BIOMASS YIELD AND QUALITY OF FODDER FROM SELECTED VARIETIES OF LABLAB IN NANDI SOUTH SUB-COUNTY, KENYA

BY

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DECLARATION

This thesis is my original work and has not been submitted for award of degree in any other university.

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This thesis is dedicated to my beloved parents Maurice Wangila Muwanga and Phaustine Nafula Wamalwa. My beloved brothers: Alloice Sifuna Wangila and Arthur Wekesa Muwanga for their consistent support and encouragement throughout the research period.

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ABBREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
ASL	Arid and Semi-arid Land
ANOVA	Analysis of Variance
CV	Coefficient of variation
DAP	Di-ammonium Phosphate
DMD	Dry Matter Digestibility
FAO	Food Agricultural Organization
GDP	Gross Domestic Product
IVDMD	Invitro Dry Matter Digestibility
ILRI	International Livestock Research Institute
KALRO	Kenya Agricultural Livestock Research Organization
LSD	Least significant difference
MCal	Mega Calories
ME	Metabolizable Energy
NRC	National Research Council
NH_3-N	Ammonia nitrogen
OMD	Organic Matter Digestibility
RCBD	Randomized Complete Block Design

ABSTRACT

Inadequate feeds, both in quality and quantity, is the main challenge facing livestock production in Kenya. Use of concentrate feeds (especially high protein) to enrich low quality fodder is mostly beyond the reach of small-scale farmers due to high cost and as such, cheaper alternative supplements such as lablab bean forage are needed. The main objective of this study was to determine biomass yield and nutritive value of both fresh and conserved fodder from eight lablab varieties. The specific objectives were; to determine biomass production and nutritive value of fodder from selected Lablab varieties and to evaluate the effect of conservation as hay or silage on the quality of lablab fodder. The varieties; DL 1002, Ngwara Nyeupe, Echo-Cream, Black Rongai, Eldoret-Kitale-Cream, Eldoret-Kitale-Black 1, Brown Rongai and Eldoret-Kitale-Black 2 were assessed in three sites of Nandi South sub County, Kenya. Eight lablab varieties, each replicated four times per site, were established in four farms in each site in a randomized complete block design and harvested after attaining 50% flowering. Data on biomass yields, nutrient content and invitro-dry matter digestibility of fresh and conserved forages was collected for all the varieties. Biomass yield differed significantly among the eight lablab varieties ranging from 5.6 to 12.6 t DM/ha across the three sites. Brown Rongai had the highest biomass yield of 12.6 t DM/ha while DL1002 recorded lowest yield of 5.6 t DM/ha. Crude protein content of lablab varied significantly between varieties and sites, ranging from 19.6 to 23.9 g/100g DM. Eldo-Kt-Cream and Black Rongai varieties had the highest crude protein content of 23.9 g/100g DM and 23.7 g/100g DM across the three sites. Neutral detergent fibre (NDF) ranged from 44.4 to 48.6 g/100g DM acid detergent fibre (ADF) ranged from 31.6 to 35.7 g/100g DM while acid detergent lignin (ADL) from 9.0 to 11.9 g/100g DM for all the varieties of lablab across the three sites. Variety DL1002 had the highest NDF content of 48.6 g/100g DM across the three sites. The highest ADF was recorded for Eldoret-Kitale-Black2 variety with 35.9 g/100g DM, whereas highest acid detergent lignin of 11.7 g/100g DM was recorded for DL1002 variety.

Invitro dry matter digestibility (IVDMD) varied significantly between varieties and sites. It ranged from 67.6 to 75.7 g/100g DM among the varieties across the three sites. Eldo Kt-cream and Black Rongai varieties had the highest IVDMD of 75.7 and 74.4 g/100g DM across the three sites respectively. The pH of the lablab silage ranged from 4.3 to 4.8 while total ammonia nitrogen content ranged from 27 to 41 g/100g. On-farm conservation of lablab as hay led to a decline of 4.8 g/100g DM of crude protein and 1.9 g/100g DM in dry matter digestibility while conservation as silage led to a decline of 6.0 g/100g CP DM and an increase of IVDMD by 4.5

g/100g DM. It was concluded that Eldoret-Kitale-Cream and Black Rongai varieties of lablab exhibited superior dry matter yield, crude protein content and low fibre fractions compared to the others signifying their potential for recommendation as alternative low quality fodder supplement among the small-scale farmers. Conservation of lablab fodder as silage resulted in a superior quality forage with higher IVDMD and crude protein content and low fibre fractions.

Key words; Lablab varieties, biomass yield, fodder, conservation

CHAPTER ONE

INTRODUCTION

1.0 Background information

The adequate provision of livestock feeds is key to food security especially in the developing countries, as animals are capable of converting feeds into high quality foods such as meat, milk and eggs (Sanford and Ashly 2008). Since 60-70% of livestock production costs is due to feeds (Njenga *et al*., 2013), increase in productivity in the tropics will rely majorly on proper utilization of locally available feed resources to meet their requirements (Kaya *et al*., 2006 and Gul *et al*., 2010).

In Kenya, during both rainy and dry season, nearly one-third of the small-scale farmers experience insufficient feeds to sustain the high numbers of livestock (Lukuyu *et al*., 2011). Within these seasons, most farmers feed their livestock on low quality feeds especially deficient in protein content such as; natural grass, maize Stover, wheat straw, bean haulms, banana pseudo stems (Syomiti *et al.*, 2011). In such developing countries, concentrate feed resources, especially grains, are costly and mostly regarded as human food (Tulu *et al*., 2018). In most parts of the world, research has focused on less-known feeds of plant origin such as use of non-conventional homegrown legumes as alternative sources in mitigating the challenge of livestock feeds (Mamer, 2017). However, their production is mostly limited to seasons of low productivity in favor of cash crops limiting their likelihood of attaining optimal biomass production for animal feed (Birech *et al*., 2014).

Dolichos bean (*Lablab purpureus*. Sweet), a vegetable crop of Indian origin, was reported by Keerthi *et al.*, (2015) as a good protein supplement for low quality feeds. This legume belongs to the family Fabaceae, sub-family Faboideae, tribe phaseoleae and sub-tribe Phaseolineae (Gupta *et al.*, 2017). Among the cultivars grown worldwide, there exists big variation in the plant and pod features (Verma *et al*., 2014). It is a strong herbaceous legume with both perennial and annual growth habits with bushy, climbing features during growth (Parmar *et al.,* 2013). The legume grows fast and can easily provide fodder within three months after planting (ILRI, 2013).

It can produce high quantity of forage legume (approximately 4-8 tonnes DM/ha) and quality (12.0-20 g CP /100g DM) depending on soil fertility and rainfall distribution (Hassan *et al.*,

2014). It is a widely cultivated, highly drought resistant legume vegetable crop that can be grown in tropics and subtropics where soil fertility is low (Renuka *et al*., 2015).

It is a multipurpose legume that can be used as human food, forage and can also serve as a cover crop for soil conservation (Kumar, 2017). It is very rich in protein, minerals and vitamins (Chaitanya *et al*., 2014). Its tap root system enables it to acquire nutrients and moisture from deep soil Karuma *et al*. (2011) and improve soil fertility through its nodules in symbiotic association with rhizobia bacteria to fix nitrogen in the soil (Omondi *et al*., 2011). Due to these features, there is on-going research on un-known legumes, as alternative feed sources in improving livestock feed quality (Mamer, 2017). Consequently, to increase feed quality, there is potential of utilization of leguminous forage crops such as *Lablab purpureus* (Tulu et al., 2018).

1.1 Problem statement

In most developing nations, livestock production depends mostly on natural grazing that comprises of pastures and crop residues that contain 2.4 MCal/kg DM of energy and 5.6 g/100g CP during dry season (Hassan *et al*., 2014). These feed resources are mainly of poor quality and poorly conserved thus insufficient to sustain large livestock numbers (Hassan *et al*., 2014). The dairy sub-sector in Kenya contributes about 70% of the gross value of livestock production to agricultural sector (Kariuki *et al*., 2015). The main challenge faced by dairy farmers in intensive, extensive and mixed production systems across East Africa is the inability to produce both sufficient quantity and good quality feeds for their livestock on a regular basis (Njenga *et al*., 2013). In Western Kenya, seasonal availability of animal feeds was reported to be a major challenge in small-scale dairy farming systems (Taruss *et al*., 2010). The major limitation was the unavailability of good quality protein sources to supplement locally produced feeds for their livestock (Njenga *et al*., 2013, Mthembu *et al*., 2018).

The commonly used feed resources by local farmers in Western and Nandi south regions of Kenya are crop byproducts such as sweet potato vines, banana leaves and pseudo-stems, stovers and straws supplemented with grazing on natural grass (Lukuyu et al., 2009). In addition, fodders such as Napier grass, Sudan grass and signal grass are used (Lukuyu *et al*., 2009). These feed resources are low in protein content and thus should be supplemented with inexpensive homegrown high protein fodder. Although commercial protein concentrates can be used to supplement the low-quality forages and crop residues to attain the recommended protein levels, the cost is beyond reach of most farmers. The information on nutritional composition of most of

the under-utilized multipurpose legumes such as *Lablab purpureus* remain scanty (Kalpanadevi and Mohan, 2013). Foyer *et al*., (2016) noted that *Lablab purpureus* was both an under-utilized and under-cultivated legume in Kenya. It is grown locally under mixed crop production systems in small-scale farms especially in Eastern (Meru), Central (Nyeri, Thika) and Coast (Lamu) regions of Kenya due to in-adequate research information on its potential for fodder production (Nahashon *et al*., 2016). Therefore documenting the quantity and qualities of various types of *Lablab purpureus* varieties will aid in solving the challenge of low poor quality forage among the livestock farmers.

1.2 Justification

In Kenya, livestock contributes over 12% to the Gross Domestic Product (GDP) and accounts for 47% of Agricultural GDP (Kabubo-mariara, 2008). Fodder crops play an essential role by providing nutritious feeds for farm animals to meet the growing demand of milk, butter and different dairy products for human utilization (Amasaib *et al*., 2016). Production and use of fodder legumes is one of the cheapest ways of increasing both the quantity and quality of livestock feeds (Njenga *et al*., 2013). Lukuyu *et al*. (2011) reported that the use of less costly and easily available indigenous feed resources such as legume forages as opposed to commercial feeds had a great ability to enhance livestock productivity especially under smallholder livestock production systems.

However, during the dry season, grazing animals rarely attain their nutrient requirements and this usually results in poor performance (Njenga *et al*., 2013). To bridge this gap, there is need for assessment of alternative under-utilized high protein feed resources. This study therefore aims at providing information on use of under-utilized multi-purpose legumes such as *Lablab purpureus*, as alternative source of low quality fodder supplements. Moreover, this study contributes to alleviating problems of food insecurity through utilization of multi-purpose legumes to increase animal and crop productivity.

1.3 Objectives

Overall objective

To determine biomass yield and nutritive value of foliage from different Lablab varieties in Nandi County, Kenya.

Specific objectives:

i. To determine biomass production and nutritive value of fodder from selected Lablab varieties
ii. To evaluate the effect of conservation as hay or silage on the quality of lablab fodder

1.4 Null hypothesis

i. There are no difference in biomass production and nutritive value of different lablab varieties
ii. There is no difference quality of lablab fodder conserved as hay and silage compared with fresh fodder

CHAPTER TWO

LITERATURE REVIEW

2.0 Role of livestock production in Kenya

Livestock, especially ruminants, play a major role in Kenya's economy and are common across all the production systems (Njarui *et al*., 2016). Livestock are an essential component of mixed farming systems that dominate in the tropics, especially in the developing countries (Titterton and Bareeba, 2000). The recent livestock census reported a population of about 67 million, out of which, 14.1 million were zebu cattle, 3.4 million were dairy cattle, 27.7 million goats, 17.1 million sheep, 2.9 million camels and 1.9 million donkeys (KNBS, 2010). According to the same report, the livestock sub-sector contributed about 40% of the agricultural Gross Domestic Product (GDP) and 10% of Kenya's total GDP.

Livestock are kept for several uses such as; provision of draught power, milk, meat, eggs and several cultural uses (Mutibvu *et al.,* 2012). They supplement cropping activities by providing manure for soil fertility upkeep, draught power for cultivation, transport, cash and food (Mutibvu *et al.,* 2012). They play vital role in the agricultural systems, as they provide chances for risk management, farm divergence and magnification and provide important living benefits (Seid and Animut, 2018). In addition to these, dairy growth especially in developing countries play significant role in increasing milk production, income level in rural areas, creating employment chances and enhancing the nutritional standards of the people, particularly for small and marginal farmers (Quddus, 2012).

2.1 Constraints to livestock production

2.1.1 Feeds

Livestock production is constrained by severe animal feed shortages, especially during the time when climate fluctuations are leading to inconsistent supply (Masikati, 2011; Scholtz *et al.,* 2013; Meissner *et al.,* 2013). The main challenge faced by the small-scale dairy farmers in intensive, extensive and mixed production systems across East Africa is the inability to produce both sufficient quantity and quality feeds for livestock consistently (Njenga *et al*., 2013). This was supported by Kassam *et al.,* (2009) who documented that, the major limitation to improved livestock production is lack of sufficient provision of good quality feeds during the dry season.

During such periods, the types of feeds produced are of poor quality and poorly preserved thus insufficient to sustain livestock population (Hassan *et al*., 2014). A similar observation was also reported in Western Kenya, where seasonal availability of feeds was a major challenge in small scale dairy farming system (Taruss *et al*., 2010).

Studies by Masikati (2011) and Djikeng *et al*. (2014) reported that feed insufficiency caused a huge decline in livestock production. Belay *et al.* (2013) and Assefa *et al.* (2013) reported that the key constraint to livestock production experienced by the farmers in the study area were; feed shortage (100%), animal diseases (73%) and water shortage during dry season (27%) effect respectively. The unavailability of good quality protein sources for livestock is one of the major feed challenge faced by small-scale farmers (Njenga *et al*., 2013, Mthembu *et al*., 2018).

Solutions to feed constraints

With increased demand for meat and other animal protein sources, there is need to enhance production of forage from each hectare of land through enhanced production of grown pastures (Aganga and Tshwenyane, 2003). According to FAO, (2002) recommendations, high quantity and quality feed for ruminants in developing countries can be attained through rigorous utilization of multi-purpose trees and shrubs, as they can be cheaply grown and managed by livestock producers. In addition, they have substantial nutritional quality, closely comparable to grain based concentrates. Many studies have concentrated on policies to enhance animal nutrition during drought seasons (Mapiye *et al.,* 2006). One such suggestion has been the utilization of improved pasture grasses and forage legumes (Mapiye *et al.,* 2006).

More research has focused on less-known feeds of plant origin like non-conventional homegrown legumes, as alternative sources in mitigating the challenge of livestock feed quality (Mamer, 2017). Therefore, to improve feed quality, there is potential of utilization of leguminous forage crops such as *Lablab purpureus* (Tulu *et al.,* 2018). *Lablab purpureus* is associated with qualities such as; being tolerant to drought, being capable of growing wide range of environmental conditions, remaining green during the dry season and being capable of providing up to six tons of dry matter/ha (Aganga and Tshwenyane, 2003).

Conserving high quality fodder is another solution to feed constraints as it reduces the necessity of purchasing protein concentrates for use in ruminant rations (Ngongon *et al.,* 2008). Ensiling or making hay of forage plants is one of the favorite methods of fodder conservation choices for

future use when feed scarcity is a major challenge for livestock production (Amodu et al., 2005). Dry seasons pose a difficult time for livestock farmers as it is associated with inadequate feed and standing hays of high fibre content that is unsuitable for animal consumption (Mako et al., 2015). Therefore, one of the major solutions for alleviating feed availability during this time is conservation during the time of plenty.

2.1.2 Other constraints to livestock production

Diseases

In a study that was carried out in Njiru district in Nairobi county Kenya, disease was identified as one of the major constraints to livestock production. The most common disease identified by farmers were; East coast fever (ECF) with mortality rate of 56%, Foot and mouth disease(FMD) 15%, Anaplasmosis 10%, Foot rot 10%, mastitis 9%, Pneumonia 4% and Bloat 4% (Mureithi and Mukiria, 2015). In another study Assefa *et al.*, (2013) listed black leg, FMD, anthrax, mastitis, pastreulosis and pox diseases as the third major constraints to livestock production after feed and water shortage. In Makueni County in Kenya, livestock diseases that occurred during the dry season was one of the major constraints to livestock production in the region (Speranza *et al*., 2010). The authors reported that diseases affecting about 72% of the households included; respiratory infections 22%, East Coast Fever 6%, foot-and-mouth disease 5%, skin infections 2% and worms and parasites 2%.

Breeding services

Desta *et al*., (2000) in their study recorded poor breeding stock as one of the major challenges facing livestock production in Ethiopia aside feeds and diseases. Kathiravan and Selvam, (2011) recorded the following cattle breed related constraints that were ailing dairy productivity in India; low productivity 66.52% and 72.18% for both cross and desi dairy cattle, low fertility 61.12% and 52.15%. In a study by (Amimo *et al*., 2011) in western Kenya local cattle were identified as the major cause of poor livestock productivity in the region. The author indicated lack of exotic cattle in the region and local sourcing of breeding bulls from indigenous Zebu cattle contributed more inbreeding that caused long term effects of poor livestock traits within the region. Similar results were reported by Mwacharo and Drucker, (2005) in the South-Eastern part of Kenya.

Marketing

The major challenges faced by the dairy sector in eastern Africa as reported by (Bingi and Tondel, 2015) was low milk productivity and marketing with only 10-20% marketed and distributed through formal channels and < 1% dairy products exported outside the region leading to low income from dairy sector. The authors also reported that the perishability of milk and high cost of trading across the borders was a major challenge to dairy productivity within the regions. Additionally, in a study by (Mwacharo and Drucker, 2005) in the South- Eastern part of Kenya, poor roads during rainy season was identified as one of the major constraints during livestock marketing. Inadequate livestock policies, credit, marketing and infrastructure were listed as some of the major constraints affecting livestock production in Ethiopia (Desta *et al.,* 2000). In India, it was reported that the major constraints that were facing dairy production of cross breeds cows and desi cows were inadequate price of milk with 73.24% response for cross cows and 69.98% responses for desi cows (Kathiravan and Selvam, 2011). Other market related constraints were 18.75% and 12.44% were lack of cognizance on insurance cover for the two types of cows (Kathiravan and Selvam, 2011).

Extension services

Among the policy interventions that were poorly implemented by the government of Kenya for livestock production in western Kenya, extension services was ranked as second poorly implemented by government and private sectors at 15% after water scarcity at 19%. The others were disease control 12 %, lack of market for their livestock products 10 % and consistent drought 9 % (Onono *et al*., 2013). Similar results were reported by Opiyo *et al*., (2011) and Ali-Olubandwa *et al.*, (2011) in western Kenya where there was limited extension services for livestock stocking density, proper plan for livestock disease control, feed resource management and right criteria for livestock breed selections. In Zimbabwe, amongst the major constraints faced by livestock keepers, extension services with (26% responses) was ranked after disease 69.3%, feed shortage 52.1% and water scarcity 39% (Mutibvu *et al.,* 2012). In another study, extension services such as; Government provision of clinical Veterinary Services, extension service equipment, transport and drugs to offer to livestock keepers collapsed in some of the developing countries due to poor leadership and management in the ministry of Agriculture,

Livestock and Fisheries (Petrus *et al*., 2011; Peeling and Holden, 2004). Similar results by Kathiravan and Selvam, (2011) indicated that poor livestock productivity in dairy cows was attributed to poor veterinary services.

2.2 Origin and distribution of *Lablab purpureus*

Lablab purpureus bean is a pulse cum vegetable crop that originated from India, South East Asia or Africa and has been reported to be common in Egypt and Sudan (Nahashon *et al*., 2016). Currently, it has been cultivated and disseminated all over the tropics and subtropics (Aganga and Tshwenyane, 2003). It is cultivated for human food such as mature seeds and also used as animal fodder (Chandra and Kushwaha, 2013). Prasad *et al.*, (2015) reported seven types of L. *purpureus* out of which five were cultivated and two were wild varieties. Of the cultivated varieties, two groups were identified (1) *L. purpureus* variety typicus, with short leaves and annual, twining herb, pods are longer and mostly raised as a garden crop for green pods, and (2) *L. purpureus* variety lignosus, with longer leaves, semi-erect, bushy and perennial.

Lablab variety "Rongai" originates from the Rongai region of Kenya and has been distributed to subtropical and tropical regions (Evans, 2002). It is a white flowering, strong productive variety (Evans, 2002). It has been reported to be a late maturing white flowering variety that will continue to grow and flower several times until it is cut or damaged (Aganga and Tshwenyane, 2003).

2.3 Agronomy of *Lablab purpureus* and its production in Kenya

Lablab purpureus does well up to 2500 m above sea level, with 200 to 2500 mm annual rainfall and temperature of between 18^{o}C to 30^{o}C (Bahadur *et al*., 2016). The crop development and growth can be affected negatively by high temperature beyond 30^{o}C (Aganga and Tshwenyane, 2003). Rainfall below 160mm was reported to result in crop failure (Sennhenn, 2016). However, the crop can tolerate low moisture during drought season due to its deep rootedness (Karuma *et al*., 2011). It can tolerate soil acidity of up to pH 5.5 but can also do well in alkaline soil pH range of up to 9.0 (Bahadur *et al*., 2016). The improved lablab legume crop takes around 110-120days to reach maturity stage (Shambhu, 2013). It starts flowering at 60-65 days after sowing, reaching 50% flowering at around 70-75 days after sowing (Shambhu, 2013). According to studies done in Nigeria, the application of 40 kg P_2O_5/ha with 40 cm intra-row spacing gave the

highest seed yields compared to the other treatments of intra-row spacing of 20cm of control and 30cm of 20kg P_2O_5/ha (Muhammad *et al.*, 2017).

In Kenya, Birech *et al.* (2014), reported that there are two main lablab varieties based on time of maturity: early maturing variety that takes 4 to 5 months to reach maturity and late maturing variety that last 6 to 7 months. The major lablab producing regions in Kenya are Eastern (Meru), Central (Nyeri, and Thika) and Coast (Lamu) where it is grown as a pure stand or as an intercrop mostly with maize (GOK, 2005). The legume has also been introduced in some areas such as Mwingi and Machakos (Kimani *et al*., 2012). Studies carried out by Kimani (2012) reported *Labla*b *purpureus* (L.) Sweet grain yield of 980 kg/ha while testing the effect of improved legumes.

2.4 *Lablab purpureus* forage varieties in Kenya

The most commonly grown *Lablab purpureus* varieties are of bush types maturing in 60 days in tropical climate with seed yield of range 700 to 2000 kg/ha (Dholakia *et al.,* 2019). Some varieties have been reported to mature in 100 to 120 days at mid-elevations and can produce the maximum seed yield of up to 5000 kg/ha (Dholakia *et al.,* 2019). *Lablab purpureus* cultivar. Rongai is a late flowering variety with white, flowers, with seeds of light brown colored (Aganga and Tshwenyane, 2003). Mwonga *et al*., (2002) in their study on selection of legumes for the cool highland frost susceptible regions of North rift Kenya, reported *Lablab purpureus* cv. Rongai as the late maturity variety. The variety started flowering at 75 days after planting and recorded the dry matter yield of 0.37 to 0.47 ton/ha in both long rain and short rain seasons. Unlike *Lablab purpureus* cv. Black seeded that were early maturity, flowering completed at 40 to 60 days after planting with dry matter yield of 0.35 to 0.45 ton/ha in both long rain and short rain seasons in North-rift part of Kenya (Mwonga *et el.*,2002). Amole *et al,* (2013) in their study on forage yield and quality of *lablab purpureus* during the late dry season in western Nigeria reported that the seeds of *Lablab purpureus* var. high worth was early flowering variety with both high foliage and seed-yielding capability and was recommended as suitable for both seed production and forage uses.

2.5 *Lablab purpureus* biomass yields

Lablab has been reported to yield large amounts of biomass rich in protein and suitable for animal fodder (Yuan *et al*., 2009). Whitbread *et al*., (2005) reported that *L. purpureus* variety Endurance produced biomass yields that ranged from 1.595–7.037 ton/ha DM during the first year in Australia. In the second year, biomass yield ranged from 4.717–6.150 ton/ha DM when lablab was harvested at 50% flowering during both short and long rain seasons in two consecutive years.

In another study, Singh *et al.,* (2010) reported biomass yield of 5-6 t/h DM from *Lablab purpureus* under minimum rainfall with good management. Hassan *et al*, (2014) in Nigeria, reported biomass yield of lablab variety Rongai white ranging from 5.25-5.94 ton/ha dry matter when forage was harvested at the age of 15 weeks. In Kenya, Karachi, (1997) reported dry matter yield (grams per plant) of *Lablab purpureus* Rongai varieties in semi-arid areas of Kenya as 17.1 to 142.6 g/plant DM for leaves and dry matter yield for stems ranged from 47.3 to 161.2 g/plant. However, the above figures could vary as Tarawali, (1991) indicated that, the yields of forage plant differ with fodder species, soil fertility, macro-climate conditions within which fodder plant is established, different locations and management at farm level.

2.6 Nutrient content for *Lablab purpureus* seeds

Lablab purpureus Rongai variety (with milky white colour seeds) was reported by Abeke *et al.,* (2008) as having dry matter content of 95.97 g/100g and crude protein content of 23.29 g/100g. These results were in agreement with those obtained by Rasha and Abdel-Ati., (2007) who reported dried seeds of *Lablab purpureus* containing 20-28 g/100g crude protein. Singh *et al.,*(2010) while supplementing kids of local goat breed (Bundelkhandi) with ground seeds of lablab as a source of different protein, reported crude protein content of 27.5 g/100g, neutral detergent fibre (NDF) of 33.5 g/100g, acid detergent fibre (ADF) 17.1 g/100g, and lignin content of 1.42 g/100g. In addition, Soetan *et al* (2010) reported proximate composition of three cultivars of *Lablab purpureus* grains in Nigeria as, Rongai Brown variety (DM-89.96 g/100g, crude protein 24.15 g/100g) Rongai white variety seeds (DM- 90.04 g/100g, crude protein of 23.10 g/100g) and High worth Black variety seeds (DM 89.87 g/100g, crude protein of 22.75 g/100g).

2.7 Nutrient composition for *Lablab pupureus* leaves and stems

In the evaluation of crude protein content of leaves of different varieties of *Lablab pupureus* that were harvested at different growth stages, Baloyi *et al.* (2013) reported the average crude protein content of leaves from cultivar Q6880B as 24.7 g/100g and 30.3 g/100g in cultivar CP152513 at 6 weeks after planting. Second harvest at 8 weeks after planting, the author reported an average crude protein of 28.0 g/100g in leaves of variety Q6880B and 33.5 g/100g in CQ3620. Nonetheless, in the third harvest at 10 weeks after planting, the figures declined as crude protein content in leaves ranged from 22.8 g/100g in variety Q6880B and 28.5 g/100g in variety CP160795 (Baloyi *et al*., 2013).

Fasae *et al*., (2010) in their study in Nigeria reported the nutritive value of the *lablab purpureus* leaves as 21-38 g/100g CP and dry matter digestibility ranging from 55-76 g/100g. Additionally, Swidiq *et al.*, (2011) also reported dry matter content of fresh *lablab purpureus* leaves to be 30 g/100g, crude protein content of 26.67 g/100g, fibre fractions in leaves was; NDF (47.87 g/100g), ADF (33.83 g/100g) and Lignin of (7.57 g/100g), with invitro dry matter digestibility of leaves ranging from 60-70 g/100g . In other study, Amole *et al*., (2013) reported crude protein content of 22.6 g/100g in lablab.

Karachi, (1997) reported *Lablab purpureus* cv. Rongai with NDF of (26.0 to 47.8 g/100g for leaves and 50.0 to 69.2 g/100g for stems), ADF (22.2 g/100g to 36.0 g/100g for leaves and 41.5 g/100g to 62.7 for stems). ADL ranged from 4.8 g/100g to 12.0 g/100g for leaves, 7.6 g/100g, and 15.5 g/100g in stems, while their invitro-dry matter digestibility (IVDMD) ranged from 56.4 g/100g to 70.0 g/100g in leaves and 42.0 g/100g to 49.2 g/100g in stems respectively (Karachi, 1997). Nsahlai and Umunna (1996) during their study on *Lablab purpureus* Rongai Variety reported dry matter yield for leaves as 76.4 g/plant and 84.1g/plant for stems, crude protein content in the leaves was 25 g/100g and 11.88 g/100g in stems.

2.8 Nutrient composition for the whole *lablab pupureus* plant

Dry matter content

Fasae *et al.* (2010), in their study reported the DM content in the whole fresh lablab plant as being 30 g/100g DM when it was harvested at 50 g/100g flowering stage while Mbuthia *et al.* (2003) reported 17.0 g/100g DM. Amodu *et al.* (2005) reported dry matter content of the whole

fresh lablab plant harvested at 50 g/100g flowering as 23.4 g/100g. When both Rongai and Highworth varieties were harvested at 50 g/100g flowering, (Alasa, 2014) reported their DM content at 31.1 g/100g and 32.4 g/100g.

Crude protein content

Amole *et al*. (2013) reported that, crude protein content of whole lablab plant varied from season to season with a range of 18.0 g/100g DM to 23.0 g/100g DM. Njarui *et al*. (2003) while studying forage legumes in semi-arid regions of eastern Kenya, reported the crude protein content of *Lablab purpureus* cv. Rongai harvested at 50% flowering as 16.1 g/100g CP. While working with the same variety, Hassan *et al.* (2014) reported CP content of the whole lablab plant as 17.2 g/100g when it was harvested at 6 weeks after sowing and low CP content of 10.1 g/100g when it was harvested at 18 weeks after sowing. Seid and Animut, (2018) reported 20.2 g/100g crude protein in the whole lablab plant.

When *Lablab purpureus* plant was harvested at different growth stages, Washaya *et al.* (2018) reported varying figures of crude protein content; 21.1 g/100g CP at pre-anthesis stage, 17.7 g/100g CP at anthesis stage and 17.5 g/100g CP at post-anthesis stage respectively. Tulu *et al*. (2018) reported different crude protein content in two varieties of lablab; variety Beresa-55 had CP content of 19.9 g/100g while variety Gebisa-17 recorded CP content of 16.1 g/100g when it was harvested at 50.0 g/100g flowering in Ethiopia.

Fibre fractions for the whole lablab plant

Njarui *et al*., (2003) reported 45.0 g/100g NDF, 34.8 g/100g ADF and 6.8 g/100g ADL for *Lablab purpureus* cv. Rongai in semi-arid regions of eastern Kenya when it was harvested at 50.0 g/100g flowering. Hassan *et al*. (2014) worked with the same variety and recorded NDF and ADF content of 53.6 g/100g and 17.1 g/100g at 6 weeks and 59.7 g/100g NDF and 20.6 g/100g ADF at 18 weeks after sowing respectively. Seid and Animut, (2018) reported 50.1 g/100g NDF, 44.3 g/100g ADF and Acid detergent lignin (ADL) of 9.7 g/100g.

Washaya *et al*. (2018) harvested *Lablab purpureus* at different growth stages. They reported 48.7 g/100g NDF, 35.1 g/100g ADF and 13.6 g/100g ADL at pre-anthesis stage, 46.5 g/100g NDF, 33.65 g/100g ADF and 12.86 g/100g ADL at anthesis stage, 52.6 g/100g NDF, 39.87 g/100g ADF and 12.74 g/100g ADL at post-anthesis stage. In Ethiopia, Tulu *et al*. (2018) reported significant variation of fibre fractions in two varieties of lablab harvested at post-

anthesis; variety Beresa-55 had NDF content of 41.0 g/100g, ADF of 37.6 g/100g and ADL of 6.3 g/100g while variety Gebisa-17 had NDF content of 45.0 g/100g, ADF 39.6g/100g and ADL of 7.9 g/100g respectively.

***Invitro* dry matter digestibility**

Njarui *et al*. (2003) reported the *invitro* dry matter digestibility (IVDMD) of *Lablab purpureus* cv. Rongai harvested at 50% flowering to be at 65.8 g/100g. Similar results were reported by Geleti *et al.* (2013) in Ethiopia for the whole Lablab as 68.7 g/100g. Tulu *et al.* (2018) working on different varieties of *Lablab purpureus* in Ethiopia, reported the organic matter digestibility (OMD) of two varieties of whole lablab plant with variety Beresa-55 having OMD of 55.1 g/100g while variety Gebisa-17 with 57.0 g/100g OMD. The data on OMD of lablab still inadequate and further research is required (Nahashon et al., 2016).

2.9 Factors affecting biomass yield and nutrient content of *Lablab purpureus*

Pests and diseases

One of the major limiting factors in *Lablab purpureus* production is aphid infestation (Mondal *et al*., 2017). The author also reported that aphid severity varied with the water content in the plant foliage, lablab with high water content was more susceptible. Njarui *et al*. (2004) reported insect damage and diseases on lablab as the main challenge on the legume production. They reported insect damage on lablab Rongai variety ranging from 24-52 indices and for the V.unguiculata variety was 25-36 indices across the study areas. The susceptibility of lablab to insects damage as shown by the above indices was reported by the author to cause decline in forage yield, grain yield and quality hence extra measures should be taken to control insects and other pests to achieve maximum forage yields from lablab. In addition, *Lablab purpureus* cv. Rongai and V. unguiculata (CPI 60452) were the most widely affected by diseases with indices of between 20-29 and 20-75 (Njarui *et al*., 2004). Kany *et al.* (2016) recorded highest thrips infestation in irrigated lablab as opposed to rain fed. They also pointed out that irrigation resulted in good growing conditions for the lablab flora to bloom thus enough shoots and plants for thrips to feed on.

Ambient temperature

Temperature enhances cell wall constituents growth, expands lignification, decline soluble starches and decline digestibility (Tjelele, 2006). Additionally, it diminishes the leaf to stem proportion of the forage, which specifically influences the digestibility of the dry matter of the forage because of the lower stems to leaf ratio. Kebede *et al*. (2016) reported that, digestibility of forage declines by 0.5 to 7 rate units for each 1^{o}C increment in temperature. Forages developed in cooler locations or seasons were reported to be of higher quality than those grown in hotter environment (Kebede *et al*., 2016). Poor harvesting, storage effects, leaf shatter, plant respiration, and leaching by rain amid field drying of hay and silage making was reported to decrease forage quality, particularly with legumes (Ball *et al*., 2001). The temperature too affects the growth rate of forage plants, as was reported earlier by Aganga and Tshwenyane (2003), *Lablab purpureus* does well within temperature of between 18^{o}C to 30^{o}C (Bahadur et al., 2016). The author further reported that the crop development and growth can be affected negatively by high temperature beyond 30^{o}C through withering and drying off.

Soil fertility

Soil fertility influences forage yields considerably more than it does quality. Williams *et al*., (2016) reported that, it is possible to raise and produce high nutritive forage on the low fertile soil; however, it is hard to deliver significant returns of forage yield with low fertile soil. In a study by Karmegam and Daniel, (2008) the soils from the plots that were applied with vermicomposit produced lablab with high total chlorophyll leaves, high number of branches per plant and total dry matter production than the control plots. In another study, Younis, (2010) reported an increase of 66% in dry matter content of water-stressed *Lablab purpureus* that was established in a soil rich in potassium.

Age at harvesting

The maturity stage of a legume affects forage quality more than any other factor (Heinritz *et al.,* 2011). The plant cell wall content increases, indigestible matter such as lignin increase with age resulting in poor quality forage. Higher accumulation of cell wall constituents was reported to cause reduction in intake and low digestibility in ruminants (Heinritz *et al*., 2011). In varieties that have different maturity dates, later maturity types tend to be lower in digestibility as

opposed to early type due to accumulation of cell wall contents (Ball *et al*., 2001). The most recommended age for fodder harvest is when it has attained 50% flowering, for at this stage the nutrient composition of the fodder plant is optimal with high dry matter digestibility (McDonald *et al*., 1991). Parmar *et al.* (2013) also reported significant positive phenotypic correlations between yields and number of days to 50% flowering. Fiber content of the forage crops increases while quality and digestibility decline with maturity (Ball *et al* 2001). In most of the tropical legume forages DM yield increases with progressing stages of maturity (Bayble *et al* 2007; Baloyi *et al* 2008).

2. 10 Conservation of *Lablab purpureus* fodder

Lablab fodder can be conserved on-farm through either hay (dry feed) or as silage (wet feed).The foliage makes good hay for both cattle and goats, however, the stem requires long time to dry hence it must be mechanically crushed for even drying (Bahadur *et al*., 2016). Silage from a mixture of lablab and sorghum species raised the protein content of resulting mix by approximately 11% with a 2:1 mixture of lablab: sorghum (Bahadur *et al*., 2016).

2.10.1 Legume silage

Use of legumes such as *lablab purpureus,* cow peas (*Vigna uinguiculata*), soybean (*Glycine max*) for ensiling in tropical feeding systems has been of great benefit to livestock production. The use of legumes results into silage of acceptable digestibility if conserved well, and can be used to enrich low quality fodder especially in crude protein and minerals (Cowan, 2000).

Tropical forages both grass and legumes are not naturally ensilage materials because at harvesting, they have low level of water-soluble carbohydrates that are required for successful ensilage (Jarrige *et al.,* 1982). High protein content in legumes increases buffering capacity resulting into protein being prone to proteolysis (Phiri *et al*., 2007). However, measures can be taken to improve level of fermentable carbohydrates by reducing buffering capacity thus inhibiting proteolysis leading to successful ensilage (Titterton and Bareeba, 2000). These include wilting and use of silage additives to enhance silage conservation by dominating lactic acid bacteria for forage fermentation phase (Barry *et al*., 1978).

Additives can be grouped into three major categories: fermentation stimulants (bacterial inoculants and enzymes), fermentation inhibitors (propionic, formic and sulphuric acids) and

substrate or nutrient sources (maize flour, molasses, urea and anhydrous ammonia) can be used during silage making to reduce silage spoilage from legumes (Seale et al., 1986). The most vital benefit of additives such as maize, sorghum, or cassava meal is to enhance dry matter content in early harvested crops when moisture content is optimal and high wilting rate is not possible or where effluent is highly prone to seepage (Phiri *et al*., 2007). Molasses is a source of carbohydrate and is commonly used in silage making to only forage with low soluble carbohydrates such as tropical legumes and grasses. Good silage was achieved when molasses was applied at 3-5% (Titterton and Bareeba, 2000).

2.10.2 Nutrient content of lablab silage

Contreras-Govea *et al.* (2009) while investigating the quality of corn silage in a mixture with climbing beans in united states reported silage from Rongai varieties of lablab (*Lablab purpureus* (L.) Sweet, as having DM content of 36.2 g/100g, CP of 78 g/100g, NDF 395 g/100g, ADF 212 g/100g and IVDMD 770g/100g. In another study Quigley *et al*. (2000) reported pH content in lablab silage as ranging from 5.0-5.1, total nitrogen from 26.6-26.3g/100g and dry matter content of 49.3-56.1 g/100g. The invitro-dry matter digestibility (IVDMD) of lablab silage ranged from 48.5-58.1 g/100g while fibre fraction such as neutral detergent fibre (NDF) was reported to be between 54.4-61.8 g/100g, ADF 44.4-49.7g/100g (Quigley *et al*., 2000). In a study by Amodu *et al.* (2005) to compare degradation qualities of fresh lablab and ensiled lablab forages that was cut at 3 weeks with CP content of 17.5 g/100g. The author further reported that, of all the chemical components, only CP varied between the fresh lablab and the ensiled. The CP content of lablab silage was much lower (6.5 g/100g) than the fresh lablab 17.5 g/100g CP (Amodu *et al.*, 2005).

2.10.3 Lablab purpureus Hay

The common challenge that is encountered when harvesting and wilting of lablab hay is the decline in nutritional quality due to high rate of leaf shattering leaving largely poor quality stemmy hay with high level of fibre fractions (Titterton and Bareeba, 2000).

2.10.4 Nutrient content of lablab hay

Diribsa *et al.* (2014) while studying on impact of supplementing natural grass (*Cynodon dactylon*) hay with *Lablab Purpureus* on growth of Horro Sheep in Ethiopia reported the nutrient

composition of lablab hay harvested at blooming stage; 88.79 g/100g DM, 18.67 g/100g CP, 8.57 g/100g Ash content was recorded, 46.71 g/100g NDF, 29.37 g/100g ADF, 7.25 g/100g ADL and 62.03 g/100g dry organic matter digestibility. In another study, Ishiaku *et al*. (2018) reported the nutrient content of *Lablab purpureus* L. Sweet hay of the whole plant harvested at 12 weeks after sowing; 94.47 g/100g DM, 22.53 g/100g CP, 52.0 g/100g NDF, 27.82 g/100g ADF and 14.22 g/100g ADL. In other studies, the CP content of Lablab hay was reported as 12.7-14.1 g/100g (Evans, 2002) and 16.4 g/100g (Aganga and Autlwetse, 2000). Mpangwa *et al*. (2006) in their study observed difference in chemical qualities between lablab hay and fresh lablab harvested at 8 weeks after emergence. They noted that, crude protein content of fresh lablab were almost similar to lablab hay (25.4 g/100g and 25.2 g/100g), the fibre fractions were higher in lablab hay than in fresh lablab NDF (37.5 g/100g and 32.5 g/100g), ADF (37.5 g/100g and 32.8 g/100g), apart from ADL (8.9 g/100g and 9.5 g/100g) that had almost similar lignin content. The authors concluded that loss of lablab leaves during sun drying resulted in a 0.2 g/100g decline of protein content and increase of fibre fractions in the resultant hay.

CHAPTER THREE

BIOMASS YIELD AND NUTRITIVE VALUE OF SELECTED VARIETIES OF (*Lablab purpureus*)

ABSTRACT

Inadequate feeds, in both quality and quantity, are the main challenges facing livestock production in Kenya. Use of concentrate feeds (especially high protein) to enrich low quality fodder is mostly beyond the reach of most small-scale farmers due to high cost. As such, cheaper alternative protein supplements are needed to improve productivity at reasonable cost. The main objective of this study was to determine biomass yield and nutritive value of fresh fodder from eight lablab varieties. The specific objectives were; to determine biomass production and nutritive value of fodder from selected Lablab varieties and to evaluate the effect of conservation as hay or silage on the quality of lablab fodder. The varieties; DL1002, Ngwara Nyeupe, Echo-Cream, Black Rongai, Eldoret-Kitale Cream, Eldoret-Kitale-Black1, Brown Rongai and Eldoret-Kitale-Black 2 were assessed in three sites of Nandi South sub-County, Kenya. The eight lablab varieties replicated four times per site were established in four farms per site in randomized complete block design and harvested after attaining 50% flowering. Data on biomass yields, nutrient content and invitro-dry matter digestibility on fresh forages was collected for all the varieties. Biomass yield differed significantly ($P<0.05$) among the eight lablab varieties ranging from 5.6 to 12.6 t DM/ha across the three sites. Brown Rongai variety had the highest biomass yield of 12.6 t DM/ha while DL1002 variety had the lowest dry matter yield of 5.6 t DM/ha. Crude protein content varied between varieties and sites and ranged from 19.6 to 23.9 g/100g. Eldoret-Kt-Cream and Black Rongai varieties had the highest crude protein content of 23.9 g/100g CP and 23.7 g/100g CP across the three sites. Neutral detergent fibre (NDF) ranged from 44.4 to 48.6 g/100g, acid detergent fibre (ADF) ranged from 31.6 to 35.7 g/100g while acid detergent lignin (ADL) ranged from 9.0 to 11.9 g/100g for all the varieties of lablab across the three sites. Variety DL1002 had the highest NDF content of 48.6 g/100g across the three sites. The highest ADF was recorded for Eldoret-Kitale-Black 2 variety with 35.9 g/100g, whereas highest acid detergent lignin of 11.7 g/100g was recorded in DL1002 variety.

Invitro dry matter digestibility (IVDMD) varied significantly between varieties and sites. The IVDMD ranged from 67.6 g/100g to 75.7 g/100g among the varieties of lablab across the three sites. Eldo-Kt-cream and Black Rongai varieties had the highest IVDMD of 75.7 g/100g and

74.4 g/100g across the three sites respectively. From the study, Eldoret-Kitale-Cream and Black Rongai had higher dry matter yield, crude protein content and lower fibre fractions than other varieties and are recommended as alternative fodder supplements to low quality roughages in small-scale farms.

3.0 INTRODUCTION

3.1 Background Information

The main challenge facing small-scale dairy farmers across East Africa is inability to provide adequate quantity and quality of feeds to their livestock on a regular basis (Lukuyu *et al*., 2009; Geta *et al.,* 2014). Seasonal fluctuations in availability of forage in these farms also limits animal productivity (Andualem *et al.,* 2015). For ruminants on forage, energy and protein are the major limiting nutritional requirements (Tibayungwa *et al.,* 2011). In Kenya, elephant grass commonly known as Napier grass in Kenya has been the main fodder in smallholder farms although it is reported to meet most of the energy requirements but it is low in protein content (Tibayungwa *et al.,* 2011). Use of low quality crop residues which are low in protein especially during the dry season necessitates supplementation with high protein supplements (Lukuyu *et al*., 2009). In most developed countries, concentrate feeds have been used to enrich low quality fodder for better livestock production, however, in developing countries these are costly and not affordable (Tulu *et al*., 2018).

To overcome the challenge of feed quality and availability, use of indigenous multipurpose legumes to improve low quality forages, especially natural grasses and crop residues, will increase livestock productivity (Speranza, 2010; Syomiti *et al* 2011). Protein content tends to decrease and fibre fractions increase with maturity in most plants. However, legumes tend to keep a high CP content with maturity making them suitable to be used as protein supplements (Mupangwa *et al.,* 2006). *Lablab purpureus* has a number of qualities that makes it good to effectively improve low quality feed under small-scale farms (Amole *et al*., 2013). It is drought resilient, can sustain its green leaves during the dry season and it is capable of providing up to six tons of dry matter per hectare (Amole *et al.,* 2013).

The whole lablab plant both roots and shoots had a dry matter digestibility of 55 and 14 g/100g CP content (Madzonga and Mogotsi, 2014). Mthembu *et al.,* (2018) reported crude protein range

for the whole lablab plant as 14.8 to 21.0 g/100g and dry matter digestibility range of 59 to 67.9 g/100g. The main advantage of its protein is that it is easily degradable in the rumen to provide microbial nitrogen to enhance breakdown of poor quality forage (Shehu *et al*., 2001). As a result, lablab can serve as a suitable supplement for low quality fodder in small scale farming systems.

Lablab is an underutilized legume for both human food and with potential use as animal fodder in tropics (Kumar *et al*., 2016). The legume can therefore be used to solve the problem of nutrient insufficiency that is one of the major factors that mostly affect livestock production (Mako *et al.,* 2015). Therefore, this study aimed at assessing biomass yield and nutritive value of eight varieties of *Lablab purpureus.*

3.2 MATERIALS AND METHODS

3.2.1 Description of the study site

The study was conducted in Nandi south Sub-County in the Rift Valley region of Kenya. The altitude ranges from 1,400m along the border with Nyando district to 2,400m ASL in the highlands. The common soil texture type is loam and clay. Temperatures range from 15 to 26^{o}C and rainfall between 1200-2000mm per annum. It has two rainy seasons; the long rains between March and June and the short rains between October and December and the dry season occurs from late December to March (Onyango *et al*., 2016). Three sites with different climatic conditions and soil fertility were selected within Nandi South: Koibem with temperature of 18^{o}C, high fertile soils with Nitrogen content of 0.38% and Carbon of 3.91%, Kiptaruswo with temperature of 20^{o}C medium soil fertility with Nitrogen content of 0.26 % and carbon content of 1.87% and Kapkarer with temperature of 22^{o}C low soil fertility of Nitrogen 0.16% and Carbon 1.44 % (Omondi *et al.,* 2011; Landon, 2014).

3.2.2 Assessment of use of lablab as a supplement to low quality fodder in the study area

Determination of sample size and data collection

Prior to the establishment of lablab in selected farms, a semi structured questionnaire was administered to assess the use of lablab by small scale farmers in study area. The selection criteria was based on farmers having participated in the project and having grown, harvested and conserved lablab fodder. The sampling frame was from a list of 63 small scale farmers who

practiced mixed farming (livestock/crop). The sample size was obtained using the coefficient of variation of 15% and a standard error of 0.02. The formula by Nassiuma (2000) was used:

$$n = \frac{NC2}{C2 + (N-1)\,e2}$$

Where n = Sample N = Population C = Covariance e = Standard error. A total of 30 farmers were considered for the survey within the three sites (10 farmers per site). The data was collected through face to face interviews. Data on commonly used fodder, attributes of a good fodder plant by farmer's perception, lablab varieties considered to have good fodder qualities and suitable on farm conservation of lablab was collected.

3.2.3 Experimental design for establishment of *Lablab purpureus*

A Randomized Complete Block Design (RCBD) was used at farm level. Four farms were selected per site and within each farm all the varieties were established. Each farm represented a block comprising of eight plots of size 5x4 m, within which eight varieties of lablab namely; DL1002, Ngwara Nyeupe, Echo-Cream, Black Rongai, Eldo-Kt-Cream, Eldo-Kt-Black1, Brown Rongai and Eldo-Kt-Black2 were randomly distributed.

3.2.4 Field establishment and management of *Lablab purpureus*

The land preparation for planting was done manually. Seeds were acquired from Kenya Agricultural Livestock and Research Organization (Kitale Centre) and University of Eldoret. Diammonium phosphate (DAP) fertilizer was applied at the rate of 30 kg DAP/ha mixed with the soil before seeds were sown. Lablab seeds were sowed at a rate of 30 kg seeds/ha with the spacing of 45 cm between rows and 30 cm between plants with two seeds per hill. Weeding was done twice at an interval of 21 days after emergence.

3.2.5 Determination of aphids severity index on lablab varieties

Data on aphid severity for eight varieties of lablab was collected when they started appearing on the leaves. This assessment was based on the aphids severity scale as described by Nagrare *et al.,* (2009). Ten plants were randomly selected in each plot and observed for aphid severity index and rated per the scale. A scale of 0-4 was used to determine infestation: Grade 0: No aphids appearance on the whole plant. Grade 1: Scattered appearance of few aphids on the plant. Grade 2: Severe infestation of aphids on any one branch of the plant. Grade 3: Severe infestation of

aphids on more than one branch or a half portion of the plant. Grade 4: Severe aphids over the whole plant. Severity index was calculated as follows; Severity index (SI) = Sum of total grade points (1-4 infestation grade G-I to G-IV, respectively) of the infested plants/Total number of infested plants observed.

3.2.6 Determination of biomass yield

Data on days to first flowering was taken only when a quarter of the total plant population in a plot had started flowering while days to 50% flowering was recorded on the day when half of the total plant population in a plot had flowered. At 50% flowering, a fresh sample was harvested for each variety by randomly cutting the plants 5cm above the ground in each plot to make approximately 1kg for each variety per plot. The harvested samples were weighed, sealed in polythene bags and transported to the nutrition laboratory in the department of Animal Production, University of Nairobi for oven drying at 60^{o}C for five days. The other plants within each plot were harvested by cutting at 5cm above the ground. They were placed into gunny bags and weighed using a hanging round scale to the nearest 1,000,000g to obtain the fresh biomass yield per plot. After drying the 1 kg fresh samples in an oven of 60^{o}C to a constant weight, weight loss was recorded and the samples were ground using a Wiley mill standard model No.3 with sieve of 0.5mm. The dry matter content for each sample was determined by drying in an oven at 105^{o}C overnight. Subsequently, the biomass yield (dry matter) per ha was estimated.

Plate 3. 1: Lablab harvesting and fresh biomass yield determination

3.2.7 Determination of nutrient variation of lablab with maturity

Foliage samples of three lablab varieties (Brown Rongai, Black Rongai and Eldo-Kt-Black2) that were already available within the farms at the time of study that were at either 50% flowering stage and at seeding stage were collected. This was done immediately after seed harvest to determine the nutrient degradation in lablab foliage after seed harvest for human consumption as opposed to harvesting the whole lablab plant at 50% flowering as a supplement to ruminants on low quality fodder.

3.2.8 Determination of nutrient composition

Dried milled samples were analyzed for dry matter, crude protein and Ash content following the AOAC (2016) procedure. Neutral detergent fibre (NDF), acid detergent fibre (NDF) and acid detergent lignin (ADL) were determined using the method of Van Soest *et al.* (1991). The two stage invitro dry matter digestibility was determined following the procedure of Tilley and Terry (1963).

3.3 DATA ANALYSIS

The data on Aphids severity index, days to 50% flowering, biomass yield per unit area, nutrient content and invitro-dry matter digestibility for different *Lablab purpureus* verities was subjected to Analysis of variance (ANOVA) using Genstat Inc. 15th edition 9 (Lawes Agricultural Trust, Rothamsted Experimental Station, UK) to determine whether the variation between varieties (both within and between sites) was significant. The significant means were separated using Tukey's statistical test at a significant level of 5%. The quantitative data that was collected on farmers' evaluation was analyzed using the SPSS 12.0 statistical package of social sciences (2003) to obtain descriptive statistics.

3.4 RESULTS

3.4.1 Types of fodder in study site

The types of commonly used fodder by small-scale farmers in Nandi-South sub-county are shown in Table 3.1. Natural grass, Napier grass and Maize Stover were the most commonly used in all the three sites. Within Koibem, all the farmers grazed livestock on natural grass with addition of maize stover, with only 20% feeding on lablab. Within Kiptaruswo, all farmers

grazed their livestock on natural grass, fed on maize stover and Napier grass with 80% feeding on banana stems and 10% on lablab. In Kapkarer, all farmers grazed their livestock, 90% used Napier grass, and 80% used maize stover while 10% used Banana stems. For all the study sites, all farmers grazed their livestock on natural grass, with 93.3% and 90% feeding maize stover and Napier grass respectively. Fewer farmers fed their livestock on banana stems 43.3%, Lablab 20% and hay made from Boma Rhodes grass 10%.

Table 3. 1: Types of fodder commonly used by small-scale famers in Nandi-south

	Koibem		Kiptaruswo		Kapkarer		Total	
Types of fodder	N=10	%	N=10	%	N=10	%	N=30	%
Napier grass	8	80	10	100	9	90	27	90
Grazing (natural grass)	10	100	10	100	10	100	30	100
Lablab fodder	2	20	1	10	3	30	6	20
Maize stover	10	100	10	100	8	80	28	93.3
Banana stems	4	40	8	80	1	10	13	43.3
Boma Rhodes hay	3	30	0	0	0	0	3	10

3.4.2 Farmer's perception on physical attributes of good fodder plant

The preferred physical attributes of a good fodder plant by the farmers are shown in Table 3.2. The most preferred fodder attributes at Koibem were those with more foliage 90%, late maturity and wide leaves 80%. The least preferred were those with early maturity, creeping and rough leaves 20% and bushy growth with soft leaves surface 30%. Within Kiptaruswo, 80% preferred fodder plants with bushy growth characteristics, 60% early maturity with more foliage while only 20% preferred those with late maturity, rough leaves, and wide leaves with creeping characteristics. At Kapkarer, 90% of the respondents preferred fodder plant with bushy growth characteristics and soft leaves, 80% those with early maturity and more foliage, 20% those with wide leaves and 10% late maturing with rough leaves surface and creeping. In all the sites, most of the respondents preferred fodder plants with more foliage 76.7% and bushy growth 66.7%.

Table 3.2: Physical attributes of good fodder plant by small-scale farmers in Nandi-South

	Koibem		Kiptaruswo		Kapkarer		Total	
A. of fodder plant	N=10	%	N=10	%	N=10	%	N=30	%
Early maturity	2	20	6	60	8	80	16	53.3
Late maturity	8	80	2	20	1	10	11	36.7
More foliage	9	90	6	60	8	80	23	76.7
Bushy growth	3	30	8	80	9	90	20	66.7
Soft leaves	3	30	5	50	9	90	17	56.7
Rough leaves	2	20	2	20	1	10	5	16.7
Wide leaves	8	80	2	20	2	20	12	40.0
Creeping	2	20	2	20	1	10	5	16.7

A= Attributes, N= Number of the interviewed farmers

3.4.3 Farmers perception on the most preferred lablab varieties for fodder production

The Lablab varieties with good fodder attributes based on farmers' perception are shown in Table 3.3. In Koibem, most of the respondents preferred lablab varieties; Echo-Cream 90%, Ngwara Nyeupe and Brown Rongai 80% while DL1002, Eldo-Kt-Black1 and Eldo-Kt-Black2 each with 20% preference were ranked as poor fodder attributes. In Kiptaruswo, lablab varieties with good fodder attributes were Ngwara Nyeupe, Echo Cream and Brown Rongai each with 70% followed by Black Rongai at 60%preferance. Varieties with lower fodder attributes were DL1002, Eldo-Kt-Cream, Eldo-Kt-Black1 and Eldo-Kt-Black2 at 30% preference. In Kapkarer, all farmers preferred Ngwara Nyeupe, Brown Rongai and Echo-Cream varieties of lablab. Across the three sites, varieties; Echo-Cream 86.7%, Ngwara Nyeupe and Brown Rongai each with 83.3 % were the most preferred varieties.

Table 3. 3: Most preferred lablab varieties for fodder production by farmers in Nandi-South

	Koibem		Kiptaruswo		Kapkarer		Total	
Varieties of Lablab	N=10	%	N=10	%	N=10	%	N=30	%
DL1002	2	20	3	30	0	0	5	16.7
Ngwara-Nyeupe	8	80	7	70	10	100	25	83.3
Echo-Cream	9	90	7	70	10	100	26	86.7
Black Rongai	3	30	6	60	0	0	9	30.0
Eldo-Kt-Cream	3	30	3	30	0	0	6	20.0
Eldo-Kt-Black1	2	20	3	30	0	0	5	16.7
Brown-Rongai	8	80	7	70	10	100	25	83.3
Eldo-Kt-Black2	2	20	3	30	0	0	5	16.7

N= Number of the interviewed farmers

3.4.4 Farmers' perception on suitable methods of on-farm conservation of *lablab purpureus*

Farmer's perception on the most suitable method of on-farm conservation of lablab fodder is shown in Table 3.4. There were difference between sites with 90% of farmers in Koibem preferring silage, while in Kiptaruswo, all the interviewed farmers preferred hay while in Kapkarer, 70% of the respondents preferred silage.

Table 3. 4: Most preferred method of on-farm conservation of lablab fodder in study site

	Koibem		Kiptaruswo		Kapkarer		Total	
Preservation. M	N=10	%	N=10	%	N=10	%	N=30	%
Hay	1	10	10	100	3	30	14	46.7
Silage	9	90	0	0	7	70	16	53.3

N= Number of the interviewed farmers

3.4.5 Aphid severity index of lablab varieties with sites

The aphids' severity index of the eight lablab varieties is shown in Table 3.5. At 28 days after emergence, high severity index was noted in farms within Kiptaruswo and Koibem. The most susceptible variety to aphids within Kiptaruswo was Eldo-Kt-Black2 at 1.6 while lowest severity index was recorded with Ngwara Nyeupe at 0.2. In Koibem high aphids severity index was recorded for DL1002 and Eldo-Kt-Black2 each with 1.5 and 1.6 while lowest with Ngwara Nyeupe 0.7. There were no significant difference in the aphids severity for all varieties between sites.

Table 3. 5: Aphids severity index of different varieties of lablab grown in the study area

Varieties of lablab	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	S E	P Value
Black Rongai	1.2^{ax}	1.1^{ax}	1.1^{abx}	1.1^{abc}	0.1	0.311
Brown Rongai	1.0^{ax}	0.9^{abx}	1.2^{abx}	1.0^{bc}	0.3	0.720
DL1002	1.6^{ax}	1.2^{ax}	1.5^{ax}	1.5^{ab}	0.2	0.429
Echo-Cream	1.2^{ax}	1.2^{ax}	1.1^{abx}	1.2^{ab}	0.1	0.569
Eldo-Kt-Black1	1.6^{ax}	1.1^{ax}	1.2^{abx}	1.3^{ab}	0.1	0.033
Eldo-Kt-Black2	1.6^{ax}	1.6^{ax}	1.5^{abx}	1.6^{a}	0.2	0.804
Eldo-Kt-Cream	1.1^{ax}	1.2^{ax}	1.2^{abx}	1.2^{ab}	0.1	0.834
Ngwara Nyeupe	1.0^{ax}	0.2^{bx}	0.7^{bx}	0.7^{c}	0.4	0.341
Mean	1.3	1.1	1.2	1.2		
SE	0.17	0.16	0.17	0.11		
P Value	0.057	<.001	0.066	<.001		

Eldo- Eldoret, Kt- Kitale, DL- Dry land Variety, ^{abc}Values with different superscripts within column are significantly different ^{xyz}Values with different superscripts within row are significantly different (P<0.05).

3.4.6 Time to maturity for lablab varieties

The days to first flowering and to 50% flowering for the eight lablab varieties is shown in Table 3.6. Both days to first flowering and to 50% flowering significantly differed ($p<0.5$) between varieties both within and between the sites. In Kapkarer site, varieties DL1002, Eldo-Kt-Black1, Eldo-Kt-Cream and Eldo-Kt-Black2 started flowering at 41 days after emergence and attained 50% flowering after 59 to 60 days after emergence. Echo-Cream, Ngwara Nyeupe and Brown Rongai took 52, 62 and 66 days to start flowering and 69, 84 and 87 days to attain 50% flowering. In Kiptaruswo, DL1002, Eldo-Kt-Black1, Eldo-Kt-Cream and Eldo-Kt-Black2 took 44-46 days to start flowering and (58-60 days to attain 50% flowering. Echo-Cream, Ngwara Nyeupe and Brown-Rongai took 57, 68 and 70 days to start flowering and attained 50% flowering after 74, 82 and 89 days. In Koibem, DL1002, Eldo-Kt-Black1, Eldo-Kt-Cream and Eldo-Kt-Black2 took 44-45 days after emergence to start flowering while 59-60 days to reach 50% flowering. Echo-Cream, Ngwara Nyeupe and Brown-Rongai took 57, 67 and 70 days to start flowering and 76, 89 and 91 days to attain 50% flowering respectively. Across the three sites, Black Rongai, DL1002, Eldo-Kt-Black1, Eldo-Kt-Cream and Eldo-KtBlack2 took 43–45 days after emergence to start flowering and 59–60 days to attain 50% flowering. Echo-Cream

variety took 66 days, Ngwara Nyeupe 55 and Brown-Rongai 70 days to start flowering and 73, 85 and 89 days to attain 50% flowering respectively. Except for Black Rongai, days to first flowering differed significantly between the sites. The Lablab varieties started to flower earlier in Kapkarer than within Kiptaruswo and Koibem.

Table 3. 6: Days to first flowering and days to 50% flowering of eight lablab varieties in the study site

Days to 1st Flower		Sites				
Treatments	Kapkarer	Kiptaruswo	Koibem	Mean	S E	P Value
Black Rongai	46^{dx}	45^{cx}	46^{dx}	45^{d}	0.8	0.832
Brown Rongai	66^{az}	70^{ay}	75^{ax}	70^{a}	0.8	<.001
DL1002	41^{ey}	44^{cx}	45^{dx}	43^{d}	0.4	0.002
Echo Cream	52^{cy}	57^{bx}	57^{cx}	55^{c}	0.8	<.001
Eldo-Kt-Black1	41^{ey}	45^{cx}	44^{dx}	43^{d}	0.7	0.008
Eldo-Kt-Black2	41^{ey}	45^{cx}	45^{dx}	44^{d}	0.6	0.001
Eldo-Kt-Cream	41^{ey}	46^{cx}	45^{dx}	44^{d}	0.8	0.009
Ngwara Nyeupe	62^{by}	68^{ax}	67^{bx}	66^{b}	0.7	<.001
Means	48	52	53	51		
S E	0.7	0.8	0.6	0.8		
P Value	<.001	<.001	<.001	<.001		
Days to 50% Flowering		Sites				
Treatments	Kapkarer	Kiptaruswo	Koibem	Mean	S E	P Value
Black Rongai	59^{cx}	60^{cx}	60^{cx}	59^{d}	0.9	0.700
Brown Rongai	87^{ax}	89^{ax}	91^{ax}	89^{a}	1.2	0.104
DL1002	58^{cx}	60^{cx}	60^{cx}	59^{d}	0.9	0.243
Echo Cream	69^{by}	74^{bxy}	76^{bx}	73^{c}	1.9	0.134
Eldo-Kt-Black1	60cx	59^{cx}	60^{cx}	60^{d}	1.2	0.668
Eldo-Kt-Black2	59^{cx}	60^{cx}	59^{cx}	59^{d}	1.4	0.851
Eldo-Kt-Cream	59^{cx}	59^{cx}	60^{cx}	59^{d}	1.2	0.885
Ngwara Nyeupe	84^{ay}	82^{aby}	89^{ax}	85^{b}	1.6	0.056
Means	67	68	69	68		
S E	1.1	1.8	1.1	0.9		
P Value	<.001	<.001	<.001	<.001		

Eldo- Eldoret, Kt- Kitale, DL- Dry land Variety, ^{abc}Values with different superscripts within column are significantly different ^{xyz}Values with different superscripts within row are significantly different (P<0.05).

3.4.7 Biomass production of different varieties of *Lablab purpureus*

Dry matter content and dry matter yield per unit area for various *Lablab purpureus* varieties in different sites is shown in Table 3.7. The dry matter content of the lablab varieties were only significantly ($P<0.05$) different within Kiptaruswo site. High dry matter content in lablab was recorded in Kapkarer with mean of 18.2 g/100g DM and lowest in Koibem with 15.3 g/100g DM. Within Kiptaruswo, varieties with high dry matter content were DL1002 18.3 g/100g DM and Eldo-Kt-Black1 18.2 g/100g. Between the sites, DL1002 recorded high dry matter content in Kapkarer 18.7 than in Koibem 15.1 g/100g. Eldo-Kt-Black1 had high dry matter content in Kapkarer and Kiptaruswo 18.8, 18.2 g/100g compared to Koibem 15.1 g/100g. Eldo-Kt Black 2 recorded high dry matter content within Kapkarer 19.4 g/100g than in Koibem 15.5 g/100g. Eldo-Kt-Cream had high dry matter content in Kapkarer and Kiptaruswo 18.0, 17.7 g/100g than in Koibem 15.2 g/100g.

Dry matter yield of lablab varieties were significantly ($P<0.05$) different both within and between sites. In Kapkarer, high dry matter yield was recorded for varieties Brown Rongai 11.9 t DM/ha and lowest for Echo-Cream 5.0 t DM/ha, Ngwara Nyeupe 6.0 t DM/ha and DL1002 6.1 t DM/ha respectively. Within Kiptaruswo, high dry matter yield was recorded for variety Brown Rongai 10.5 t DM/ha while the rest of the varieties performed averagely. In Koibem high dry matter yield was observed in varieties Brown Rongai 15.4 t DM/ha and Echo-Cream 12.1 t DM/ha, while Eldoret-Kitale-Cream 4.4 t DM/ha, DL1002 4.8 t DM/ha and Eldoret-KitaleBlack2 5.6 t DM/ha recorded the lowest dry matter yield respectively. Across the three sites, Brown Rongai variety had the highest dry matter yield with mean of 12.6 t DM/ha while the rest of the varieties their dry matter yields were intermediate. Between sites, Echo-Cream variety recorded highest dry matter yield of 12.1 t DM/ha in Koibem site than Kapkarer and Kiptaruswo 5.0, 3.9 t DM/ha. Eldo-Kt-Cream had the highest dry matter yield of 9.5 t DM/ha in Kapkarer than between Kiptaruswo 5.2 and Koibem 4.4 t DM/ha. The other varieties had similar dry matter yields between the sites.

Table 3.7: Dry matter content (g/100g) and yields (t/ha) of *Lablab Purpureus* varieties in the study area at 50 % flowering

DM g/100g Lablab varieties	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Black-Rongai	17.9^{ax}	16.7^{abx}	14.8^{ax}	16.5^{a}	11.6	0.154
Brown Rongai	17.3^{ax}	16.5^{abx}	15.9^{ax}	16.6^{a}	7.0	0.474
DL1002	18.7^{ax}	18.3^{axy}	15.1^{ay}	17.4^{a}	7.8	0.012
Echo-Cream	16.8^{ax}	15.7^{abx}	15.4^{ax}	16.0^{a}	5.9	0.277
Eldo-Kt-Black1	18.8^{ax}	18.2^{ax}	15.1^{ay}	17.4^{a}	5.2	0.021
Eldo-Kt Black2	19.4^{ax}	17.7^{abxy}	15.5^{ay}	17.5^{a}	7.1	0.027
Eldo-Kt-Cream	18.0^{ax}	17.7^{abx}	15.2^{ay}	17.0^{a}	4.8	0.005
Ngwara Nyeupe	18.8^{ax}	15.0^{bx}	15.5^{ax}	16.4^{a}	20.4	0.373
Mean	18.2	17.0	15.3.5	16.8		
SE	13.23	6.15	7.13	6.39		
P Value	0.875	0.008	0.971	0.621		
T DM/ha Lablab varieties	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Black-Rongai	8.2^{abx}	6.8^{abx}	8.9^{bcx}	8.0^{b}	1.5	0.722
Brown Rongai	11.9^{ax}	10.5^{ax}	15.4^{ax}	12.6^{a}	2.9	0.414
DL1002	6.1^{bx}	6.0^{abx}	4.8^{cx}	5.6^{b}	0.9	0.585
Echo-Cream	5.0^{by}	3.9^{by}	12.1^{abx}	7.0^{b}	1.3	0.003
Eldo-Kt-Black1	7.6^{abx}	5.6^{bx}	6.4^{bcx}	6.5^{b}	0.9	0.355
Eldo-Kt Black2	7.2^{abx}	7.7^{abx}	5.6^{cx}	6.8^{b}	1.2	0.476
Eldo-Kt-Cream	9.5^{abx}	5.2^{by}	4.4^{cy}	6.3^{b}	1.2	0.026
Ngwara Nyeupe	6.0^{bx}	5.5^{bx}	8.7^{bcx}	6.8^{b}	1.7	0.461
Mean	7.7	6.4	8.3	7.5		
SE	1.87	1.0	1.3	0.97		
P Value	0.263	0.007	<.001	<.001		

Eldo- Eldoret, Kt- Kitale, DL- Dry land Variety, ^{abc}Values with different superscripts within column are significantly different ^{xyz}Values with different superscripts within row are significantly different (P<0.05).

Plate 3. 2: Lablab plot in the study site

3.4.8 Proximate composition of different varieties of *Lablab purpureus*

The crude protein and ash content of different lablab varieties within and between sites is shown in Table 3.8. Crude protein and ash content of lablab varieties varied significantly ($P<0.05$) within and between the sites.

The mean crude protein content was significantly higher in Koibem (23.7 g/100g) and lowest at Kapkarer (20.2 g/100g). Within Kapkarer, variety Eldo-Kt-Black2 had the highest CP (22.0 g/100g) and Eldo-Kt-Black1 lowest (18.6 g/100g). In Kiptaruswo, highest CP was recorded for DL1002 26.3 g/100g and lowest for Brown Rongai 18.0 g/100g while in Koibem site, Eldo-Kt Cream variety had the highest crude protein of (26.5 g/100g) and Echo-Cream variety the lowest (20.0 g/100g).

Between the sites, Black-Rongai had the highest CP in Koibem (25.6) compared to Kapkarer (21.2) and Kiptaruswo (24.1 g/100g). Variety DL1002 had the highest CP (26.3) in Kiptaruswo compared to Kapkarer (18.7 and Koibem (23.1 g/100g). Eldo-Kt-Black1 had higher CP of 24.7 and 22.6 g/100g in Koibem and Kiptaruswo compared to Kapkarer at 18.6 g/100g. Eldo-Kt-Black2 had the highest CP in Koibem (25.8 g/100g) than in Kapkarer (22.0) and Kiptaruswo

(20.9 g/100g) while Eldo-Kt-Cream recorded the highest CP content of (26.5 g/100g) in Koibem compared to Kapkarer (21.7) and Kiptaruswo (23.6 g/100g). The other varieties showed no significant difference in CP content between the sites. Across the three sites, Eldo-Kt-Cream (23.9 g/100g) and Black-Rongai (23.7 g/100g) had the highest average crude protein content while lowest CP was recorded with Brown Rongai (19.6 g/100g) and Echo-Cream variety with 20.0 g/100g.

The ash content significantly ($P < 0.05$) differed between the varieties of lablab within the three sites. Eldo-Kt-Cream had highest ash content (11.6 g/100g) and 9.0 g/100g in Kapkarer and Koibem sites while Brown-Rongai had the lowest in Kapkarer (7.2 g/kg) and Kiptaruswo 6.2 g/100g sites respectively. In Koibem site, high ash content was recorded for Eldo-Kt-Black1 (10.1 g/100g) and Eldo-Kt-Black2 (9.7 g/100g) with Echo-Cream variety (7.4 g/100g) and Ngwara-Nyeupe (7.5 g/100) having the lowest. Between the sites, only Eldo-Kt-Black1 had a higher ash content of (10.1 g/100g) within Koibem compared to Kapkarer (9.4 g/100g) and Kiptaruswo (8.5 g/100g). In general, high ash content was recorded with Eldo-Kt-Cream (9.9 g/100g) and lowest with Brown-Rongai variety (7.2 g/100g) across the three sites.

Table 3. 8: Crude protein (DM) and ash content (DM) (g/100g) of *Lablab Purpureus* varieties at 50 % flowering

Varieties of lablab	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Crude Protein						
Black-Rongai	21.2^{abcy}	24.1^{abxy}	25.6^{abx}	23.7^{a}	1.0	0.013
Brown Rongai	19.3^{abcx}	18.0^{cx}	21.4^{bcx}	19.6^{b}	1.1	0.111
DL1002	18.7^{bcy}	26.3^{ax}	23.1^{abcx}	22.7^{ab}	0.7	<.001
Echo-Cream	19.6^{abcx}	20.5^{bcx}	20.0^{cx}	20.0^{b}	1.3	0.895
Eldo-Kt-Black1	18.6^{cy}	22.6^{abx}	24.7^{abcx}	22.0^{ab}	0.9	0.004
Eldo-Kt-Black2	22.0^{ay}	20.9^{bcy}	25.8^{abx}	22.9^{ab}	1.1	0.011
Eldo-Kt-Cream	21.7^{aby}	23.6^{abxy}	26.5^{ax}	23.9^{a}	1.2	0.028
Ngwara Nyeupe	20.6^{abcx}	20.2^{bcx}	22.5^{abcx}	21.1^{ab}	1.0	0.219
Mean	20.2	22.0	23.7	22.0		
SE	1.02	0.92	1.04	0.79		
P Value	0.159	<.001	0.002	<.001		

Varieties of lablab	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Ash content						
Black Rongai	8.7^{abx}	8.9^{abx}	8.7^{abx}	8.8^{abc}	0.51	0.940
Brown Rongai	7.2^{bx}	6.6^{bx}	7.9^{abx}	7.2^{c}	0.65	0.087
DL1002	9.2^{abx}	8.5^{abx}	9.0^{abx}	8.8^{abc}	0.77	0.723
Echo Cream	8.0^{abx}	8.1^{abx}	7.4^{bx}	7.8^{bc}	0.48	0.740
Eldo-Kt-Black1	9.4^{abxy}	8.5^{aby}	10.1^{ax}	9.3^{ab}	0.27	0.089
Eldo-Kt-Black2	10.1^{abx}	7.8^{abx}	9.7^{ax}	9.2^{ab}	0.35	0.138
Eldo-Kt-Cream	11.6^{ax}	9.0^{ax}	9.2^{abx}	9.9^{a}	0.99	0.233
Ngwara Nyeupe	8.4^{abx}	8.6^{abx}	7.5^{bx}	8.1^{bc}	0.66	0.366
Mean	9.1	8.2	8.7	8.7		
SE	0.83	0.49	0.46	0.39		
P Value	0.038	0.05	0.003	<.001		

Eldo- Eldoret, Kt- Kitale, DL- Dry land Variety, ^{abc}Values with different superscripts within column are significantly different ^{xyz}Values with different superscripts within row are significantly different (P<0.05).

3.4.9 Fibre fraction of eight selected *Lablab purpureus* varieties

The fibre fractions of the eight *Lablab purpureus* varieties are shown in Table 3.9. The fibre fractions differed significantly (P<0.05) within and between the sites. High neutral detergent fibre (51.4 g/100g) was recorded in Kapkarer and lowest in Koibem at 42.9 g/100g.

Within Kapkarer, Eldo-Kt-Black2 variety had the highest NDF of 55.5 g/100g while other varieties ranged between 48.5 and 53.2 g/100g. In Kiptaruswo, Brown-Rongai had the highest NDF content of 49.4 g/100g while Black-Rongai and Eldo-Kt-Black1 had the lowest of 43.2 and 43.8 g/100g respectively. In Koibem, DL1002 variety had the highest NDF of 47.0 g/100g while lowest was recorded for varieties Echo Cream (40.4 g/100g) and Black-Rongai (40.4 g/100g) respectively. The mean NDF content of all the varieties varied significantly between sites except DL1002 that had similar NDF content within the three sites. Across the three sites, highest NDF was recorded for DL1002 (48.6 g/100g) and lowest for Black-Rongai (44.4 g/100g).

Eldo-Kt-Black2 had the highest ADF at 42.1 g/100g in Kapkarer while lowest was Eldo-Kt-Black1 (28.5 g/100g). In Kiptaruswo, highest ADF was recorded with Eldo-Kt-Cream (37.0 g/100g) with lowest with Black Rongai (28.7 g/100g). Within Koibem site, high ADF was recorded with Black Rongai variety (45.4 g/100g) and lowest with Eldo-Kt-Cream (24.4 g/100g). Between the sites, all the varieties except DL1002 and Ngwara Nyeupe had significant variations in ADF content. Across the three sites, high ADF was recorded with Eldo-Kt-Black2 variety (35.9 g/100g) while lowest recorded with Eldoret-Kitale-Cream at 31.6 g/100g.

In Kapkarer, high acid detergent lignin (ADL) was recorded for Eldo-Kt-Cream (13.3 g/100g) and DL1002 (12.7 g/100g) varieties with lowest for Eldo-Kt-Black1 (7.3 g/100g). In Kiptaruswo no significant variation was observed in ADL content among the different varieties. Within Koibem, Eldo-Kt-Black1 had the highest ADL (12.1 g/100g) with Echo-Cream having the lowest at 7.0 g/100g. Between the sites, Eldo-Kt-Black1 had the highest ADL in Koibem (12.1 g/100g) and Kiptaruswo (10.0 g/100g) compared to 7.3 g/100g in Kapkarer. Eldo-Kt-Cream had a significantly higher ADL in Kapkarer (13.3 g/100) compared to Koibem 10.1 g/100g. In general, Eldo-Kt-Cream had the highest mean ADL (11.9 g/100g) while lowest recorded with Echo Cream at 9.0 g/100g across the three sites.

Table 3. 9: Fibre fractions DM (g/100g) of *Lablab purpureus* varieties in study sites at 50 % flowering

Varieties of lablab	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Neutral detergent fibre						
Black Rongai	49.5^{bx}	43.2^{by}	40.4^{cy}	44.4^{b}	0.97	<.001
Brown Rongai	53.2^{abx}	49.4^{ax}	41.1^{cy}	47.9^{ab}	0.94	<.001
DL1002	52.2^{abx}	46.7^{abx}	47.0^{ax}	48.6^{a}	2.13	0.190
Echo Cream	49.5^{bx}	45.1^{abxy}	40.4^{cy}	45.0^{ab}	1.23	0.002
Eldo-Kt-Black1	50.0^{bx}	43.8^{by}	45.9^{abxy}	46.6^{ab}	1.66	0.060
Eldo-Kt-Black2	55.5^{ax}	46.1^{aby}	43.3^{bcy}	48.3^{ab}	1.99	0.009
Eldo-Kt-Cream	53.0^{abx}	46.1^{aby}	41.4^{cz}	46.8^{ab}	0.55	<.001
Ngwara Nyeupe	48.5^{bx}	44.6^{abxy}	43.6^{abcy}	45.5^{ab}	0.93	0.012
Mean	51.4	45.6	42.9	46.6		
SE	1.62	1.85	0.77	1.48		
P Value	0.072	0.393	<.001	<.001		

Varieties of lablab	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Acid detergent fibre						
Black Rongai	33.0^{bcy}	28.7^{cy}	45.4^{ax}	35.7^{ab}	1.8	<.001
Brown Rongai	34.4^{bx}	36.2^{abx}	28.3^{bcy}	33.0^{ab}	1.2	0.040
DL1002	33.8^{bcx}	30.1^{cx}	34.4^{bx}	32.8^{ab}	1.7	0.185
Echo Cream	32.4^{bcy}	29.4^{dy}	41.8^{ax}	34.5^{ab}	1.1	0.002
Eldo-Kt-Black1	28.5^{cy}	34.6^{abx}	33.4^{bx}	32.2^{ab}	1.3	0.070
Eldo-Kt-Black2	42.1^{ax}	35.1^{aby}	30.4^{bcz}	35.9^{a}	0.8	<.001
Eldo-Kt-Cream	33.4^{bcx}	37.0^{ax}	24.4^{cy}	31.6^{b}	0.9	<.001
Ngwara Nyeupe	33.5^{bcx}	31.2^{bx}	33.7^{bx}	32.8^{ab}	1.0	0.134
Mean	33.9	32.8	34	33.6		
SE	1.17	1.92	1.49	1.51		
P Value	<.001	0.026	<.001	<.001		

Acid detergent lignin						
Black Rongai	9.8^{abx}	9.1^{ax}	9.8^{abx}	9.6^{ab}	1.15	0.881
Brown Rongai	9.3^{abx}	9.7^{ax}	11.2^{abx}	10.1^{ab}	0.76	0.295
DL1002	12.7^{ax}	11.6^{ax}	10.8^{abx}	11.7^{a}	1.18	0.551
Echo Cream	9.6^{abx}	9.5^{ax}	8.0^{bx}	9.0^{b}	0.68	0.217
Eldo-Kt-Black1	7.3^{by}	10.0^{ax}	12.1^{ax}	9.8^{ab}	0.75	0.006
Eldo-Kt-Black2	11.3^{abx}	12.2^{ax}	11.1^{abx}	11.5^{a}	0.37	0.295
Eldo-Kt-Cream	13.3^{ax}	12.2^{axy}	10.1^{aby}	11.9^{a}	0.92	0.114
Ngwara Nyeupe	11.1^{abx}	10.6^{ax}	10.1^{abx}	10.6^{ab}	0.6	0.503
Mean	10.6	10.6	10.4	10.5		
SE	0.88	1.05	0.74	0.88		
P Value	0.002	0.251	0.033	0.001		

Eldo- Eldoret, Kt- Kitale, DL- Dry land Variety, ^{abc}Values with different superscripts within column are significantly different ^{xyz}Values with different superscripts within row are significantly different (P<0.05).

3.4.10 *Invitro* dry matter digestibility of different lablab varieties

Invitro dry matter digestibility (IVDMD) of the *Lablab purpureus* varieties is shown in Table 3.10. The IVDMD of lablab varieties differed significantly (P ≤0.05) both within and between the sites. Of the three sites, high mean (IVDMD) 73.4 g/100g was observed with those established at Koibem site as opposed to Kapkarer 69.6 g/100g and Kiptaruswo 69.7 g/100g sites. Within Kapkarer site, there was no significant varietal difference in IVDMD as opposed to Kiptaruswo site where high dry matter digestibility was recorded for Eldo-Kt-Cream (76.3 g/100g) and Black-Rongai variety (75.3 g/100g) and lowest recorded for Eldo-Kt-Black2 (59.6 g/100g). In Koibem, Eldo-Kt-Cream and Black Rongai variety had highest IVDMD of 80.4 g/100g and 79.4 g/100g while lowest was DL1002 (61.4 g/100g) and Ngwara Nyeupe at 65.4 g/100g.

Between the sites, all the varieties varied significantly in IVDMD from site to site except EldoKt-Black1 that was high in Koibem but the difference was not statistically significant across sites. Across the three sites, Eldo-Kt-Cream (75.7 g/100g) and Black Rongai (74.4 g/100g) had the highest mean IVDMD while DL1002 (67.6 g/100g), Brown Rongai (67.8 g/100g) and Ngwara Nyeupe (68.5 g/100g) had the lowest.

Table 3. 10: Invitro-dry matter digestibility DM (g/100g) of Lablab varieties grown in the study area at 50 % flowering

Varieties of lablab	Sites					
	Kapkarer	Kiptaruswo	Koibem	Mean	SE	P Value
Black Rongai	68.6^{az}	75.3^{ay}	79.4^{abx}	74.4^{ab}	0.64	<.001
Brown Rongai	69.4^{ay}	60.5^{bcz}	73.7^{bx}	67.8^{b}	0.97	<.001
DL1002	69.2^{ax}	72.1^{ax}	61.4^{cy}	67.6^{b}	1.67	0.002
Echo Cream	68.6^{ay}	71.7^{ay}	76.5^{abx}	72.3^{ab}	1.09	0.001
Eldo-Kt-Black1	68.3^{ax}	71.2^{ax}	74.8^{abx}	71.4^{ab}	2.13	0.354
Eldo-Kt-Black2	72.5^{ax}	59.6^{cy}	75.8^{abx}	69.3^{ab}	2.15	<.001
Eldo-Kt-Cream	70.3^{az}	76.3^{axy}	80.4^{ax}	75.7^{a}	1.54	0.003
Ngwara Nyeupe	69.6^{axy}	70.6^{abx}	65.4^{cy}	68.5^{b}	1.36	0.028
Mean	69.6	69.7	73.4	70.9		
SE	1.58	2.22	1.2	1.62		
P Value	0.663	<.001	<.001	0.002		

Eldo- Eldoret, Kt- Kitale, DL- Dry land Variety, ^{abc}Values with different superscripts within column are significantly different ^{xyz}Values with different superscripts within row are significantly different (P<0.05).

3.4.11 Nutrient composition of lablab fodder harvested at two stages of growth

The nutrient composition of three lablab varieties harvested at two different growth stages is shown in Table 3.11. The three varieties differed significantly (P ≤0.05) in their DM and CP content at different growth stages. The other chemical composition were not affected by the two harvesting stages. The dry matter content of Black Rongai and Eldo-Kt-Black2 increased by 4.8 and 4.9 g/100g from flowering stage to seed stage. There was no difference in DM content for Brown Rongai variety between the two harvesting stages. The CP content of Black Rongai decreased by 4.6 g/100g from flowering stage to seed stage while the rest of the varieties CP content were not affected by the two stages of harvesting.

Table 3. 11: Nutrient composition DM of lablab varieties (g/100g) harvested at different stages of growth

Chemical Composition	Growth stages					
	Varieties of lablab	Flowering stage	Seed stage	Mean	SE	P value
DM	Black Rongai	16.2[b]	21.0[a]	18.6	8.0	0.013
	Brown Rongai	16.9[a]	20.5[a]	18.6	14.6	0.146
	Eldo-Kt-Black 2	16.1[a]	21.0[b]	18.6	8.5	0.016
CP	Black Rongai	24.6[a]	20.0[b]	22.3	0.69	0.009
	Brown Rongai	19.2[a]	17.0[a]	18.1	1.58	0.381
	Eldo-Kt-Black 2	24.0[a]	20.8[a]	22.4	1.06	0.098
Ash	Black Rongai	8.7[a]	8.5[a]	8.6	0.43	0.753
	Brown Rongai	7.4[a]	8.1[a]	7.8	1.02	0.68
	Eldo-Kt-Black 2	10.4[a]	9.0[a]	9.7	0.88	0.346
NDF	Black Rongai	45.3[a]	48.7[a]	47.0	2.13	0.329
	Brown Rongai	46.7[a]	52.7[a]	49.7	1.84	0.081
	Eldo-Kt-Black 2	43.7[a]	49.4[a]	46.6	2.59	0.194
ADF	Black Rongai	39.5[a]	37.1[a]	38.3	2.69	0.569
	Brown Rongai	34.4[a]	35.8[a]	35.1	0.73	0.247
	Eldo-Kt-Black 2	33.6[a]	35.8[a]	34.7	2.6	0.583
ADL	Black Rongai	8.9[a]	10.6[a]	9.8	1.31	0.419
	Brown Rongai	11.9[a]	11.9[a]	11.9	0.47	0.994
	Eldo-Kt-Black 2	11.6[a]	10.5[a]	11.0	0.53	0.222
IVDMD	Black Rongai	73.9[a]	66.2[a]	70.0	3.62	0.207
	Brown Rongai	68.3[a]	63.2[a]	65.7	3.7	0.391
	Eldo-Kt-Black 2	70.9[a]	67.6[a]	69.2	3.27	0.517

Eldo- Eldoret, Kt- Kitale, row means with different superscripts are significantly different (P ≤0.05).

3.5 DISCUSSION

3.5.1 Types of fodder used by small scale farmers in Nandi-south sub-county.

The commonly used fodder types by the small-scale farmers in Nandi-south sub-county were all grown locally. Grazing livestock on natural pastures was practiced by all the farmers and this can be attributed to being readily available and cheap compared to other fodder types. Napier grass was the most common grown fodder due to high awareness of its dry matter yield by farmers. Maize was grown by all farmers thus explaining the availability of stover in almost all the farms. *Lablab purpureus* fodder was rarely used in the study area and this was attributed to its being grown as human food rather than for animal feed. Only six farms used locally made hay from Boma Rhodes grass to feed their livestock as majority of the respondents were not aware that

could be preserved as hay. Livestock feeds are categorized as natural pasture, crop residues, enriched pasture and forage, agro-industrial by products, other by-products such as vegetable refusals, the first two contributing the largest portion of feed (Jimma *et al.,* 2016). The main coping strategy for small scale livestock keepers during the time of feed scarcity is changing feed resources based on cost and availability (Nyaata *et al*., 2000 and Katongole *et al*., 2012) When smallholder farmers in developing countries are encountered with shortage of good quality feed resources for their livestock, they adapt by using locally available materials (Jayasuriya, 2002). Farmers in the study area adapted in a similar way. Heavy reliance on natural pastures and crop residues by farmers has been reported (Rao and Hall, 2003 and Syomit *et al*., 2011). This has been reported with low livestock productivity in return due to use of low quality feeds with nearly 2.4 MCal/kg DM of energy and 5.6 g/100g CP that are deficient in protein content (Negesse *et al*., 2009; Hassan et al., 2014). To overcome this challenge, growing and use of multipurpose legumes as supplement to low quality forages such as natural grasses and crop residues in the study area is one of the best technology that local farmers should embrace to improve their livestock productivity at a low cost (Speranza, 2010; Syomiti et al 2011).

3.5.2 Farmers' perception on physical attributes of good fodder plants

The most common physical attributes of good fodder plants that were given by local farmers were bushy growth characteristics, smooth surface leaves and early maturity. Ball *et al*., (2001) reported leafiness as an important feature of a fodder plant noting that the higher the leaf content, the higher the quality of the forage especially in terms of CP content and digestibility. They noted that texture was also an attribute of good fodder plant because it could determine the rate at which animals select forages as smooth leaf surface forage plants are selected mostly by animals than rough leaf surface plants due to high palatability. Dubey *et al.,* (1995) reported that the fodder yields of oats can be increased with plants having higher plant height, more plant leaves and greater leaf area. In this study, few farmers preferred creeping plants which were regarded as having less fodder. In pigeon pea and chickpea, high biomass yield of foliage was reported to correlate with the number of primary and secondary branches and plant height (Bhatia et al., 1993; Paul et al., 1996). This may explain why farmers chose bushy plants due to higher biomass yields. Fast growth and high foliage biomass production have been used to promote Calliandra (Tuwei *et al.*, 2003). In this study, farmers from Kapkarer and Kiptaruswo

preferred plants with high growth rate and early maturity aside Koibem farmers who preferred late maturity due to provision fodder during dry season when other fodder plants have dried off.

3.5.3 Farmers' perception on lablab varieties with good attributes of fodder plant

Brown Rongai, Ngwara Nyeupe and Echo-Cream varieties were selected as possessing the best qualities for a fodder plant. Their ranking was based on the earlier mentioned attributes of a good fodder plant. These varieties were among the late maturing thus took longer before flowering, accumulated more foliage and more branches resulting in higher biomass yields. Brown-Rongai was also preferred in the study area due to its regrowth several times after harvest, high foliage accumulation tolerance to aphids attack, tolerant to drought, well adapted to the area of study and good seeder. The same agronomic features were also noticed with varieties Ngwara Nyeupe and Echo-Cream. Jain and Patel, (2013) noted that the most desirable agronomic features of fodder plant were ease of establishment, be more competitive and suppress weeds by high biomass accumulation, persistent productive after several cutting, well adapted to the climatic conditions and edaphic factors within which is established, be resistant to pests and diseases and should be of high palatability. Similar features of fodder plant was also reported by Rao and Hall, (2003) and Nouman *et al.* (2014).

3.5.4 Farmers' perception on suitable methods of on-farm conservation of lablab.

After having conserved lablab as hay and silage, majority of the farmers preferred conserving lablab as silage. Conservation as hay was not preferred due to high leaf loss through shattering during drying. In some instances, what remained after drying were dried stems with few leaves. This was as opposed to ensilage where the conserved material was leafy as long as wilting was under shade. Leaf loss through wilting has been reported by Ball *et al.* (2001) especially in legumes wilted for hay making leading to low quality fodder.

3.5.5 Aphids severity index for *Lablab purpureus* varieties

The scale by Nagrare *et al.,* (2009) of 0-4 was used to rate aphid severity index and infestation as follows: Grade 0: No aphids appearance on the whole plant. Grade 1: Scattered appearance of few aphids on the plant. Grade 2: Severe infestation of aphids on any one branch of the plant. Grade 3: Severe infestation of aphids on more than one branch or a half portion of the plant. Grade 4: Severe aphids over the whole plant. Severity index was calculated as follows; Severity

index (SI) = Sum of total grade points (1-4 infestation grade G-I to G-IV, respectively) of the infested plants/Total number of infested plants observed.

The mean aphids severity index for the eight lablab varieties ranged from 1.1 to 1.3 respectively. The variation in aphids severity in lablab plants has been associated with the water content in the plant foliage at early growth stages (Mondal *et al*., 2017). They noted that lablab varieties with high water content in foliage were typically those with high growth rate and were prone to aphids due to easy sucking of plant sap. In a study by Singh and Sinhal, (2011) on effects of aphids on nutrient composition of mustard (Brassica juncea) plant revealed that aphids reduced the protein content from the leaves by 7.0 % at the age of 70 days and by 5.7% at the age of 130 days. The author reported that with age, the structural carbohydrates of legume plant increases within the leaves reducing the rate at which aphids sucks the protein content in leaves. The study that was carried out by Ahmed *et al.* (2019) and Amin *et al*. (2020) effects of aphids on lablab plant indicated that, aphids infestation on lablab plant caused herbage yield reduction by reducing the number of branches and causing stunted growth. The affected plants mostly suffers from withering and general yield reduction such as; leaf yellowing and curling, decline of leaf canopy, fresh shoot and dry weight that eventually affects forage utilization by livestock (Ahmed *et al*., 2019 and Amin *et al*., 2020).

High aphid severity has been reported to be related to cloudy sky, high relative humidity and dew point with low rainfall being associated with reduction (Hasan *et al*., 2009). The differences in climatic conditions might have caused variations in aphids severity among the varieties in different sites. Mondal *et al*. (2017) reported that legume plants grown in cool weather conditions were prone to aphids attack more than those grown in warm weather conditions. Omondi *et al* (2011) reported the following temperature range within the three sites of Nandi south; Koibem 18^0C, Kiptaruswo 20^0C and Kapkarer 22^0C respectively and these variations in temperature could be the cause of aphids severity difference between Koibem and Kiptaruswo sites. Therefore, high aphids severity index in Kapkarer site (1.3) was due to cool humid climate that was experienced during the time if establishment that favored aphids survival.

Mondal *et al*., (2017) observed that the flower petal color was a key factor in determining the susceptibility of lablab to aphids. They reported that lablab with pink color flower petal were the most susceptible varieties to aphids while one with white/light cream color petal were more

resistant. This finding concurred with the results from this study where varieties DL1002, EldoKt-Black1, Black Rongai and Eldo-Kt-Black2 with pink flowered petals were more susceptible to aphids. Brown Rongai, Ngwara Nyeupe, Eldo-Kt-Cream and Echo Cream with white/light cream flower petals were more tolerant varieties. The difference in aphids severity index could also be due to genetic resistance of some of the lablab varieties as Brown-Rongai and Ngwara Nyeupe varieties were tolerant to aphids compared to DL1002 and Eldo-Kt-Black2.

3.5.6 Days to first and to 50% flowering for different varieties

The varieties of lablab differed in their time to maturity and were categorized into three groups.

Early maturity were DL1002, Eldo-Kt-Black1, Eldo-Kt-Cream, Black Rongai and Eldo-KtBlack2 which started flowering at 40-45 days after emergence and attained 50% flowering at 55-60 days after emergence. The medium maturity was Echo-Cream which started flowering at 50-60 days after emergence and attained 50% flowering at 65-75days after emergence. The late maturity varieties were Ngwara Nyeupe and Brown-Rongai which started flowering at 65-75 days after emergence and attained 50% flowering by 80-90 days after emergence. Significant variation in days to 50% flowering of varieties of lablab ranging from 57-115 days after emergence has been reported (Chattopadhyay and Dutta, 2010). Arup-Barua *et al.,* (2014) in their study reported some of the lablab varieties started flowering at 6 weeks after emergence. In this study, days to 50% flowering for all varieties of lablab were within the range reported by the two authors.

Asaduzzaman *et al.,* (2015) concluded that variations between days to 50% flowering among lablab varieties were due to genetic differences which could apply to the results in this study. In another study by Parmar *et al*., (2013), they reported that days to 50% flowering for legume was not affected by the environment in which the plants were grown. Karmegam and Daniel (2008) reported an increase in growth rate of lablab with increased soil fertility. Despite Koibem site being more fertile than both Kapkarer and Kiptaruswo sites, there was no difference between sites. The difference in soil fertility between the three sites might have been too small to cause the variations in days to 50% flowering of lablab varieties. Days to 50% flowering is very important in determining the quality of any forage plant. In most cases, the nutrient content of forage plant decline as plant matures beyond flowering stage. At 50% flowering, the nutrient

content of forage plant especially crude protein and digestibility is at its optimal level beyond which they start declining with maturity (McDonald *et al.*, 1991).

3.5.7 Dry matter content and biomass yield for different *Lablab purpureus* varieties

Dry matter content of fresh lablab fodder harvested at 50% flowering in this study ranged from 16.5 to 17.6 g/100g across the three sites. These results were in agreement with those reported by other authors for different varieties of lablab with DM content ranging from 17-18.8 g/100g (Hossain *et al.*, 2016; Ngongoni *et al*., 2008 and Mbuthia *et al.*, 2003). However, higher DM content of the whole lablab plant harvested at 50% flowering ranging from 23-30 g/100g has been reported (Ajayi *et al*., 2009; Okpeze *et al.*, 2007 and Fasae *et al.*, 2010).

In this study, high DM content was associated with early maturity varieties such as DL1002, Eldo-Kt-Black 1 and 2 and Eldo-Kt-Cream. Difference in dry matter content among the varieties of lablab in this study with those in literature could be attributed to genetic differences among the lablab varieties and time of harvesting. The sites variation in dry matter content of lablab varieties was attributed to difference in climatic conditions as was reported by Omondi *et al.* (2011) and Landon, (2014). In their study Kapkarer site had a high temperature of 22^{o}C that could have caused high dry matter content in lablab varieties compared to Koibem site with temperature of 18^{o}C.

Biomass yield is one of the key attributes of good fodder plant. The dry matter yield ranged from 5.6 to 12.6 t DM/ha in the three sites. The higher mean dry matter yield of 12.6, 8.0 and 7.0 t DM/ha was recorded with Brown-Rongai, Black Rongai and Echo Cream lablab varieties across the three sites. These varieties exhibited bushy growth characteristics with more foliage branches that contributed to higher dry matter yields per unit area. The lower yield was observed for varieties DL1002 (5.6 t DM/ha) and Eldo-Kt-Cream (6.3 t DM/ha) in this study. These varieties exhibited early flowering (40-45 days after emergence), had no bushy growth characteristics and had fewer branches thus minimal foliage. Biomass yield results from this study concurred with 5.7-6.1 t DM /ha reported earlier (Jingura *et al.*, 2001; Amole *et al.*, 2013). However the yields were higher than 4 t DM/ha reported by Hassan *et al.*, (2014). The differences in biomass yield in this study could be due to genetic variations among the varieties of lablab or difference in rainfall distribution and soil fertility within the three sites (Omondi, *et al*., 2011).

These variations could also be attributed to different soil characteristics within the three sites where some varieties did well in the sandy loam soils in Kapkarer unlike in Kiptaruswo and Koibem that had loam clay soils (Omondi, *et al* 2011). Omondi *et al.* (2011) and Landon, (2014) during their earlier study reported that, Koibem site had high fertile soils compared to Kiptaruswo with medium soils and Kapkarer with low fertile soils. As such, the high biomass yields per unit area in Koibem could be attributed to high fertile soils that supported robust growth of lablab.

The biomass yield of lablab varieties in this study was comparable to other high protein forages. *Moringa olifera* was reported to yield between 4.2 and 8.3 t DM/ha with CP content of 21.8 g/100g under favorable environmental conditions and L. leucocephala with biomass of between 4 and 5 t DM/ha (Oliveira et al. 1999; Sanchez et al. 2006; Tiemann et al., 2008).

3.5.8 Proximate composition of different varieties of *Lablab purpureus*

The crude protein content of the eight varieties used in this study ranged from 18.0 to 26.5 g/100g.

This was in agreement with results from other studies where the whole lablab plant harvested at 50% flowering had CP ranging from 18-23 g/100g (Okpeze *et al*., 2007; Fasae *et al*., 2010 and Amole *et al*., 2013). Lower CP content of lablab has also been reported in various studies ranging from 15-17 g/100g (Ahmad *et al* ., 2000; Jingura *et al*.,2001; Mbuthia *et al*., 2003; Njarui *et al*.,2003 and Mapiye *et al*., 2007). These variations in CP among the varieties of lablab could be due to variations in fibre fractions that lead to decline in cell contents. The drop in CP content of the forage at late harvesting might be due to the accumulation of structural carbohydrates of forages harvested late (Nworgu and Ajayi, 2005). This confirms the Brown Rongai variety in this study that was late maturing variety. The protein content of lablab forage in this study was comparable to other legumes like red clover fodder (17.99-22.58 g/100g), M. sativa (18-20 g/100) and whole cowpea plant (18.78 to 20.22 g/100g) (Carlier *et al*., 2008; Călina and Călina, 2015, Hasan et al., 2010). However the CP content in this study was higher than other legumes like Clitoria (*Clitoria ternata lav*) and Lubia at 17.0g/100 (Mohamedl and Abusuwara, 1996). In addition, some of the lablab varieties in this study had higher protein content compared to other legumes such as cow peas (19.6) and Cluster bean (19.43) g/100g (Iqbal et al., 2012).

The variations of crude protein content among the varieties of lablab and others in literature was attributed to difference in lablab genotypes that were used and soil fertility from different experimental sites. Koibem soils were reported to have higher %N content of 0.38 as opposed to Kapkarer with %N of 0.16 and Kiptaruswo % N of 0.26 (Omondi., *et al* 2011, Landon, 2014). Zamfir *et al.,* (2001) and Zaki (1999) reported an increase of dry matter yield and crude protein content of fodder plants with increase of soil nitrogen content.

The ash content ranged from 7.2 to 9.9 g/100g for the lablab varieties in this study. These results were within the range reported by various authors (Jingura *et al.,* 2001; Njarui *et al*., 2003 and Okpeze *et al.,* 2007). Ash encompasses all inorganic matter (inclusive of mineral matter) in the feeds, as well as inorganic impurities, such as soil, sand or dirt. The major essential minerals in ash fraction of forage are Ca, P, K and Mg (Bahadur et al., 2011). The average ash content in legumes was reported by Hoffman, (2005) to be 9.0 g/100g on DM basis while legume grass forages with ash content between 10-18 g/100g were likely to be contaminated with soils. Low ash content was noted among the late flowering lablab varieties; Brown Rongai, Ngwara Nyeupe and Echo-Cream in this study. The difference in ash content among the varieties can be attributed to difference in growth rate, which could be due to ash reduction naturally as dry matter increases surpasses mineral uptake as the forages mature (Amole *et al.,* 2013).

3.5.9 Fibre fraction composition of eight *Lablab purpureus* varieties

The neutral detergent fibre (NDF) content of the eight lablab varieties in this study ranged from 44.4 and 48.6 g/100g for the three sites. Similar NDF content of 45-48 g/100g has been reported by others (Jingura *et al.,* 2001; Njarui *et al.,* 2003 and Fasae *et al.,* 2010). However, lower NDF content of 40.09 and 39.0 g/100g for the whole lablab plant was reported by Ahmad *et al*., (2000) and Mbuthia *et al*., (2003). The whole fiber content of fodder is confined in the cell walls as NDF and gives the best approximation of the entire fiber content of a feed. Neutral detergent fibre value is negatively associated with feed intake, increase in NDF leads to reduced feed consumption (Garcia *et al.,* 2003). The ideal NDF content of the forage consumed by ruminant ranges from 30 to 60 g/100g on a DM basis (Ruddell *et al.,* 2002).

Fiber digestibility varies amongst legumes and swards harvested at similar stage of maturity and even for the same species established under diverse weather conditions (Garcia *et al.,* 2003). Decline in digestible NDF are typically a reflection of higher lignin content in the NDF fraction

(Garcia *et al.,* 2003). The variation in NDF content of the lablab varieties in this study could be related to physiological variations that occurred as plant matures, that lead to a decline in cell cytoplasm that is extremely soluble constituents (cell contents), caused by an increase in cell wall fibre fractions (Ruddell *et al.,* 2002). This was observed with Brown-Rongai, one of the late flowering lablab varieties.

The site variations in NDF content of lablab could be due to variation in soil fertility between the sites. In a study by Turk, (2010) fertile soils increased the forage dry matter yield and crude protein content which resulted in reduction of NDF and ADF content. This observation concurred with the results of NDF content of lablab varieties in between the sites in this study, Koibem site with high fertile soils had lablab with lower NDF content compared to Kapkarer site.

The acid detergent fibre (ADF) content of the lablab varieties in this study ranged from 31.6 to 35.7 g/100g. These values were in agreement with 33-35 g/100g reported earlier by several authors (Jingura *et al.,* 2001; Njarui *et al*., 2003; Mapiye *et al.,* 2007; and Fasae *et al*., 2010). Lower ADF content of 25-28 g/100g in lablab fodder were also reported (Ahmad *et al*., 2000 and Mbuthia *et al.,* 2003). Acid detergent fibre is an indication of the amount of cellulose and lignin in forage. It is normally negatively associated with digestibility, high ADF leads to lower digestibility. A standard range of ADF in feed was reported to be between 25 to 45 percent on a DM basis (Ruddell *et al.,* 2002). The higher the ADF content, the less digestible and the lower the energy of a feed (Garcia *et al*., 2003). The high ADF content of some varieties in this study was associated with early flowering variety such as Eldo-Kt-Black2 compared with the rest of the varieties. The difference in ADF content among the varieties of lablab could also be due to genetic variation. Acid detergent fibre has been broadly used as an indicator of the energy value of forages because the fraction of lignin, that is indigestible, is greater in ADF than in NDF (Robinson and Putnam, 1998).

The lignin content of the lablab varieties ranged from 9.0 to 11.9 g/100g in this study. These results were within the range of 6.3 to 13.7 g/100g reported by several authors (Ahmad *et al.,* 2000; Njarui *et al*., 2003; Fasae *et al*., 2010; Fasae *et al*., 2010). The lignin content of lablab in this study was lower than those reported in non-leguminous forage such as C. pentandra 14.2 g/100g and K. Africana 16.8 g/100g (Ogunbosoye and Babayemi, 2010). However, it was higher

than those reported in alfalfa ranging from 4-4.7 g/100g (Sima and Sima, 2015). Lignin is a polymer fraction of the plant cell walls that offers rigidity and mechanical support to plants and is not digestible by animals. It increases with plant maturity and is greater when the same plant species are established under warm weather conditions (Garcia *et al.*, 2003). The difference in lignin content among the varieties of lablab might be due to genetic difference between the varieties, different climatic conditions within the three sites and different flowering stages as high lignin content was recorded with early flowering varieties; DL1002, Eldo-Kt-Black1 and 2 compared with the late flowering varieties.

3.5.10 Invitro dry matter digestibility of *Lablab purpureus* varieties

The mean *invitro*-dry matter digestibility of the various lablab varieties in this study ranged from 67.6 to 75.7 g/100g across the three sites. Mapiye *et al.,* (2007) reported the *invitro*-dry matter digestibility of lablab to range from 55 to 76 g/100g in agreement with those obtained in this study. However Ahmad *et al*., (2000) reported a lower figure of dry matter digestibility of lablab foliage harvested at 50% flowering as 48.9 g/100g. McLeod and Minson, (1998) in their study reported IVDMD range for tropical grasses as 30-75 g/100g temperate grasses 45-85 g/100g, tropical legumes 36.0-69.3 g/100g, temperate legumes 45-85 g/100g (Minson, 1988; Ruddell *et al*., 2002). None of the lablab varieties' digestibility was below this digestibility range for both temperate and tropical legumes in this study. The recommended forage digestibility for high lactating cows is >67 g/100g, lactating beef cow producing 10 kg of milk daily 66 g/100g while a cow producing 5 kg of milk on daily basis will require forage with IVDMD of 53 g/100g (Burns, 1982).

Digestible dry matter content can be estimated from the ADF content, an increase lower fodder digestibility (Garcia *et al.,* 2003). The difference in the IVDMD among the lablab varieties in this study was attributed to different amounts of fibre fractions in form of NDF, ADF and ADL content. However, the higher IVDMD of lablab varieties in this study with some literature could be due to difference in age at harvest as early harvest is associated with high digestibility while late harvest with low digestibility due to high accumulation of fibre fractions. Varieties with high dry matter digestibility in this study such as Eldo-Kt-Cream and Black Rongai were associated with either low NDF, ADF or ADL content. Varieties with low dry matter digestibility such as DL1002, Ngwara Nyeupe and Brown Rongai were associated with high NDF, ADF and ADL

and late maturity except DL1002. The difference in varietal dry matter digestibility could also be attributed to genetic differences among the lablab varieties.

3.5.11 Nutrient content in *Lablab purpureus* at two stages of growth

The dry matter content of Black Rongai and Eldo-Kt-Black 2 increased by 4.8 and 4.9 g/100g from flowering stage to seed stage while CP content of Black Rongai variety decreased by 4.6 g/100g from flowering stage to seed stage. Washaya *et al*. (2018) in a similar study reported 3.6 g/100g crude protein reduction and an increase of 4.74 g/100g in acid detergent fibre (ADF) which could be attributed to decrease in quality of plant fodder with maturity (Heinritz *et al*., 2011). This decrease in quality is due to an increase of cell wall content and decrease of cell content which reduces feed intake and plant digestibility by animals (Heinritz *et al*., 2011).

Fiber content of the forage crops increases while quality and digestibility decline with maturity (Ball *et al* 2001). In most of the tropical legume forages DM yield increases with progressing stages of maturity (Bayble *et al* 2007; Baloyi *et al* 2008). Baloyi *et al.,* (2013) in their study reported variation of crude protein content among the lablab varieties and reported genetic variations as the major reason. They further reported high crude protein content at the early stages of growth than at the later stage in lablab. Miller-Cebert *et al.,* (2009) reported similar results in canola leaves where considerably higher crude protein content was found at pre-bolting age than rosette and blooming growth stages. In this case, if a farmer will harvest lablab at flowering stage as a supplement to low quality fodder for dairy animal, milk yield will be higher than when harvested at seed stage. This is because at flowering stage, nutrient composition of any fodder plant is at its optimal stage as opposed to seed stage (Miller-Cebert et al., 2009). However, for the farmer who will wait to harvest lablab seeds before being fed to dairy animal as a supplement to low quality fodder will compensate the declined milk yield by consuming lablab seeds or by selling for cash.

3.6 CONCLUSION

From the study, it can be concluded that: the dry matter yield and nutrient content of *L. purpureus* varieties differed across the sites of Nandi South sub-County. Brown Rongai variety had superior biomass yield compared to other varieties. However Eldoret-Kitale-Cream and Black-Rongai varieties with medium biomass yield were better in crude protein content, had lower fibre fractions and high invitro-dry matter digestibility than other varieties of lablab across the three sites. Therefore, they can be recommended for use as a supplement for low quality fodder by small-scale farmers.

CHAPTER FOUR

EFFECT OF DIFFERENT ON-FARM PRESERVATION METHODS ON QUALITY OF LABLAB FODDER

ABSTRACT

Shortage of livestock feeds during the dry season is a major constraint to livestock production in the country. This scenario is due to dependence on rain fed forage production resulting in shortages during the dry season and excess during the wet season. This situation can be ameliorated through conservation but losses occur when forages are conserved. The main objective of this study was to assess the effects of on-farm conservation methods on quality of lablab fodder. Fodder from eight varieties of lablab; DL1002, Ngwara Nyeupe, Echo-Cream, Black Rongai, Eldo-Kt-Cream, Eldo-Kt-Black1, Brown Rongai and Eldo-Kt-Black2 were conserved on-farm either as hay or silage. The conserved and fresh fodder were analyzed for dry matter content, crude protein, ash content, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and invitro-dry matter digestibility. Lablab silage was analyzed for pH and total ammonia nitrogen. Crude protein content declined by 4.2 g/100g when material was conserved as hay and 6.0 g/100g in silage. The NDF content increased by 7.6 g/100g in hay but declined by 4.2 g/100g in silage while ADF increased by 6.1 g/100g in hay and declined by 5.0 g/100g in silage. A decline of 3.2 g/100g of lignin was observed in silage with no difference in hay. *In-vitro* dry matter digestibility declined by 2.8 g/100g for hay and increased by 4.5 g/100g in silage. The pH of lablab silage ranged from 4.37 to 4.89 while total ammonia nitrogen ranged from 27 to 41 g/100g for different varieties. Conservation of lablab as silage was a superior on-farm method compared hay making.

4.0 INTRODUCTION

Fodder growth of tropical and subtropical perennial forages often surpasses the feed requirements of livestock during the wet seasons. Ensiling has been recommended as the favorite conservation choice during the wet season when feeds are in excess for use during the dry period (Amodu *et al.,* 2005). In the semi-arid tropical regions, where insufficient feeds is a challenge during the dry season (Phiri *et al.,* 2007), preservation of excess in wet season through ensilage is the suitable method to overcome feed shortage in adverse weather conditions (Phiri *et al.,* 2007). *Lablab purpureus* has been used as animal fodder and can be fed fresh or conserved

either as hay or silage. The leaves are very palatable as opposed to stems and it is one of the most palatable legumes for animals (Abdallah *et al*., 2015). It is among the favored fodder crops with high potential for incorporation into livestock production systems (Amodu *et al*., 2005). It is highly persistent to a wide range of agronomic conditions with dry matter yields of 2.7–7.7 t/ha in localities varying from the semi-arid to the sub-humid regions (Amodu *et al.,* 2005).

Hay from the whole lablab foliage is an important feed resource for livestock and can substitute costly supplements that are expensive and not readily available to small-scale dairy farmers (Mthembu *et al*., 2018). With the improvement of small-scale intensive systems and increasing costs of concentrate feeds, conservation of forage crops should be an essential part of livestock production. Conserving high quality fodder reduces the necessity of purchasing protein concentrates for use in ruminant rations (Ngongon *et al*., 2008).

Fodder can be conserved as hay or silage, however, legumes alone do not ensile well due to their high moisture content and high buffering ability, causing high nutrient losses and unstable silage of unacceptable pH where the proper conditions can only be achieved when the right silage additives and proper procedure are followed (Ngongon *et al.,* 2008). However, during conservation, the preserved materials changes in quality depending on method used. This study therefore aimed at assessing quality of lablab fodder preserved on-farm either as hay or silage.

4.1 MATERIALS AND METHODS

4.1.1 Description of the study site

The lablab materials for on-farm conservation was established within three sites of Nandi South Sub county with ecological conditions as described in chapter three under the materials and methods section.

4.1.2 Assessment of on-farm conservation of *Lablab purpureus* as silage

Lablab fodder was harvested at 50% flowering and wilted for two days to reduce moisture content. The material was chopped into pieces of approximately 2.5cm length using forage chopper. A 2 kg sample was then mixed thoroughly with 5%w/w of maize flour to increase dry matter content of the resultant silage. Molasses solution (diluted with 1:3 parts water) was included at 3%v/w of lablab forage. The material was placed into heavy gauge plastic bags in

duplicate for each variety per site. After compacting by hand to expel all air, the bags were sealed with cello tape to ensure they remained airtight. They were stored in a shade and raised floor for 60 days prior to opening for nutrient analysis. A sub-sample of the silage was collected from top, middle and bottom part of the bag to make a 220 g sample from each silage sample for chemical analysis. One hundred and twenty grams was oven dried at 60^{o}C for one week and ground through a Wiley mill standard model No.3 with sieve of 0.5mm and stored for further nutrient analysis.

4.1.3 Treatments

The treatments were made up of composited fresh lablab, Hay and silage from eight lablab varieties from the three sites of Nandi South Sub-County.

4.1.4 Experimental design

Complete randomized design was used with three treatments of lablab (Fresh, Hay and silage) replicated three times (from three sites of Nandi South Sub-County).

4.1.5 Determination of silage pH

This was done following the procedure of Nadeau *et al*. (2000) and Fellner *et al*. (2000). A mixture of 100 g silage and 1litre of distilled water was blended for 60 seconds using a kitchen blender, it was covered with aluminum foil and left to settle for two hours. The pH of the silage extract was measured using a glass electrode pH meter that was standardized with buffers of pH 4 and pH 7. The blended material was filtered through two layers of cheese cloth and centrifuged at 2500 rpm for 30 minutes. The aliquot measuring 100 ml was treated with 15 ml 20% sulphuric acid and frozen for ammonia nitrogen determination.

4.1.6 Determination of ammonia nitrogen and proximate composition of lablab silage

The total ammonia nitrogen in silage and proximate composition of both hay and silage was attained by following the procedure of Kjeldahl method (AOAC, 2016). The invitro-dry matter digestibility and fibre content of silage was analyzed following the procedures described in chapter three section 3.1.8.

4.1.7 Assessment of hay as on-farm conservation method of *Lablab purpureus*

Lablab fodder harvested at the same time of silage preparation (4.2.2 above) was air dried for four days after harvesting at 50% flowering. The material was turned regularly to allow even drying before baling to avoid mold formation. Each bale of hay weighed approximately 20 kg and was prepared manually for each variety in duplicate per site using a baling box of 85cm length 55cm width and 45cm height open on both ends (Plate 4.1). After baling, the bales were stored under waterproof shade on raised wooden base for 60 days.

Plate 4. 1: Lablab hay baling and releasing

4.2 DATA ANALYSIS

The data was subjected to analysis of variance (ANOVA) using Genstat Inc. 15th edition 9 (Lawes Agricultural Trust, Rothamsted Experimental Station, UK) to determine whether there was lablab quality difference between the two methods of on-conservation compared with the fresh lablab. The means were separated using Tukeys statistical test at a significant level of 5%.

4.3 RESULTS

4.3.1 Nutrient composition of fresh and conserved *Lablab purpureus*

The nutrient composition of fresh and conserved lablab forage is shown in Table 4.1. Nutrient composition of fresh and conserved lablab varied significantly ($P < 0.05$) from the fresh material. The highest CP content was observed in fresh lablab (22.0 g/100g) with silage (16.0g/100g) having the lowest. For fibre fractions, lablab hay had the highest neutral detergent fibre (54.2 g/100g), acid detergent fibre (39.7 g/100) and acid detergent lignin of (10.4 g/100g). The silage had lowest fibre fractions of 42.4, 28.6 and 7.3 g/100g for NDF, ADF and ADL respectively. Invitro dry matter digestibility was highest for lablab silage (75.5g/100g) with both hay (68.1 g/100g) and fresh lablab fodder (70.9 g/100g) being similar.

Table 4. 1: Nutrient content (g/100gDM) of conserved and fresh lablab forage

Treatments	DM	CP	Ash	NDF	ADF	ADL	IVDMD
Fresh	16.9^{c}	22.0^{a}	8.7^{a}	46.6^{b}	33.6^{b}	10.5^{a}	70.9^{b}
Hay	83.5^{a}	17.8^{b}	8.8^{a}	54.2^{a}	39.7^{a}	10.4^{a}	68.1^{b}
Silage	42.7^{b}	16.0^{c}	8.9^{a}	42.4^{c}	28.6^{c}	7.3^{b}	75.4^{a}
Means	477.0	18.6	8.8	47.7	33.9	9.4	71.5
S E	8.29	0.42	0.28	0.83	0.5	0.32	0.94
P Value	<.001	<.001	0.803	<.001	<.001	<.001	<.001

DM-dry matter, CP-Crude Protein, NDF-Neutral detergent fibre, ADF-Acid detergent fibre, ADL-Acid detergent lignin, IVDMD-Invitro dry matter digestibility, ^{abc} column means with different superscripts are significantly different (P <0.05)

4.3.2 Ammonia nitrogen and pH of lablab silage

The ammonia N content and the pH of lablab silage are shown in Table 4.2. The pH and ammonia nitrogen (NH_3N) content varied significantly ($P < 0.05$) between varieties. Highest pH was observed in silage from Ngwara Nyeupe variety (4.81) while low pH was recorded for Brown Rongai variety at 4.37. The highest ammonia nitrogen was observed in Eldo-Kt-Cream variety silage (41.0 g/100g) with the lowest being for Brown-Rongai at 27.0 g/100g.

Table 4. 2: Ammonia nitrogen content and pH of lablab silage

Varieties of lablab	Silage quality	
	pH	NH_3N g/100g
Black Rongai	4.42^{b}	30.3^{ab}
Brown Rongai	4.37^{b}	27.0^{b}
DL1002	4.63^{ab}	33.6^{ab}
Echo Cream	4.52^{ab}	30.3^{ab}
Eldo-Kt-Black1	4.43^{b}	31.5^{ab}
Eldo-Kt-Black2	4.38^{b}	34.8^{ab}
Eldo-Kt-Cream	4.49^{ab}	41.0^{a}
Ngwara Nyeupe	4.81^{a}	29.1^{b}
Mean	4.51	32.2
SE	0.068	3.67
P Value	0.006	0.282

NH_3N-ammonia N, Eldo- Eldoret, Kt- Kitale, and DL- Dry land Variety, Column means with different superscripts are significantly different (P <0.05).

4.4 DISCUSSION

4.4.1 Proximate composition of hay and silage

The mean dry matter content of lablab hay and silage was 83.5 and 42.7.4 g/100g. The dry matter content of lablab hay in this study was below 85.4 g/100g reported by Kabirizi *et al.*, (2000) 91.8 g/100g by Mpangwa *et al*., (2000) and 90.4 g/100g by Hassan *et al.,* (2016). This difference in dry matter content could be attributed to variation in weather at drying, length of drying and time of harvest, as late harvest is associated with high dry matter content (Barry *et al*., 1978). The lower dry matter content of lablab hay in this study compared with other studies could be due to lack of proper drying prior to baling as reported by Titterton and Bareeba, (2000). They recommended moisture content prior to hay baling should be reduced to 15.0-20.0 g/100g in order to restrict plant actions and microbial enzymes.

The dry matter content in lablab silages was reported ranging from 17.1–20.8 g/100g by Ngongoni *et al.* (2008), 18.5-37.0 g/100g by Morris and Levitt, (2010) and 31.3 g/100g by Heinritz *et al*. (2012) which are all lower than the silages in this study. The difference could be due to harvesting age of the ensiled materials, ensiling conditions and variation in length of time

of wilting prior to ensiling, as a long wilting time is associated with high DM in silages as opposed to short time (Milford and Haydock, 1965). However, the DM content of the silage was above the recommended minimum of 30.0 g/100g in order to restrict the growth of clostridia bacteria (McDonald *et al.*, 1991). The *Clostridium botulinum* and *Listeria monocytogenes* bacteria in low DM silages have been associated with botulism and meningoencephalitis in animals that consume such silage (McDonald *et al.*, 1991). The same author also noted that too much dry matter in ensiled material restricted fermentation process resulting to high pH and soluble carbohydrates in the end product.

The crude protein content of fresh lablab, hay and silage was 22.0, 17.8 and 16.0 g/100g. The hay CP content was within earlier range (12-18 g/100g) reported by various authors (Aganga and Autlwetse, 2000; Kabirizi *et al*., 2000; Mpangwa *et al.*, 2000, Mupangwa *et al.*, 2000;Hassan *et al.*, 2016). The decline in CP content of hay compared with fresh lablab was due to loss of lablab leaves during hay baling and drying as shown in Plate 4.2b below. There was also considerable decline of crude protein during the ensiling process which could be related to protein degradation that has been reported during fermentation of many legumes (Uchide and Kitemine, 1987). Amodu *et al.* (2005) reported that the reduction in CP in Columbus grass silage was attributed to proteolysis during the ensiling process.

4.4.2 Fibre fractions in lablab hay and silage

The mean fibre fractions for lablab hay and silage were; neutral detergent fibre (NDF) was 54.2 and 42.4 g/100g, Acid detergent fibre (ADF) 39.7 and 28.6 g/100g and acid detergent lignin (ADL) 10.4 and 7.3 g/100g. The mean ash content in lablab hay and silage was 8.8 and 8.9 g/100g respectively. The fibre fractions content in lablab hay in this study were within the range of those reported by others (NDF 47.3-58.3 g/100g, ADF 29.4-41.5 g/100g and ADL 6.4-11.3 g/100g) (Kabirizi *et al*., 2000 and Mupangwa *et al*., 2000). The increase in the fibre fractions after lablab was conserved as hay was attributed to the high rate of leaf shattering that was experienced during drying process unlike silage where wilting had no effect on the leaves.

The NDF content of lablab silage (42.4g/100g) in this study was similar to 39.5 g/100g reported by Contreras-Govea *et al.,* (2009). The authors also reported an ADF content of 21.2 g/100g. Quigley *et al*. (2000) reported NDF and ADF content in lablab silage in the range of 54.4-61.8 g/100g and 44.4-49.7 g/100g respectively which were higher than in this study. Rooke and

Hatfield, (2003) explained the low NDF and ADF content in silages as due to low pH conditions that is favorable for cell wall hydrolysis, that declined NDF concentration and in some extent also ADF concentration. They further noted that the ADF fraction was predisposed to hydrolysis, but at a lesser grade than NDF.

Drying lablab for hay baling was a challenge as the stems contained a lot of moisture compared to leaves. This resulted in leaves drying faster and detaching from the undried stems. The complete drying of stems was necessary to discourage molds formation within hay after baling. In an attempt to even drying, most of leaves were lost through shattering hence increasing the percentage of lignin in the resulting hay as opposed to silage. The ash content in both lablab hay and silage in this study concurred with those 8.78 g/100g reported by Hassan *et al.,* (2016).

The dry matter digestibility of conserved lablab was 68.1 g/100g hay and 75.4 g/100g silage compared to 70.9 g/100g for fresh fodder. Diribsa *et al*. (2014) reported a lower IVDMD of lablab hay (62.03 g/100g) which was lower than in this study. Digestibility of lablab silage from this study was in agreement with Contreras-Govea *et al*. (2009) who reported IVDMD of 77.0 g/100g. Quigley *et al*. (2000) reported lower IVDMD in lablab silage ranging from 48.5-58.1 g/100g.

The difference in IVDMD of hay and silage was due to variation in fibre fractions as reported by Rooke and Hatfield, (2003). The authors reported that decline in fibre fractions in silage was associated with low pH that enabled cell wall hydrolysis. This might have caused similar effects of lablab silage having high IVDMD compared with hay that had higher fibre fractions due to loss of leaves during baling and drying.

4.4.3 Physical and chemical quality of hay and silage

All silages in this study had pH level ranging from 4.37 to 4.89. Previous studies have reported pH range of f 4.0-4.9 (Morris and Levitt, 2010) and 4.0-4.5 (Heinritz *et al*., 2012) in lablab silage. In another study, Abu-Bakr *et al*., (2015) reported the pH range of 4.3 to 5.6 in silages made with a mixture of legumes and other fodder materials. Higher pH values in legume silages (5.3–5.7) have been reported (Muhammad *et al*., 2008, Muhammad *et al*., 2009). Tjandraatmadja *et al*. (1993) recommended pH of 4.2 for tropical silages. As such, the pH of silages in this study ranged from good to average based on the classification by Kung and Shaver, (2001); pH <4.0 (excellent), 4.1 to 4.3 (good), 4.4 to 5.0 (average) and > 5.0 (bad). The pH of an ensiled material

is an indication of its acidity, and is influenced by the buffering capacity of the crop. The buffering capacity measures to what extent ensiled material forage will tolerate a change in pH, with all forages having different buffering abilities. Fresh forage with a high buffering capacity and low DM will need more acid to reduce its pH than forage with a low buffering capacity (Kung and Shaver, 2001).

Legumes have been associated with low DM content at the time of harvest for silage making, high buffering capacity due to low soluble carbohydrates making them difficult in making quality silage (Phiri *et al*., 2007) as was observed in this study. Silage from legumes can be made successfully through pre-wilting up to 50% moisture and use of silage additives like molasses, mixing with other cereals and microbial inoculants. This results in improved rate of fermentation and increases soluble carbohydrates thus resulting in better silage from legumes (Chatterjee and Maiti, 1978).

A **B**

Plate 4. 2: Hay bales (a) and observed leaf loss (b) during drying and baling

Ammonia-N content in silage is pointer of fermentation quality and a gauge of the degree of protein degradation during conservation (Driehuis *et al*., 2001). Well-conserved silage contains less than 100 g NH_3-N/kg (10%) of total Nitrogen (McDonald *et al*., 1991). All silages in this

study appeared acceptable based on physical appearance and pH but the NH_3N content was unsatisfactory as it ranged from 27 to 41 g/100g. Buxton and O'Kiely (2003) reported an increase in ammonia-N as the quantity of lablab increased in the mixture of corn silage. They noted that this was expected because legumes have high CP content that is favorable to greater proteolysis compared to corn silage. In addition, they reported that legumes had superior buffering capacity than grasses hence high NH_3N content (Buxton and O'Kiely, 2003). Therefore, higher ammonia-N formation was expected in the mixture as the proportion of legumes increases (McDonald *et al.*, 1991).

4.5 CONCLUSION

Results from this study show that conservation of lablab fodder as silage resulted in a superior quality product with higher IVDMD and low fibre fractions.

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.0 General discussion

One of the best ways to overcome the use of low quality forages at farm level by small scale farmers is through enriching the same with highly nutritious legume forages (Njarui, 1990). High dry matter yields in this study were observed with late flowering varieties of lablab; Brown Rongai, Echo-Cream and Ngwara-Nyeupe while early flowering varieties; DL1002, Eldo-KtBlack1 and 2 had lower dry matter yields. The late flowering varieties had faster growth rates with high biomass accumulation and bushy growth characteristics. The early flowering varieties produced short plants with little biomass accumulation due to less branching as opposed to late varieties.

These results concurred with Ewansiha *et al.* (2007) who reported similar growth characteristics for different lablab varieties. The farmers' participatory evaluation of quality fodder also concurred with the DM yields in this study. Njarui *et al.* (2004) while studying forage legumes reported that *Lablab purpureus* cv. Rongai had the highest dry matter yields of 2.6-11.0 t/ha compared to other legumes such as lablab K1002 (2.6 t/ha), short-lived annuals, V. unguiculata M66 (2.3 t/ha), *Desmodium intortum* cv. Greenleaf (0.046 t/ha), *Macrotyloma africanum* CPI 24972/60207 (0.896 t/ha), *Centrosema pascuorum* CPI 65960 (0.399 t/ha), Red (0.761 t/ha) (Njarui *et al.*, 2004). These results were lower than values obtained for lablab varieties in this study. Additionally, some of the lablab varieties in this study had higher protein content compared to other legumes such as cow peas (19.6 g/100g) and Cluster bean (19.43 g/100g) (Iqbal *et al.*, 2012). Variation in dry matter yields and CP content of lablab varieties in this study and with other literature was majorly caused by rainfall distribution, soil fertility and genetic differences among the legumes (Thairu and Tessema 1987). The dry matter yields of different legumes also could vary with seasons of harvest and sites (Njarui *et al.*, 2004).

Variation in crude protein content among the lablab varieties and between sites could also be due to difference in fibre fractions that reduces cell content hence decline in crude protein as reported by Nworgu and Ajayi (2005). The difference in ash content could be due to variation of mineral content among the varieties of lablab or due to silica contents (Hoffman, 2005). Lablab varieties

in this study varied in fibre fractions content and this was attributed to difference in the maturity age at harvest or difference in temperatures within the three sites. High temperatures have been reported to decline the soluble carbohydrate concentration of plants, causing an increase in fibre content and decrease in digestibility (Mupangwa *et al.,* 2000). The difference that was observed in the *invitro*-dry matter digestibility of lablab varieties was due to difference in fibre fractions recorded among the lablab varieties.

When lablab was conserved as hay, a decline of 4.2 g/100g CP was recorded and a decline of 6.0 g/100g CP recorded in lablab silage compared to the CP content of the fresh lablab. The NDF content in lablab varieties increased by 7.6 g/100g in hay samples and declined by 4.2 g/100g in silage samples compared to the fresh lablab. Conserving lablab as hay led to an increase of ADF by 6.1 g/100g and a decline of 5.0 g/100g ADF in silage. No difference in lignin content was recorded in lablab hay to fresh as opposed to silage that recorded a decline of 3.2 g/100 of lignin. A decline of 2.8 g/100g DMD was recorded in lablab hay and an increase of 4.5 g/100g DMD in lablab silage compared with fresh lablab values. Therefore, on-farm conservation of lablab either as hay or silage leads to decline in its quality. However, if the right measures are taken during lablab hay making by controlling leaf shattering, hay method can be cheaper than silage making due to cost of silage additives and critical conditions that have to be met for successful silage from legumes.

The difference in quality between the lablab hay in this study and those reported in literature could be due to differences in leaf to stem ratio during baling or after storage or variation in the stage of growth at which the material was harvested (Mupangwa *et al.,* 2000). The decline in the fibre fractions in lablab silages was attributed to low dry matter concentration at the time of ensiling and low pH in lablab silages that made the fibre fractions in the cell wall susceptible to hydrolysis (Govea *et al*., 2011). Rooke and Hatfield (2003) also reported that, ensiling environments would have an effect on carbohydrates pools. They concluded that, those structural carbohydrates were more prone to acid hydrolysis even under weak acid environments that was also reported by (Govea *et al.,* 2011).

The pH level of the silages in this study ranged from 4.3 to 4.8 and were similar to 4.0 to 4.8 reported by Govea *et al*. (2011), who attributed the high pH in legume silage to high buffering capacity and extended fermentation during ensiling process. High levels of ammonia nitrogen in

lablab silage was attributed to high buffering capacity due to high crude protein content that is favorable for higher proteolysis unlike other forages (McDonald *et al.*, 1991, Buxton and O'Kiely, 2003). Low crude protein in lablab silage as opposed to hay was due to high proteolysis occurring before silage was fully fermented (Amodu *et al*., 2005). High fibre fractions content in lablab hay was attributed to leaf loss that was experienced during baling and storage as reported by Rayburn, (2002). Additionally, when fodder plants goes through natural respiration, they convert plant tissue carbohydrates into carbon dioxide, heat and moisture that is lost in air causing an increase of fibre fractions of forage (Madzonga and Mogotsi, 2014).

5.1 CONCLUSIONS

i. The biomass yield and nutrient content of L. purpureus varieties differed within and between sites. Brown Rongai variety had superior biomass yield compared to other varieties. Eldoret-Kitale-Cream and Black-Rongai varieties had medium biomass yield, higher crude protein content, lower fibre fractions and high invitro-dry matter digestibility compared to the others.

ii. Between the two lablab conservation methods, results from this study show that the silage was superior in quality compared to hay due to higher IVDMD and low fibre fractions.

5.2 RECOMMENDATIONS

i. All the lablab varieties in this study attained the required threshold of being used as a supplement to low quality fodder for ruminant animals, however, the most recommended varieties based on this study were; Eldo-Kitale-Cream, Black-Rongai and Eldoret-Kitale Black2.

ii. Due to site variation with biomass yields of lablab varieties, Kapkarer farmers can grow Brown-Rongai, Eldoret-Kitale-Cream and Black-Rongai. Farmers in Kiptaruswo site can grow Brown-Rongai and Eldoret-Kitale-Black2. In Koibem, farmers can grow Brown Rongai, Echo-cream, and Black-Rongai varieties as supplement to low quality fodder.

iii. Both hay and silage can be used as on-farm conservation of lablab as their product met the threshold as supplement to low quality forage.

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APPENDIX 1

Table 1: Percentage plant stand of lablab in the three sites at different growth stages

After 14 days of emergence Varieties of lablab	Sites			
	Kapkarer	Kiptaruswo	Koibem	Mean
Black-Rongai	66.2	58.8	87.1	70.7
Brown Rongai	62.4	64.4	81.7	69.5
DL 1002	59.8	69.1	78.9	69.3
Echo-Cream	44.1	35.0	66.7	48.6
Eldo-Kt-Black 1	54.6	52.6	72.9	60.0
Eldo-Kt-Black 2	63.2	60.9	82.7	69.0
Eldo-Kt-Cream	68.6	56.0	74.2	66.3
Ngwara Nyeupe	42.8	52.1	71.7	55.6
Mean	57.7	56.1	77.0	63.6

After 28 days of emergence Varieties of lablab	Sites			
	Kapkarer	Kiptaruswo	Koibem	Mean
Black Rongai	62.1	54.7	73.4	63.4
Brown Rongai	58.8	62.1	76.3	65.7
DL 1002	57.4	62.4	74.7	64.8
Echo-Cream	39.2	34.0	64.1	45.8
Eldo-Kt-Black 1	50.8	52.6	66.2	56.5
Eldo-Kt-Black 2	61.9	60.8	79.7	67.5
Eldo-Kt-Cream	66.2	53.6	73.0	64.3
Ngwara Nyeupe	42.3	51.0	68.3	53.9
Mean	54.8	53.9	72.0	60.2

After 42 days of emergence Varieties of lablab	Sites			
	Kapkarer	Kiptaruswo	Koibem	Mean
Black Rongai	60.1	53.9	71.4	61.8
Brown Rongai	57.4	60.5	71.2	63.0
DL 1002	53.8	60.9	69.0	61.2
Echo-Cream	35.0	33.2	62.9	43.7
Eldo-Kt-Black 1	50.8	51.5	62.7	55.0
Eldo-Kt-Black 2	59.2	59.0	77.9	65.4
Eldo-Kt-Cream	62.9	50.5	71.1	61.5
Ngwara Nyeupe	38.9	49.2	67.5	51.9
Mean	52.2	52.3	69.2	57.9

APPENDIX: 2

FARMERS' PARTICIPATORY EVALUATION QUESTIONNAIRE

INTRODUCTION

This was semi-structured questionnaire that involved multiple responses by farmers on the evaluation of their perception on the entire project of **Biomass yield and quality of fodder from selected varieties of lablab and their on-farm conservation within Nandi south sub-county, Kenya.** The survey aimed at smallholder livestock farmers within the region.

Questionnaire number……... Date…….

1. Name of the location/Site……
2. Name of the farmer……...
3. Contact of the farmer…….
4. What types of fodder does the farmer commonly use?
   a. Napier grass……. ☐
   b. Grazing…… ☐
   c. Lablab…….. ☐
   d. Maize stover……. ☐
   e. Banana stems…… ☐
   f. Hay…… ☐
5. What do you consider as characteristics of good fodder crop?
   a. Early maturity……..
   b. ate maturity…… ☐
   c. More foliage…… ☐
   d. Bushy growth……... ☐
   e. Soft leaves…… ☐
   f. Rough leaves……... ☐
   g. Wide leaves……. ☐

h. Creeping……..

6. Give rating of the different lablab varieties based on attributes of good fodder

Lablab Varieties	Rating
a. Black Rongai……	☐
b. Brown Rongai……...	☐
c. DL1002…….	☐
d. Echo-Cream……..	☐
e. Eldo-Kt-Black 1……	☐
f. Eldo-Kt-Black	☐☐2……
g. Eldo-Kt-	☐Cream……..
h. Ngwara Nyeupe…….	☐

7. Having been involved in on-farm conservation of lablab, which method was suitable for retaining more qualities of good fodder

a. Hay……. ☐

b. Silage…….. ☐