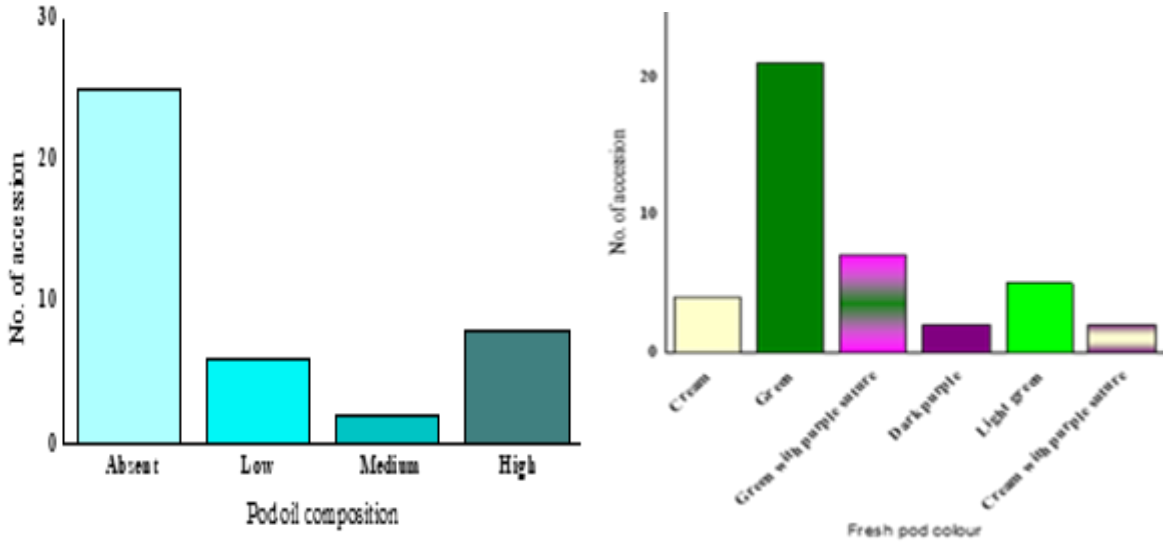


Figure 5: Frequency distribution of lablab bean accessions based on pod traits

(iv) Seed Characteristics of Lablab Bean Accessions

Fresh and dry seed vary considerably in terms of colour, form and shape. From Table 6, the results showed that the seed colour was directly related to the colour of the flowers. Most genotypes with pink or purple flowers produced black coloured seed. D163, D27, Katumani, D151, D135, D210, D149, D208, DI, D107, D196, D7, D10, D95, D203, D223, D220 and D165 produced black seed with purple or pink flowers the rest produced cream or brown seed with white, cream and yellow seed. Similarly, Pandey *et al.* (2011) reported that there was a direct relationship between seed and flower colours. However, the fresh seed coat colour varies from green (39.0%), cream (29.3%) and pale purple (22.0%), mottled brown (7.3%) to mottled purple (2.4%) of accession D149, which can be easily distinguished from other accessions. Referring to the accessions, the dry seed coat colours were 19.5% cream and black while others were brown (36.6%), mottled brown (14.6%). Results also indicated that 2.4% of the accession D203 was purple and 7.3% were mottled black for accessions D195, D208 and D220 which can be used as a selection criterion in the breeding program. Based on fresh seed helium colour most of accessions were white (95.1%) in colour and this was dominant over tan and white with black suture which accounted for the less than 5% of total dry seed helium colour. These distinctions were observed in accessions D223 and D95, respectively. On the other hand, on evaluating seed shapes, the oval shape was dominant on both fresh (65.9%) and dry (61.0%) seeds followed by round fresh and dry seed making 19.5% each. The flat dry seed (19.5%) was greater compared with fresh seed shape (14.6%).

The seed texture was smooth (85.4%) followed by moderately ridged (14.6%) and with no accession observed to have markedly ridged.

Table 6: Frequency distribution (%) of seed characteristics of the studied accessions

Traits	Level	Number of accession	Frequency (%)
Fresh seed colour	1. Green	16	39
	2. Cream	12	29.3
	3. Purple	9	22
	4. Mottled brown	3	7.3
	5. Black	0	0
	6. Mottled red	0	0
	7. Mottled purple	1	2.4
Fresh seed helium colour	1. White	41	100
	2. Tan	0	0
Fresh seed shape	1. Round	8	19.5
	2. Oval	27	65.9
	3. Flat	6	14.6
Dry seed colour	1. White	0	0
	2. Green	0	0
	3. Cream	8	19.5
	4. Red purple	1	2.4
	5. Brown	15	36.6
	6. Black	8	19.5
	7. Mottled brown	6	14.6
	8. Mottled black	3	7.3
Dry seed helium colour	1. White	39	95.1
	2. Tan	1	2.4
	3. White with black suture	1	2.4
Dry seed shape	1. Round	8	19.5
	2. Oval	25	61
	3. Flat	8	19.5
Dry seed texture	3. Smooth	35	85.4
	5. Moderately ridged	6	14.6
	7. Markedly ridged	0	0

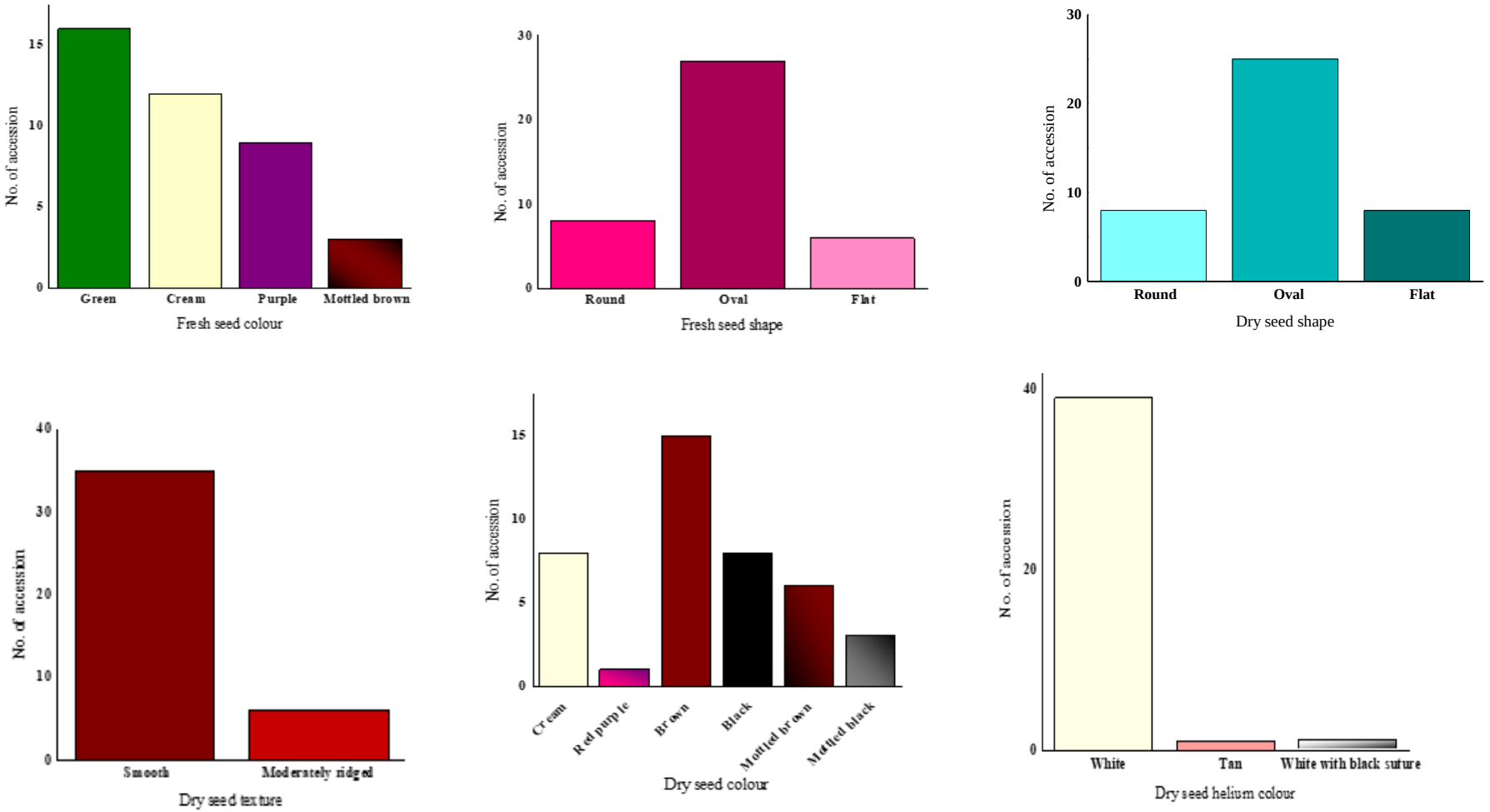


Figure 6: Frequency distribution of lablab bean accessions based on seed traits

			
a) brown seed colour	b) black dry seed	c) cream dry seed	d) purple seed
			
e) mottled brown with white helium	f) Pale brown	g) mottled black	h) white with black suture helium

Plate 3: Morphological variation in seed colour, shape and size of Lablab bean accessions.

4.1.2 Descriptive Statistics of the Quantitative Traits

Results of the mean, standard deviations (SD), coefficient of variation (CV) and range (minimum and maximum values) for the 21 traits of lablab germplasms are presented in Table 7. The result from this study showed that accession D208 was the tallest (565.98 cm) compared to the check Katumani (415.67 cm) in respect to growth habit. Accession D211 was taller (169.02 cm) than HA4 (81.94 cm). The mean value of days to 50 % flowering were 147.64, ranged from 106 for accession D151 to 201 for D7. In addition, accession D151 are early flowering crop compared to the rest of accessions and checks. However, accession D137 took longest time of 270 days for maturity as compared with D163, HA4 and Katumani which matures in 154, 172 and 182 days, respectively. This indicated that among 41 accessions there are different rate of maturity ranged from early to rate maturity. In addition, days to flower from planting is a key determinant of the category of maturity. Thus the planting time of lablab beans should be carefully observed to avoid experimental error since most of lablab accessions are indeterminate therefore planting this crop in off season would prolong the maturity due to the effect of flowers and pods synchronization as a results of

droppings in the growing season (rain season) thus, accelerate growth circle of the crop. The greater number of days taken to flower was highly influenced by the impact of climate change such as high temperature, strong wind and uneven distribution of rainfall patterns which cause flowers and premature pods to drop. Khan (2003) reported that the significant variation in number of pods per plant resulted from difference in number of flowers per plant, pods per raceme and flower dropping tendency of the genotypes. The highest number of pods per plant (70.80) and seed per pod (5.68) with overall mean value of 28.29 were observed in accessions D163 and D222, respectively. Similar result was observed by Islam *et al.* (2011) when evaluated 44 lablab beans genotype. In present study, the pod length and width varied from 5.49 cm (D204) to 12.42 cm (D208), and 1.15 cm (D168) to 3.44 cm (D10), respectively. Pengelly and Maass (2001) had similar results on the pod length and width which ranged from 2.5 to 14.0 cm and l.6 to 3.2 cm among 249 genotypes, respectively. The average value of 100 dry seed weight is 36.00 g in which the highest value was observed in D200 (50.00 g) which is greater than Katumani (34.00 g). The lowest weight was found in D217 (21.20 g) which was equivalent to the check HA4 (20.85 g). However, D208 produced more seed yield per plant (100.60 g) and the least was noticed in D217 (4.38 g).

Furthermore, 21 quantitative traits were evaluated for variability. The highest Coefficient of Variation (CV) was recorded in secondary branches (72.88%), followed by seed yield per plant (62.05%), number racemes per fresh pod (54.22%) and number of pods per plant (53.74%), indicating high level of diversity among lablab bean accessions, which broadened the genetic pool of this crop for breeding and development. Naghavi and Jahansouz (2005) reported that the highest CV value was associated with pods per plant, seeds per pod, yield per plant, seeds per plant, pods per plant, and branches per plant indicated higher level of divergence among Iranian chickpea accessions.

The lowest CV values were found in fresh pod width (19.79%) followed by 50% podding (17.61%), days to 50% flowering (15.84%), leaflet length (15.69%), days to fresh pod harvest (13.93%), days to 90% maturity (13.34%). Similar trend was observed in dry seed length, width and thickness with CV of 11.55%, 10.23% and 17.09%, respectively, which this narrowed the genetic base, thus, limited the utilization of these traits in crop improvement. Therefore, more research is required to study the level of genetic divergence to obtain the accessions with superior traits which can be used for future crop improvement.

Table 7: Descriptive statistics of morphological traits measured in 41 lablab bean accessions

Traits	Mean ±SD	CV	Range				Mean ±SD	
		(%)	Min	Accession	Max	Accession	HA4	Katumani
Leaflet length	31.45±4.93	15.69	20.44	D217	44.6	D195	31.99±3.07	35.24±2.96
Primary branches	11.09 ±5.33	48.07	4.2	D7, D204	21.2	D140	5.00±0.31	13.37±2.08
Secondary branches	19.32 ±14.08	72.88	3.6	D204	62.4	D137	3.67±0.61	29.30±2.15
Plant height (cm)	355.60 ± 92.37	25.98	169.02	D211	565.98	D208	81.94±6.40	415.67±24.69
Days to 50% flowering	147.64 ± 23.39	15.84	106	D151	201	D7	129.17±3.2	132.33±2.62
No of raceme/plant	22.92 ± 12.43	54.22	4.4	D204	57.2	D88	25.74±2.56	41.80±3.36
No of flower bud/raceme	24.75 ± 10.84	43.78	2.44	D225	43.4	D208	42.11±4.80	35.03±5.14
Raceme length (cm)	18.42 ± 9.16	49.72	2.05	D225	37.64	D199	23.88±2.68	20.10±1.84
Days to 50% podding	159.10 ± 28.01	17.61	111	D163	243	D137	134.5±2.10	138.67±3.35
No of pod/plant	28.29 ± 15.20	53.74	4.8	D190	70.8	D163	64.07±8.93	81.47±4.19
Fresh pod length (cm)	7.59 ± 2.17	28.54	5.49	D204	12.42	D208	5.95±0.39	5.63±0.18
Fresh pod width (cm)	2.21 ± 0.44	19.79	1.15	D168	3.44	D10	1.75±0.06	2.42±0.06
No of locules/fresh pod	4.24 ± 0.90	21.31	2.72	D164	6.28	D222	4.35±0.15	3.54±0.31
No of seed/fresh pod	3.44 ± 0.85	24.71	2.12	D112	5.68	D222	3.75±0.11	2.94±0.26
Days to fresh pod harvest	185.18 ± 25.80	13.93	143	D27	262	D137	162.00±0.00	165.00±0.07
Days to 50% maturity	199.41 ± 26.61	13.34	154	D163	270	D137	172.00±0.00	182.00±0.00
Dry 100 seed weight (g)	36.00 ± 7.72	21.44	21.2	D217	50	D200	20.86±0.18	34.00±0.19
Dry seed length (mm)	12.09 ± 1.40	11.55	9.56	D207	14.6	D7	0.96±0.01	1.26±0.07
Dry seed width (mm)	8.88 ± 0.91	10.23	7.2	D199	10.6	D10	0.81±0.04	0.94±0.03
Dry seed thickness (mm)	6.21 ± 1.06	17.09	4.32	D223	8.56	D225	0.50±0.02	0.60±0.01
Seed yield/plant (g)	35.59 ± 22.08	62.05	4.38	D217	100.6	D208	50.72±0.67	87.90±2.34

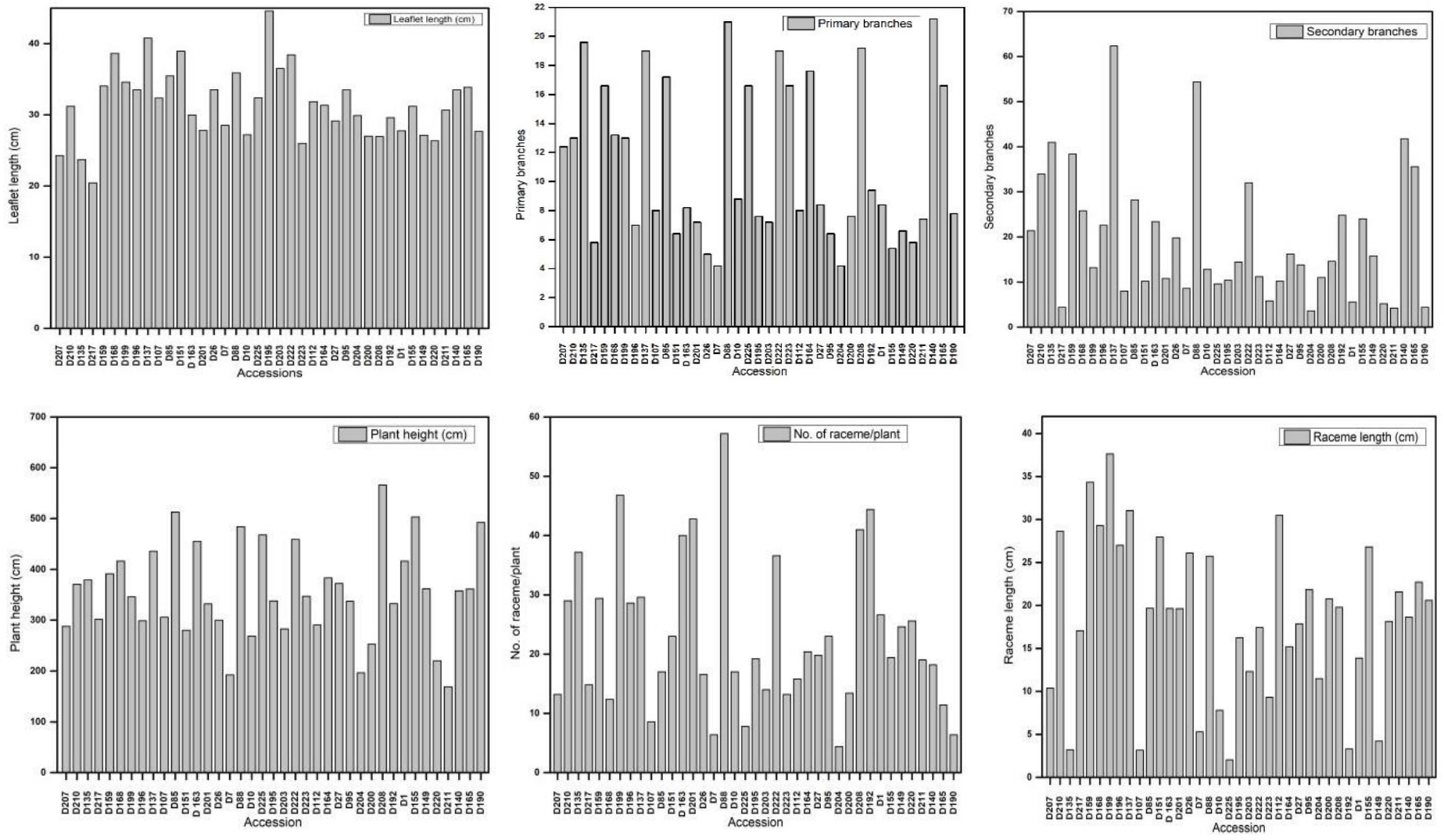


Figure 7: Frequency distribution of leaflet length, primary and secondary branches, plant height, and number of raceme per plant and raceme length of lablab accessions

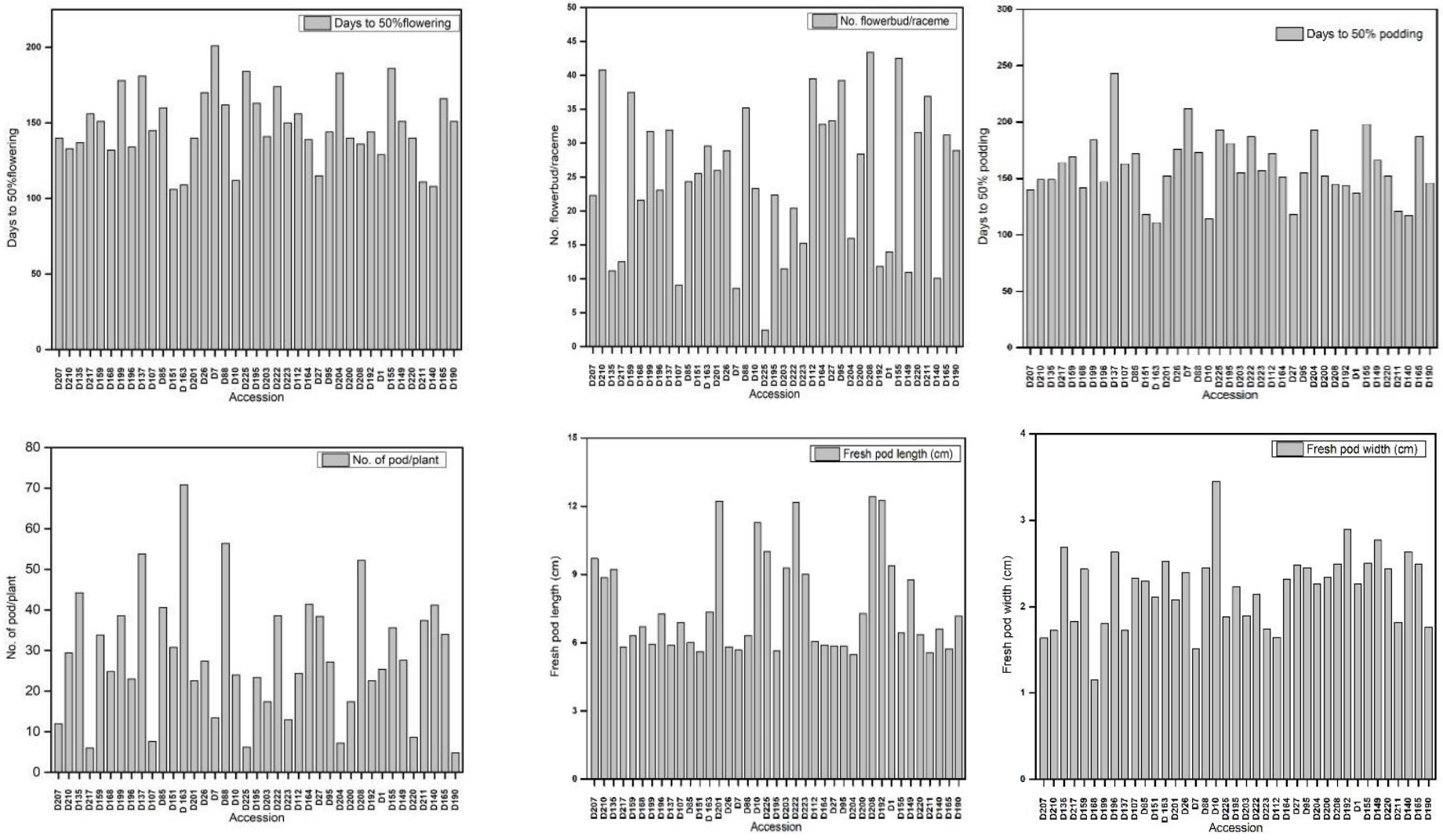


Figure 8: Frequency distribution of 50% flowering, number of flower/raceme, 50% podding, number of pod/plant, fresh pod length and width of lablab accessions

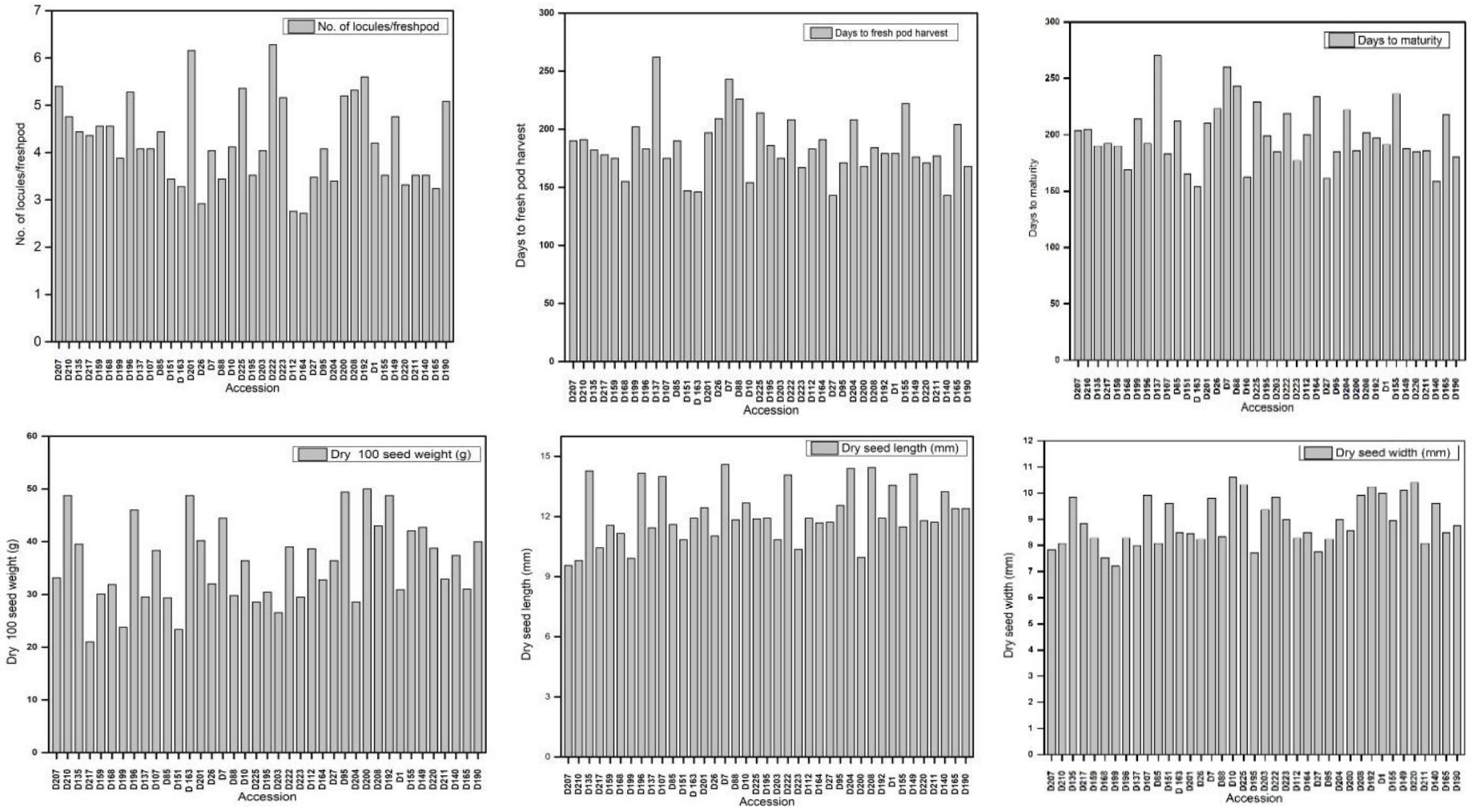


Figure 9: Frequency distribution of number of locules per pod, day to fresh pod harvest, days to maturity, 100 seed weight, dry seed length and width length of lablab accessions

4.1.3 Correlation Coefficient of 21 Quantitative Traits

In the present study, the correlation coefficient between mean of the 21 important traits was quantified for 41 lablab genotypes and are presented in Table 8. The matrixes developed illustrate the relationship between the germplasm collections at 95% confidence interval. The strongest positive association was observed between maturity duration with harvest duration of green pod (r=0.977**), days to fruit setting (r=0.855**), and days to flowering (r=0.821**) while this trait had no relationship with number of seed per pod. This indicating that days to 50% flowering had significant effect on plant maturity. It is also found that, seed yield per plant had strong and positive association with number of pods per plant (r=0.793**), number of raceme per plant (r=0.708**). Also, had positive correlation with secondary branches (r=0.434*), plant height (r=0.433*), 100 dry seed weight (r=0.416*), number of flower per raceme (r=0.415*), primary branches (r=0.363*), and pod length (r=0.303*) while negative correlated with days to flower (r= -0.260). This results indicated that selection for these traits separately can effectively bringing about improvement in seed yield. Islam *et al.* (2011) also found that pods per plant and pod length highly correlated with seed yield per plant. However, the trait number of pods per plant showed positive and strong association with number of raceme per plant (r=0.640*), followed by secondary branches (r=0.505**), and number of flowers per raceme (r=0.505**). So, these traits should be kept in breeders' mind during planning of breeding activities because improving the trait of number of pods per plant largely influence seed yield per plant.

The analysis showed very strong inter-relationship between number of seeds per pod with number of locules per fresh pod (r=0.937**) and pod length (r=0.693**). Similar correlation was revealed by Islam *et al.* (2011) when evaluated forty four hyacinth bean genotypes. Therefore, high correlation exist between complex traits studied, simplify the selection and simultaneously breeding of early maturing, denser biomass and high yielding varieties.

Table 8: Correlation matrix between mean of the 21 important traits of 41 lablab accessions

Trait	LLL	PB	SB	PH	RP	FR	RL	PP	PL	PW	LP	SP	DSL	DSW	DST	100 DSW	DF	DP	DFPH	DM	SY
LLL	**1.000**																				
PB	0.204	**1.000**																			
SB	**0.369***	**0.694****	**1.000**																		
PH	0.172	**0.595****	**0.471***	**1.000**																	
RP	0.112	**0.338***	**0.445***	**0.321***	**1.000**																
FR	0.163	0.010	0.122	0.097	**0.324***	**1.000**															
RL	**0.438***	0.069	0.274	0.118	0.271	**0.734****	**1.000**														
PP	**0.311***	**0.392***	**0.505****	0.290	**0.640***	**0.505****	**0.362***	**1.000**													
PL	-0.306	0.213	0.005	0.255	0.293	-0.280	**-0.438***	-0.133	**1.000**												
PW	-0.139	0.044	0.170	0.134	0.296	-0.020	-0.264	0.206	0.223	**1.000**											
LP	-0.230	0.160	0.018	0.187	0.147	-0.278	-0.254	-0.256	**0.742****	-0.099	**1.000**										
SP	-0.197	0.129	-0.034	0.168	0.187	-0.161	-0.148	-0.220	**0.693****	-0.189	**0.937****	**1.000**									
DSL	-0.117	0.073	0.027	0.231	-0.142	**-0.378***	-0.277	**-0.443***	0.253	0.246	0.103	0.020	**1.000**								
DSW	-0.240	0.052	-0.046	0.188	-0.188	**-0.469***	**-0.383***	**-0.573****	**0.387***	0.250	0.155	0.078	**0.890****	**1.000**							
DST	-0.171	0.032	-0.096	0.232	-0.059	-0.279	-0.194	**-0.488****	**0.456***	0.156	0.247	0.210	**0.781****	**0.837****	**1.000**						
100 W	-0.252	-0.124	0.067	0.150	0.149	0.093	-0.164	-0.024	**0.322***	**0.340***	0.259	0.246	**0.351***	0.286	0.261	**1.000**					
DF	0.159	0.040	0.094	0.146	-0.156	-0.139	-0.016	-0.261	-0.124	-0.268	0.056	0.074	0.178	0.113	0.166	-0.130	**1.000**				
DP	0.290	0.125	0.250	0.152	-0.121	-0.084	0.079	-0.168	-0.177	-0.274	0.007	-0.004	0.191	0.108	0.113	-0.147	**0.944****	**1.000**			
DFPH	0.189	0.176	**0.322***	0.158	0.064	-0.001	0.060	-0.048	-0.033	-0.234	0.041	0.032	0.206	0.120	0.181	-0.074	**0.841****	**0.886****	**1.000**		
DM	0.189	0.217	0.297	0.188	0.056	0.036	0.065	-0.029	-0.070	-0.221	-0.014	0.000	0.190	0.111	0.163	-0.076	**0.821****	**0.855****	**0.977****	**1.000**	`
SY	0.130	**0.363***	**0.434***	**0.433***	**0.708****	**0.415***	0.208	**0.793****	**0.303***	0.278	0.204	0.255	-0.162	-0.291	-0.149	**0.416***	-0.260	-0.212	-0.073	-0.067	**1.000**

Values in bold are different from 0 with a significance level (P≤0.05* and P≤0.001**)

***LLL**=Leaflet length; **PB**=Primary branches; **SB**=Secondary branches; **PH**=Plant height; **RP**=Raceme/plant; **FR**= No. of flower per raceme; **RL**=Raceme length; **PP**=No. of pod per plant; **PL**=Pod length; **PW**=Pod width; **LP**=No. of locules per pod; **SP**=No. of seed per pod; **DSL**=Dry seed length; **DSW**=Dry seed width; **DST**=Dry seed thickness; **100 DSW**=100 dry seed weight; **DF**=Days to 50% flowering; **DP**=Days to 50% podding; **DFPH**= Days to fresh pod harvest; **DM**=Days to 50% maturity; **SY**= Seed yield per plant.*

4.1.4 Multivariate Analysis

(i) Principle Component Analysis of 21 Quantitative Traits

Results from the Principle Component Analysis (PCA) showed the contribution of each trait to the principle component (Table 9). The PC with eigenvalue >1 was used for interpreting the results. The criteria followed for selecting the PC to be included in further analysis were based on Eigen-values of principal components. The first 6 PCs eigenvalue >1 clarified 83.3% of variation of 21 characters among 41 accessions. This variation is supported by the findings of the studies conducted by Malik *et al.* (2010) and Mekonnen *et al.* (2014). The most important traits that contributed to the greater genetic divergence are raceme length, seed yield per plant, number of racemes per plant, number of flowers per raceme, dry seed width, length and seed thickness, 100 dry seed weight, and maturity duration. Others are the days to 50% flowering, days to 50% podding, pod length, pod width, and days to fresh pod harvest. Similar observation was reported by Rana *et al.* (2015) with the important traits identified being 100 seed weight, pod length, number of seeds per pod in four PC's that accounted for about 80.44 % of the variability.

The first component (PC1) contributed to 22.6% of the total variation and had positive relationship with number of flowers per raceme (0.379), number of racemes per plant (0.306) and had negative correlation with number of seed per pod (-0.372), days to fresh pod harvest (-0.336) and number of locules per fresh pod (-0.330). The PC2 accounted for 19.9% of the variation and can be designated as a component of production which is crucial in predicting grain and biomass yield. The major contributors were 100 dry seed weight (0.435) followed by days to 50% maturity (0.433), dry seed thickness (0.424), and dry seed width (0.383). On the other hand, the number of pods per plant increased negatively (-0.114). In agreement with these findings, similar associations were reported by Saba *et al.* (2017). The PC3 can be considered as a productivity component since 18.5% of the variation was related to the important traits such as seed yield per plant (0.385), days to 50% podding (0.369) and days to 50% flowering (0.332). The pod length (0.448) and pod width (0.493) were the most important characters associated with great variation of 10.1% in PC4 while 50% flowering had no significant contribution in this variation. Furthermore, 6.6% of the total variation in PC5 was positively associated with dry seed length (0.489) and number of racemes per plant (0.475), while had negative association with primary (-0.473) and secondary branches (-0.247). The PC6 accounted for 5.7% of the total variation where the strongly positive

association was shown in raceme length (0.539) followed by days to fresh pod harvest (0.304). The strongly negative association in this component was shown by the number of pods per plant (-0.394). This study indicated that selection of representative genotypes can be done from the first 6PCs where the divergence among traits was observed. However, PC1 and PC2 biplot revealed that the crop breeding will be more valuable due to the significant component traits such as number of racemes per plant, number of flowers per raceme, dry seed width, dry seed thickness, 100 dry seed weight and days to 50% maturity.

Table 9: Eigen value, variability, cumulative variance and eigenvector

Statistical parameters	Levels of Principal Component Analysis					
	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	4.7	4.2	3.9	2.1	1.4	1.2
Variability (%)	22.6	19.9	18.5	10.1	6.6	5.7
Cumulative %	22.6	42.5	61	71.1	77.7	83.3
Traits	Eigenvector					
Leaflet length	0.170	0.225	-0.055	-0.084	-0.180	0.289
No. of primary branches	0.065	0.218	0.261	-0.061	-0.473	0.107
No. of secondary branches	0.136	0.278	0.226	-0.152	-0.247	-0.022
Plant height	0.007	0.204	0.296	-0.127	-0.152	0.221
Days to 50% flowering	0.192	0.100	0.332	0.000	0.114	-0.114
No. of raceme/plant	0.306	0.074	0.025	-0.025	0.475	0.225
Raceme length	0.275	0.154	-0.048	-0.019	0.265	0.539
No. of flower/raceme	0.379	0.098	0.189	-0.080	-0.036	-0.196
Days to 50% podding	-0.204	-0.075	0.369	0.197	-0.035	-0.049
No. pods/plant	0.001	-0.114	0.216	-0.389	0.050	-0.394
Pod length	-0.189	-0.018	0.286	0.448	-0.023	0.090
Pod width	-0.153	-0.010	0.271	0.493	0.054	0.152
No. of locules/fresh pod	-0.330	0.053	0.108	-0.360	0.071	0.160
No. of seed/pod	-0.372	-0.007	0.105	-0.315	-0.005	0.162
Days to fresh pod harvest	-0.336	0.030	0.141	-0.216	0.141	0.304
Dry seed length	-0.092	-0.076	0.257	-0.110	0.489	-0.131
Dry seed width	-0.176	0.383	-0.143	0.113	0.097	-0.147
Dry seed thickness	-0.136	0.424	-0.137	0.063	0.060	-0.109
100 seed weight (g)	-0.125	0.435	-0.058	0.059	0.140	-0.185
Days to maturity	-0.111	0.433	-0.062	0.035	0.135	-0.182
Seed yield/plant (g)	0.228	0.055	0.385	0.021	0.168	-0.111

Scatter plot was generated from the first two PCs contributing to 40.79% of the total variation for the 21 quantitative traits to visualize the interrelationships among 39 lablab bean accessions and two checks the Katumani and HA4 (Fig. 10). The dispersion of observations among accessions in all four sections of PCs biplot indicated that there is equal or fair

distribution of genetic diversity. The pairs of accessions such that D95 and D168, D140 and D211, D151 and D27, D203 and D207 and D149, D192, D190, D217, D223, D1 and D220 were closer to each other and had little or no differences. Accessions D137, D222, D88, D225, D7, D10, and the checks were far from the origin and revealed that there is more variability for the quantitative traits. The dispersed accessions could be utilized as diverse parents in broadening the genetic base of lablab beans through hybridization. El-Hashash (2016) described the genetic divergence on seed yield in soybean using principle component biplot and identified 5 accessions which can be easily discriminated between 10 genotypes.

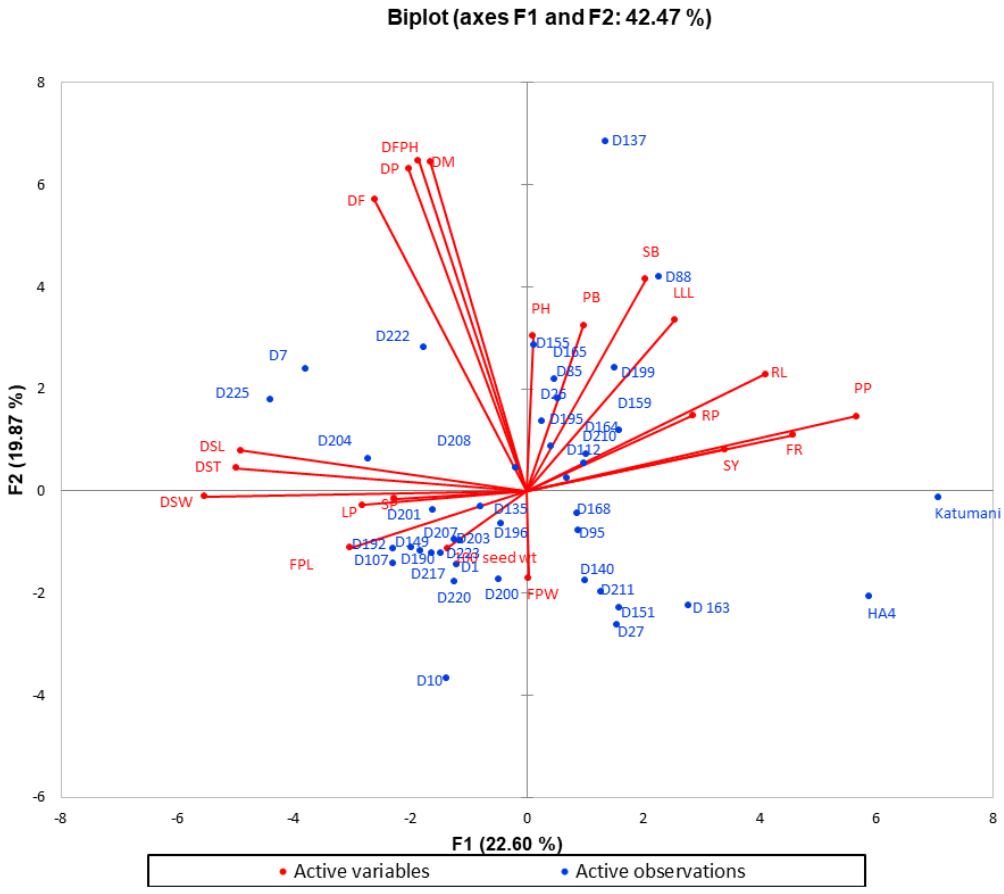


Figure 10: Scatter plot of the first two principal components contributing to 40.79% of the total variation for the 21 quantitative traits in 41 lablab bean accessions.

Therefore, the principal component analysis is a useful technique in breeding as it provides information about the groups through similarity indices and pattern. Also, it helps to evaluate the potential breeding value of the available germplasm. Keneni *et al.* (2005) quantified the degree of variability between populations using PCA to assess the relative contribution of different components to the total divergence operating at intra and inter-cluster levels. In the present study the principle components produced accounted for the variations occurring at

farm level, which are contributed by the interaction between genotypes and the environment. The broad traits diversity evidenced among the lablab beans suggests ample opportunity for genetic improvement of this crop through direct selection from the core germplasm for future hybrid programs.

(ii) Cluster Analysis

Cluster analysis depicted the main two major groups (A and B), which were divided into seven clusters I, II, III, IV, V, VI and VII as presented in Fig 11. The cluster analysis helps to group larger sets of data pool based on the morpho-genetic traits. This study presented the cluster membership among 41 lablab beans accessions in Table 10. However, the cluster mean of quantitative characters of 41 genotypes from descriptive statistics are presented in Table 11. Group A consisted of clusters VII and V making total of 4 accessions while group B consisted of cluster I, II, III, IV and VI with 37 accessions.

Cluster I comprised 27 accessions namely D220, D200, D10, D140, D27, D1, D168, D164, D135, D159, D210, D165, D199, D149, D223, D195, D95, D192, D201, D196, D112, D26, D203, D151, D107, D217 and D207. These accessions were characterized by medium maturity reflected by days to 50% flowering, days to 50% podding, and days to fresh pod harvest with average number of seeds per pod, and low seed yield per plant. Bisht *et al.* (1998) had similar results in cluster IV when evaluated the diversity of green gram (*Vigna radiata* (L.). In addition, these accessions had low number of pods per plant, and plant biomass with medium seed weight. This finding indicated that the accessions in this cluster can be selected for further utilization in crop improvement. However, this genotypes were assembled without considering their source of origin as they come from different countries. Cluster II had only 1 accession (D137) originated from India which possessed large biomass with medium number of pod, medium seed yield per plant and low weight of 100 seeds. Moreover, this accession was characterized by late maturity trait. Therefore, incorporating this accession in breeding activities results into development of variety with prolong growth and maximum biomass production for fodder and cover crop which then improve the animal health while increasing soil nutrient, retain moisture and improve soil aeration.

The genotypes grouped in cluster III are D190, D225, D222, D88, D155, D85 which were medium maturing with maximum number of seeds per pod, medium seed size, denser leaves with large number of primary and secondary branches, highest plant stand and medium seed yield per plant. These findings indicated that breeding of medium maturing with average

yielding capacity variety can be selected from this cluster. Moreover, accessions were grouped together regardless of their place of origin. Cluster IV comprises two accessions such as D163 and Katumani, which originated from Tanzania, and were characterized by higher plant stand with larger number of primary and secondary branches, larger number of pods per plant, medium number of seeds per pod, and maximum dry seed weight. These accessions were also early maturing with high seed yield per plant (g) which was indicated by the few number of days required to flower and harvest the fresh pod. Similarly, Mahmood *et al.* (2018) identified desired characters such as large number of pods per plant, harvest index, yield and earliness which can be useful traits in breeding programs. Therefore, accessions within this cluster had high yielding potential and contained traits for earliness such that any improvement of this crop group is expected to increase productivity with great adaptation to impacts of climate change.

Cluster V consisted of two accessions such as D7 and D204, which are originated from Tanzania and Thailand. These accessions are described by late maturity with minimum number of pods per plant, low seed yield per plant, and low number of primary and secondary branches indicating that selection for breeding of late maturing and low plant biomass accessions can be done from this cluster. Clusters VI comprised D208 which signifies divergence within a core collection and is characterized by tallest plant stand, maximum number of raceme per plant and had medium maturity originated from India. Also it was found that this accession had large pod and seed size, maximum seed weight and seed yield per plant which was contributed seed length, width and thickness. This accession has superior traits which have breeding advantage in improving grain yield of this crop. Accessions D211 and HA4 in cluster VII are originated from India. These accessions characterized by less number of days to flower, podding and mature but had low biomass, seeds per pod, and low mean seed weight with medium seed yield per plant. This finding signifies that selection and breeding of determinate type, photoperiod insensitive, early and/or medium maturing crop and medium seed yield per plant with much little emphasis on other traits could be possible in these clusters since the HA4, had very short stand thus possessed determinate growth habit. Similar result was reported by Girish and Gowda (2009) where HA4 had high yielding capacity, short duration, photoperiod insensitive and possessed determinate type of growth. Therefore, accessions with high mean values and genetic distance for these characters were grouped in the same cluster. This could simplify the selection of desired accessions for use in the crop improvement (Sharma *et al.*, 2009; Meza *et al.*, 2013).

Moreover, there was much variation among clusters compared to inter-clusters variations (Table 13). The results showed that there is greater inter-cluster distance between clusters VII and VI (446.745) followed by clusters VI and V (399.907), clusters VII and III (373.677) and clusters VII and II (366.164) and the lowest inter-cluster distance was observed between cluster VI and III (119.457). This finding depicts that the genotypes in such clusters could be effectively considered in improvement of this crop due to its ability to yield segregants during hybridization and can be exploited for crop improvement through pyramiding of the component traits (Mahbub *et al.*, 2016) observed clusters with maximum inter-cluster variation such as II and IV, II and V, III and I while the minimum was found in cluster II and III.

Table 10: Cluster membership of 41 lablab bean accessions

Clusters	No. of accession	Name of accessions
I	27	D220, D200, D10, D151, D140, D27, D1, D168, D164, D135, D159, D210, D165, D199, D149, D223, D195, D95, D192, D201, D196, D112, D26, D203, D151, D107, D217,D207
II	1	D137
III	6	D190, D225, D222, D88, D155, D85
IV	2	D163, Katumani
V	2	D204, D7
VI	1	D208
VII	2	D211, HA4

Table 11: The cluster means of important morpho-genetic traits of lablab bean accessions

Traits	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
	Accessions (27)	Accession (1)	Accessions (6)	Accessions (2)	Accessions (2)	Accession (1)	Accessions (2)
Leaflet length (cm)	31.06	40.80	33.51	32.61	29.22	26.96	31.33
No. of primary branches	10.50	19.00	14.50	10.79	4.20	19.20	6.20
No. of secondary branches	17.93	62.40	25.43	26.35	6.10	14.60	3.94
Plant height (cm)	330.88	435.86	486.63	435.43	194.45	565.98	125.48
No. of raceme/plant	22.56	29.60	24.07	40.90	5.40	41.00	22.37
No. of flower/raceme	23.90	31.92	25.63	32.30	12.28	43.40	39.50
Raceme length (cm)	18.42	31.04	18.72	19.88	8.40	19.80	22.74
No. of pod/plant	25.42	53.80	30.37	76.14	10.30	52.20	50.74
Pod length	7.61	5.88	8.02	6.50	5.58	12.42	5.76
Pod width	2.25	1.72	2.17	2.47	1.89	2.49	1.79
No. of locules/pod	4.21	4.08	4.69	3.41	3.72	5.32	3.94
No. of seed/pod	3.41	2.84	3.86	2.81	3.02	2.48	3.30
Dry seed length (mm)	11.85	11.44	12.21	6.59	14.50	14.44	6.34
Dry seed width (mm)	8.85	8.00	9.05	4.71	9.40	9.92	4.45
Dry seed thickness (mm)	5.95	5.20	6.95	3.36	6.94	8.44	3.39
100 seed weight (g)	35.84	29.52	34.81	41.38	36.51	43.02	26.88
Days to 50% flowering	141.48	181.00	169.50	120.67	192.00	136.00	120.09
Days to 50% podding	152.26	243.00	178.17	124.84	202.50	145.00	127.75
Days to fresh pod harvest	176.82	262.00	204.67	155.50	225.50	184.00	169.50
Days to maturity	191.26	270.00	219.83	168.00	241.00	202.00	179.00
Seed yield per plant (g)	31.26	45.50	40.20	90.18	12.94	100.60	44.51

Table 12: Intra and inter-cluster distances (D^2) for 41 accessions of lablab bean

Clusters	I	II	III	IV	V	VI	VII
I	**0.000**						
II	194.279	**0.000**					
III	165.825	122.453	**0.000**				
IV	140.430	209.071	134.176	**0.000**			
V	172.696	265.021	299.405	303.478	**0.000**		
VI	248.927	213.130	119.457	144.427	399.907	**0.000**	
VII	211.859	366.164	373.677	316.643	163.009	446.745	**0.000**

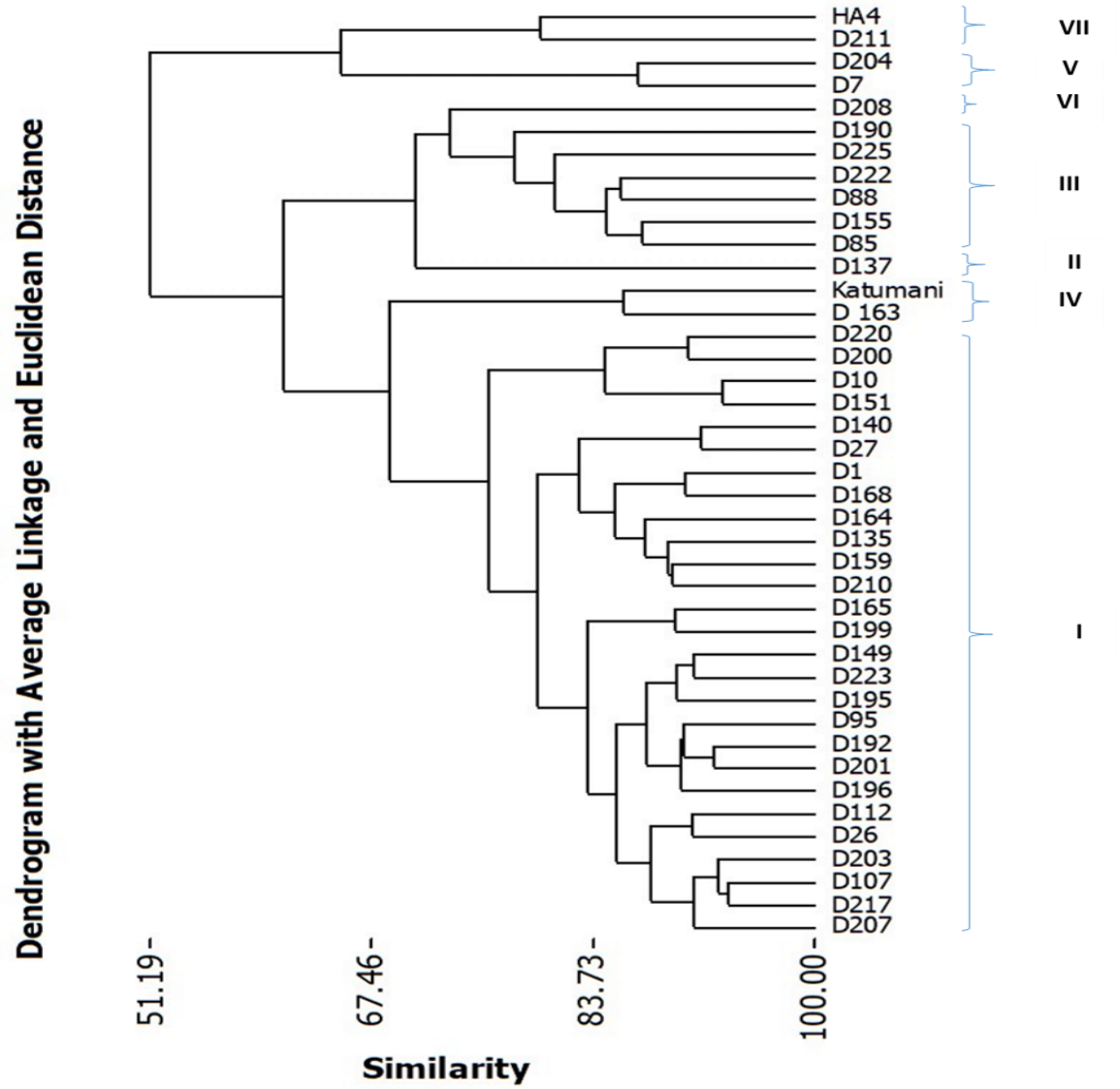


Figure 11: UPGA Dendrogram for Agglomerative hierarchical clustering of lablab bean accessions constructed from 21 quantitative characters

Therefore, clustering the large number of germplasm collection into few numbers of homogenous clusters allows the selection of diverse parents (Sultana *et al.*, 2002). It also permits precise comparison among all the possible pairs of populations and provides an opportunity for bringing together gene pools that yield desirable progenies. In addition, integrating all the above mentioned characteristics in the selection of parents of the accessions D10 in cluster I, D137 in cluster II, D88, D222 and D225 in cluster III, D163 and Katumani in cluster IV, D7 in cluster V, D208 in cluster VI and HA4 in cluster VII could be of importance as they carry the superior traits for the breeding purposes of lablab crop.

4.2 Farmers' Assessment Based on Agronomic Traits

4.2.1 Demographic Nature of Rural Farming Community

Thirty (30) farmers from six village participated in preference study to evaluate 41 lablab accessions in the experimental field. Of them 53.3% were female and 46.7% were male. Majority (33.3%) of farmers were in the age group of 46-51 and few (16.6%) were in between 19-34 (Table 13). However, 76.7% of the total farmers participated in the survey had reasonable farming experience of more than 5 years. Despite the farming experience of majority of farmers who had age of above 46 years in growing lablab, its production has been decreasing gradually year after year. This could be due to the low proportion of able-bodies farmers who shift to cities and mining areas for better life resulting into shortage of labour in the resources poor farming communities (Lahiff, 2000). Also, old farmers were largely employed as cheap labour in coffee plantation. Most of respondent had attained primary education level, and few had tertiary level of education indicating that literacy level among participant was low which corroborates with findings of Manyevere *et al.* (2014) who also found that literacy levels in the rural households in South Africa was very low. However, the farmers with tertiary level of education were few in Kindi kati (3.3%) and Sambarai (3.3%) and none of respondent in Kibosho kirima, Shirimatunda and Karanga village. This showed great diversification in the education level where majority of respondent can write and read but are limited to indigenous language "Kiswahili". In the research point of views, it is great opportunity to building capacity through training sessions, on-farm experimentation and demonstrations. Most farmers interviewed were both crop cultivators and livestock keepers (83.3%) with small land sizes ranging from 0.5 to 2 acre. Of the participants interviewed, 13.3% were employed in other sectors and agriculture was reported as their part time activity and only 3.3% engaged themselves in entrepreneurship apart from agricultural activities.

Therefore, farming activities could provide a good source of employment and entrepreneurship opportunity for the youth in Kirima, Kindikati, Boro, Shirimatunda and Karanga village, where large portion of the population are unemployed. Hebinck and Monde (2007), stated that the rate of unemployment is highly attributed to shortage of land or lack of interest among youth due to dependency on the guardians. All this will influence farmers to underutilize the crop either as a monocrop for sale or as intercrop in mixed farming system. Generally, participated farmers were very receptive and it seems that participatory research with these farmers require more awareness programme on the importance of lablab crop in food security, nutritional needs and poverty alleviation through market value. These are likely to influence re-use and adoption of the lablab crop in farming system.

Table 13: Demographic distribution, farming experiences and farm size of the respondent.

Demographic category		Village						
		Kirima	Kindi Kati	Boro	Shirimatunda	Karanga	Sambarai	Total
		(%)	(%)	(%)	(%)	(%)	(%)	(%)
Gender	Female	6.7	6.7	10.0	6.7	13.3	10.0	53.4
	Male	10.0	10.0	6.7	10.0	3.3	6.7	46.6
Age (years)	19-34	0.0	3.3	3.3	3.3	0.0	6.7	16.6
	35-45	6.7	0.0	0.0	6.7	6.7	3.3	23.4
	46-51	3.3	6.7	10.0	3.3	6.7	3.3	33.3
	>51	10.0	10	0.0	0.0	0.0	6.7	26.7
Education level	Primary	16.7	10	10.0	16.7	13.3	6.7	73.4
	Secondary	0.0	3.3	3.3	0.0	3.3	6.7	16.6
	University	0.0	3.3	0.0	0.0	0.0	3.3	6.6
	Vocational	0.0	0.0	3.3	0.0	0.0	0.0	3.3
Occupation	Farmer + L/Keeper	13.3	13.3	13.3	16.7	16.7	10.0	83.3
	Employee	3.3	3.3	3.3	0.0	0.0	3.3	13.2
	Entrepreneur	0.0	0.0	0.0	0.0	0.0	3.3	3.3
Farming experience (years)	<5	3.3	3.3	3.3	3.3	0.0	10.0	23.2
	10	3.3	0.0	3.3	0.0	3.3	3.3	13.2
	20	3.3	0.0	0.0	6.7	6.7	0.0	16.7
	>20	6.7	13.3	10.0	6.7	6.7	3.3	46.7
Farm size cultivated (acre)	0.5 - 2	10.0	13.3	13.3	10.0	16.7	13.3	76.6
	2.1- 3	3.3	3.3	3.3	3.3	0.0	0.0	13.2
	>3	3.3	0.0	0.0	3.3	0.0	3.3	9.9

4.2.2 Leguminous Crops Grown

Farmers prefer to grow indigenous and improved varieties of common beans, cowpeas, bambaranut, pigeon peas, and green gram for food, feed to livestock and as well as cover crops to improve soil fertility in farming systems. Results indicated that the common beans and cowpeas were not significant different from all village at 95% confidence interval (Fig. 12). It was also found that 28.20% of the farmers grow common bean as a major legume grain in their fields followed by cowpea (24.30%), pigeon pea (20.40%), green gram (16.50%) and bambaranuts (10.70%). However, the cultivation preferences of bambaranut by participating farmers were significantly different from common beans, cowpeas, pigeon pea and green gram. This indicated that bambaranut had little weight among participating farmers. Therefore, the results suggest that common bean and cowpeas were the major grain legume preferred by farmers which used to compliment main meal. However, there was no single farmer who currently cultivated lablab bean as a grain legume during the period when this survey was conducted regardless of many years of farming experience and area of production. The main source of seeds are farmers' exchange and farmers' saved seeds indicating that indigenous cultivar are dominant over improved varieties in the study area.

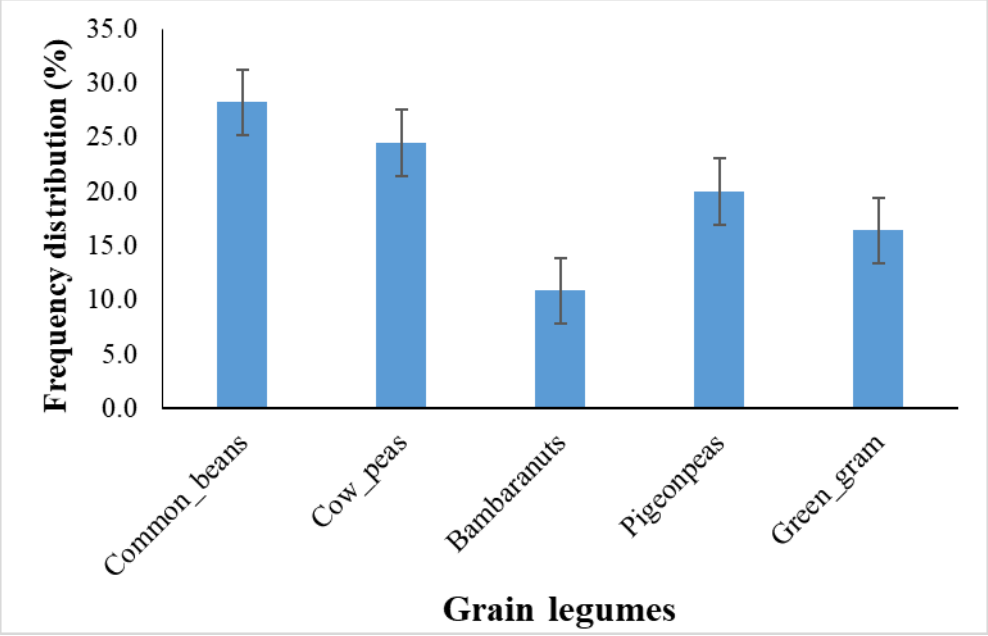


Figure 12: Distribution of grain legumes grown in the study area

4.2.3 Determinants for Lablab Beans Crop Adoption and Utilization in the Study Area

The majority of smallholder farmers participated in this study are willing to cultivate lablab bean crop in the future. Correlation results in Table 14 showed that adoption rate and utilization of lablab crop can be strongly and positively influenced by the ability of the person to make decisions (r=0.400*), purpose of cultivation like feeds for livestock (r=0.386*), and the availability of improved variety with determinate type (r=0.361*). However, purpose of use as food had negative correlation (r= -0.426) with the adoption of this crop this due to the fact that farmers are willing to reuse the beans only if the available cultivar are improved based on sensory attribute. In addition, lablab beans for food, area of residence, marital status of the farmers are significant key determinants of adoption. Thus indicating that the adoption rate of variety is highly influenced by presence of preferred criteria such as high yield per cropping season, high market demand with better price, time of maturity and disease resistance in reference to season of food deficit and impact of climate change and purpose of the crop. However, in most cases farmers preferred criteria are not considered by researchers and extension staffs thus limit the dissemination of new variety and adoption. Similarly Gichangi *et al.* (2012) explained the importance of incorporating farmers' preferred criteria in breeding.

Table 14: The correlation between willingness to cultivate lablab bean crop and key determinants for cultivation.

S/N	Determinants	Correlation Coefficient	*P-value*
1.	Decision maker	**0.400***	0.028
2.	Farm size	0.112	0.556
3.	Improved variety	**0.361***	0.050
4.	Food	-0.426*	0.019
5.	Feed	**0.386***	0.035
6.	Sale	-0.155	0.414

** Correlation coefficient is significant at 0.05 level*

4.2.4 Factors Hindering the Production, Consumption and Adoption of Lablab Beans

Farmers who previously cultivated lablab beans from the six village listed eight major constraints in the production and commercialization of this grain legume (Fig. 13). Crop production, utilization and adoption are influenced by many factors ranging from environmental and socioeconomic influences, beneficiaries' type, to the approaches used by extension personnel (Ndove *et al.*, 2004). The overall results from this survey indicated that poor storage facilities (26.67%) is the most important factor limiting the production and

utilization of lablab bean in Kibosho kirima, low rains during cropping season (23.08%), and unavailability of improved seeds (20.00%). The main storage pest listed by sample farmers was bruchids beetles which cause damage to the lablab seeds or grains hence reduced the quality and increases postharvest losses. However, farmers from Kindi kati ranked unavailability of improved seed (20.00%) as the major production constraint which compel them to settle for the available local cultivars which lead into low yield (14.29%). Other factors were diseases and insect pests' infestations (15.79%) and low rains (15.38%) per cropping season. On the other hand, poor storage facilities, poor market demand, poor cooking quality and high cost of agro-chemicals such as insecticides, pesticides and herbicides had little contribution to crop abandonment. In Boro village, Low rainfall per growing season (7.69%) was said to be less contributor while the most important factors mentioned by farmers were poor cooking quality (23.53%), followed by expensive agrochemicals (21.05%) and poor storage facilities (20.00%). In Shirimatunda village, high cost of agricultural inputs (21.05%) was a major constraint to lablab bean production. Some farmers also mentioned low grain yield per harvest and poor cooking quality as drivers to poor adoption rate. The cost to purchase the agrochemicals was mentioned as the factor limiting production where sample farmers' community was regarded as resource poor farmers. Thus, the rate of crop abandonment increases as most of the farmers were not able to afford the high cost of agro-chemicals to protect their crop from invasive insect pests, and diseases. Poor marketability of lablab beans in the local market and high diseases and field insect pests' infestation were the major reasons for neglecting this crop in Karanga village. In Sambarai village, the participants rated more or less similar to all production constraints of lablab crop.

Also, farmers mentioned the insect pests which invade this crop in the field such as aphids, grasshopper, stink bugs (*Coptasoma eribraria*), leaf miner, stem borer, pod boring noctuid caterpillars (*Adisura atkinsoni*), and the spotted pod borer (*Maruca testulalis*) to be some of the major constraints. The field diseases such as bacterial leaf spot, and leaf curly virus were also listed. This result is accompanied by Duke (1981) illustration which indicated the biotic factors increasing cost of production in legume crops. Other constraints considered as minor but were listed by the farmers are poor soil fertility and poor extension services. Among the production constraints which cannot be addressed with improved, earliness or tolerant varieties, listed by famers was poor market demand and poor storage facilities.

Therefore, this study suggests that availability of new or improved varieties is important factor in determining crop production, consumption and early adoption of this crop. This due to the fact that majority of the sample farmers highlighted unavailability of new or improved as the major constraint which compel them to settle for local cultivars or farmers saved seeds that are susceptible to both abiotic and biotic stresses with low yield potential.

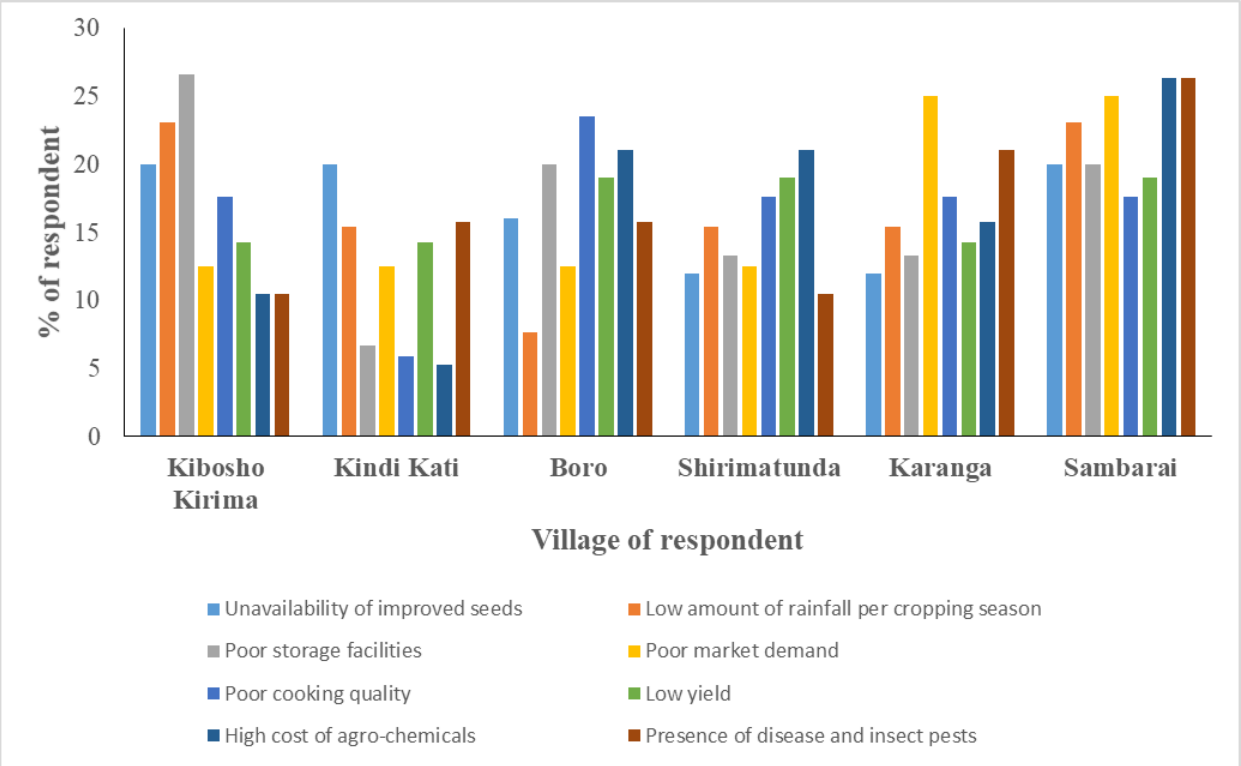


Figure 13: Factors for abandonment of lablab bean in the study area

4.2.5 Farmers' Selection Criteria of Lablab Bean

Farmers assessed the performance of lablab bean under their indigenous growing soil. They identified and used similar criteria in selecting the lablab bean accessions grown in the experimental unit. The varietal attributes perceived by farmers are presented in Fig. 14. The results revealed that the varietal attributes perceived by farmers to choose the accessions that satisfy their needs were drought/heat tolerant, number of pod per plant, disease and field insect pest resistance, high yielding capacity, maturity rate, leaf density, seed colour, plant height, seed size and growth type. This results are accompanied by Sperling *et al.* (1993) results where the important criteria identified in selection of a common bean variety were high yield, earliness, resilience to abiotic stress, taste, cooking time and price. Contrary, Gurmu (2013) results indicated that the selection criteria of common bean ranked by the

farmers were seed color, earliness, drought tolerance, disease resistance, marketability, pod load, insect pest resistance, seed size, shattering tolerance, vigorousity, growth habit (erect), pod length, first pod height from the ground, taste and cooking time. Moreover, each criterion was chosen according to the existing farming situation and consumers' need in the study area.

In this study the first five attributes identified by participating farmers have agronomic advantage in the breeding program. Contrary, Beebe (2012) reported that yield, maturity time and drought tolerance are traits of agronomic importance in common bean breeding. Farmers ranked the high yield trait as fourth criterion used because they understood the complexity of this traits. In this regard, they used other attributes in combination which are important in varietal selection and are key determinants of the crop yield. For instance, farmers considered number of pods per plant as the second attribute in the selection of lablab beans as it can be used to predict the potential yielding per crop. Therefore, results showed that there is no significant different between means of 10 identified traits used by farmers to choose the accessions. Thus, all traits perceived by participating farmers had equal chance to be included in selection process.

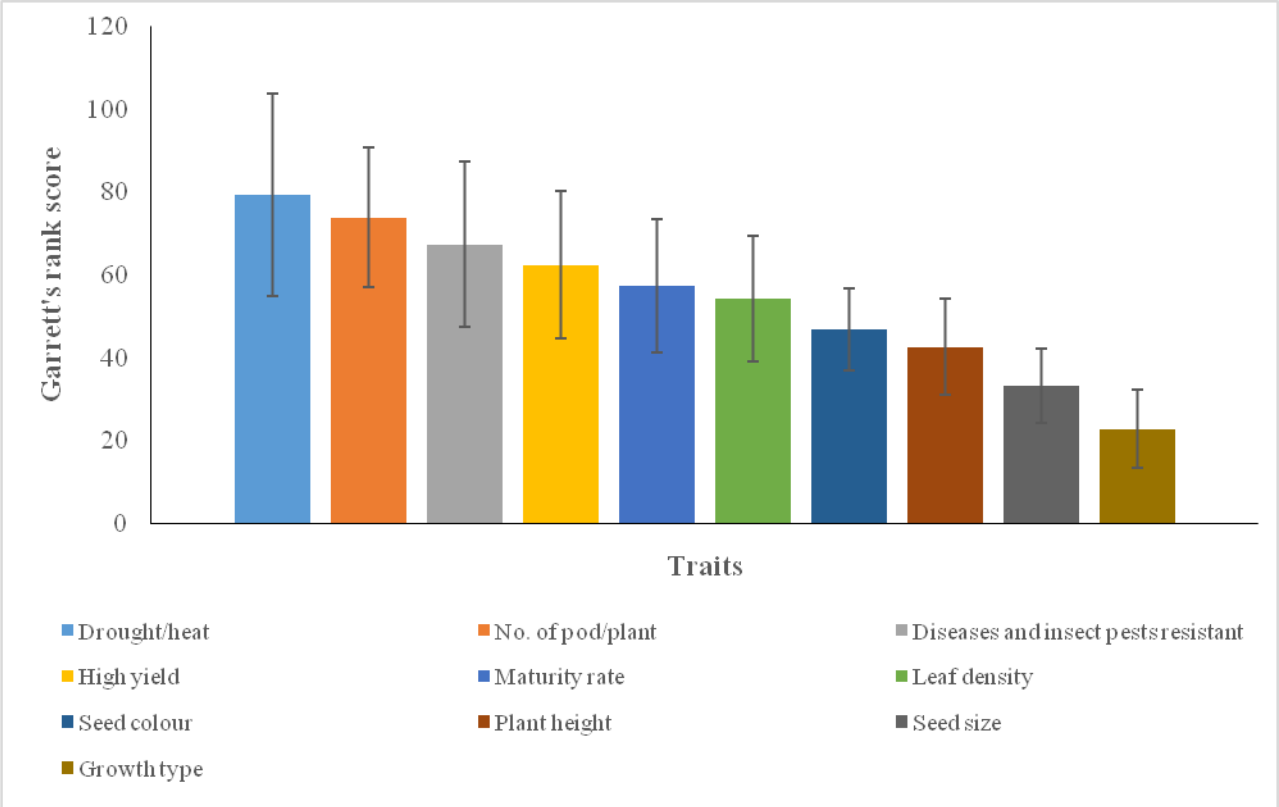


Figure 14: Identified selection criteria of lablab bean accessions

4.2.6 Farmers' Choice of Accessions

Farmers may opt more than one accessions because of their different qualitative and quantitative traits. However, the number of accessions chosen depend on the perceivedcriteria such as yielding capacity and stability, diseases and insect pests resistance, early maturity, drought or heat tolerant, and other superior traits (Soleri and Cleveland, 2009). Nevertheless, the variability of farmers' resources, growing environments, crop reproductive cycle and social variability among the farming communities are key factors which limit the number of the varieties chosen in farmers' crop stock (Zimmerer *et al.*, 2002). The best 10 accessions out of 41 lablab bean which score large number of ballot during farmers' field evaluation are presented in Fig. 15. The results showed that accessions D163 scored higher votes followed by D137, D88, D27, D85, D155, D7, D159, D151 while the least preferred accession were D140. However, the selection of these accessions were attributed by the contributions of each trait perceived by farmers. The major important varietal criteria perceived by farmers to choose the best accessions were those with less diseases and insect pests infestation, maximum number of pod per plant, earliness, bulk leaves, high yielding capacity, seed colour, seed size and drought or heat resistance (Table 15). Moreover, the purpose of use, high marketability, compatibility to their local production environment, and preference were the key determinant of variety selection and utilization (Gichangi *et al.*, 2012). Results from Garrett mean score revealed that ability to resist diseases and insect pest infestation (D7), number of pods per plant (D85, D163,D27, D159, D88), earliness to mature (D163, D151, D85, D140), high yielding capacity (D27, D88, D163, D151, D140, D85), cream seed colour (D159, D140), large seed size (D7) and drought and heat tolerant (D137, D155, D88) were the most important agronomic traits used by farmers to select these accessions.

In addition, the selection of appropriate accessions was based on forage and grain availability for both animal and human consumption by 80% of the farmers and livestock keepers. In this study farmers chose accessions D137, D88 and D155 due to its denser leaves for livestock feed in the time of drought or during dry season when the fodder are scarce commodity due to prolonged maturity. Similar purpose was identified by Abdullahi (2003), when evaluated adoption of cowpea in Nigeria where farmers preferred variety of long growth cycle for animal feeds.In addition, farmers chose the accessions D163, D27, D140, and D85 due to their earliness, less diseases and field insects' infestation, higher number of pods per plant and high yielding. However, cream seed colour made farmers to choose accessions D137, D155 and D159 over other accessions, which were black in colour. Grain

seed colour and size has great implication in the market and consumer demands because farmers consider these traits for planting (Papa and Gepts, 2003).

Additionally, high yielding varieties, earliness maturity, seed colour, abiotic and biotic stresses resistance have an added advantage of improving food and nutritional security and sustain livelihood through lessening of uncertainties and unpredicted crop failure. Moreover, high yielding was considered as acceptable trait in the presence of other preferences related traits. Therefore, it is important for plant breeders or scientists to understand how and why farmers choose varieties of their interest. Farmers' choice of the germplasm within plant population is essential in determining the adoption rate, utilization of new or improved variety, and diversity available in the locality for hybridization and subsequently selection of the plant. Therefore, it is clear that there is a link between selection criteria and the choice of accessions. Thus, the diversification of the traits of choice has great impact in breeding of new or improved lablab bean varieties for human consumption and climate change resilient.

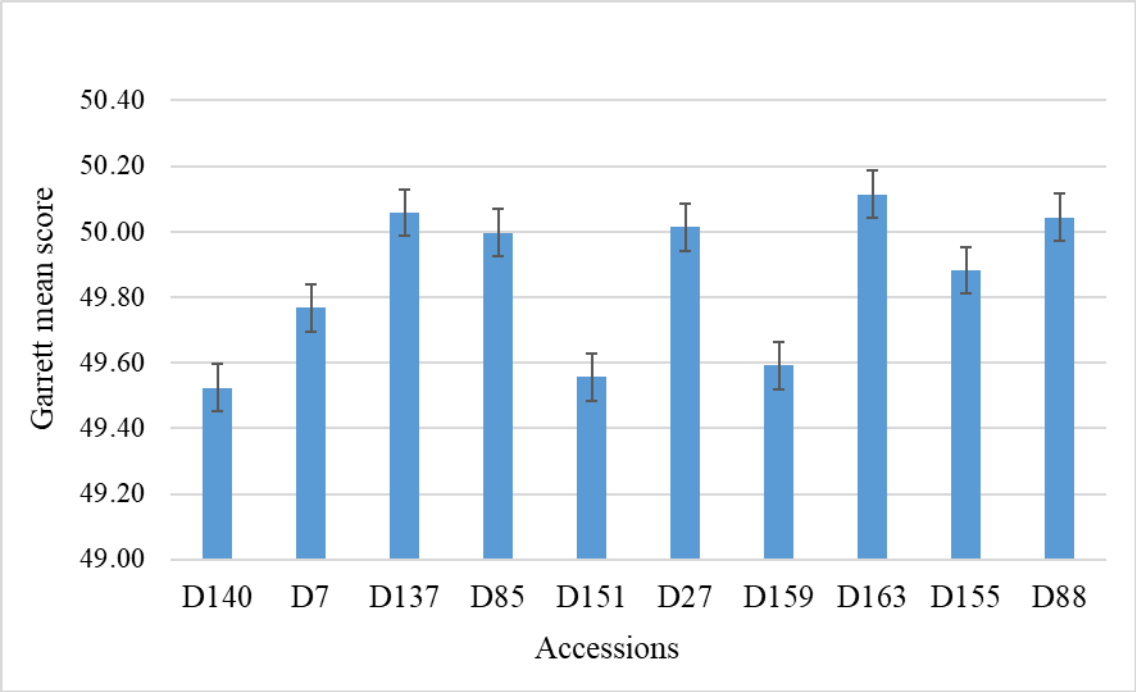


Figure 15: Ten best accessions selected during agronomic farmers' assessment

Table 15: Agronomic selection criteria of the Lablab bean accessions in the study areas (N=30)

Traits	**D140**		**D7**		**D137**		**D85**		**D151**		**D27**		**D159**		**D163**		**D155**		**D88**	
	GS	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**	**GS**	**R**
Disease/ pests resistance	66.17	**3**	71.40	**1**	65.17	**3**	60.73	**3**	24.37	**10**	62.50	**3**	31.27	**10**	25.37	**10**	63.17	**3**	48.30	**6**
Pod/plant	46.83	**5**	35.80	**8**	42.47	**7**	64.17	**2**	60.65	**3**	62.90	**2**	66.90	**2**	71.47	**1**	33.83	**9**	66.80	**1**
Maturity	66.87	**2**	30.70	**10**	29.53	**10**	70.83	**1**	73.00	**1**	50.90	**5**	34.53	**8**	58.83	**3**	44.90	**6**	51.00	**5**
Denser leaf	45.40	**6**	49.30	**5**	71.80	**1**	47.03	**5**	51.83	**4**	34.50	**8**	45.27	**6**	44.33	**6**	73.23	**1**	61.60	**4**
High yielding	68.50	**1**	32.20	**9**	39.07	**8**	56.20	**4**	69.07	**2**	69.20	**1**	32.47	**9**	69.60	**2**	28.73	**10**	65.70	**2**
Seed colour	49.93	**4**	49.10	**6**	45.67	**5**	39.73	**8**	41.00	**9**	31.20	**10**	73.23	**1**	37.07	**8**	50.80	**5**	41.40	**7**
Seed size	37.87	**8**	70.20	**2**	36.20	**9**	39.10	**9**	42.50	**6**	56.80	**4**	54.77	**4**	58.30	**4**	41.33	**8**	36.30	**8**
Plant height	39.47	**7**	51.70	**4**	45.20	**6**	41.27	**7**	42.43	**7**	49.40	**7**	49.07	**5**	36.97	**7**	44.67	**7**	33.10	**10**
Growth type	36.77	**10**	47.00	**7**	52.77	**4**	36.93	**10**	41.33	**8**	33.00	**9**	63.80	**3**	41.30	**9**	50.83	**4**	31.10	**9**
Drought tolerant	37.43	**9**	60.30	**3**	72.70	**2**	43.97	**6**	49.50	**5**	49.80	**6**	44.60	**7**	57.90	**5**	67.33	**2**	65.20	**3**
Total GMS	**49.52**		**49.77**		**50.06**		**50.00**		**49.56**		**50.02**		**49.59**		**50.11**		**49.88**		**50.05**	
Total Rank	**10**		**7**		**2**		**5**		**9**		**4**		**8**		**1**		**6**		**3**	

Traits with highest Garrett mean score is the most important; GS= Garrett score; R= Rank, GMS= Garrett mean score.

4.2.7 Implications of Farmers' Preferred Criteria on Lablab Bean Breeding

Farmers' selection, choice, knowledge and skills provide valuable insights for plant breeders. Incorporation of farmers' preferred traits into a newly improved lablab variety would increase the adoption rate and utilization of this crop. Results showed that majority of respondents ranked high yield (71.83), better taste (60.57), early maturity (54.40) and less cooking time (54.20) traits as the major traits to be incorporated for future beans breeding (Table 16). Other traits perceived by representative's farmer were diseases and pest's resistance (49.50), long storage period (48.90), drought and heat tolerant (45.83), and brown seed colour (40.70). These findings on grain yields are consistent with results reported by Sperling *et al.* (1993). Moreover, this study indicated that breeding of the varieties with high yielding potentials accompanied by farmers' preferences has great possibility of increasing adoption rate. In addition, high yielding varieties have great value in maintaining food and nutritional needs while improving the livelihood of farming communities. Also, farmers prefer varieties that will give them market advantage. Whereas, the marketing opportunities exist, market preferences may facilitate breeding for wider adaptability.Furthermore, incorporation of farmers' perceived traits in breeding reduce farmer's risks associated with crop production and unpredictable crop failures. In addition, this strategy will supports in-situ conservation of crop genetic diversity (Ceccarelli *et al.*, 2007) and increases varietal collections available (Ceccarelli *et al.*, 2003; Vom Brocke *et al.*, 2003), through farmer-to-farmer exchange as an alternative to the development of a small number of varieties for large-scale adoption.

Therefore, crop improvement programme needs to be precisely target farmers' needs while breeders should put more effort in improving this crop based on farmers' preferences to satisfy their needs while increasing the demand of the released varieties.

Table 16: Consumers satisfactory traits on lablab crop improvement (N=30)

S/N	Factors/ traits	Total score	Garrett mean score	Ranks
1	High yielding	2155	71.83	**I**
2	Better taste	1817	60.57	**II**
3	High storability	1467	48.90	**VI**
4	Less cooking time	1626	54.20	**IV**
5	Early maturity	1632	54.40	**III**
6	Disease and pest resistance	1485	49.50	**V**
7	drought or heat tolerant	1375	45.83	**VII**
8	Determinate or intermediate type	1044	34.80	**X**
9	Brown grain colour	1221	40.70	**VIII**
10	Medium grain size	1104	36.80	**IX**

The trait of highest Garrett mean score is significant

4.3 Overall Sensory Acceptability of Cooked Beans

4.3.1 Hedonic or Liking Test

Hedonic testing is a consumer test which measures the individual response of a product, a product idea or specific product characteristics (Tomlins *et al.*, 2007). It measures the liking and exploit other information that could explain consumers' reasons for acceptability. This includes past consumption of the product, purchasing power and various demographic information such as age, gender, income, employment, geographical location and ethnics. In the present study the hedonic testing used to determine which lablab accession is most preferred over another. However, higher consumers' preference of the most promised accessions was mainly contributed by seven sensory drivers such as aroma, tenderness, colour, taste, texture and cooking time. The result from analysis of variance (ANOVA) of the preference scores indicated that acceptability of cooked lablab accessions were significant different according to Tukey's Test ($P< 0.05$). From Table 17 accessions D137, D88 and D85 with higher means value of 4.367 and 4.033 respectively, were highly preferred by panelists due to good sensory potential for home consumption and market demand. However, accessions HA4 had lowest mean value of 2.667 followed by Katumani (2.867) and D27 (2.900), thus were not preferred for immediately release in Tanzania. This phenomenon was mainly associated with longer cooking time of about 2:30 hrs. However, it was observed that uniformity of cooking time and texture were the most important attributes compared with taste and aroma. Demooy and Demooy (1990) found the variation in cooking time of cowpea (*Vigna unguiculata* (L.) Walp).

Therefore, overall acceptability indicated that there was a clear significant difference between food samples due to difference in liking scores. In addition, accessions D137 was highly preferred by panelists due to fact that it has good sensory characteristics.

Table 17: Mean hedonic score for lablab cooked sample based on sensory attributes (n=30)

	Sensory Attributes					Cooking	Overall
Samples	**Aroma**	**Tenderness**	**Colour**	**Taste**	**Texture**	**time**	**Acceptability**
D159	2.867^{a}	3.467^{abc}	4.000^{cd}	3.533^{ab}	3.667^{ab}	1.667^{ab}	3.167^{ab}
D7	3.400^{ab}	3.467^{abc}	2.767^{a}	3.533^{ab}	3.333^{a}	1.967^{bc}	3.067^{ab}
C1	3.433^{ab}	2.867^{a}	3.833b^{cd}	3.300^{a}	3.367^{a}	1.233^{a}	2.667^{a}
D163	3.467^{ab}	3.567^{abc}	3.200^{abc}	3.667^{ab}	3.867^{ab}	2.300^{c}	3.167^{ab}
C2	3.500^{ab}	3.933^{bc}	3.033^{ab}	3.967^{abc}	3.467^{ab}	1.433^{ab}	2.867^{ab}
D27	3.600^{abc}	3.200^{ab}	2.967^{a}	3.533^{ab}	3.567^{ab}	1.767^{abc}	2.900^{ab}
D85	3.633^{abc}	3.900^{bc}	4.367^{d}	3.933^{abc}	4.100^{ab}	4.633^{d}	4.033^{cd}
D155	3.767^{bc}	3.667^{abc}	3.967^{cd}	3.967^{abc}	4.067^{ab}	1.800^{bc}	3.400^{bc}
D88	4.100^{bc}	4.033^{bc}	4.067^{d}	4.167^{bc}	4.133^{ab}	4.500^{d}	4.033^{cd}
D137	4.367^{c}	4.300^{c}	4.533^{d}	4.633^{c}	4.233^{b}	4.200^{d}	4.367^{d}
MEAN	**3.613**	**3.64**	**3.673**	**2.55**	**3.823**	**3.78**	**3.367**
L.S.D.	**0.5181**	**0.5587**	**0.5074**	**0.3395**	**0.5132**	**0.513**	**0.4133**
P-value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**

The different superscript along the columns indicate values are significantly different at ($p<0.05$)

4.3.2 Principle Component Analysis (PCA) of Hedonic Sensory Data

The PCA on the average sensory attributes of ten cooked lablab beans and 30 consumers data matrix yield a dimensional preference space (Fig. 16). The first two principle components (PC) contributed 88.38% of the total variation where PC1 accounted for 77.16% and on the other hand PC2 explained only 11.22%. The accessions in PC1 were different from PC2 in term of sensory attributes. The preference of accessions D137 and D88 was highly associated with attributes tenderness, taste and aroma while D155 and D85 were associated with cooking duration, texture and colour. Moreover, accessions D137, D88, D85 and D155 were positively correlated with the attributes tenderness, aroma, taste, cooking duration, texture, and colour. The accessions with the highest average preference scores point in the same direction confirming the relative importance of the sensory attributes of lablab beans. However, they correlated negatively with the accessions C2, D7, D163, D27, D159 and C1

based on mentioned attributes indicating that lablab beans with black colour, pungent smell and bad mouth feels with long cooking duration were disliked by consumers. For instance accessions HA4 and Katumani which is a control took longer cooking time of 2.30 hrs and 2:15 hrs respectively, as a results they scored less in term of preference. Therefore, the results showed that the preference variability between the lablab food samples was explained by all sensory attribute on the right hand side of PC1 because most of preferred accessions had combined attributes.

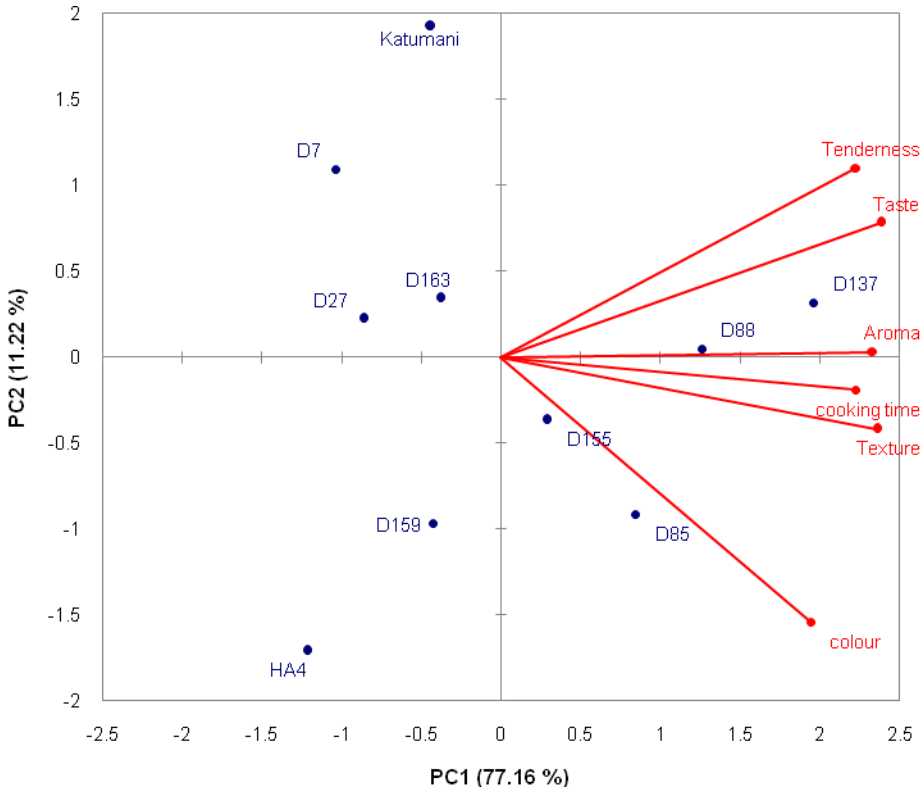


Figure 16: Biplot from PCA of consumers' liking score for lablab beans samples.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Considerable variation exists among lablab bean accessions based on both qualitative and quantitative traits. Morphological variation is highly influenced by genetic makeup and the interaction between gene and environment. In the present study, flower and premature pods dropping was observed which might be attributed to fluctuation in the temperature during flowering this lead to delay in flowering and maturity.

For successful breeding programme, crosses between parents with maximum variation and superior traits would be of importance since they are likely to yield segregants with higher heterosis and desirable gene recombination. Furthermore, it was observed that, the selection of desired parental materials can be done within a particular cluster or by selecting a specific variety from a cluster as well as by choosing traits with relative contribution to the total divergence. In this study the desired accessions with superior characters were selected from cluster I (D10), cluster II (D137), cluster III (D88, D222 and D225), cluster IV (D163 and Katumani), cluster V (D7), cluster VI (D208) and cluster VII (HA4). The identified superior traits where the number of raceme per plant, raceme length, number of flower per raceme, seed yield per plant, dry seed length, width and thickness, 100 dry seed weight, pod length and width, and days to 50% flowering, podding, fresh pod harvest and maturity. Thus, these accessions can be selected as parents during hybridization / breeding programme.

Involvement of farmers in assessing crop performance, contributed to raising awareness about the importance, thus increasing the chances for future crop adoption and utilization. During the farmers' participatory selection, it was observed that farmers were excited to see diversity among lablab accessions. From, the structured questionnaire, it has been noticed that majority of participated farmers are willing to readopt and reuse the crop for subsistence and for commercial purpose. However, the farmers highlighted that the preferred traits such as high yielding, better taste, high storability less cooking time and early maturity to be incorporated in breeding for development of improved variety. Thus, Farmers chose ten preferred accessions based on their agronomic performance as follows in ascending order D163, D137, D88, D27, D85, D155, D7, D159, D151 and D140. Based on sensory evaluation panelists rank number one accession as D137 followed by D88, D155, D85 and D27 as the best five. The results from this study can guide the breeders by including some of

the potential accessions to breed the improved variety which is high yielding, early maturity, less cooking time with better taste. In addition, accessions D137, D88 and D85 have high variability and are preferred by farmers in term of agronomic performance, cooking quality and time. While D163 and D7 showed great phenotypic variability and are preferred by farmers based on agronomic performance but have poor cooking quality due to food colour (black) and high cooking time.

Therefore, understanding the genetic diversity of available germplasm, integrating farmers' knowledge and preference would give the plant breeders a clear insight of the future crop improvement, dissemination and utilization of improved variety. This is due to the fact that diversity studies are important for parental selection which is the core of any crop improvement. Also, it is the key determinant of the future breeding strategies and facilitating the introgression of diverse germplasm. In addition the use of descriptive profiling is highly encourage as it helps in development of specific food descriptors which could be useful in sensory evaluation of this crop.

5.2 Recommendations

(i) More research needed for future crop improvement to obtain superior accessions which will be thermo-insensitive because most of lablab accessions are sensitive to temperature variations.

(ii) Future research work should focus on the agronomic management and evaluation of genotypes across a range of environments to identify and select location specific and widely adaptive genotypes.

(iii) Farmers should be involved in the bean breeding program from initial stage of objectives setting and exploit their indigenous knowledge and selection criteria in order to develop farmer preferred varieties that could suite their local production environment, fulfill farmers' preferences and local market demand to facilitate easily and quickly dissemination to farmers.

(iv) Assessment of molecular diversity of the available germplasm could be an added value as it is independent of environment fluctuations.

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APPENDICES

Appendix 1: Questionnaire for agronomic farmers' preference study of lablab beans

SECTION A: Particulars information

Questionnaire number	
Respondent's name	
Village	
District	
Region	
Phone number (If available)	
Date	

Put tick (√) for were necessary

A. Gender of respondent

1. Female ( ) 2. Male ( )

B. Age of respondent

1. Below 18years ( ) 2. 19-34 ( )

3. 35-45 ( ) 4. Above 51 ( )

C. Education level of respondent

1. Primary ( ) 2. Secondary ( )

3. University ( ) 4. Vocational training ( )

D. Occupation status of the respondent

1. Farmer ( ) 2. Employee ( )

3. Entrepreneur ( ) 4. Others (mention)…….

E. Marital status of respondent

1. Married ( ) 2. Single ( )

3. Divorced ( ) 4. Widow ( )

F. For how long did you engage in farming activities ……..

G. At the family level do you make decision?

1. Yes **( )** 2. No **( )**

H. If **NO** what is the relationship with one who make decision at your family?

1. Mother ( ) 2. Child ( ) 3. Relatives ( )

4 House maid ( ) 5. Others (specify)……..

I. What is the size of land are you using for cultivation……

SECTION B: Agronomic survey

1. **Is there any type of beans available in your village?**
   a) Yes
   b) No
2. If **YES** what type of legumes are you using other than Lablab beans
   a) Common beans
   b) Cowpea
   c) Bambara nut
   d) Pigeon peas
   e) Others (specify)
3. **What type crops are you growing with regard to season?**
   a) Long rains (March to June)
      i. Maize
      ii. Maize and beans
      iii. Vegetable
      iv. Others (Specify)…….
   b) Short rains (September to November)……
      i. Maize
      ii. Maize and beans
      iii. Vegetable
      iv. Others (Specify)…….
4. **What is the source of quality seed**
   a) Farmers saved seeds
   b) Quality Declared Seed (QDS)
   c) Purchase from Agro-dealers
5. **What is the common constraints that hinder production and utilization of lablab bean? Put a tick (√)**

   a) Disease and Pest ( ) b) Unavailability of Quality seed ( )
   c) Less Rainfall / no rainfall ( ) d) Poor cooking quality ( )
   e) Low yield ( ) f) Poor storage ( )
   g) High cost of Agrochemicals ( ) h) Poor marketability ( )
   i) Others (specify)……

6. **Have you ever seen or heard about lablab (Ngwara) you have seen in the field?**
    a) Yes
    b) No
7. **Would you like to grow lablab beans?**
    a) Yes
    b) No
8. **If YES, what type of lablab beans do you prefer /grow?**
    a) Determinate type (short duration)
    b) Indeterminate type (long duration)
9. **If NO, are you willing to grow it in future?**
    a) Yes
    b) No
10. **If the answer of (6 and 8) above is YES for which purpose**
    a) Food
    b) Fodder
    c) Cover crop
11. **If the answer of (6 and 7) above is NO why?**

    .....
    .....

12. **If they use it as food in which state they consume**
    a) Leaves as vegetable
    b) Dry grains
    c) Green beans
    d) Green pod
13. **In which seasons do you prefer to grow lablab?**
    a) Short rain season (September to November)
    b) Long rain season (March to June)
14. **Do you intercrop legumes specifically beans with cereals?**
    a) Yes
    b) No
15. **If YES could you name the beans**
    i.
    ii.
    iii.

16. If No specify

……
……
……

17. If you follow intercropping system what type of cereal crops are you using?

a) Maize

b) Wheat

c) Sorghum

d) Others (specify)……..

18. We would like to promote these crops, what would you like to see improved in your selected crops?

.....……
…...……
……
……

Respondent signature:……Date of Interview……

Thank you for your time

Appendix 2: Checklist for traits identification and ranking of accessions

Question 1: Identify 10 most preferred traits of your choice to be used in the selection of 10 best accessions observed in experimental unit and rank accordingly (group of 5)

S/N	Identified traits of interest	Rank
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Question 2: Select the best 10 lablab bean accessions of your choice and rank accordingly

S/N	Accession name	Rank
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Question 3: List and rank preferred traits to be incorporated in the future lablab breeding

S/N	Traits to be incorporated in breeding	Rank
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Appendix 3: Individual sensory evaluation form

As a representative of the consuming population, indicate the degree of liking or disliking of the product by using 5-point hedonic scale. Put the appropriate number against each accessions that best describes your opinion of the product. Please try to give the reasons to your opinion under comments.

1. Dislike very much **2.** Dislike slightly **3.** Neither like nor dislike **4**. Like slightly **5.** Like very much

Date		Respondent name		Panel Number	Age	
		Sex		**Time**	Education	

Sensory Attributes

Accession code	Food colour	Taste	Tenderness	Aroma	Texture	Cooking time	Overall acceptability	Preference to consume (Yes/No)	Remarks
796									
298									
654									
662									
218									
944									
472									
690									
257									
149									

Are you the frequent user of this lablab beans? (a) Yes (b) No

Comments ……..

Appendix 4: Garret's Ranking Conversion Table

Percent	Score	Percent	Score	Percent	Score
0.09	99	22.32	65	83.31	31
0.20	98	23.88	64	84.56	30
0.32	97	25.48	63	85.75	29
0.45	96	27.15	62	86.89	28
0.61	95	28.86	61	87.96	27
0.78	94	30.61	60	88.97	26
0.97	93	32.42	59	89.94	25
1.18	92	34.25	58	90.83	24
1.42	91	36.15	57	91.67	23
1.68	90	38.06	56	92.45	22
1.96	89	40.01	55	93.19	21
2.28	88	41.97	54	93.86	20
2.69	87	43.97	53	94.49	19
3.01	86	45.97	52	95.08	18
3.43	85	47.98	51	95.62	17
3.89	84	50.00	50	96.11	16
4.38	83	52.02	49	96.57	15
4.92	82	54.03	48	96.99	14
5.51	81	56.03	47	97.37	13
6.14	80	58.03	46	97.72	12
6.81	79	59.99	45	98.04	11
7.55	78	61.94	44	98.32	10
8.33	77	63.85	43	98.58	9
9.17	76	65.75	42	98.82	8
10.06	75	67.48	41	99.03	7
11.03	74	69.39	40	99.22	6
12.04	73	71.14	39	99.39	5
13.11	72	72.85	38	99.55	4
14.25	71	74.52	37	99.68	3
15.44	70	76.12	36	99.80	2
16.69	69	77.68	35	99.91	1
18.01	68	79.17	34	100.00	0
19.39	67	80.61	33		
20.93	66	81.99	32		

The conversion of orders of merits into units of amount of scores

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Output 1: Paper Presentation

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Assessment of Farmers' Indigenous Knowledge and Preferences: A Tool for Sustainable Lablab Bean (*Lablab purpureus*. L. Sweet) Improvement and Utilization in Northern Tanzania

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Authors' contributions

This work was carried out in collaboration among all authors. Author KGC designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors PBV and PAN managed the analyses of the study. Author PAN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Participatory farmers' selection of preferred lablab bean *(Lablab purpureus* L. Sweet) was conducted in Moshi Rural, Kilimanjaro in northern Tanzania to identify farmers preferred traits and accessions. An experimental plot was laid down in augmented block design where a total of 41 accessions including the local check (Katumani) and improved variety (HA4) were sown in three blocks at the spacing of 75 cm x 40 cm. Semi-structured questionnaire and checklists were prepared to gather the farmers' preferences and knowledge as well as factors for lablab crop abandonment. The factors for crop abandonment identified were unavailability of quality and improved varieties, low yield, the high cost of agro-chemicals, the presence of diseases and insect pests. In this study, farmers' selection criteria of the accessions were resistance to diseases and insect pest, the number of pods per plant, early maturity, high yielding capacity, seed colourand size. The results showed that accessions D163 scored higher votes followed by D137, D88, D27,

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D85, D155, D7, D159, and D151 while the least preferred accession was D140 with Garrets' mean score of 50.11, 50.06, 50.05, 50.02, 50.00, 49.88, 49.77, 49.59, 49.56 and 49.52, respectively. Farmers' ranked traits to be incorporated for future bean breeding in order of importance as; high yielding, better taste, earliness and short cooking time. Therefore, successful selection of germplasm through participatory research can raise awareness, adoption, and utilization of the lablab crop which change the portfolio of varieties available in the area and open the new door for plant breeders.

Keywords: *Lablab bean; preferred traits; accessions; Garrett mean score.*

1. INTRODUCTION

Lablab bean *(Lablab purpureus* L.) is a reputable source of protein (20-38%), balanced amino acids with high lysine content (6-7%), vitamins and mineral contents compared with cereals for the majority of rural dwelling communities [1].Pulses particularly lablab beans contain large amounts of iron (155 mg/100 g dry weight) among other legumes [2]. Lablab beans complement heavy staple diets and fight against malnutrition in situations with nutrients deficit [3].

Furthermore, it is environmental friendly due to their symbiotic association with rhizobium in fixing nitrogen into soil rhizosphere thereby improving soil fertility and conserve nature in mixed cropping system. Thus sustaining agricultural productivity of lablab crop and its component crops in intercropping systems [4]. Pulses production in African subsistence farming community is a panacea against food and nutritional balances. However, the average production of lablab beans in the farming community is unknown due to the negative influence of environmental constraints such as unavailability of high quality, productive and improved cultivars; lack of awareness on the importance of this crop on food security and its impact on climate change resilient; lack of research and farmers involvement in breeding of this crop which results to poor adoption rate and crop abandonment.

Generally, farmers' participation in crop breeding is essential in the selection and testing of new varieties in their local production environment. Farmers need high yielding and early maturity varieties, diseases and insect pests resistance, drought and heat tolerant, bulk leaves, large grain size, good taste, less cooking time, and better cooking quality that meet their preferences [5,6]. Furthermore, farmers need plants that can adapt well to their growing conditions and which are compatible with their traditional cultivation practices [7]. However, farmers' preferences and perception are subjective depending on the varieties and location; thus, the involvement of farmers in breeding activities is a key determinant of adoption decisions [8]. However, not all improved varieties released are equally accepted by farmers because the process of developing the variety relying on conventional and modern plant breeding programme which does not consider farmers' criteria. Moreover, the involvement of farmers' preferred criteria in breeding has positively resulted in early adoption and accessibility of newly improved varieties [9]. In the heterogeneity rain-fed agriculture, farmers' participation has gained popularity in crop breeding for instance, rice breeding in Nepal [10], pearl millet in North Sudan [11], and maize in Burkina Faso [12]. Identification of preferred varieties of common beans in Tanzania provides an indication of rapid acceptability and adoption by farmer upon selection [13]. However, there is no available publication regarding the involvement of both researchers and farmers on orphan crops like the lablab beans. This limits crop diversity and exploitation of germplasm and as it causes genetic erosion and narrowing the genetic base for crop improvement.

Therefore, this study focuses on spinning up the existing breeding gap of neglected crops such as lablab beans and the importance of integrating farmers' knowledge in breeding activities. The main objectives were: (i) identification of farmers' selection criteria for lablab bean accessions; (ii) Farmers' choice of the best 10 lablab bean accessions (iii) evaluation of the major factors for lablab beans abandonment in the production environments of the northern Tanzania; (iv) identification of the most important criteria preferred by farmers for future lablab bean improvement and development.

2. MATERIALS AND METHODS

2.1 Descriptions of the Study Area

The study was conducted in Mosh Rural, Kilimanjaro region in the northern part of

Tanzania, where there is wide diversity of pulses and with cropping history of lablab beans. The experimental site was located at latitude 3°13'59.59"S and longitude 37°20'35"E with the elevation of 888 meters above sea level. The soil was originated from volcanic ash and characterized by low levels of total nitrogen and available phosphorus. The average annual rainfall is above 1200 mm with the temperature range of 23.4°C annually.

2.2 Sampling Procedure

Moshi Rural was purposively selected as representative because it is agriculturally potential area and traditionally it was one among the area where lablab beans were cultivated previously in Tanzania. A stratified random sampling procedure was used to randomly select six villages. Five farmers were selected from each village to capture the inherent variability within the district. A total of thirty (30) farmers were randomly selected based on their farming experiences of lablab beans production and assessed through the semi-structured survey. The composition of 30 respondents was such that 16 female and 14 male were involved in this survey to evaluate these trial objectively and effectively.

2.3 Field Layout and Experimental Design

The participatory variety selection was done at an experimental site. The experiment was laid down in augmented block design where thirty-nine (39) lablab bean accessions and two controls (HA4 and Katumani) were assigned at randomly in three blocks at a spacing of 75 cm x 40 cm. A total of 10 seeds of the single accession were planted in each row. To evaluate farmers' preferences on lablab bean cultivars, thirty (30) farmers were invited four times at different stage of crop growth and operations. This included at planting time, vegetative phase, flowering/podding phase and maturity phase. A group of five participants identified ten attributes for ranking the accessions. 300 paper ballots of different colours were prepared for the evaluation process. Ten (10) ballots of different colours were given to male and female farmer-participants where red colour represent (female) and green colour represent (male). Farmers were allowed to rank the accessions based on their preferred traits and uses. A scale of 1–10 was used to choose preferred accessions based on their traits of interest as follows: 1= extremely preferred and 10= not preferred. The participants were allowed to freely vote for the best accessions throughout the field trials by depositing paper ballots in front of the plots. The votes were counted and the highest total number was first classified. The participants were requested to observe and explain the reasons for their selected accessions.

2.4 Data Collection

Primary data was collected by using a semi-structured questionnaire and checklist through both formal and informal surveys. Local agricultural extension staff and contact personnel facilitated the survey by creating a good relationship with local people, mobilizing farmers for discussion and providing a list of farmers to be sampled for the formal surveys. A questionnaire designed had two sections including demographic and general cropping and production information. This approach enables the self-explanatory of individual farmer regarding the crop. While the group interview, the checklist was structured to collect farmer's preferences for lablab bean and factors for its abandonment. Throughout the process, a facilitator guided the activity, while enumerators focused on taking notes.

2.5 Statistical Analysis

The collected qualitative and quantitative data from the semi-structured questionnaires and checklists were classified, coded and analyzed using Microsoft Excel and IBM SPSS statistics version 20 software. The Pearson correlation coefficient was used to assess the future association of key determinants for the adoption and use of lablab beans. The data were subjected to simple tabular analysis and the results were compared, contrasted and interpreted according to the study's objectives.

The Garrett Ranking Technique was used to analyze the farmers' selection criteria and preferred traits for different lablab bean cultivars adoption and utilization in the study area. Also to identify the farmers, most preferred traits to be incorporated in the future lablab bean breeding. The technique ranks the set of parameters as perceived by the representative respondents based on certain criteria. According to Garrett [14] the order of merit assigned by the respondents was converted into percentage position by using the formula as follows;

$$Percent\ position = \frac{100(Rij - 0.5)}{Nj}$$

Whereby;

Rij = Rank given for i^{th} traits by j^{th} individual;
Nj = Number of traits ranked by the j^{th} individual.

By referring the Garrett's ranking conversion table, the percent position of each rank calculated was converted into the Garrett score. Then, for each factor, the scores of various respondents were added and the Garrett mean score was determined. The factor with the highest mean score was considered the most important factor.

3. RESULTS

3.1 Demographic Nature of Rural Farming Community

The results from Table 1.showed that 53.3% female and 46.7% male were participated in the preference study. Of which majority (33.3%) of farmers were in the age of 46-51 and few (16.6%) were in between19-34. From six villages, the results showed that 76.7% of the participants had reasonable farming experience of lablab beans for more than 5 years. Most of the respondents (73.4%) had attained primary education level, and few had a tertiary level of education indicating that literacy level was low in the study area. Most farmers (83.3%) interviewed in all villages were both crop cultivators and livestock keepers with small land sizes ranging from 0.5 to 2 acres. Of the participants interviewed, 13.3% were employed in other sectors and agriculture was reported as their part-time activity and only 3.3% engaged themselves in entrepreneurship apart from agricultural activities.

3.2 Leguminous Crops Grown in the Study Area

The results indicated that the means of common beans and cowpeas were not significantly different from all village at 95% confidence interval (Fig. 1). It was also found that 28.20% of the farmers grow common bean as a major legume grain in their fields followed by cowpea (24.30%), pigeon pea (20.40%), green gram (16.50%) and bambara groundnuts (10.70%). However, the cultivation preferences of bambara groundnuts by participating farmers were significantly different from common beans, cowpeas, pigeon pea and green gram in all village. However, there was no single farmer who currently cultivates lablab bean legume according to this survey.

3.3 The Determinants for Lablab Beans Crop Adoption and Utilization in the Study Area

The majority of smallholder farmers in the study area in northern Tanzania are willing to cultivate lablab bean crop in the future. Correlation results from Table 2 showed that adoption rate and utilization of lablab crop can be strongly positively influenced by the ability of the person to make decisions (r=0.400*), purpose of cultivation like feeds for livestock (r=0.386*), and the availability of improved variety with determinate type (r=0.361*) at p-value 0.05. However, the purpose of use as food had a negative correlation (r= -0.426) with the adoption of this crop because farmers were willing to reuse the beans only if there is an improved variety with a good sensory attribute. In addition, lablab beans for food, an area of residence, marital status of the farmers are significant key determinants of adoption with the p-value of 0.019, 0.020, and 0.022, respectively. Correlation results depicted that education level (r=-0.711**) with the p-value less than 0.01 has a direct association with crop utilization and adoption.

3.4 Factors Hindering the Production, Consumption and Adoption of Lablab bean in Northern Tanzania

Farmers who previously cultivated lablab beans mentioned eight major constraints in the production and commercialization of this grain legume (Fig. 2). The overall results of this survey indicated that poor storage facilities (26.67%) are the most important factor limiting the production and utilization of lablab bean in Kibosho Kirima, followed by low rains during cropping season (23.08%), and unavailability of improved seeds (20.00%). However, in Kindi Kati, the major production constraint was the unavailability of improved seeds (20.00%) which lead to low yields (14.29%). Other factors were diseases and insect pests' infestations (15.79%) and low rains (15.38%) per cropping season. On the other hand, poor storage facilities, poor market demand, poor cooking quality and the high cost of agrochemicals such as insecticides, pesticides, and herbicides had little contribution to crop abandonment. In Boro village, low rainfall per growing season (7.69%) was said to be less contributor while the most important factors

mentioned by farmers were poor cooking quality (23.53%), followed by expensive agrochemicals (21.05) and poor storage facilities (20.00%). In Shirimatunda village, the high cost of agricultural inputs (21.05%) was a major constraint to lablab bean production. Some farmers also mentioned low grain yield per harvest and poor cooking quality as drivers to poor adoption rate. Poor marketability of lablab beans in the local market and high diseases and field insect pests' infestation were the major reasons for neglecting this crop in Karanga village. In Sambarai village, the participants rated more or less similar to all production constraints of lablab crop. Also, farmers mentioned the insect pests which invade this crop in the field such as aphids, grasshopper, stink bugs, leaf miner, stem borer, pod boring noctuid caterpillars, and the spotted pod borer to be some of the major constraints. The field diseases such as bacterial leaf spot and leaf curly virus were also listed. During this survey, bruchids were mentioned by farmers and considered as the most dangerous storage pest of lablab grains. Other constraints considered as minor but were listed by the farmers are poor soil fertility and poor extension services.

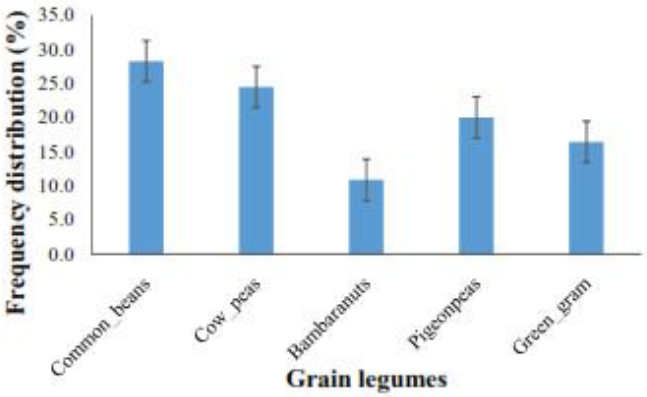

Fig. 1. Distribution of grain legumes grown in the study area

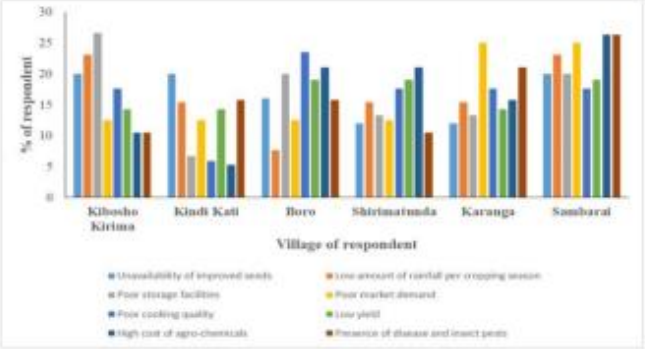

Fig. 2. Factors for the lablab bean abandonment in the study area

Table 1. Demographic characteristics, farming experiences and farm size of the respondent

Demographic category		Village						
		Kirima	Kindi Kati	Boro	Shirimatunda	Karanga	Sambarai	Total
		(%)	(%)	(%)	(%)	(%)	(%)	(%)
Gender	Female	6.7	6.7	10.0	6.7	13.3	10.0	53.4
	Male	10.0	10.0	6.7	10.0	3.3	6.7	46.6
Age (years)	19-34	0.0	3.3	3.3	3.3	0.0	6.7	16.6
	35-45	6.7	0.0	0.0	6.7	6.7	3.3	23.4
	46-51	3.3	6.7	10.0	3.3	6.7	3.3	33.3
	>51	10.0	10	0.0	0.0	0.0	6.7	26.7
Education level	Primary	16.7	10	10.0	16.7	13.3	6.7	73.4
	Secondary	0.0	3.3	3.3	0.0	3.3	6.7	16.6
	University	0.0	3.3	0.0	0.0	0.0	3.3	6.6
	Vocational	0.0	0.0	3.3	0.0	0.0	0.0	3.3
Occupation	Farmer + L/Keeper	13.3	13.3	13.3	16.7	16.7	10.0	83.3
	Employee	3.3	3.3	3.3	0.0	0.0	3.3	13.2
	Entrepreneur	0.0	0.0	0.0	0.0	0.0	3.3	3.3
Farming experience (years)	<5	3.3	3.3	3.3	3.3	0.0	10.0	23.2
	10	3.3	0.0	3.3	0.0	3.3	3.3	13.2
	20	3.3	0.0	0.0	6.7	6.7	0.0	16.7
	>20	6.7	13.3	10.0	6.7	6.7	3.3	46.7
Farm size cultivated (acre)	0.5 - 2	10.0	13.3	13.3	10.0	16.7	13.3	76.6
	2.1- 3	3.3	3.3	3.3	3.3	0.0	0.0	13.2
	>3	3.3	0.0	0.0	3.3	0.0	3.3	9.9

Table 2. The correlation between willingness to cultivate lablab bean crop and key determinants for cultivation

S/N	Determinants	Correlation coefficient	*P-value*
1	Location	-0.423*	0.020
2	Gender	0.029	0.878
3	Age	0.345	0.620
4	Education	-0.711**	0.000
5	Occupation	-0.137	0.470
6	Marital status	-0.416*	0.022
7	Decision maker	0.400*	0.028
8	Farm size	0.112	0.556
9	Determinate type	0.361*	0.050
10	Food	-0.426*	0.019
11	Feed	0.386*	0.035
12	Sale	-0.155	0.414

*** Correlation coefficient is significant at 0.01 level*
** Correlation coefficient is significant at 0.05 level*

3.5 Farmers' Selection Criteria of the Best Exotic Lablab Bean Accessions

Farmers assessed the performance of lablab bean under their indigenous growing soil. They identified and used similar criteria in selecting the lablab bean accessions grown in the experimental unit. Results showed the 10 most significant agronomic traits preferred by farmers for selecting newly introduced lablab bean accessions are presented in Fig. 3. The results revealed that the varietal attributes perceived by farmers to choose the accessions that satisfy their needs were drought/heat tolerant, number of pods per plant, disease and field insect pest resistance, high yielding capacity, maturity rate, leaf density, seed colour, plant height, seed size and growth type. The results showed no significant difference between the mean of 10 identified traits used by farmers to choose the accessions at a 95% confidence interval. Thus, all traits perceived by participating farmers had an equal chance to be included in the selection process.

3.6 Farmer's Choice of Lablab Bean Accessions

The best 10 accessions out of 41 lablab bean which score a large number of ballot during farmers' field evaluation are presented in Fig. 4. The results showed that accessions D163 scored higher votes followed by D137, D88, D27, D85, D155, D7, D159, D151 while the least preferred accession were D140 with the Garrets' mean scores of 50.11, 50.06, 50.05, 50.02, 50.00, 49.88, 49.77,49.59, 49.56, and 49.52, respectively (Table 3). However, the selection of these accessions was attributed by the contributions of each trait perceived by farmers. The major important varietal criteria perceived by farmers to choose the best accessions were those with low diseases and insect pests infestation, the maximum number of pods per plant, earliness, bulk leaves, high yielding capacity, seed colour, seed size, and drought or heat resistance. Results from Garrett mean score revealed that ability to resist diseases and insect pest infestation as well as large seed size (D7), number of pods per plant (D85, D163, D27, D159, D88), earliness to mature (D163, D151, D85, D140), high yielding capacity (D27, D88, D163, D151, D140, D85), cream seed colour (D159, D140), and drought and heat tolerant (D137, D155, D88) were the most important agronomic traits used by farmers to select these accessions.

3.7 Farmers' Preferred Criteria and Perceptions on the Lablab Crop Improvement

The various traits to be taken into consideration by the researcher during the breeding of lablab bean crop in the future are presented in Table 4. Results showed that majority of the respondents ranked high yielding (71.83), better taste (60.57), early maturity (54.40) and less cooking time (54.20) traits as the major traits to be incorporated for future beans breeding. Other traits perceived by representative's farmer were diseases and pest's resistance (49.50), long storage period (48.90), drought and heat tolerant (45.83), and brown seed colour (40.70). The least preferred characters were medium grain size (36.80) and determinate growth type

(34.80). These findings on grain yields are consistent with results reported by Sperling et al.,[15].

4. DISCUSSION

4.1 Demographic and Socio-economic Characteristics of the Farmers

Despite the farming experience of the majority of farmers who had an age of above 46 years of growing lablab, its production, and the consistent use has been decreasing gradually year after year. This could be due to the low proportion of able-bodied farmers who shift to cities and mining areas for better life resulting in a shortage of labour in the resources poor farming communities [16]. Also, old farmers were largely employed as cheap labour in the coffee plantation. Most of the respondent had attained primary education level, and few had a tertiary level of education indicating that literacy level among participant was low which corroborates with findings of Manyevere et al., Manyevere,et al. [17] who also found that literacy levels in the rural households in South Africa were very low. This showed great diversification in the education level where the majority of the respondent can write and read but are limited to indigenous language "Kiswahili". In the research point of views, it is a great opportunity to building capacity through training sessions, on-farm experimentation, and demonstrations. Most farmers interviewed were both crop cultivators and livestock keepers (83.3%) with small land sizes ranging from 0.5 to 2 acres. Farming activities could provide a good source of employment and entrepreneurship opportunities for the youths in Kirima, Kindikati, Boro, Shirimatunda and Karanga villages, where a large portion of the population is unemployed. Hebinck and Monde [18] stated that the rate of unemployment is highly attributed by shortage of land or lack of interest among youth due to dependency on the guardians. Generally, participated farmers were very receptive and it seems that participatory research with these farmers requires more awareness programme on the importance of lablab crop in food security, nutritional needs, and poverty alleviation through market value. These are likely to influence re-use and adoption of the lablab crop in the farming system.

4.2 Leguminous Crops Grown in the Study Area

Farmers prefer to grow indigenous and improved varieties of common beans, cowpeas, bambara groundnuts, pigeon peas, and green gram for food, feed to livestock and as well as cover crops to improve soil fertility in farming systems. The area under production for most farmers ranged from 0.5 to 2 acre in which both mixed and mono-cropping systems are practiced depending on the growing season. During the long rainy season, farmers usually cultivate common beans and cereals like maize, sorghum and oily crops such as sunflower and groundnut. However, from the survey, it was found that farmers' reuse

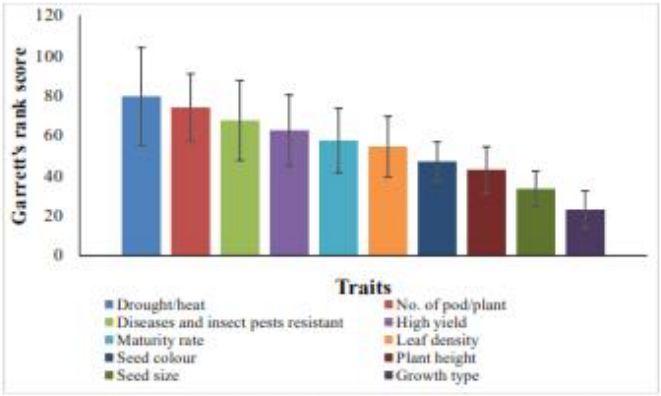

Fig. 3. Identified selection criteria of lablab bean accessions

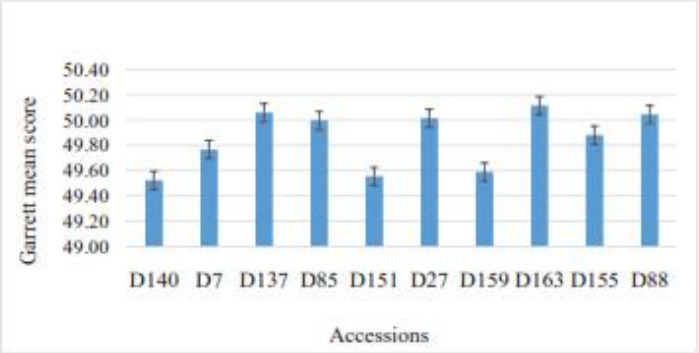

Fig. 4. 10 Best accessions selected during agronomic farmers' assessment

their local cultivars through farmers' exchange and farmers' saved seeds as the source of seed indicated that indigenous cultivars are dominant over improved varieties in the study area. Inaccessibility and unavailability of improved seeds are the major constraints that compel farmers to settle for local cultivars. Therefore, the results suggest that common bean and cowpeas were the major grain legume preferred by farmers which used to complement the main meal.

4.3 Factors Hindering Production, Utilization and Adoption of the Lablab Bean Crop

Crop production, utilization and adoption are influenced by many factors such as environmental and socioeconomic influences, beneficiaries' type, and the approaches used by extension personnel and breeders [19]. In this survey, the availability of new or improved varieties is an important factor determining lablab bean production, consumption, and early adoption. This is due to the fact that majority of the farmers highlighted unavailability of improved varieties as the major constraint which compels them to settle for local cultivars or farmers saved seeds that are susceptible to both abiotic and biotic stresses with low yield potential. In addition, abiotic and biotic stresses are the key determinants of yield losses in different agro-ecosystems. The biotic factors mentioned by the farmers are increasing in aphids (*Aphis craccivora*), stink bugs (*Coptasoma eribraria*), leaf miner, stem borer, pod boring noctuid caterpillars (*Adisura atkinsoni*), and the spotted pod borer (*Maruca testulalis*) infestation in the field. Bruchid beetles are the major storage pests mentioned by farmers, which damage the lablab grains. Lablab bean plants are vulnerable to viral diseases such as white clover mosaic, yellow mosaic virus and root rot nematodes, particularly in late maturing indeterminate type. Duke [20], indicated the biotic factors which are responsible for increasing costs of production in legumes. However, lack of research and development of neglected crops like lablab beans result in a lack of improved varieties which are resistant to both abiotic and biotic stresses. However, improved, early or tolerant varieties cannot address production constraints such as poor market demand and poor storage facilities. These two factors could be aggravated by the lack of awareness, clear approaches of seeds dissemination used by researchers, poor extension services and incubation center. David [21] described the dissemination approaches used by researchers for new varieties to the farming communities which encourage seed diffusion, adoption, and market demand. In addition, farmers also are highly concerned with the cost of purchasing the insecticides, herbicides, fungicides, and pesticides as among of the factors limiting the production of the lablab beans. These findings indicate that the rate of crop abandonment increases as most farmers cannot afford the high cost associated with agro-chemicals. Low yield is one of the constraint mentioned which can be attributed by a combination of other factors such as timely availability of high quality and improved varieties, sufficient rainfall per growing season, soil fertility and other agronomic practices due to its complexity.

Table 3. Agronomic selection criteria of the Lablab bean accessions in the study areas (N=30)

Traits	D140		D7		D137		D85		D151		D27		D159		D163		D155		D88	
	GS	R	GS	R	GS	R	GS	R	GS	R	GS	R	GS	R	GS	R	GS	R	GS	R
Disease/ pests resistance	66.17	3	71.40	1	65.17	3	60.73	3	24.37	10	62.50	3	31.27	10	25.37	10	63.17	3	48.30	6
Pod/plant	46.83	5	35.80	8	42.47	7	64.17	2	60.65	3	62.90	2	66.90	2	71.47	1	33.83	9	66.80	1
Maturity	66.87	2	30.70	10	29.53	10	70.83	1	73.00	1	50.90	5	34.53	8	58.83	3	44.90	6	51.00	5
Denser leaf	45.40	6	49.30	5	71.80	1	47.03	5	51.83	4	34.50	8	45.27	6	44.33	6	73.23	1	61.60	4
High yielding	68.50	1	32.20	9	39.07	8	56.20	4	69.07	2	69.20	1	32.47	9	69.60	2	28.73	10	65.70	2
Seed colour	49.93	4	49.10	6	45.67	5	39.73	8	41.00	9	31.20	10	73.23	1	37.07	8	50.80	5	41.40	7
Seed size	37.87	8	70.20	2	36.20	9	39.10	9	42.50	6	56.80	4	54.77	4	58.30	4	41.33	8	36.30	8
Plant height	39.47	7	51.70	4	45.20	6	41.27	7	42.43	7	49.40	7	49.07	5	36.97	7	44.67	7	33.10	10
Growth type	36.77	10	47.00	7	52.77	4	36.93	10	41.33	8	33.00	9	63.80	3	41.30	9	50.83	4	31.10	9
Drought tolerant	37.43	9	60.30	3	72.70	2	43.97	6	49.50	5	49.80	6	44.60	7	57.90	5	67.33	2	65.20	3
Total GMS	49.52		49.77		50.06		50.00		49.56		50.02		49.59		50.11		49.88		50.05	
Total Rank	10		7		2		5		9		4		8		1		6		3	

Traits with highest Garrett mean score is the most important; GS= Garrett Score; R= Rank, GMS= Garrett Mean Score

Table 4. Farmers and consumers satisfactory traits on lablab crop improvement (N=30)

S/N	Factors/ traits	Total score	Garrett mean score	Ranks
1	High yielding	2155	71.83	I
2	Better taste	1817	60.57	II
3	High storability	1467	48.90	VI
4	Less cooking time	1626	54.20	IV
5	Early maturity	1632	54.40	III
6	Disease and pest resistance	1485	49.50	V
7	Drought or heat tolerant	1375	45.83	VII
8	Determinate or intermediate type	1044	34.80	X
9	Brown grain colour	1221	40.70	VIII
10	Medium grain size	1104	36.80	IX

The trait of highest Garrett mean score is significant

4.4 Farmers' Selection Criteria

The selection criteria for the lablab bean accessions identified by farmers are large seed size, the number of pods per plant, high yielding, plant height, disease and insect-pest resistance, early maturity, grain colour, leaf density, growth type, drought and heat tolerant. Sperling et al., [15] found that the important criteria identified in the selection of common bean variety were high yield, earliness, resilience to abiotic stress, taste, cooking time and price. However, the results from this survey indicated that drought and heat tolerance, number of pods per plant, diseases and field insect pests resistance are the most important attributes used by farmers to choose the accessions that satisfy their needs. In a similar study, Gurmu [22] indicated that the selection criteria of common bean ranked by the farmers were seed colour, earliness, drought tolerance, disease resistance, marketability, pods load, insect pest resistance, seed size, shattering tolerance, vigorousity, growth habit (erect), pod length, first pod height from the ground, taste and cooking time. The findings from the survey are such that the first five attributes identified by the farmers have an agronomic advantage in the breeding program. Beebe [23] reported that yield, maturity time and drought tolerance are traits of agronomic importance in common bean breeding. Farmers ranked high yielding as the fourth criterion used because they understood the complexity of this trait. Therefore, they used other attributes in combination which are important in varietal selection and are key determinants of the crop yield. For instance, farmers considered the number of pods per plant as the second attribute in the selection of lablab beans as it can be used to predict the yielding potential of the crop [24]. Furthermore, farmers preferred earliness accessions with short growing cycles which enable bean varieties to utilize minimum rains, food insecure households to access food quickly. Also, it was found that farmers prefer late maturity accessions and resistance to drought or heat in drought-stressed environments because the accessions of this character have prolonged growth with denser leaves which can be used as food and feed in the time where these commodities are scarce resources.

4.5 Accessions Selected by Farmers

Farmers may opt more than one accessions because of their different qualitative and quantitative traits. However, the number of accessions chosen depends on the perceived criteria such as yielding capacity and stability, diseases and insect pests resistance, early maturity, drought or heat tolerant, and other superior traits [25]. Nevertheless, the variability of farmers' resources, growing environments, crop reproductive cycle and social variability among the farming communities are key factors which limit the number of the varieties chosen in farmers' crop stock [26]. Moreover, the purpose of use, high marketability, compatibility to their local production environment, and preference were the key determinant of variety selection and utilization [27]. In addition, the selection of appropriate accessions was based on forage and grain availability for both animal and human consumption by 80% of the farmers and livestock keepers. In this study, farmers chose accessions D137, D88, and D155 due to its denser leaves for livestock feed in the time of drought or during the dry season when the fodders are scarce commodity due to prolonged maturity. A similar purpose was identified by Abdullahi [28], when evaluated adoption of cowpea in Nigeria where farmers preferred long growth cycle variety for animal feeds. In addition, farmers chose the accessions D163, D27, D140, and D85 due to

their earliness, fewer diseases and field insects' infestation, the higher number of pods per plant and high yielding. However, cream seed colour made farmers to choose accessions D137, D155, and D159 over other accessions, which were black in colour. Grain seed colour and size has great implication in the market and consumer demands because farmers consider these traits for planting [29].

Additionally, high yielding varieties, earliness maturity, seed colour, abiotic and biotic stresses resistance have an added advantage of improving food and nutritional security and sustainable livelihood through the lessening of uncertainties and unpredicted crop failure. Moreover, high yielding was considered an acceptable trait in the presence of other preferences related traits. Therefore, it is important for plant breeders or scientists to understand how and why farmers choose varieties of their interest. Farmers' choice of the accessions within plant population is essential in determining the adoption rate, utilization of new or improved variety, and diversity available in the locality for hybridization and subsequent selection of the plant. Therefore, it is clear that there is a link between selection criteria and the choice of accessions. Thus, the diversification of the traits of choice has a great impact on the breeding of new or improved lablab bean varieties for human consumption and climate change resilient.

4.6 Implications for Lablab Crop Improvement

This study found out farmers preferred lablab varieties which are high yielding, early maturing with better taste and short cooking time. These findings on grain yields are consistent with results reported by Sperling et al., [15]. Moreover, this study indicated that breeding of the varieties with high yielding potentials accompanied by farmers' preferences has a great possibility of increasing the adoption rate. In addition, high yielding varieties have great value in maintaining food needs and nutritional security while increasing income per capital farmer by reducing the risks of production and unpredictable crop failures. Farmers prefer varieties that will give them a marketing advantage. This implies that different resources poor farmers chosen varieties for cultivation would actually be quite different from those anticipated by breeders [25]. Understanding farmers' selection, choice, knowledge, and skills can provide valuable insights for plant breeders. Ceccarelli and Grando [30] indicated that crop improvement programme needs to precisely target farmers' needs and fit their growing environment. These results have important breeding implications, such as high yielding varieties, which mature early with a better taste and a short cooking time. More consideration should be given to these characteristics in the breeding of lablab beans in all agro-ecological zones to ensure food security. Therefore, more effort is needed on improving this crop based on farmers' and consumers' preferences to satisfy their customers while increasing the demand for the released varieties.

5. CONCLUSION

Integration of farmers' knowledge and criteria using their overall preference scores with the breeder's criteria during cultivars selection have a great impact in plant breeding program development. Farmers' germplasm evaluations revealed their power on varieties choice and selection. However, farmers' involvement should be considered from the initial stage of developing appropriate technologies. Participatory variety selection is an efficient and effective approach of quantifying both farmers' and breeders' preferences. This approach can help researchers to understand and appreciate farmers' perception, skills, cultural crop management practices, and complexities of local agriculture in the heterogeneous environment. In addition, farmers' participation has great implication in breeding development as it helps to understand which varieties perform better and preferred by farmers. This study reveals that every farmer desires to adopt a variety which yields more, tastes better and maturing early, and short cooking time for food and nutritional security. Most respondents are willing to consume and adopt the lablab crop if the traits mentioned are incorporated during breeding so as to satisfy their needs. However, sample size, financial resource and access to literatures were the major limiting factors of this study. A small number of participants involved in the study, lack of enough capital to facilitate multi-locations at different growing seasons as well as lack of scientific literatures regarding lablab beans limits research development. It is important to have large number of participants, multi-location trials at different cropping seasons to increases accuracy of the results which reflect the actual population and breeding strategies. Therefore, breeders should take farmers' preferences as a

protocol in bean breeding programme to facilitate easy variety dissemination, early market fusion, crop consumption and adoption in the heterogeneity environment where poor resource farmers are the key stakeholders.

ACKNOWLEDGEMENT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Output 2: Poster Presentation

TITLE: MORPHOLOGICAL SCREENING AND FARMERS' ACCEPTABILITY OF SELECTED LABLAB BEAN (*Lablab purpureus*) ACCESSIONS IN MOSHI DISTRICT, TANZANIA.

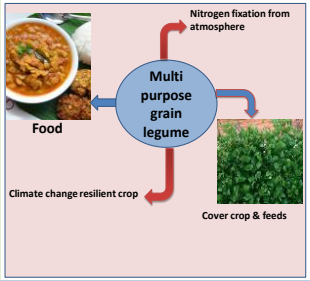
*Kissa G. Chawe; Pavithravani B. Venkataramana and Patrick A. Ndakidemi

Abstract

This study identified the best accessions such as D85, D88, D137, D208, D163, Katumani, D151, D27, D140, HA4 and D155 which can be used as parental material in the selection and breeding programme as they carry the superior characters such as high yielding potential, early and medium maturity, late maturity, heavy leaf density and good sensory attributes. Also, farmers preferred traits such as high yield, better taste, early maturity and less cooking time to be incorporated in the future breeding were identified.

Introduction

Lablab bean (*Lablab purpureus*) is a self pollinated herbaceous perennial belonging to Leguminaceae family originated in Africa and distributed in Asia and America (Maas *et al*., 2005). The characterization of this crop has significant impacts on the breeding program due to the fact that any variation detected are vital in the improvement and development of superior variety for food production and productivity, research development, farmer's welfare, poverty eradication and sustainability of food security.



Objective

The overall objectives of this study is to screen the lablab bean accessions for morphological traits and assess the farmer's acceptability of selected lablab accessions in order to obtain the genotypes with superior characters for future crop improvement.

Methods and Materials

1. **Experiment design**: Augmented block design were 39 treatments and 2 control were assigned in three blocks at randomly at Spacing 75cmX40cm.
2. **Agronomic preference analysis (agronomic traits):** 300 paper ballots prepared and given to farmers for free vote for best ten accessions and give the reasons for selection.
3. **Sensory evaluation (eating & cooking qualities):** 10 most preferred lablab accessions were evaluated and given a code randomly to each sample. Sample were cooked for affective analysis. Farmers were requested to chose the accession of their interest based on named sensor attributes using the 5- point hedonic scale.

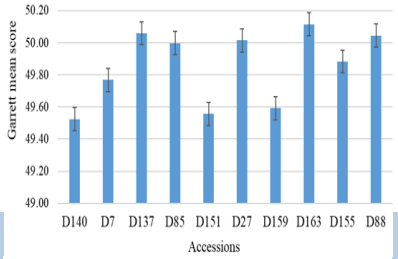


Fig. 1: Ten best accessions selected during agronomic farmers' assessment

Results

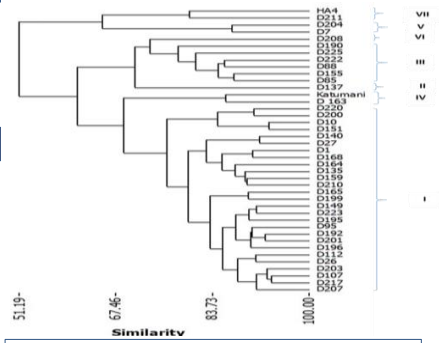


Fig. 2: Dendrogram for lablab bean accessions constructed from UPGMA based on 21 traits

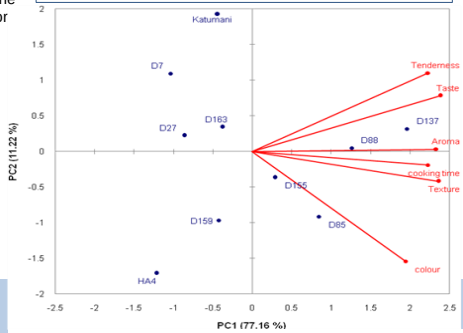


Fig. 3: Biplot from PCA of consumers' liking score for sensory attributes of lablab beans samples.

Discussion

41 accessions of Lablab showed high level of genetic variation based on both qualitative and qualitative straits in term of colour, shape, size, and form. The integration of farmer in breeding program facilitate the selection of desirable accessions with superior traits which open the new insight for breeders in the selection and breeding programme of this crop. This is due to the fact that diversity studies are important for parental selection which is the core of any crop improvement. Also, it is the key determinant of the future breeding strategies and facilitating the introgression of diverse germplasm.

Participatory variety selection

Conclusion

Accessions D137 preferred by farmers based on agronomic and sensory attributes has high potentiality to be included in the cropping system after testing them in different agro-ecological zones. The high variability in the tested accessions proves to be a good genetic pool for further selection for breeding programme.

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