RESPONSE OF LABLAB (*Lablab purpureus* L. Sweet) TO PHOSPHORUS APPLICATION AND CUTTING TREATMENTS.

BY

SUNDAY AGHAFEKOKHIAN OGEDEGBE

JUNE 2011

RESPONSE OF LABLAB (*Lablab purpureus* L. Sweet) TO PHOSPHORUS APPLICATION AND CUTTING TREATMENTS.

By

SUNDAY A. OGEDEGBE
PhD/AGRIC/40066/2004-2005

A DISSERTATION SUBMITTED TO
THE SCHOOL OF POSTGRADUATE STUDIES,
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN
AGRONOMY

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA-NIGERIA

JUNE 2011

DECLARATION

I declare that the work in the dissertation entitled "Response of Lablab (*Lablab purpureus* L. Sweet) to Phosphorus Application and Cutting Treatments" has been performed by me in the Department of Agronomy under the supervision of Professors V.B Ogunlela and O.O. Olufajo and Dr E.C. Odion.

The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

Sunday A. Ogedegbe	----------	----------
Candidate	Signature	Date

The above declaration is confirmed by me.

Prof. V.B. Ogunlela
(Major Supervisor) Signature: ----------

Date: ……

CERTIFICATION

This dissertation entitled "RESPONSE OF LABLAB (*Lablab purpureus* L. Sweet) TO PHOSPHORUS APPLICATION AND CUTTING TREATMENTS" by Sunday A. Ogedegbe meets the regulations governing the award of Doctor of Philosophy of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

Professor V.B. Ogunlela ----------
Chairman, Supervisory Committee Signature & Date

Professor O.O. Olufajo ----------
Member, Supervisory Committee Signature & Date

Dr E.C. Odion ----------
Member, Supervisory Committee Signature & Date

Dr B.A.Babaji ----------
Acting Head of Department Signature & Date

Professor A.A.Joshua ----------
Dean, School of Postgraduate Studies Signature & Date

AHMADU BELLO UNIVERSITY, ZARIA

DEDICATION

This work is dedicated to my late parents (Edmund Iduorobo and Esther Amadin Ogedegbe) of blessed memory who both toiled to ensure that I became a success in life.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my major supervisor, Prof. V.B. Ogunlela whose intellectual capacity is beyond literary expression. His insight and know-how pulled me through several difficult situations during the course of this programme. His tireless effort and guidance through constructive criticism and positive verbal encouragement enabled the completion of this manuscript. Similarly, the other members of my supervisory team Professor O.O. Olufajo and Dr E. C. Odion were magnificent in their support of this work in particular and my PhD programme in general, such that Dr E.C. Odion granted me accommodation in Zaria during much of my sojourn there.

I am indeed very grateful for the support and encouragement I received from the Head and Acting Head, Department of Agronomy Professor M. Mahmud and Dr B.A.Babaji respectively and other members of the department especially Professors I.U. Abubakar, U.F. Chiezey, B. Tanimu, M.K. Ahmed and Drs D. A. Labe, N.C. Kuchinda and Mallams Aminu Ringim and Lucky Arunah to mention a few. May God reward each of you abundantly for your friendship.

The financial and moral support I enjoyed from the former Executive Director of the National Veterinary Research Institute, Vom (The Honourable Dr. (Mrs.) L.H. Lombin) contributed immensely to the successful completion of this programme. I am forever indebted to her foresight and serious work ethic which enabled several staff including myself obtain higher degrees during her tenure in Vom. I am grateful for the Department of Agronomy and Ahmadu Bello University facilities utilized for my training and research. In the same vein, I owe the Legume and Oil-Seeds Research Programme of the Institute for Agricultural Research my deep gratitude for the financial and material support provided for my research. Thank-you, Professors C.A. Echekwu and O. Alabi.

My gratitude also goes to many technicians in the Department of Agronomy, especially Mallam Ahmed Mohammed and also to Mr Kwano Ibrahim of the Department of Animal Science for their technical support and friendship during those three hectic years of my field research at Samaru. May God reward you all abundantly.

My appreciation goes to my wife (Collette Ogedegbe) who coordinated the typing of the entire Thesis and to Mr Christian Edokpolor who carefully typed several sections of this manuscript. In the same vein, I gratefully acknowledge the encouragement I received from my lovely children (Oghowenyemwen, Osakiemwenaho, Efosa, Osasumwen, Osamuede and Osayamwen). My prayer is that each of you will surpass me in every regard. I wish also to appreciate my immediate and extended family for their patience with me over many years of being detached from them as I pursued this programme. Your love and support are highly appreciated.

Finally, I thank my Lord and Savior Jesus Christ for sustaining and uplifting me through these years.

ABSTRACT

Field trials were conducted during the 2006, 2007 and 2008 cropping seasons at the Institute for Agricultural Research (IAR) Experimental Farm, Samaru in the northern Guinea savanna zone of Nigeria, to study the response of lablab (*Lablab purpureus* (L.)Sweet) to phosphorus application rate, cutting height and cutting age with regards to growth, herbage yield, seed yield and herbage quality. The treatments were composed of factorial combinations of four levels of phosphorus fertilizer (0, 12, 24 and 36 kg P ha^{-1}) and two cutting heights (10 and 20cm) in the main plot and four cutting ages (6, 12, 18 weeks and maturity) in the sub-plot of a split-plot experimental design with three replications. The application rate of 12 kg P ha^{-1} increased lablab sward height, 100-seed weight and ground cover score by up to 4% while 24 kg P ha^{-1} increased leaf area index (10%), leaf area per plant (18%), number of root nodules (42%) and nodule dry weight (50%) above the control. Cutting lablab to a 20cm stubble height produced significantly higher sward, ground cover score, pod length and 100-seed weight, whereas a 10cm cutting height produced significantly higher calcium and phosphorus concentrations in the dry herbage. The highest sward height, cumulative fresh, dry and initial herbage yields of lablab were obtained at the 18-week cutting age. Cutting lablab at 6 weeks did not decrease seed yield, relative to cutting at maturity. The highest crude protein and crude fibre concentrations of lablab herbage were obtained at the 12-week and maturity cutting ages respectively, and both parameters were enhanced by cutting age. Lablab ether extract concentration decreased while Ca: P ratio increased as cutting age increased but cutting age did not increase the value of either of the two parameters. Combination of phosphorus application rate of 36 kg P ha^{-1} and 20cm cutting height produced the highest sward. The highest number of root nodules was obtained when lablab

was supplied with 24 kg P ha^{-1} and cut to a height of 10cm, while the heaviest 100-seed was produced by a combination of 12 kg P ha^{-1} application rate and a 20cm cutting height. In addition, a phosphorus application rate of 12 kg P ha^{-1} produced the highest ether extract, ash, number of primary branches, and proximate dry matter concentration in lablab herbage when cutting was done at 6, 12 and 18WAS, and at maturity respectively. However, the highest phosphorus concentration of lablab herbage was produced when no P was applied (0 kg P ha^{-1}) at a cutting height of 10cm. Crude protein concentration of lablab herbage was highest at the application rate of 0 kg P ha^{-1} combined with a cutting age of 6 weeks while crude fibre was highest when lablab plants received no phosphorus application and was cut at maturity. The highest cumulative dry herbage yield obtained at 18 weeks was 62 and 117% higher than those obtained at maturity and the 6-week cutting age respectively, irrespective of the cutting height. A positive and significant correlation was observed between cumulative dry herbage yield and stand count, sward height, ground cover score, number of root nodules and nodule dry weight of lablab. The path coefficient analysis showed that nodule dry weight, sward height and stand count had positive direct contributions. However, nodule dry weight was the highest individual contributor to the cumulative dry herbage yield of lablab even though the residual contribution was 76.7%. The polynomial response analysis did not produce a best fitting curve for cumulative dry herbage yield of lablab in this study. It is suggested that lablab be fed pre-rather than post-harvest maturity to reduce dry matter(about 67%) and crude protein(about 35%) wastages and also to develop lablab as a ley (temporary) pasture crop in the farming systems of the northern Guinea savanna in order to enhance its contribution to the livestock industry.

CHAPTER ONE

1.0 INTRODUCTION

The problem of inadequate supply and poor quality of fodder for livestock production in sub-Saharan Africa is partly responsible for the food insecurity prevalent in Africa. This scenario could be ameliorated through improvement of the yield and nutritive value of grasses and forage legumes grown for livestock in the region. The yield, chemical composition and nutritive value of the grasses and legume species grown in Nigeria vary greatly, depending on the species and period of growth at which the grasses are cut or grazed (Aina and Onwukwe, 2002). According to Odunze *et al*. (2004), ruminant performance in the northern Guinea savanna of Nigeria is affected by seasonal variation in the availability and quality of pasture. In Nigeria, as well as in other tropical countries, quantity and quality of forage particularly during the dry season, which vary between 5 – 7 months in the savannas, are major constraints for optimum livestock production from the savanna rangelands (Omokanye *et al.,* 2004). Poor nutrition is a major constraint to livestock production in small-holder farming systems and small-holder dairy development in coastal low-land Kenya (Mureithi *et al*., 1998), especially during the dry season when available feed quantity is low and quality extremely poor. During the dry season, in the savanna, not enough plant biomass is available to maintain the large stock of animals, resulting partly in the seasonal migration of animals (Odion *et al*., 2007). Even though the northern Guinea, Sudan and Sahel savanna regions are best suited for ruminant livestock production due to the absence of tsetse-fly, there is a persistent shortage of high quality fodder during most of the year. Provision of fodder for livestock during the dry season therefore constitutes a formidable challenge.

The use of introduced forage legumes is a viable means of correcting the livestock feed constraint. Suitable legume species have the potential to alleviate feed constraints, especially for

cattle and other ruminants, during the dry season, through their higher nutritive value relative to natural fallows (Minson, 1990). Good quality forage legumes can either be grazed or harvested and fed straight or conserved before feeding to the animals. They can also be used as a high protein supplement in the diets of some farm and laboratory animals (Harricharan *et al*., 1987).

Most tropical forage legumes can be utilized as green manures to enhance soil fertility with a short fallow period while also providing the much-needed livestock feed (Tarawali *et al*., 1999). Benefits derived from the incorporation of pasture legumes to ley-farming or phase-farming systems include nitrogen fixation benefiting companion crop or a non–legume in crop rotation. Other benefits derivable from tropical legumes include high protein animal feed, increased soil fertility and structure, decreased erosion risk, reduced growth of weed species, break in disease and pest life cycles, especially by annual legumes, and some capacity for high water use and nutrient recycling, particularly for perennial legumes (Loi *et al*., 2005). Among the many introduced forage legumes evaluated in Nigeria, lablab *(Lablab purpureus*) has been reported to be a promising crop for the northern Guinea savanna (Thomas and Sumberg, 1995; Iwuafor and Odunze, 1999; Ewansiha *et al*., 2007). According to Das (1990), lablab cultivars that are late-maturing, with their high drought tolerance and biomass yield, are used as forages and Ewansiha *et al*.(2007) selected six lablab accessions (ILRI 147, ILRI 7279, PI 164302, TLN 29, TLN 7, PI 345608) for the sub humid zone of Nigeria based on good establishment and forage production.

Lablab purpureus (L.) Sweet (family Fabaceae, sub-family Papilionaceae, tribe Phaseoleae) is a multi (quintuple) purpose legume for soil improvement, weed control, food, medicine and feed. For soil improvement, lablab produces about 6.2 tonnes of dry matter per hectare and about 22.7 kg of nitrogen per tonne of dry matter (NRCS, 2007). With its viny growth habit, fast early growth and ability to grow with little applied water, lablab can effectively smother weeds and quickly provide an

effective ground cover to protect the soil from erosion. Lablab is a popular vegetable in India, China, South-east Asia, West-Africa, Japan and the Caribbean. Dishes are prepared both with its immature pods and the dry beans. Lablab seeds are used in folk medicine as alexerite and antispasmodic treatments and the leaves and flowers have been prescribed in menorrhagia and leucorrhaea. Leaves and pods are also used in popular medicine (Duke *et al*., 1981). Lablab can be grazed or used for hay or silage. The foliage has high protein content (15 – 30%) with high levels of lysine and about 55% digestibility (Valenzuela and Smith, 2002). Lablab makes excellent hay if harvested at the right time, when most of the leaves are still intact. The hay is high in crude protein (>17%), ash (>8%) and digestibility (>54%) (Murungweni *et al*., 2004).

Even though the potential of lablab to provide good quality fodder for livestock is no longer in doubt, its adoption rate has been particularly low. Presently, lablab is grown as a crop residue generator rather than a pasture crop thereby wasting much needed nutrients for livestock productivity. Efforts are currently being made to get resource-poor farmers to grow forage legumes such as lablab to supplement dry-season fodder. However, because farmers do not have sufficient knowledge on the proper management practices in the production of good quality fodder, the full potential of the practice has not been realised.

Carsky *et al*. (2001) suggested that the introduction of improved legume fallows is not adequate where phosphorus is limiting as legumes grow best in the presence of adequate phosphorus supply. Phosphorus often limits establishment and persistence of legumes (Hague *et al*., 2008) and limitations of phosphorus, calcium, iron and molybdenum in particular can reduce legume productivity by affecting nodule development and function (O'Hara, 2001). The suggested critical level of phosphorus for plant growth in Nigeria is 9 mg kg^{-1} (IITA, 1975). Phosphorus requirements of legumes are higher than those of other dicotyledonous crops because phosphorus

is needed for both plant growth and rhizobial activity in nodulation and nitrogen fixation. Although legumes may nodulate with indigenous rhizobia that are adapted to low phosphorus concentrations, they require a minimum level of available phosphorus in the soil for optimum nodulation. Phosphorus is undoubtedly an important limiting nutrient in the establishment of tropical pasture legumes. Pasture establishment is usually restricted to inherently low phosphorus soils. The amount of phosphorus to be applied depends mainly on soil type, the native phosphorus level of the soil, climate and growth conditions (De-Geus, 1977).

Although low soil phosphorus level can be growth-limiting, soil phosphorus level/fertility does not affect crude protein and digestibility of forages (Andrae and Pinkerton, 2009). Forage maturity has by far the greatest effect on crude protein and total digestible nutrients (TDN) levels in forages (Andrea and Pinkerton, 2009). Forage crude protein levels should therefore be managed by plant maturity at harvest through haying or grazing management (Andrae and Pinkerton, 2009). As forage develops from early bud stage to full maturity, the protein content decreases and the crude fibre increases, which result in lower nutritive value (Swift and Sullivan, 1962). Stage of plant maturity when consumed is the most important single factor affecting feed value (Swift and Sullivan, 1962). The importance of good re-growth, cutting height and age of pasture to its nutritive value and overall biomass production has been reported by several workers (Lowe *et al*., 1985; Slarke and Mason, 1987; Adjei and Gentry, 1996; Odion and Singh, 2005a), consequently, these factors deserve closer attention by scientists to intensify pasture legume production. For example, Kitalyi *et al*. (2008) recommended from studies to evaluate lablab haulm (harvested from a six-month old mono-stand of the crop after harvesting the grain) as a low cost, locally grown nitrogen supplement to cross-bred cows receiving diets based on sorghum stover crop residue, the need for more agronomic studies on the optimum time of harvesting lablab grain and herbage as well as post-harvest handling to minimize losses of leaf during field drying.

1.1 Justification

Based on the relevance of phosphorus application to legume productivity and given the many factors that affect soil phosphorus availability, it is necessary to determine the rates of phosphorus fertilizer that could affect lablab productivity. Many of the introduced forage lablab accessions have not been subjected to adequate agronomic management evaluations, thereby retarding their prospects for inclusion in animal response trials and ultimately recommendation for their use in farming systems. In the northern Guinea savanna, only limited studies have been carried out on cutting of lablab such as those by Hena *et al*. (1990) and Lamidi *et al*. (1997) on Rongai and Highworth varieties respectively. Research information on cutting of newer lablab accessions bred for improved quality is lacking.

With concurrent increases in human and ruminant livestock populations, in conjunction with intensification of arable crop cultivation, grazing land area has decreased and animal husbandry is tending toward restricted free-range and zero grazing. Faced with degradation of over-utilized grazing land, farmers have to spend more time in search of sufficient feed for livestock, especially in the dry season.

The non-availability of planting materials such as seeds, has been emphasized by farmers in Kenya as one of many factors affecting the adoption of planted forage legumes (Mureithi *et al*., 1998). This is because pasture seed production is accorded low priority in developing sub-Saharan African nations including Nigeria. Forage seed production is mostly limited to government farms and research institutes. Consequently, utilization of both selected and adapted species is usually constrained by lack of seed (Adeoye and Onifade, 2000).

In view of the aforementioned reasons, there is urgent need to search for creative solutions that can be integrated into the existing crop/livestock systems of the region. Lablab could be cut

and fed directly, grazed in rotation or cut and preserved as silage during the peak rainy season or cut and stored as hay when the weather permits. Alternatively, lablab could be cut and incorporated as green manure for soil fertility improvement. It is therefore important to further evaluate lablab accession (ILRI 147) to determine the appropriate stages of growth and maturity at which to cut and obtain the maximum dry matter (DM), crude protein (CP), energy (NFE) and mineral content (ash) and also to ascertain if cutting will affect lablab's ability to produce seeds important for re-establishment of subsequent crops. The effect of cutting on lablab's ability to produce seeds is information that is currently unknown.

The objectives of this study therefore were:

1). To evaluate the effect of rates of phosphorus fertilizer and cutting height on the growth, dry matter and seed yield of lablab

2). To evaluate the effect of cutting age on the growth, dry matter, hay quality and seed yield of lablab.

3) To evaluate the effect of phosphorus application, cutting height and cutting age on the proximate analysis of lablab fodder

CHAPTER TWO

LITERATURE REVIEW

2.1 Effect of Phosphorus on Yield of Lablab and Other Forage Legumes

High forage yields have been obtained with the application of phosphorus in the order of 18-30 kg P ha^{-1} on legumes (Muhammed and Abubakar, 2004). Fertilization with single superphosphate (SSP) at three rates (0,150 and 300 kg $P_2 0_5$ ha^{-1}) under conditions of low levels of available soil phosphorus increased legume productivity (Peters *et al*., 1997).It has been asserted from studies in Zimbabwe that the lablab forage system with phosphorus (P), sulphur (S) and lime applied has the potential to restore soil fertility to a greater extent and contribute to increased subsequent crop yield than a weed fallow (Maasdorp and Titterton, 1997). A phosphorus rate of 30 kg ha^{-1} applied as single superphosphate resulted in significant increases in dry matter production in *Lablab purpureus* cv. Rongai whereas cultivar Highworth did not respond to the same treatment (Jibrin *et al*., 2003).It is therefore evident that there are variations in the response of legume as well as their varieties to phosphorus application. Application of 17 kg P ha^{-1} on lablab in India increased dry matter yields by 34% and seed yields by 23% compared with the zero-P. Although application of 35 kg P ha^{-1} gave further yield increases, this was not economical (Verma, 1975). Applying four levels of P, Ariba *et al.* (1988) found that seed yields increased with fertilizer levels of up to 60 kg P ha^{-1} for the lablab varieties studied at Shika, Nigeria. In a 2–year study at Bauchi, Nigeria, the crude protein and phosphorus levels in shed lablab leaves were increased by most fertilizer treatments that contained phosphorus, but consistent benefits in dry matter (DM) yield or plant composition were not observed (Shehu *et al*., 2001). The annual forage legume lablab produced the highest

shoot dry matter yield of 6.2 tonnes ha^{-1} after 2.5 months growth with 40 kg P ha^{-1}, which was significantly ($P<0.05$) greater than the 5.0 tonnes ha^{-1} produced with 10 kg P ha^{-1} (Singh *et al*., 2004). In field and laboratory experiments conducted with seed crop of lablab, the NPK combination of 12:18:18 g pot^{-1} as basal dressing with 6N and 8 g pot^{-1} as topdressing at 30 days after sowing significantly increased the seed yield (604g) and the seed quality such as 100-seed weight (17.66g), germination (94%), root and shoot length (29.2 and 31.6 cm respectively), dry matter production (16.3 mg $seedling^{-1}$) and vigour index (5530) (Kathiravan *et al*., 2008).

The most efficient dry matter (10% CP) and seed yields (40% CP) of soyabean were obtained with 80 kg P ha^{-1} and fertilizer P exerted greater influence on soyabean forage yield than on seed yield (Akinola and Onifade, 1984). Akinola *et al*. (1985) in a separate study also at Shika found that yields of soyabean rose with increasing phosphorus application level up to 100 kg P ha^{-1} but there was no economic justification for exceeding 60 kg P ha^{-1} for the vegetative and seed yields. In a study in a sub-humid area involving different P levels; P fertilized plots of phasey bean (*Macroptilium lathyroides*) produced 58-60% more DM yields than the unfertilized plots and total DM increased with advanced plant growth (Omokanye *et al*., 2004). Application of phosphorus increased herbage yields progressively in (*Centrosema pubescence*) at Shika with each increment in the application of P. The highest P level (26 kg P ha^{-1}) almost doubled the yield at the initial harvest and trebled yield at the regrowth harvest and concentrations of nitrogen , phosphorus and calcium increased with increasing P application although the Ca: P ratios were unaffected (Omokanye, 2001). Stylo DM yields were increased by 60% with the application of rock phosphate as P source (Hague *et al*., 1999). Phosphorus application (40 kg P ha^{-1}) had a positive effect ($P < 0.006$; $P < 0.05$) respectively on plant vigour and ground cover but had no effect ($P> 0.10$) on dry matter productivity on 12 stylosanthes species in semi-arid Mozambique (Muir and Abrao, 1999). Compared to the control, a phosphorus application rate of 60 kg P_20_5 ha^{-1} resulted in maximum grain yield, while 80

kg P_2O_5 ha^{-1} caused maximum biomass yield of field-grown chickpea, whereas phosphorus application of 100 kg P_2O_5 ha^{-1} depressed both the grain and biomass yields (Idris *et al*., 1989). In the same study, phosphorus did not increase percent shoot or grain nitrogen or phosphorus. Increasing P level from 0 to 60 kg ha^{-1} progressively increased the forage yield of cowpea varieties in India. Significantly higher yields of green forage (260.73 q ha^{-1}), dry matter (51.97 q ha^{-1}) and crude protein (11.30 q ha^{-1}) were obtained with the application of 60 kg P ha^{-1} (Bhilare, 2003).

In their research with burr medic (*Medicago polymorpha* L.) fertilization with 0 or 25 kg P ha^{-1} did not affect forage accumulation, but seed production increased with P at the high seeding rate (Muir *et al*., 2001).In a study involving P fertilizer application, Bolland *et al*. (2001) found that yield of dried shoots and seed (grain) of faba bean (*Vicia faba* L.) increased with P application (0-30 kg P ha^{-1} in experiment 1 and 0-45 kg P ha^{-1} in experiment 2), but were unaffected by the method of P application (drilled or banded) or inter-row spacing (19 cm and 38 cm) between seed and fertilizer rows. Scott *et al*. (2003) reported that grain yield of lupin (*Lupinus angustifolius* L.) in southern New South Wales, Australia was increased by P application at four sites, despite the medium to high P status of three of the four sites. Banding P fertilizer below the seed depth had little advantage (P = 0.09) over direct seed contact in grain responsiveness to applied fertilizer P. Fitted response curves indicated that when P was applied at 15 kg ha^{-1}, grain yield increased by 60 kg ha^{-1} at one site and 30 kg ha^{-1} at the other three sites if P was deep placed rather than applied in seed contact. In a study to evaluate the effect of banded - P and temporary flooding stress on alfalfa seedling growth in the autumn, Teutsch *et al*. (2000) found that before flooding, banded – P increased seedling dry weight by 60%, but flooding reduced seedling dry weight regardless of P treatment. In Chile, a study in two groups of soils indicated that the effect of phosphorus was evident in clay soils, where the dry matter production of *Lotus corniculatus* increased 25% (from 7.48 to 9.51 tonnes of DM per ha per year) when the annual P application was increased from 10 to 20 kg ha^{-1} (Acunapommiezi, 2007).

According to Tag El Din and Assaeed (1995), application of fertilizer P under irrigation in Saudi Arabia, significantly increased fresh forage yield in alfalfa where the annual forage yield without P (81.2 tonnes ha^{-1}) increased to 93.8 and 108.9 tonnes ha^{-1} $year^{-1}$ when 25 and 50 kg P were added after each cut respectively. Similarly, in the same study, forage dry yield significantly increased with P fertilization (20.5, 24.4 and 27.8 tonnes $ha^{-1}year^{-1}$ for the P fertilizer treatments 0, 25, 50 kg P ha^{-1} cut^{-1} respectively). In addition, protein yield increased by 18 and 34% for 25 and 50 kg P ha^{-1} cut^{-1} respectively compared to the control. Alfalfa response to (DAP/18-46-0) fertilizer in the first year of a six-year study conducted in the United States, showed a linear increase in yield with increasing P across the range of rates (Mullen *et al*., 2000). In China, results showed positive correlation between decrease in soil available P and total forage yield of alfalfa after three-year alfalfa stand. Moreover, after 3-year alfalfa growth, the ratio of soil organic carbon (SOC) to available phosphorus (SOC/P) increased significantly in all treatments compared to pre-sowing. The increase in SOC in dry years promoted the accumulation of soil available P, but in wet years the increase in SOC limited the accumulation of soil available P (Yu *et al*., 2007).

In a study conducted in Turkey, phosphorus treatments (0, 5, 10 and 15 kg ha^{-1}) significantly affected dry matter and crude protein yields in white clover cultivars. The highest dry matter yield (965.8 kg ha^{-1}), crude protein ratio (19.23%) and crude protein yield (185.3 kg ha^{-1}) were obtained with 10 kg ha^{-1} phosphorus application (Tongel and Albayrak, 2006). In another experiment in the Ethiopian highlands, *Trifolium* species fixed 55-122 kg N ha^{-1} when P fertilizer was applied, while in a separate experiment, phosphorus applied at 50 kg P ha^{-1} increased biological N fixation from 11 to 72 kg N ha^{-1} on the broad bed and furrow landform and from 10-64 kg N ha^{-1} on the flat landform (Hague and Lupwayi, 1999). Testing varying levels of nitrogen (0, 40 and 60 kg ha^{-1}) with those of phosphorus (0, 30, 60 and 90 kg P_20_5 ha^{-1}), Zaman and Malik (1999) found that the combination of N and P_20_5 at 40 and 60 kg ha^{-1} respectively resulted in highest leaf area index, crop growth rate,

number of pods plant^{-1}, number of seeds pod^{-1}, 1000-seed weight and grain of rice bean (*Vigna umbellata*) in Pakistan. Significant grain yield increases of canola (*Brassica napus* L.) resulting from applied P (0-40 kg P ha^{-1} as single superphosphate) occurred in two experiments that were conducted in South-western Australia and these responses increased as rates of applied N (0-138 kg N ha^{-1} as Urea) increased. However, application of P had no effect on the concentration of oil and protein in canola grain (Brennan and Bolland, 2007).

In the semi-arid region of Jordan, a combination of early seeding (14 Jan), high seeding rate (80 plants m^{-2}) and banded P application (52.5 kg P ha^{-1}) produced maximum yield of narbon vetch (*Vicia narbonensis*) (Turk *et al*., 2003). Yilmaz (2008) from his study in Turkey reported that the highest P rate (75 kg P_20_5 ha^{-1}) caused narbon vetch plants to flower 5 days earlier than when 25 kg P_20_5 ha^{-1} was applied. A 10cm difference in height was also observed between the lowest and highest P rates. Furthermore, the P rate significantly increased the number of primary branches, the highest number being obtained with the highest P fertilization. In addition, the highest P treatment recorded 10% higher green forage yield and 6% more dry matter yield than the lowest P rate. Increased P levels improved narbon vetch's aboveground biomass at harvest by 18.5%. Finally, P fertilization increased crude protein content of forage and seeds and the highest increase in crude protein was observed when P was increased from 25 kg to 50 kg ha^{-1}.

Under greenhouse conditions on silt loam surface soil (*Typic Hapludult*), phosphorus enhanced dry matter yield of the tropical forage legume *Clitoria ternatea* L. in the first cutting. Amount of P required to produce maximum plant yield dropped from 200 mg kg $^{-1}$ soil at the first cutting to 50 – 100 mg kg $^{-1}$ soil at the second cut. At optimal P and S, symbiotic and N (NH_4 $N0_3$ supplied) plants yielded alike. In symbiotic plants, soluble sugar concentrations were higher than in N–treated plants and were increased by P and S treatment (Zaroug and Munns, 1980). In a

greenhouse study, *Centrosema pubescens, Centrosema plumeris* and *Stylosanthes gracilis* responded to phosphorus application, whereas *Pueraria phaseoloides* did not. In the species, the K, Na and Ca concentrations in plants given phosphorus were higher than the control except in *S. gracilis* where K and in *C. plumeris* where the Ca concentration was lowered by phosphorus. The concentration of Mg in *C. plumeris* was increased but unaffected in other species by phosphorus addition. Phosphorus depressed the plant sulphur but had no effect on nitrogen. The percentages of phosphorus in the species for maximum growth at 65 days from sowing were: *C. pubescens* (0.293), *C. plumeris* (0.280), *S. gracilis* (0.270) and *P. phaseoloides* (0.228) (Falade, 2006). White clover (*Trifolium repens* L.), suckling clover (*T. dubuim* Sibth) and lotus (*Lotus pedunculatus* Lav) were grown in a controlled environment at various levels of P supply and shoot P concentrations were similar at all levels of supply. Of the fractions, inorganic and residual P showed the largest increases in concentration (Hart and Jessop, 2006).

2.2 Effect of Cutting Height and Age on Yield of Lablab and Other Forage Legumes

It has been established that the ability of forage to re-grow is a function of cutting height and stored reserve in the crop (Humphreys, 1987). For example, high stubble leaves a photosynthetic area that provides additional energy for the initial regrowth after cutting two forage legumes, namely, birdsfoot trefoil and alfalfa (Smith and Nelson, 1967). Unlike other legumes, lablab can be mowed nearly at ground level and will still be able to regrow, although at a slower pace than when cut higher (Valenzuela and Smith, 2002).

Luck (1965) recommended lenient defoliation to ensure maximum herbage regrowth of lablab (Rongai) swards. Watkins and Lewy-van Severen (1951) examined the effect of cutting heights of 5-15 cm and 4, 8 and 12 week intervals on herbage yield of some forage species under rainfed conditions and found that all plants died following the second defoliation, irrespective of

cutting height. Philpotts (1969) reported that Rongai swards grazed by sheep at 10 and 16 weeks after sowing experienced a reduction in plant density from 7.7 to 4.0 plants sq m^{-1}. Defoliation of lablab at the onset of flowering led to rapid regrowth, renewed flowering and higher seed yields up to 90% of those obtained from undefoliated treatments, demonstrating the benefits of timely defoliation (Wood, 1983). In a series of 11 trials in Tennessee, leaf proportion was high in ungrazed swards of lablab and in regrowth which occurred when cutting height was more than 10 cm (Fribourg *et al*., 1984). Under irrigated conditions, there were lower total herbage yields of lablab where stands were cut every four weeks compared with stands not cut at all and reduced grain yields were reported when the crop was defoliated at first flowering (Hendricksen and Minson, 1985b). Wood (1983) observed that a single cutting reduced grain yield of lablab by 36% from 2200 to 1400 kg ha^{-1} or 6% from 1600 to 1500 kg ha^{-1} depending on the sowing period. When Lablab *purpureus* cv. Highworth, *Macroptilium bracteatum* (CPI 27404) and *Macroptilium daltonii* were compared in terms of response to defoliation (2, 4 or 6 weekly intervals) and nutritive value, under glasshouse conditions, Dalzell *et al*. (1977) found that *Macroptilium bracteatum* (CPI 27404) was the most productive legume under frequent defoliation, producing more growing points than the other species (*Lablab purpureus* and *Macroptilium daltonii*) when cut at 7 cm. However, all *Macroptilium daltonii* plants died after the initial cutting when cut at 7 cm. Furthermore, lablab top-growth yield declined more than the others with increasing severity of cutting. In the Sahelian agro-ecological zone of sub-Saharan Africa, delaying the first harvest of lablab to 50-70 days post-sowing increased the total (first plus final harvests) dry matter yield with a greater first harvest and reduced second harvest dry matter yield (Shehu *et al*., 2008).

Brink (1995) found that dry matter yield of all cultivars of white clover studied was reduced by harvesting at 2.5 cm compared to 10.0 cm stubble regardless of cutting interval and within a cutting height, increasing the harvest interval from 7 or 28 to 49 days generally resulted in greater

DM accumulation. Clipping of dual-purpose cowpea at 7-8 weeks after planting gives over one tonne of fodder per hectare, and this is available for green manure (Odion *et al*., 2007). Clipping enhances the reproductive growth of dual-purpose cowpea when planted early and at closer inter-row spacing. In various clipping experiments carried out in 1994, clipping at 15 cm produced significantly higher pod yield than clipping at 25 cm, while in 1996, clipping at both heights produced statistically similar pod and seed yields that were significantly higher than that produced by the no clipping control (Odion and Singh 2005b). Harvested yield of subterranean clover (*Trifolium subterraneum L.*), significantly ($P<0.05$) increased from 6.2 to 7.4 tonnes DM ha^{-1} as interval between harvest was extended, and plots harvested to 2.8 cm aboveground level yielded more (7.7 tonnes DM ha^{-1}; $P<0.05$) harvested herbage than those harvested to 7.0 cm (6.0 tonnes, DM ha^{-1}). Production of above and below-ground seed increased significantly ($P <0.05$) as interval between harvest increased, and was greater ($P<0.05$) at the higher defoliation height (7 cm) (Stockdale, 2005). Dry matter production of a late maturing, tall line (H11743) of *Melilotus albus* (Medik) decreased as the number of cuts increased, with production reduced to 6 tonnes ha^{-1} when it was cut every month between October and March inclusive, whereas one or two cuts per season yielded more than 13 tonnes ha^{-1} of DM (Evans *et al*., 2004). Seedling regeneration closely followed seed yields, being highest (4000 seedlings m^{-2}) with two cuts and being adequate (more than 2000 seedlings m^{-2}) when the last cut was in December (Evans *et al*., 2004).

In Tanzania, Mero and Uden (1997) found that 2-cutting regimes of 10 week intervals gave the highest mean DM yields ($P<0.05$) for legumes, and crude protein levels declined on average by 2% between cuttings. According to Trujillo *et al*. (1996), both total DM harvested and leaf yield were greatest when *Desmanthus virgatus* plants were harvested every two weeks at a stubble height of 100 cm. In addition, close (5 cm) and frequent harvesting (2 and 4 weeks) resulted in low yields, very few shoots and stand loss following a year of defoliation. Alfalfa harvested four times

(42 days between harvest) yielded 7% (0.8 Mg ha^{-1}) more per year than when harvested five times (34 days between harvest) and 28% (3.1 Mg ha^{-1}) more than when harvested six times (28 days between harvest) (Kallenbach *et al*., 2002).

Alfalfa dry matter yield increased and leaf percent of DM decreased from 3 to 5 regrowth weeks (Romero *et al*., 1987). According to Ahmadi *et al*. (2009), harvest frequency had positive effect on DM yield of snail medic (*Medicago scutellata* var. Robinson). Plants harvested at two-week interval produced highest DM yield (5343 kg ha^{-1}) while control(one harvest at 50% flowering) produced the lowest(3507 kg ha^{-1}) DM yield .Increasing the length of harvest cycle from 20 to 40 days increased alfalfa and total dry matter production (10.1 to 14.9 Mg ha^{-1}) in a binary mixture with ryegrass. Alfalfa's low productivity (7.3 to 8.4 Mg ha^{-1}) in a 20-day cycle was significantly improved (16.4 to 17.4 Mg ha^{-1}) when the cycle was changed to 40 days in an alfalfa–ryegrass mixture (Jung *et al*., 1996).

The DM and organic matter yields of tropical kudzu (*Pueraria phaseoloides*) at 40-day cutting interval were significantly lower than that at 60-day cutting interval (Van Hiep *et al*. 2008). Total yield and yield of legume (*Desmodium intortum* cv Greenleaf) in a sub-tropical environment increased with increasing cutting interval, the mean legume yields were 4.23, 6.54 and 8.03 tonnes DM ha^{-1} $year^{-1}$ for three cutting treatments (4, 8 and 12 weeks) and increasing the cutting height reduced weed yield and total yield at each cutting interval (Jones, 1973). Plant numbers increased linearly ($P<0.01$) with increase in cutting height (CH) from 7.2 to 9.5 plants m^{-2}. Weed percentage declined as both cutting interval (CI) and cutting height were increased. For legume yield, the CI x CH interaction was significant ($P<0.01$) (Jones,1973). Frequent cutting and high densities reduced both the vegetative and reproductive fractions of cocksfoot (*Dactylis glomerata* L.), but the reduction was greater in the reproductive fraction. As high yields were associated with the

reproductive fraction, the highest yields were obtained from the uncut plants or from plants cut infrequently (8-week intervals) (Knight, 1970). In Canada, a management study on Birdsfoot trefoil (*Lotus corniculatus* L.) showed that late-cut material out-yielded that cut early while material cut at a stubble height of 5.08 cm out-yielded that which was cut at 15.24 cm (Twamley, 2006).

2.3 Effect of Cutting Height and Age on Lablab and Forage Legume Quality

The fibre, protein and mineral content are either directly or inversely related to the age and stage of maturity at which grasses are cut (Oyenuga, 1960). Forage quality can be improved if more frequent and intense cutting is practised, but the beneficial effects of improved forage quality may be out weighed if forage growth rates are severely reduced (Hare *et al.*, 2001). Adjei and Gentry (1996) reported that dry matter production, crude protein and *in-vitro* organic matter digestion can be improved by clipping management of lablab bean in the semi-arid tropics. The phosphorus content of lablab has been reported to vary from a high of 0.76% down to 0.11% depending on maturity stage (Henricksen and Minson., 1985a). In their study, Hena *et al*. (1990) showed that the nutritive value of lablab varied with stage of maturity, but levels of variations differed among the varieties. The Rongai black was superior to both Rongai white and Highworth black in terms of crude protein (CP) and calcium (Ca) contents and digestibility. They also found that the best combinations of nutritive qualities are obtained if the crops are harvested at 3 to 3½ months after sowing. In a study conducted in Thailand to examine the effect of time and severity of cutting lablab, both in sole crops and intercropped with maize (*Zea mays*), Devkota and Rerkasem (2000) found that irrespective of cropping system, the total N yield of lablab at 130 DAS was 24% less when lablab was cut at 60 DAS compared to that cut at 40 DAS. Cropping system and cutting time significantly affected the total N fixation by lablab at 130 DAS. However, effect of cutting height on total N yield of lablab was not significant. Delaying the first harvest till 50 – 70 days post-sowing reduced the crude protein concentration of lablab but increased its modified acid-detergent

(MAD) fibre concentration. The delay in harvest increased the crude protein concentration but decreased the MAD fibre concentration of the second harvest. The total crude protein yield of both harvests increased with late interim harvesting. The first-harvest plant calcium concentration increased and phosphorous concentration decreased with a delay in the interim harvest (Shehu *et al*., 2008).

In fresh and dried (flue-cured) samples of common vetch (*Vicia sativa* L.) harvested at three maturity stages, flowering (>50% of plants with flowers), seed filling phase 1 (280g DM kg^{-1} seed) and seed filling phase 2 (380g DM kg^{-1} seed), non-fibre carbohydrates (NFC) and neutral detergent fibre (NDF) were evenly distributed and were not affected by maturity, whereas CP insoluble in neutral detergent but soluble in acid detergent, which was less than 100 g kg^{-1} of total CP increased with maturity (Caballero *et al*., 2001). Vetch (*Vicia sativa*) and barley (*Hordeum vulgare*) were grown in either a mixed culture or a monoculture system under rainfed conditions in a semi-arid region and harvested sequentially (115, 146, 167 days after planting and physiological maturity). The quality of harvested material declined from the first to the second of the sequential harvests for all cropping systems, with minimal change between the second and third harvests. Material harvested once at physiological maturity consistently had higher levels of crude fibre and cell wall constituents than material from any of the sequential harvests. However, a single cut at physiological maturity yielded more digestible energy and protein per hectare than serial cuts (Al-Masri, 1998).

In a study conducted by Stockdale (2005), nutritive characteristics (DM digestibility, crude protein, neutral detergent fibre) of subterranean clover harvested herbage were similar for heights of defoliation (2.8 and 7.0 cm) and intervals of harvest (4, 6, 9 and 12 weeks). Harvesting alfalfa more frequently, improved forage quality but had little impact on plant density (Kallenbach *et al*.,

2002). In another study, alfalfa dry matter yield increased and leaf percent of DM decreased from 3 regrowth weeks to 5 regrowth weeks. Neutral detergent (NDF) and acid detergent (ADF) fibre contents were higher for stems than leaves but did not change with maturity and average crude protein was 27% in leaves and 11% in stems (Romero *et al*., 1987). In the same study, Romero *et al*. (1987) found that in summer, peanut DM yield increased with maturity but leaf percent decreased. Maturity had no effect on leaf NDF or ADF, but stem NDF and ADF increased with maturity and average peanut CP was 19% in leaves and 9.2% in stems. Smith and Nelson (1967) found that yields of forage and protein decreased as cutting frequency increased for birdsfoot trefoil (*Lotus corniculatus* L.) and alfalfa (*Medicago sativa* L.). Leafy stubble was needed to maintain the yields of all cutting frequencies for trefoil, but only with the most frequent cutting schedule for alfalfa.

Increase in the harvest frequency of snail medic (*Medicago scutellata* var. Robinson) raised the CP concentration of plants significantly, such that weekly harvest interval (with 24.7% DM) had maximum CP concentration, which was 41% more than control (one harvest at 50% flowering) (Ahmadi *et al*., 2009). In a binary mixture of alfalfa (*Medicago sativa* L.) and perennial ryegrass (*Lolium perene* L.), crude protein concentration in alfalfa decreased from 248 to 200 g kg^{-1} as harvest cycle increased from 20 to 40 days (Jung *et al*., 1996). At Kyabram in northern Victoria, the effects of growth stage at cutting on DM yield and quality of lucerne was determined during the hay making period. Growth stages at cutting were pre-flower bud, flower bud, 10% bloom and full bloom. Cutting at the pre-flower bud stage, compared with cutting at the 10% bloom stage reduced DM yield by 18% (16.4 vs. 13.5 tonnes ha^{-1}), but increased crude protein content of the lucerne from 19.3 to 24%. Cutting lucerne at the flower bud stage rather than at 10% bloom gave increased protein content and digestibility (Slarke and Mason, 1987).

When tropical kudzu (*Pueraria phaseoloides*) was subjected to different cutting intervals, results showed decreasing leaf proportion, CP content and increasing DM and ADF contents with increasing length of cutting interval (40, 50, 60 and 70 days) (Van Hiep *et al*., 2008). In Ghana three tropical legumes, namely, *Cajanus cajan, Stylosanthes humilis* and *Clitoria ternatea* had decreasing leaf CP content with increasing cutting interval from 60 to 120 days. Significant variable response to cutting interval was exhibited by the legumes for ether extract, nitrogen-free-extract, P and Ca levels (Adjei and Fianu, 1985). Nutritive value of rhizome peanut (*Arachis glabrata* Benth) was consistently lower for 60-day harvests than for 30-day harvests. Rhizome peanut harvested at 30-day intervals had 50 g kg^{-1} greater CP, 72 g kg^{-1} greater *in vitro* true digestibility (IVTD) and 40 g kg^{-1} greater digestible neutral detergent fibre (DNDF) coupled with 80 g kg^{-1} lower neutral detergent fibre (NDF) than rhizome peanut harvested at 60-d intervals(Romero *et al*.,1987).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

Field trials were conducted during the 2006, 2007 and 2008 cropping seasons at the Institute for Agricultural Research (IAR) Experimental Farm, Ahmadu Bello University, Samaru (lat $11^0 11'\mathrm{N}$, long. $7^0 38'\mathrm{E}$, 686m above sea level) in the northern Guinea savanna zone of Nigeria. Samaru has a long-term mean annual rainfall of 1100 mm, which is spread between April and October (Kowal and Knabe, 1972). The rainfall distribution pattern is unimodal.

3.1.1 Cropping history

Appendix I shows the previous cropping history of the various sections of the experimental site used in the study

3.1.2 Meteorological data

Records of rainfall, air temperature, sunshine hours and relative humidity at Samaru during the experimental periods were obtained from the Meteorological Unit of the Institute for Agricultural Research and are shown in Appendices II, III and IV.

3.1.3 Soil analysis

Prior to land preparation, composite soil samples from the experimental field were randomly taken at depths of 0-15 cm and 15-30 cm using a soil auger. The soil samples were bulked, air-dried and ground to pass a 2 mm mesh before subjecting them to laboratory analysis. Physical and chemical properties of the soil samples were determined using standard procedures as described by Black (1965). Results are presented in Table 1.

Table 1: Physical and chemical properties of soils from two depths (0-15 and 15-30cm) of the experimental fields during 2006- 2008 cropping seasons at Samaru.

	Years					
	2006		2007		2008	
	0-15	15-30	0-15	15-30	0-15	15-30
Particle size distribution						
Sand (%)	46	40	46	46	46	44
Silt (%)	40	42	44	42	44	40
Clay (%)	14	18	10	12	14	16
Textural class	Loam	Loam	Loam	Loam	Loam	Loam
Chemical composition						
pH in H_20 (1:2.50)	5.90	5.60	6.00	6.10	5.50	5.60
pH in 0.01 M $CaC1_2$ (1:2.50)	5.20	4.90	4.60	4.80	5.00	4.80
Organic carbon (g kg^{-1})	7.6	3.7	3.2	2.3	4.3	3.8
Total nitrogen (g kg^{-1})	0.7	0.3	1.4	1.4	0.7	0.5
Available phosphorus (mg kg^{-1})	8.40	5.25	17.50	17.50	13.13	12.30
Exchange bases (cmol kg^{-1})						
Ca	3.62	2.82	2.20	1.86	2.60	2.00
Mg	0.87	1.04	0.84	0.73	0.84	0.46
K	0.15	0.25	0.14	0.12	0.15	0.12
Na	0.12	0.16	0.10	0.12	0.16	0.14
(H+AL)	0.20	0.20	0.40	0.40	0.40	0.40
CEC	7.60	6.80	5.70	5.70	5.10	4.60

3.2 Treatments and Experimental Design

The treatments were composed of factorial combinations of the following:

Four rates of phosphorus application (0, 12, 24 and 36 kg P ha^{-1})

Two cutting heights (10 and 20 cm)

Four cutting ages (6, 12, 18 weeks after sowing (WAS) and maturity)

Phosphorus and cutting heights constituted the main plots, while cutting ages were the sub-plots. The gross plot size was 5m x 3m = $15m^{2.}$ There were 10 rows of 16 stands each, giving a total of 160 stands in the 5m x 3m gross sub-plot area. The experimental design was a split-plot with three replications.

3.3 Description of the Test Crop

The lablab accession ILRI 147 (black seeded and late maturing) which was introduced by International Livestock Research Institute (ILRI), Ibadan, Nigeria from International Center for Tropical Agriculture (CIAT), Colombia, South America and multiplied by International Institute for Tropical Agriculture (IITA) sub-station, Samaru, Nigeria was used in the study. ILRI 147 was chosen among other accessions because of its seed sufficiency. ILRI 147 is of Highworth parentage and a common accession in Nigeria. According to Wood (1983), Highworth lablab dry matter yields range from 2.8-5.8 tonnes ha^{-1}, while leaf and stem dry matter yields are 1.5-1.9 and 1.3-3.9 tonnes ha^{-1} respectively.

3.4 Cultural Practices

3.4.1 Land preparation

After the rains were established, the experimental site was harrowed appropriately to prepare a fine seed bed for sowing. The main and subplots were marked out such that there was a 2m border between the main plots and a 1.5m border between the subplots.

3.4.2 Seed treatment

The lablab seeds were dressed with Apron star (20% w/w thiamethoxam, 20% w/w metalaxyl-M, 2% w/w difenoconazole of active ingredient (a.i.)) at the rate of 10g per 3 kg seed before sowing to protect the seeds against attack from soil borne pests and diseases.

3.4.3 Seed sowing

Three seeds per hill were sown at 3 cm depth and spaced accordingly (30 cm inter x 30 cm intra row) for fodder production (Amodu *et al*., 2003) with a seed rate of 24 kg ha^{-1} as recommended for the northern Guinea savanna (Muhammed and Abubakar, 2004). The sowing was carried out on 22/7/06, 24/6/07 and 21/6/08. Stands were thinned to one seedling per stand at 3 weeks.

3.4.4 Fertilizer application

Phosphorus fertilizer as single superphosphate (41.2%P_2O_5) at 0, 12, 24 and 36 kg P ha^{-1} was incorporated along side of each seedling to the respective plots depending on the treatment as source of P. Also, 20 kg N ha^{-1} as urea (46%N) was similarly incorporated uniformly across plots at 3WAS.

3.4.5 Weed and pest control

Integrated weed management (chemical, hoe weeding and hand pulling) was employed to ensure adequate plant establishment and surface cover. Glyphosate (1.8 kg a.i. ha^{-1}) was applied

before land preparation, while Pendimethalin (2.0 kg a.i.ha^{-1}) was applied after sowing at 3WAS. At 6WAS, supplementary hoe weeding was carried out. Undesirable weed species that grew above the canopy were hand pulled as observed.

Incidence of insect pests and diseases was monitored and these were effectively controlled. *Zonocerus variegates* (variegated grasshopper),*Mylabris bifasciata* (Degeer) a flower feeder, *Clavigralla tomentosicollis* (Stal) and *Clavigralla shadabi* (Dolling) both pod suckers and larvae of *Maruca spp.,* a pod borer, were the major insect pests observed. Generally, these insect pests manifested at the onset of pod formation and were controlled through bi-weekly applications of Cypermethrin/Dimethoate combination at 2 litres ha^{-1}.

During the peak of rainy season, signs of web blight and cercospora leaf spot diseases were observed. The systemic fungicide Benlate, (50% benomyl) applied at the rate of 2 kg ha^{-1} biweekly was used to control these diseases.

3.4.6 Cutting management (harvest of herbage)

The crop in the gross sub-plot (10 rows of 16 stands each, 160 stands in 5m x 3m area) was cut with a sharp sickle at the appropriate height and shed leaves were raked, bagged and weighed at each cutting age (6, 12, 18 weeks after sowing (WAS) and maturity which corresponded to 28 WAS), while five plants were randomly uprooted from each sub-plot at each cutting age to determine the growth parameters measured.

3.5 Observations and Data Collection

3.5.1 Initial stand count

At 3 WAS, the number of surviving seedlings in each sub-plot was counted and recorded after thinning and thereafter fertilizer was applied as described in 3.4.4.

3.5.2 Sward height

Four random measurements from the ground level to the top of the canopy were taken at 6, 12 and 18 WAS for each sub-plot using a metre rule before cutting was imposed; and the mean value computed and recorded in centimetre.

3.5.3 Ground cover score

The area of ground covered by foliage was scored at 6, 12 and 18 WAS using a scale of 1-5 where 1 represented low and 5 total land cover, before cutting was imposed.

3.5.4 Number of root nodules per plant

Nodules were detached from the roots of five randomly sampled plants from the gross sub-plot, and cleaned of soil particles. The nodules were counted and the mean recorded.

3.5.5 Nodule dry weight per plant

After counting, the detached nodules(from 3.4.5), were dried to a constant weight in a Gallenkamp oven (Model ov-440) at a temperature of 70^0C before weighing with a sensitive balance (Thelco(GCA) precision scientific) and recorded in gramme.

3.5.6 Number of primary branches

The five randomly uprooted plants from 3.5.4 were stripped of their leaves to count the branches, after which the mean value was recorded.

3.5.7 Leaf area (LA) per plant

Detached leaves (3.5.6) were used to determine the leaf area at 6, 12 and 18 WAS, by the cork borer method which is based on the concept of leaf area ratio. Total leaf area is calculated by multiplying the area: weight ratio found in the disc samples by total dry leaf weight described by Watson, 1958; Larson, 1965; Kvet and Svoboda, 1971.

$$\text{Leaf area} = \frac{Area\ of\ discs}{Dry\ weight\ of\ discs}\ x\ Total\ leaf\ dry\ weight \qquad (cm^2)$$

3.5.8 Leaf area index (LAI)

The LAI, a unit-free ratio which is the leaf area over the area of land sampled, was determined at 6, 12 and 18 WAS as described by Watson (1958) as follows:

LAI = *Leaf area per plant/ Area of ground occupied by plant*

3.5.9 Mean net assimilation rate (NAR)

Net assimilation rate is a measure of the photosynthetic efficiency of the plant within a given period of time. This was determined as described by Radford (1967) as follows:

$$\overline{NAR} = \frac{W_2 - W_1}{A_2 - A_1} \quad \frac{(\log e\ A_2 - \log e\ A_1)}{(t_2 - t_1)} \qquad (g.\ dm^{-2}.wk^{-1})$$

Where W_2 and W_1 are dry weights in g $plant^{-1}$, A_2 and A_1 are leaf areas in cm^2 at times t_2 and t_1, respectively.

3.5.10 Mean relative growth rate (RGR)

This is the increase of plant material per unit of material present per unit of time. This was calculated as described by Radford (1967) as follows:

$$\overline{RGR} = \frac{\log e\ W_2 - \log e\ W_1}{t_2\ \ t_1} \qquad (g.\ g^{-1}.wk^{-1})$$

Where W_2 and W_1 are dry weights in g plant^{-1} at times t_2 and t_1 in weeks respectively.

3.5.11 Mean crop growth rate (CGR)

This is the increase of plant material per unit of time. This was determined as described by Radford (1967) as follows:

$$\overline{CGR} = \frac{W_2 - W_1}{t_2 - t_1}.1/GA \qquad (g.m^{-2}.wk^{-1})$$

Where W_2 and W_1 are dry weights in g plant^{-1} at times t_2 and t_1 in weeks, respectively and GA= ground area occupied by the plants.

3.5.12 Initial dry herbage

At each cutting age, the fodder from a gross sub-plot was weighed and sub-sampled for dry weight determination. The sample was dried to constant weight using a Gallenkamp oven at 70^{o}C for some days. The total dry weight was then expressed in tonnes ha^{-1}.

3.5.13 Final harvest

The final harvest was carried out on 25/1/2007, 21/1/2008 and 20/1/2009 with the cutting of all the 96 experimental gross sub-plots.

3.5.14 Cumulative dry herbage

This is a summation of 3.5.12(for sub-plots cut that were cut at 6, 12 and 18 WAS) and 3.5.13(for sub-plots cut at maturity). It is a measure of the total fodder produced per sub-plot in each season; thus for sub-plots cut at 6,12 and 18 WAS it is first and second harvest; and for plots cut at maturity it is first harvest.

3.5.15 Relative regeneration rate (RRR)

This estimates the ability of a crop to re-grow when it is cut at certain stages of growth using the formula described by Odion and Singh (2005a) as follows:

$$RRR = \frac{B - A}{A} \; x \; 100$$

Where A = fodder from control plots; B = total fodder from clipped plots (cumulative dry herbage)

3.5.16 Number of days to 50% flowering

The days from sowing to the time when 50 %(visual estimate) of the plants within the plot had produced flowers was recorded.

3.5.17 Number of pods per plant

The weight and number of pods in 25 samples was used to establish a factor. With that factor, the number of pods from each sub-plot was extrapolated from the pod weight. Finally, the number of plants harvested per sub-plot was used to divide the pod number to obtain this parameter.

3.5.18 Mean pod weight

After harvest, twenty randomly selected pods were obtained from each sub-plot and then weighed to determine the mean pod weight in grammes.

3.5.19 Mean pod length

Each of the 20 randomly selected pods from 3.4.18 was measured and then the mean pod length determined in centimetres.

3.5.20 Number of seeds per pod

After obtaining pod weight and pod length, the 20 randomly selected pods were threshed and the seeds contained there-in were counted before the mean value was computed.

3.5.21 100-seed weight

After threshing, pods from each sub-plot, 100 seeds were picked at random and weighed with an Escali professional scale. This process was repeated to obtain the mean of two samples that was recorded in grammes.

3.5.22 Seed yield

The pods from plants within a gross sub-plot were harvested at maturity, air- dried and later threshed to determine the seed yield in kg ha^{-1} through extrapolation by using a conversion factor.

3.6 Proximate Analysis

The dried samples from 3.5.12 were ground in a Christy 8”lab mill (Christy and Norris Ltd, England) and labeled for proximate analysis.

Proximate analysis was carried out to determine the quantities of dry matter, crude protein, ash, ether extract, crude fibre and nitrogen-free-extract. The concentration of minerals (calcium and phosphorous) were also determined. Proximate and mineral analyses were carried out according to the AOAC (1990) methods.

3.6.1 Determination of dry matter (DM)

Percent DM was calculated with the formula below.

%DM=100- % moisture

To obtain percent moisture, a dry metallic dish was weighed (W1) and 1-5g of the ground sample was placed in the dish and weighed again (W2). The sample and dish were weighed after drying in an oven (set at 70^{o}C) to constant weight (W3). Finally, percent moisture was calculated with the formula below.

% moisture =W2-W3/ W2-W1 x100

Where W1=weight of dish

W2=weight of dish and sample before drying

W3=Weight of dish and sample after drying

3.6.2 Determination of crude protein (CP)

Nitrogen (N) content was determined by the macro kjeldahl method of AOAC (1990) and crude protein calculated as N x 6.25.

To determine N, 2.3g of the ground sample was put into a macro kjeldahl flask into which a catalyst (cupric sulphate plus sodium sulphate anhydrous) and 25 ml of concentrated H_2SO_4 were

added and digested in a well ventilated area under low heat. After digestion (when liquid was clear) the liquid was transferred into a 100ml volumetric flask and made up to mark with distilled water; following which distillation was carried out with 10ml of the aliquot (digest) and 10ml of 40% NaOH. The liberated ammonia (NH_3) was trapped with 10ml of 2% boric acid in the receiving flask. When 30-40ml of distillate had been collected into the receiving flask, distillation was terminated. Next, titration apparatus was set up. The distillate was liberated with 0.1N H_2SO_4 and the process was stopped at the proper end point.

Subsequently, the nitrogen content was calculated based on the formula below:

% N_2=Normality of the acid ammonia x volume of distillate x 100 x T/

Sample wt (mg) x volume of digest (aliquot)

Where T=titre volume

3.6.3 Determination of Ash

To determine ash, a dry crucible was weighed and the weight recorded (W1). A 1-5g of the ground sample was weighed and put into the crucible which was then reweighed (W2). The crucible with sample was transferred to a muffle furnace set at 600^{o}C to ash. After ashing the crucible was taken out and placed in a desiccator to cool, following which it was weighed again (W3).

The quantity of ash in percentage was calculated with the formula below

% Ash = W3 –W1/ W2-W1 x 100

where W3 = ash + crucible weight

W2 =sample + crucible weight

W1=crucible weight.

3.6.4 Determination of ether extract (EE)

Ether extract determination was carried out with a soxhlet extractor, a reflux condenser and a round bottom flask of 500ml capacity. A 3-5g of the ground sample was placed in a weighed fat free thimble (W1). The thimble was lightly plugged with cotton wool and weighed again (W2), before it was placed in the extractor and the solvent (petroleum spirit of 40-60^{o} C) added appropriately. The condenser was then replaced and the flask was placed on a heating mantle to boil gently for 6 hours. After boiling, the condenser was detached and the thimble removed and placed in a fat free beaker to dry to a constant weight in an oven set at 70^{0}C. After drying, the thimble was put in a desiccator to cool and then weighed (W3).

Subsequently, the weight of the extracted lipid was then calculated with the formula below:

%EE= W2 –W3/ W2-W1x100

Where W1=weight of sample plus fat free thimble

W2=weight of sample, thimble plus cotton wool

W3=weight of thimble after desiccation

3.6.5 Determination of crude fibre (CF)

To obtain percent crude fibre, 1-1.5g of ground sample (W1) was placed into a dry 600 ml beaker and 100ml H_2SO_4 was added and boiled for 30 minutes. After boiling it stood for 1 minute before pouring through a cheese cloth. The acid was washed off the residue with hot water. Then, the residue was collected back into the original beaker by means of a wash bottle with 100ml of dilute NaOH and boiled slowly for 30 minutes. Again, it stood for 1 minute before it was filtered through a cheese cloth. The residue was then washed thrice with hot water and rinsed with acetone.

The insoluble material was then transferred to a weighed crucible (W2) and dried in an oven to constant weight before weighing again (W3). Next, the sample in the crucible was ashed in a muffle furnace set at 600^0C and after ashing, the crucible and ash were cooled in a desiccator before the ash was weighed (W4).

Finally, percent crude fibre was calculated with the formula below:

% CF = (W3-W2) – (W4-W2)/ W1 x 100

Where W1 = weight of sample

W2= weight of crucible

W3= weight of crucible plus dry sample

W4= weight of ash.

3.6.6 Determination of nitrogen-free-extract (NFE)

Percent nitrogen-free-extract was calculated as a difference from 100 of the total percentages of CP, ash, EE and CF with the formula below:

%NFE= 100 – (%CP + % ash + % EE + % CF)

3.6.7 Determination of calcium (Ca)

Percent calcium was determined by the titrimetric method of AOAC (1990) in which 2 grams of the sample was weighed into a porcelain crucible and ashed in a muffle furnace at 600^0C for 3 hours. The ash was then dissolved in a known volume of 25% HCl with a few drops of concentrated nitric acid (HNO_3). The mixture was boiled and filtered into a 100ml volumetric flask after which 4 ml of the solution was pippeted into a centrifuge tube and 3ml of 4.2 % ammonium oxalate was added and the $_P$H adjusted to 2.5-3.0.

The new mixture stood overnight and was then centrifuged at 3,000 rpm for 5 minutes, following which the supernatant was discarded and 3ml of 2% ammonium hydroxide was added and centrifuged again at the same rate and time as above. Subsequently, the supernatant was discarded and 2ml of 2% H_2SO_4 was added. Thereafter, the content was heated at 60-70^0C and then titrated with 0.01 normal potassium permanganate.

Ultimately, percent calcium was calculated with the formula below:

% Ca = T x 0.25Ca / 100 gm sample

where T=titre value

3.6.8 Determination of phosphorus (P)

To determine percent phosphorus, a 1ml sample of the ash solution (ash plus known volume of 25% HCl and a few drops of concentrated HNO_3) from calcium determination was pippeted into a 25ml volumetric flask. Then 5ml of molybdo-vanadate colour reagent was added and allowed to stand for 10 minutes for colour development. After colour development, the optical density (OD) in spectrophotometer at 470nm was read. The percent P was then calculated with the formula below:

%P = OD test sample/ OD standard x concentration of standard

Where OD= optical density.

3.7 Statistical Analysis

The data collected were subjected to analysis of variance to test the significance of treatment effects as described by Snedecor and Cochran (1967), and the means were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1955). The correlation coefficients were computed and further partitioned into their direct and indirect contributions to the dependent variable. Furthermore, because these contributions are from different entities and units, in order to make them out of a single entity and unit-free, they were further worked out on a percent basis to get over the problems of different entities and units (Ahmed, 1997). Regression analysis was also done to determine the polynomial response of the herbage yield to the factors tested (Little and Hills, 1978).

CHAPTER FOUR

4.0 RESULTS

4.1 Growth Parameters

4.1.1 Sward height

Effects of phosphorus application, cutting height and cutting age on sward height at 6 and 12WAS in 2006, 2007 and 2008 along with the combined data of the three years are shown in Table 2. Phosphorus did not affect lablab sward height at 6WAS in 2006 and 2008 and at 12WAS in 2008. However, at 6WAS in 2007, the highest P application rate (36 kg P ha^{-1}) produced a taller lablab sward than the control, which was at par with the other P application rates. In the combined data at 6WAS, a 12 kg P ha^{-1} rate of application produced a significantly taller sward than the control. Whereas, the P application rates of 12, 24 and 36 kg P ha^{-1} produced similar sward heights; those of 0, 24 and 36 kg P ha^{-1} were also at par with respect to this lablab parameter. In 2006, the lablab sward height at 12WAS with 12 kg P ha^{-1} was significantly higher than that with 36kg P ha^{-1}, which was at par with the control and 24 kg P ha^{-1} application rates. In 2007, the sward heights at 12WAS with the two higher P rates of 24 and 36 kg P ha^{-1} were at par but produced swards that were taller than those of the control and 12 kg P ha^{-1}, both of which were also at par. In the combined data, the rates of 12, 24 and 36 kg P ha^{-1} were at par with 24 and 36 kg P ha^{-1} recording higher sward height values than the control. However, the 12 kg P ha^{-1} application rate produced a lablab sward height that was at par with that of the control.

Cutting height did not significantly influence sward height of lablab except in the combined analysis at 12WAS where the higher cutting height (20cm) produced a taller sward than the lower cutting height (10cm).

The effect of cutting age on sward height was not significant at 6WAS in any year or in the combined data. However, at 12WAS cutting age exerted a significant influence on the sward height of lablab across the three years of study and in the combined data. The consistent trend showed that the older cutting ages (12-, 18 weeks up to maturity) was at par and produced significantly taller swards than the 6-week cutting age (by 62.9 and 108.7 % in 2007 and 2008 respectively). However, in 2006 the lablab sward produced at the 12-week cutting age was significantly taller than those produced at 18 weeks and maturity that were at par. In 2008 the swards produced at the 12 and 18 week cutting ages were statistically similar and significantly taller than that produced at maturity. In the combined data, the sward produced at 12-week cutting age was significantly higher than those produced at 6 weeks and at maturity. However, the 12-week and 18-week cutting ages had similar sward heights, while 18 weeks and maturity were also at par in terms of sward height of lablab.

The phosphorus rate x cutting height interaction for sward height was significant in the combined data of both 6WAS and 12WAS (which are presented below), while the cutting height x cutting age interactions for sward height were significant at 6WAS in 2008, 12WAS in 2007, 2008 and in the combined data at 12WAS (which are not presented). The other interactions were not significant. With regards to the significant phosphorus rate x cutting height interaction for sward height in the combined data at 6WAS (Table 3); holding cutting height constant and varying phosphorus, at 10cm cutting height the P application rates of 12 and 24 kg P ha^{-1} produced similar sward height that was statistically higher than the sward produced with the 0 kg P ha^{-1}, however 12 and 36 kg P ha^{-1} also were at par in sward height at this growth stage (Table 3). At the 20cm cutting height, 36 kg P ha^{-1} was statistically but superior to 24 kg P ha^{-1} while 0, 12 and 36 kg P ha^{-1} were similar in terms of sward height in lablab. Holding P constant and varying cutting height, sward

height of lablab was similar irrespective of cutting height except at 24 kg P ha^{-1} where the lower cutting height (10cm) produced a statistically taller sward than the higher cutting height (20cm).

The significant phosphorus rate x cutting height interaction for sward height at 12WAS combined over 2006-2008 is presented in Table 4. Holding cutting height constant and varying phosphorus, at 10cm the control (0 kg P ha^{-1}) produced the shortest sward height that was at par with the highest P application rate (36 kg P ha^{-1}). At 20cm, the higher P rates of 24 and 36 kg P ha^{-1} were at par and produced significantly taller swards than the zero-P control and 12 kg P ha^{-1}. In holding P constant and varying cutting height, sward height of lablab was statistically similar at all P application rates except at the highest rate (36 kg P ha^{-1}) where the 20cm cutting height produced a significantly higher lablab sward than the 10cm cutting height.

Sward height of lablab as influenced by phosphorus application, cutting height and cutting age at 18WAS in 2006,2007 and 2008 with the combined data over 2006-2008 are presented in Table 5.Phosphorus application did not affect sward height significantly in any year(2006-2008) except in the combined data. Application rate of 12 kg P ha^{-1} produced a higher sward than the control. However, the sward heights produced with the P application rates of 12, 24 or 36 kg P ha^{-1} on one hand and 0, 24 and 36 kg P ha^{-1} on the other hand were statistically similar.

Cutting height affected sward height of lablab at 18WAS significantly in 2007, 2008 and in the combined analysis in a similar manner. A cutting height of 20cm produced a higher sward than a cutting height of 10cm. The influence of cutting age on sward height of lablab was consistent and significant across the years (2006-2008) and in the combined data. The sward heights produced when lablab was cut at either 18 weeks or at maturity were at par and significantly higher than the sward produced from cutting at 6 weeks which was also significantly higher than the sward produced from cutting at 12 weeks except in 2006, when the sward produced at 6-, 18 weeks and at

maturity were at par. The sward height produced at the12-week cutting age in 2007, 2008 and in the combined data was strikingly lower than the rest. When the combined data is considered, the mean sward height of 18 weeks and maturity was 106.6% while that of 6 weeks was 84.2% greater than the sward height produced by lablab at the 12-week cutting age. While the other interactions were not significant, the significant cutting height x cutting age interaction for sward height in 2007 is not presented.

4.1.2 Ground cover score

Effects of phosphorus application, cutting height and cutting age on ground cover score at 6 and 12WAS in 2006, 2007 and 2008 with the combined data of the three years are presented in Table 6. Phosphorus application did not significantly affect ground cover score at 6WAS in 2006, 12WAS in 2007 and 2008. At 6WAS in 2007 and in the combined data the effect of phosphorus was similar. The substantive P application rates of 12, 24 and 36 kg P ha^{-1} were at par and covered the ground quicker than the control (0 kg P ha^{-1}). However, in 2008 the 12 kg P ha^{-1} application rate was statistically superior to the 0, 24 and 36 kg P ha^{-1} rates of application that were also at par in terms of ground cover score. At 12WAS in 2006, the 12 kg P ha^{-1} rate of application was statistically superior to the 0 kg P ha^{-1} and 36 kg P ha^{-1} rates of application. However, 12 and 24 kg P ha^{-1} rates of P application were at par while 0, 24 and 36 kg P ha^{-1} rates of application were also at par in terms of ground cover score. The result of the combined analysis at 12WAS was similar to the one obtained in the combined analysis at 6WAS.At both sampling stages the control (0 kg P ha^{-1}) had a significantly lower ground cover score than the substantive P application rates that were at par for this parameter.

Cutting height did not affect ground cover score either at the 6 or 12WAS sampling stages. Similarly, cutting age exerted no influence on ground cover score at 6WAS in 2007, 2008 and in the

combined data of 6WAS as well as at 12WAS in 2006.At 6WAS in 2006, cutting at 6-, 18 weeks and maturity produced similar ground cover score that was statistically higher than the one produced when cutting was done at 12 weeks of age. At 12WAS in 2007, 2008 and in the combined data, cutting age affected lablab ground cover score in a similar manner. The longer cutting ages of 12 weeks, 18 weeks and maturity were at par and produced lablab ground cover scores that were significantly higher than what was produced when cutting was at the youngest age of 6 weeks.

The phosphorus rate x cutting height interaction for ground cover score at 12WAS in 2008, and the cutting height x cutting age interaction for ground cover score in the combined data were significant. The significant phosphorus rate x cutting height interaction for ground cover score at 12WAS in 2008 is shown in Table 7. Holding cutting height constant at 10cm and varying phosphorus, the ground cover score at 24 kg P ha^{-1} was statistically higher than that at 12 kg P ha^{-1} whereas at 20cm cutting height, the various P rates were at par. On the other hand, holding P constant and varying cutting height, it was observed that ground cover score was similar at all P application rates except at 24 kg P ha^{-1} where a cutting height of 10cm resulted in a higher ground cover score than 20cm cutting height.

Table 8 shows the data on the effects of phosphorus application, cutting height and cutting age on lablab ground cover score at 18WAS in 2006-2008 and the combined data of the three years. Phosphorus application did not influence ground cover score at any sampling period.

Cutting height affected ground cover score of lablab significantly in 2007, 2008 and in the combined analysis in a similar manner; the 20cm cutting height produced a statistically higher score than the lower height, but in 2006 the effect of cutting height was not significant. The effect of cutting age on ground cover score was consistent and significant across the years of study and in the combined analysis. Generally, cutting at the 12-week age produced the lowest ground cover score

(by some 55.6-80.0%) compared to the mean of the longer cutting ages that were at par, while cutting at either 18 weeks or at maturity were at par and significantly higher than the ground cover score produced at 6 weeks, except in 2006 when these cutting ages (i.e. 6-, 18 weeks and maturity) were at par in terms of lablab ground cover score.

The cutting height x cutting age interaction for ground cover score in 2006 and 2008 was significant but is not presented.

4.1.3 Number of primary branches

Effects of phosphorus application, cutting height and cutting age on number of primary branches at 6 and 12WAS in 2006, 2007 and 2008 and the combined data of the three years (2006-2008) are presented in Table 9. Phosphorus application affected the number of primary branches of lablab only at 6WAS in 2007 when the higher rates (24 and 36 kg P ha^{-1}) of P application which were at par produced significantly more lablab primary branches than the control (0 kg P ha^{-1}). However, the 12, 24 and 36 kg P ha^{-1} application rates on one hand and 0 and 12 kg P ha^{-1} application rates on the other hand produced similar primary branches.

Cutting height did not significantly affect number of primary branches at any sampling period. The influence of cutting age on number of primary branches was not significant at 6WAS in 2006-2008 and the combined data as well as at 12WAS in 2006 and the combined data. At 12WAS in 2007 and 2008 no particular trend was evident in the significant effect of cutting age on lablab primary branches. In 2007 for example, cutting at 6-, 12- and 18-week ages produced similar primary branches while cutting at 6-, 18 weeks or maturity also produced similar primary branches.

However, in 2008 maturity produced significantly more primary branches than cutting at either 12 or 6 weeks. The number of primary branches produced when cutting was carried out at 12 weeks was significantly more than when cutting was done at 6 weeks. However, cutting at 12 or 18 weeks produced similar primary branches as was cutting at either 18 weeks or maturity which were also at par in the number of primary branches. The interactions were not significant.

Table 10 shows the effects of phosphorus, cutting height and cutting age on the number of primary branches at 18WAS in 2006, 2007 and the combined data of both years. Phosphorus application significantly affected lablab number of primary branches in 2006 and in the combined data in a similar manner. A 12 kg P ha^{-1} rate of application produced more primary branches than the 36 kg P ha^{-1} application rate. However, the P application rates of 0, 12 and 24 kg P ha^{-1} were at par while 0, 24 and 36 kg P ha^{-1} rates of application were also at par in terms of number of primary branches of lablab.

Cutting height did not significantly affect the number of primary branches. With regards to cutting age, the number of primary branches of lablab was affected by this factor only in 2007 when the cutting ages of 6-, 18 weeks and maturity produced similar primary branches that were significantly more than those obtained when lablab was cut at 12 weeks.

The phosphorus rate x cutting age interaction for number of primary branches in 2006 and in the combined data of both years was significant. However, the significant phosphorus rate x cutting age interaction for number of primary branches in the 18WAS combined data of 2006-2007 is presented in Table 11. At a constant cutting age with varying levels of phosphorus, number of primary branches of lablab was similar except at the 18-week cutting age where an application rate of 12 kg P ha^{-1} produced significantly more primary branches than all the other P rates that were at par. At a constant rate of P application, with variable cutting ages, number of primary branches in

lablab was similar at the P application rates of 0 and 36 kg P ha^{-1} but varied significantly when 12 or 24 kg P ha^{-1} was applied. However, at 12 kg P ha^{-1} cutting lablab at 18-weeks of age produced the most primary branches whereas at 24 kg P ha^{-1}, waiting until maturity before cutting, favoured number of primary branches in lablab over cutting at 12-weeks of age.

4.1.4 Leaf area per plant

Table 12 shows the effects of phosphorus, cutting height and cutting age on leaf area per plant at 6 and 12WAS in 2006-2008 and the combined data of the three years. Phosphorus application only affected leaf area per plant of lablab at 6WAS in 2007 and in the combined data of the same growth stage (6 weeks).In 2007, a phosphorus application rate of 24 kg P ha^{-1} produced a significantly higher leaf area than the control. In addition, the 24 and 36 kg P ha^{-1} rates of application were at par while 12 and 36 kg P ha^{-1} and 0 and 12 kg P ha^{-1} rates of application were at par in terms of leaf area per plant of lablab. In the combined data, the 24 kg P ha^{-1} application rate produced a significantly higher leaf area per plant than the 0 and 36 kg P ha^{-1} rates of application. However, 12 and 24 kg P ha^{-1} on one hand and 0, 12 and 36 kg P ha^{-1} on the other hand, had similar leaf area per plant.

Cutting height did not significantly affect leaf area per plant at these growth stages (6 and 12 weeks). Whereas, cutting age influenced leaf area per plant significantly in most cases (Table 12). At 6WAS in 2007, cutting at 6 weeks produced lablab leaf area that was significantly larger than those produced at 12 weeks (by 25.5%) and maturity (by 18.2%). However, the leaf area produced at the 6- and 18 weeks cutting ages were similar while leaf area produced at 12, 18 weeks and maturity were also at par. In the combined data of 6WAS, cutting at either 6-, 18 weeks or maturity produced similar leaf area per plant in lablab, which was significantly larger than the one produced at the 12-week cutting age. However, the leaf area produced at the cutting ages of 12 weeks and maturity

were also at par. At 12WAS, the noticeable trend was that the longer cutting ages were favourable to leaf area production. In 2006, leaf area produced at the 12, 18 weeks and maturity cutting ages were at par and their mean was greater than the one produced at the 6-week cutting age by as much as 71.9%, although 6 and 18 weeks produced similar leaf area per plant. In 2008, the leaf area produced at maturity was significantly greater than the ones produced at 6 weeks by 138.0% and at 12 and 18 weeks by 36.0%. In addition, leaf area produced at 12 and 18 weeks were at par and significantly greater than the leaf area produced at 6 weeks by 75.0%.In the combined data, leaf area produced at maturity was significantly greater than those produced at the 6- and 18-weeks cutting ages. However, cutting at 12 weeks and maturity had similar leaf area per plant as was cutting at either 12 or 18 weeks. The interactions were not significant.

At 18WAS in 2006, 2007 and in the combined data of both years, neither phosphorus application nor cutting height exerted any significant effects on leaf area per plant of lablab (Table 13).Whereas, cutting age significantly affected leaf area per plant in 2007 and in the combined data in a similar manner. Cutting at 12 weeks produced a statistically lower (by 106 and 84.2% in 2007 and in the combined data respectively) leaf area than the other cutting ages (6-, 18 weeks and maturity) which were at par in terms of this parameter. The interactions were not significant.

4.1.5 Leaf area index

Table 14 shows the effects of phosphorus, cutting height and cutting age on leaf area index (LAI) at 6 and 12WAS in 2006, 2007 and 2008 and the combined data of the three years (2006-2008).Phosphorus application significantly affected LAI only at 6WAS in 2007 and in the combined data of 6WAS.These results were similar to those obtained for leaf area per plant. At 6WAS in 2007, an application rate of 24 kg P ha^{-1} produced a significantly higher (by some 19.4-33.3%) leaf area index than 0 and 12 kg P ha^{-1} rates which had similar leaf area indices. However, 24 vs. 36, 12 vs. 36

and 0 vs.12 kg P ha^{-1} application rates had leaf area index values that were at par with each other at this stage of growth. In the combined analysis, 24 kg P ha^{-1} produced a leaf area index value that was statistically superior to the LAI values produced with 0, 12 and 36 kg P ha^{-1} application rates that were at par, although 12 and 24 kg P ha^{-1} application rates also produced similar LAI values in lablab.

Cutting height did not affect leaf area index of lablab significantly at the 6 and 12 WAS sampling periods and cutting age also did not significantly affect leaf area index at 6WAS in 2006 and 2008 and at 12WAS in 2007. At 6WAS in 2007, cutting at 6 weeks produced a leaf area index that was significantly higher than those obtained at 12 weeks (by 24.4%) and maturity (by 17.9%) but was similar to the LAI obtained at 18 weeks cutting age. In addition, the leaf area index value of lablab at 18 weeks was at par with those of the 12 week and maturity cutting ages. In the combined analysis, the cutting ages of 6-, 18 weeks and maturity were at par in terms of leaf area index. However, only the 6 and 18 week leaf area index values were significantly higher than the 12-week LAI value, which was at par with the LAI value obtained at maturity. At 12WAS, the trend showed that leaf area index obtained at maturity was significantly higher than the one produced at the 6-week cutting age, while those of 12 and 18 weeks were generally similar. However, in 2006 leaf area index at 6 and 18 weeks were at par whereas in the combined analysis the leaf area index at 12 weeks and maturity were also similar. The interactions were not significant.

At 18WAS, the effect of phosphorus was significant in the combined data of 2006 and 2007(Table 15). The lower P application rates of 0 and 12 kg P ha^{-1} were at par and produced significantly higher lablab leaf area index values than the higher P application rates of 24 and 36 kg P ha^{-1} which were also at par.

Cutting height did not affect leaf area index significantly, whereas cutting age did in the combined analysis (Table 15). Cutting at 12 weeks produced a lablab leaf area index value that was

significantly lower than those produced at the other cutting ages (i.e. 6, 18 weeks and maturity) which were at par. The cutting height x cutting age interaction for leaf area index in the combined data was significant but is not presented.

4.1.6 Number of root nodules

Table 16 shows the effects of phosphorus, cutting height and cutting age on the number of root nodules at 6 and 12WAS in 2006, 2007 and 2008 including the combined data of the three years (2006-2008). Application of phosphorus significantly affected the number of root nodules of lablab at 6WAS in 2006, 12WAS in 2006, 2007 and in the combined data of 12WAS. At 6WAS in 2006, the application rates of 0, 24 and 36 kg P ha^{-1} were at par and produced significantly more root nodules than the 12 kg P ha^{-1} application rate. At 12WAS in 2006, the substantive P application rates (i.e. 12, 24 and 36 kg P ha^{-1}) produced similar number of root nodules that was significantly more than that produced with the zero P control. Phosphorus application affected lablab root nodules at 12WAS in 2007 and in the combined data in a similar manner (Table 16). An application rate of 24 kg P ha^{-1} which was at par with 12 and 36 kg P ha^{-1} rates of application produced more root nodules than the control (0 kg P ha^{-1}) although the control was also at par with 12 and 36 kg P ha^{-1} rates of application in the number of root nodules produced by lablab.

Cutting height did not influence the number of primary branches at 6 or 12WAS, whereas cutting age affected this parameter in the combined data of 6WAS and also at 12WAS in 2007, 2008 and in the combined data (2006-2008) of 12WAS. The combined data at 6WAS showed that cutting at 6 weeks produced significantly more root nodules than cutting at 12 weeks. However, the numbers of root nodules of lablab produced at either 6, 18 weeks or maturity or at 12-, 18 weeks or maturity were similar. Cutting age affected the number of root nodules produced by lablab at 12WAS in 2007, 2008 and in the combined data in a similar manner. The older cutting ages (i.e. 12,

18 weeks and maturity) were at par and produced significantly more root nodules than the youngest age of 6 weeks.

The phosphorus rate x cutting height interaction for number of root nodules at 6WAS in 2006 was statistically significant (Table 17). Holding cutting height constant at 10cm, the P rates of 0, 12 and 24 kg P ha^{-1} were similar with respect to number of root nodules in lablab while 12 kg P ha^{-1} produced statistically more root nodules than 36 kg P ha^{-1}. At 20cm cutting height, the lower P rates of 0 and 12 kg P ha^{-1} were favourable to root nodule production compared to the higher P rates(24 and 36 kg P ha^{-1}). Holding phosphorus rate constant and varying cutting height, it was observed that number of root nodules in lablab was similar at both cutting heights except at 24 kg P ha^{-1} where the lower cutting height (10cm) had statistically more root nodules than the 20cm cutting height.

The phosphorus rate x cutting height interaction for number of root nodules at 12WAS combined over 2006-2008 was significant (Table 18). At a constant cutting height of 10cm, lablab produced the most root nodules, when 24 kg P ha^{-1} was applied. However, root nodules obtained at this application rate (24 kg P ha^{-1}) was similar to that produced with the application rate of 36 kg P ha^{-1}.At 20cm, the least root nodules were produced with 0 and 36 kg P ha^{-1} application rates. In holding P constant and varying the cutting height, the number of root nodules in lablab was similar at all levels of P fertilization (0, 12, 24 and 36 kg P ha^{-1}).

4.1.7 Nodule dry weight

Table 19 shows the effects of phosphorus, cutting height and cutting age on nodule dry weight at 6 and 12WAS in 2006, 2007 and 2008 along with the combined data across the years (2006-2008). The effects of these factors on nodule dry weight of lablab were for the most part similar to their effects on number of root nodules. Phosphorus application affected nodule dry

weight significantly at 6WAS in 2006 and at 12WAS in 2006, 2007 and in the combined data of this growth stage. At 6WAS in 2006, an application rate of 12 kg P ha^{-1} produced a nodule dry weight which was significantly heavier than those produced with 0,24 and 36 kg P ha^{-1} rates of application that were at par. The lablab nodule dry weight produced with 24 kg P ha^{-1} application rate was significantly higher than the nodule dry weight produced with 0 and 12 kg P ha^{-1} at 12WAS in 2006. In addition, 24 and 36 kg P ha^{-1} application rates produced similar nodule dry weight while 0, 12 and 36 kg ha^{-1} also produced similar nodule dry weights in lablab. At 12WAS in 2007, an application rate of 24 kg P ha^{-1} produced the heaviest nodule dry weight that was significantly higher than that produced with the zero P control. However, the substantive phosphorus application rates produced similar nodule dry weight although the 12 and 36 kg P ha^{-1} rates of application were at par with the zero P control in terms of lablab nodule dry weight. In the combined analysis of 12WAS the higher P application rates were at par and produced significantly heavier nodule dry weight than the control (0 kg P ha^{-1}).However, the 12 kg P ha^{-1} rate of application was at par with 0 kg P ha^{-1} on one hand and with 24 and 36 kg P ha^{-1} on the other hand in terms of nodule dry weight of lablab.

Cutting height did not affect nodule dry weight significantly throughout the 3-year study. Contrarily, cutting age affected nodule dry weight in the combined data at 6WAS. Cutting at 6 weeks produced nodule dry weight that was significantly heavier than that produced at 12 weeks. However, nodule dry weights of lablab cut at 6-, 18 weeks or at maturity were similar while those produced at 12-, 18 weeks or at maturity were also at par. At 12 WAS, cutting age affected lablab nodule dry weight in 2007, 2008 and in the combined data of the three years in the same manner. The older cutting ages of 12-, 18 weeks and maturity produced nodule dry weights that were at par and significantly greater than the one produced at the 6 weeks cutting age.

The phosphorus rate x cutting height interaction for nodule dry weight at 6WAS in 2006 was statistically significant (Table 20). Holding cutting height constant and varying P, at the 10cm cutting height, nodule dry weights were not statistically different whereas at 20cm,cutting height, 12 kg P ha^{-1} produced a markedly higher nodule dry weight than application of 24 kg P ha^{-1}(by 166.6%) Holding P constant and varying cutting height, at 0, 12 and 36 kg P ha^{-1} nodule dry weights of lablab were similar irrespective of cutting height. However, at 24 kg P ha^{-1} cutting height of 10cm produced statistically higher nodule dry weight than a 20cm cutting height. Nodule dry weight for 10cm cutting height was twice as high as that for the 20cm cutting height.

4.1.8 Mean Net Assimilation Rate

Effects of phosphorus application, cutting height and cutting age on mean net assimilation rate(NAR) at 6-12 and 12-18 WAS in 2006, 2007 and the combined data are shown in Table 21. Whereas, phosphorus application influenced mean net assimilation rate of lablab at 6-12WAS significantly across the three years of experimentation, mean net assimilation rate at 12-18WAS throughout the sampling periods was unaffected by phosphorus application. At 6-12WAS in 2006, the highest P application rate (36 kg P ha^{-1}) resulted in significantly higher (by 33.3%) mean net assimilation rate than application of 24 kg P ha^{-1}. Whereas, 36 kg P ha^{-1} was at par with the lower P application rates of 12 kg P ha^{-1} and control, the P application rates of 0, 12 and 24 kg P ha^{-1} were also at par in terms of their mean net assimilation rates in lablab. In 2007, the control produced significantly higher mean net assimilation rate than the 24 kg P ha^{-1} application rate. However, 0, 12 and 36 kg P ha^{-1} rates were at par while 12, 24 and 36 kg P ha^{-1} were also at par in terms of mean net assimilation rate of lablab. The combined data for 6-12WAS revealed that the control (no phosphorus) and 36 kg P ha^{-1} application produced significantly higher mean net assimilation rates in lablab compared to the 24 kg P ha^{-1} application rate. In addition, 12 and 24 kg P ha^{-1} were similar

while the control, 12 and 36 kg P ha^{-1} were also similar in their effects on mean net assimilation rate of lablab at this particular growth stage.

Cutting height did not affect mean net assimilation rate of lablab at any of the two periods of sampling in the two years that this parameter was assessed. However, cutting age affected mean net assimilation rate of lablab at all sampling periods during the years of study (2006-2008). The results revealed that at 6-12WAS mean net assimilation rate of lablab increased as cutting age increased from 6 weeks to either 12 or 18 weeks and maturity, which were at par in 2006. In 2007, the 12-week cutting age produced a NAR value that was significantly faster than those of the 6-week age and maturity. The trend of the combined data was similar to that for 2006. At 12-18WAS, mean net assimilation rate of lablab was slowest when lablab was cut at 12 weeks of age. Generally, cutting at 6 and 18 weeks of age produced similar mean net assimilation rate values that were significantly higher than that produced at 12-week cutting age. In addition, mean net assimilation rates of lablab at 18WAS and maturity were similar. The cutting height x cutting age interaction for this parameter (mean net assimilation rate) was statistically significant at 12-18WAS in 2007 but is not presented.

4.1.9 Mean relative growth rate

Effects of phosphorus application, cutting height and cutting interval on mean relative growth rate at 6-12 and 12-18 WAS in 2006, 2007 with the combined data for both years are shown in Table 22. Phosphorus application did not affect mean relative growth rate of lablab at 6-12WAS in 2006 and the 12-18WAS sampling period in 2006, 2007 and the combined data. At 6-12WAS in 2007 the control had significantly higher mean relative growth rate than all the substantive P application rates. However, lablab's relative growth rate in the control was statistically similar to the value obtained for the P application rate of 36 kg P ha^{-1}.The combined analysis revealed that the

control produced significantly higher relative growth rate than the P application rates of 12 and 24 kg P ha^{-1}. In addition, the control was at par with 36 kg P ha^{-1} while 12 and 24, and then 12 and 36 kg P ha^{-1} were each at par with respect to their values for relative growth rate of lablab.

Cutting height did not affect mean relative growth rate at each of the two sampling stages and years. On the other hand, cutting age exerted significant effect on mean relative growth rate of lablab throughout the sampling periods. At 6-12WAS mean relative growth rate in both years and the combined was favoured by older cutting ages and generally, cutting ages longer than 6 weeks up to maturity resulted in similar mean relative growth rates that were significantly higher than cutting at the youngest age of 6 weeks (Table 22). At 12-18WAS, the relative growth rate of lablab was significantly lowest when cutting age was 12 weeks. Furthermore, cutting at 6-weeks of age produced significantly faster relative growth rate than cutting at 18 weeks and maturity, except in 2007 when all the three cutting ages (6- , 18- weeks and maturity) resulted in similar mean relative growth rates in lablab. The cutting height x cutting age interaction for mean relative growth rate at 12-18WAS in 2007 was significant but is not presented.

4.1.10 Mean crop growth rate

Effects of phosphorus application, cutting height and cutting age on mean crop growth rate (CGR) at 6-12 and 12-18WAS in 2006, 2007 and the combined data over 2006 and 2007 are shown in Table 23. Phosphorus application affected mean crop growth rate at 6-12WAS in 2007 significantly. At this growth stage, the control produced significantly higher crop growth rate in lablab compared to the P applied rate of 24 kg P ha^{-1}.There was also a similarity in the crop growth rates of the P applied rates (12, 24 and 36 kg ha^{-1}) on the one hand, and (0,12 and 36 kg ha^{-1}) on the other. At 12-18WAS, phosphorus application also exerted significant influence on crop growth rate in 2006 and in the combined data (Table 23). At this growth stage the response of lablab to phosphorus application

in terms of crop growth rate was the same in 2006 and in the combined data. The control produced significantly higher crop growth rate than the P applied rate of 36 kg P ha^{-1}, which produced the lowest CGR value. In addition, the control had similar crop growth rate with plots fertilized with 12 and 24 kg P ha^{-1}, whereas plots that received 12, 24 and 36 kg P ha^{-1} were also at par in respect of crop growth rate of lablab.

Cutting height did not affect mean crop growth rate of lablab at any sampling period, in each of the two years. Contrarily, cutting age affected mean crop growth rate at all sampling periods in both years (2006-2007). At 6-12WAS, cutting at 6 weeks of age significantly reduced the crop growth of lablab compared to the older cutting ages (12, 18 weeks and maturity) that were at par. At 12-18WAS, cutting at 12-weeks of age produced significantly slower crop growth rates than the other cutting ages that were at par, except for 2006 when maturity was also at par with the 12-week cutting age in terms of crop growth rate of lablab.

4.1.11 Relative regeneration rate

The data on relative regeneration rate of lablab as influenced by phosphorus application, cutting height and cutting age for each of the three years (2006-2008) and the combined of the three years are presented in Table 24. Phosphorus nor cutting height did not significantly affect relative regeneration rate of lablab throughout the duration of the study.

Contrarily, cutting age significantly affected relative regeneration rate throughout the three years of study (2006-2008). As was the case with dry matter accumulation, relative regeneration rate of lablab was highest when cutting was carried out at 18-weeks of age. However, in 2006 and 2008 cutting at 12- and 18-week ages had similar rates of relative regeneration. In addition, the relative regeneration rate of lablab was usually at par when cutting was done at either 12-week age or at maturity, and based on the combined analysis, relative regeneration rate was slowest when

lablab was cut at 6-week age. The cutting height x cutting age interaction for relative regeneration rate was significant in 2006 only but is not presented.

4.1.12 Days to 50% flowering

The effect of phosphorus application, cutting height and cutting age on number of days to 50% flowering of lablab in 2006-2008 and the combined for the three years is shown in Table 25. Phosphorus application did not affect number of days to 50% flowering significantly in any of the years of study.

Cutting height affected number of days to 50% flowering of lablab in 2007 and 2008 but in an opposite manner. Whereas, the lower cutting height (10cm) resulted in earlier 50% flowering in 2007 it delayed 50% flowering in 2008. Opposite to this situation, 20cm cutting height delayed flowering in 2007 but caused lablab to reach 50% flowering earlier than the 10cm cutting height in 2008.

Cutting age significantly affected number of days to 50% flowering throughout the three years and in the combined analysis. The consistent trend was that cutting at 18-week age delayed 50% flowering of lablab significantly relative to the other cutting ages. However, cutting at 12WAS also delayed 50% flowering of lablab compared to the 6-week cutting age and maturity both of which were at par. In 2006, cutting at 6- and 12-week ages delayed number of days to 50% flowering compared to the 18-week age and maturity that were similar to the 6-week cutting age in terms of the number of days to 50% flowering of lablab. The cutting height x cutting age interaction for 50% flowering was significant in 2008 but is not presented.

4.2 Yield Parameters

4.2.1 Cumulative fresh herbage yield

Effects of phosphorus application, cutting height and cutting age on cumulative fresh herbage yield in 2006, 2007 and 2008 along with the combined data for the three years are shown in Table 26.

Phosphorus application and cutting height did not significantly affect lablab cumulative fresh herbage yield throughout the years of study. The influence of cutting age was significant in all the years and in the combined data. In 2006, the cumulative fresh herbage yields produced using the 12- and 18-week cutting ages were similar and significantly higher by 65.3% than that produced at maturity, which in-turn was statistically higher than the least fresh herbage yield produced at the youngest cutting age of 6 weeks. In addition, cutting age affected fresh herbage yield of lablab in 2007, 2008 and in the combined data in a similar manner. The fresh herbage yield produced at 18 weeks was statistically greater than that produced at the other cutting ages (Table 26). However fresh herbage yield produced at 12 weeks was statistically superior to that produced at maturity which in-turn is statistically greater than the least produced at 6 weeks cutting age. Using cutting ages of 6 and 12 weeks produced cumulative fresh herbage yields that were 91.6 and 27.1% lower than using the 18-week age respectively in 2007. Relative results in 2008 and the combined data were 82.1% and 29.0% for 2008 and 87.4 and 24.4% for the combined data. The cumulative fresh herbage yields for 18-week age were 65.8, 75.7 and 67.2% higher than that for maturity in 2007, 2008 and the combined data respectively. The interactions of factors on cumulative fresh herbage yield in each of the three years and the combined data were statistically not significant.

4.2.2 Cumulative dry herbage yield

The data on cumulative dry herbage yield of lablab as influenced by phosphorus application, cutting height and cutting age in 2006-2008 with their combined analysis are presented in Table 27. Application of P fertilizer significantly influenced dry herbage yield only in 2008. The application of 36 kg P ha^{-1} produced significantly higher cumulative dry lablab herbage by as much as 13.4% than the control. However, the P application rates of 0, 12 and 24 kg ha^{-1} produced similar values of cumulative dry herbage while the application rates of 12, 24 and 36 kg P ha^{-1} were also at par in terms of the quantity of cumulative dry herbage produced by lablab.

The differences in cumulative dry herbage due to cutting height were not significant throughout the 3 years (2006-2008) of study (Table 27). Cutting age, however, significantly affected cumulative dry herbage of lablab in all the years of experimentation, although the trend varied slightly from year to year. Generally, cutting at 18-week age produced the highest cumulative dry herbage of lablab, while cutting at 6-week age produced the lowest cumulative dry herbage yield. On the basis of the mean of the three years, cutting at 18-week age produced cumulative dry herbage that was 117.0% and 64.5% higher than cutting at 6-week and 12-week ages respectively.

The cutting height x cutting age interaction on cumulative dry herbage in 2008 was significant (Table 28). At a fixed cutting age, it was revealed that cumulative dry herbage was similar except at the youngest cutting age (6 weeks) where the higher cutting height of 20cm produced significantly more dry herbage than the lower cutting height (10cm). At a fixed cutting height, the result showed that the highest cumulative dry herbage was produced under the 18-week cutting age, followed by the 12-week age, while the lowest dry herbage yield was produced when the cutting of lablab was done at 6-week age irrespective of the cutting height.

4.2.3 Initial dry herbage yield

The data on initial dry herbage (i.e. dry herbage obtained at the 1st cutting of a particular cutting age) of lablab as influenced by phosphorus application, cutting height and cutting age in 2006-2008 and the mean of the three years over the same period are presented in Table 29. The differences among the treatments due to phosphorus application and cutting height were not significant in the three years of experimentation and neither was the mean of the three years.

Conversely, cutting age affected initial dry herbage significantly in all the three years and in the combined analysis. The result showed that lablab consistently produced the highest dry herbage when cutting was carried out at 18-week age. Throughout the study, lablab produced significantly higher dry herbage yield when the cutting was carried out at maturity compared to cutting at 6-week age which usually produced the least initial dry herbage yield. Generally, cutting at 12 weeks or at maturity produced similar initial dry herbage of lablab.

The phosphorus x cutting height interaction for initial dry herbage in 2007 was significant (Table 30). If cutting height is held constant and varying phosphorus application rate, at 10cm 12 kg P ha^{-1} produced more dry herbage than the control, and there was no advantage in applying P above 12 kg P ha^{-1}. At 20cm, there was no difference in initial dry herbage when P application rate is varied. Holding phosphorus constant and varying cutting height, initial dry herbage of lablab was similar irrespective of the cutting height, except at 12 kg P ha^{-1} where cutting at 10cm produced significantly higher dry herbage yield than a cutting height of 20cm.

4.2.4 Mean pod weight

The effects of phosphorus application, cutting height and cutting age on mean pod weight in 2006-2008 and in the combined of the three years are shown in Table 31.Phosphorus application and cutting height did not affect mean pod weight significantly throughout the years of study.

Mean pod weight responded significantly to cutting age in 2007, 2008 and in the combined analysis but not in 2006. Generally, the mean pod weight of lablab was heaviest when lablab was cut at maturity and lightest when cutting was at 18 weeks. The pods from plots cut at 6 weeks were significantly heavier than those cut at 12 weeks in 2007, but in 2008 and in the combined data, pods from plots cut at these growth stages (i.e. 6 and 12 weeks) were at par.

4.2.5 Mean pod length

The effects of phosphorus application, cutting height and cutting age on mean pod length in 2006-2008 and in the combined analysis is shown in Table 32.Phosphorus application and cutting height affected mean pod length in 2008 only, when the mean pod length of lablab in the control and that given 12 kg P ha^{-1} application was significantly longer than the lengths obtained when 24 and 36 kg P ha^{-1} rates of phosphorus were applied. The lablab plots that were cut at a 20cm height in 2008 produced significantly longer pods than those cut at 10cm.

The differences in mean pod length due to cutting age were significant in 2007, 2008 and in the combined for the three years. The plots cut at 18 weeks produced the shortest pods (by 56.9% in the combined data), compared to those cut at the other ages, which had similar pod lengths.

4.2.6 Number of pods per plant

The data on the number of pods per plant of lablab as influenced by phosphorus application, cutting height and cutting age in 2007 and 2008 with the combined data of the two years are presented in Table 33. Phosphorus application and cutting height did not affect number of pods per plant in either year or in the combined analysis.

The effect of cutting age on number of pods per plant of lablab was significant in both years (2007 and 2008) and in the combined data. However, number of pods per plant at different cutting ages varied between the years. In addition, plants cut at 18-weeks failed to produce pods in both

years. In 2007, cutting at 12 weeks produced significantly more pods per plant than cutting at 6 weeks. In 2008, the plots cut at maturity produced the most pods per plant followed by those cut at 6 weeks and then those cut at 12 weeks. However, when the data were combined, plots cut at maturity had significantly more pods per plant than those cut at 6 weeks, while cutting lablab at 12 weeks and maturity produced similar numbers of pods per plant as was cutting at both 6 and 12 weeks.

4.2.7 Number of seeds per pod

Table 34 shows the effects of phosphorus application, cutting height and cutting age on number of seeds per pod of lablab in 2006-2008 and the combined for the three years. Phosphorus application and cutting height did not affect number of seeds per pod significantly throughout the 3-year study.

The differences in number of seeds per pod of lablab due to cutting age were not significant in 2006, whereas in 2007, 2008 and in the combined data the differences were significant. Across the years and in the combined analysis, cutting lablab at 18 weeks resulted in immature green pods and therefore no viable seeds were produced. The consistent trend showed that cutting lablab at 6 weeks produced significantly fewer seeds per pod compared to cutting at older ages of 12 weeks and maturity which had similar numbers of seeds per pod. The interactions between phosphorus and cutting height in 2008 and phosphorus x cutting age in 2006 for number of seeds per pod were significant but are not presented.

4.2.8 100-seed weight

Effects of phosphorus application, cutting height and cutting age on 100-seed weight of lablab in 2006-2008 and the combined data are presented in Table 35. Phosphorus application caused significant differences in 100-seed weight of lablab only in 2007 and in the combined data.

Consistently, plots which received phosphorus application of either 12, 24 or 36 kg P ha^{-1} were at par and produced significantly heavier 100-seeds than the control (0 kg P ha^{-1}) in 2007 and in the combined analysis.

Cutting height also affected 100-seed weight of lablab in 2007 and in the combined analysis in the same manner as phosphorus did. Cutting lablab at 20cm produced significantly heavier seeds than cutting at 10cm.Average seed weight for the former cutting height was some 23.8% higher than that for the latter cutting height.

The response of lablab's 100-seed weight to cutting age was significant across the years (2006-2008) and in the combined analysis. Cutting lablab at 18-week age did not allow the production of mature pods and therefore no seeds were produced in the three years of experimentation. Generally, cutting lablab at 6-week age and maturity produced similar 100-seed weights that were significantly heavier than seeds produced when lablab was cut at 12 weeks, except in 2006 when the youngest cutting at 6 weeks produced a 100-seed weight that was significantly heavier than those produced under maturity.

The phosphorus x cutting height and phosphorus x cutting age interactions for 100-seed weight in 2007 and in the combined data and cutting height x cutting age interaction of the same parameter in 2007, 2008 and in the combined analysis were significant (Table 35). Table 36 shows the interaction between phosphorus and cutting height for 100-seed weight combined over 2006-2008. At a constant cutting height of 10cm, 100-seed weight was similar at all the phosphorus rates. However, when the cutting height was raised to 20cm, the no-P control produced a significantly lighter 100-seed weight than the other P application rates that were statistically similar. On the other hand, at a constant rate of phosphorus application, when no fertilizer was applied (control) 100-seed weight was similar irrespective of cutting height. However, when P rates of 12, 24 or 36 kg

P ha^{-1} were applied; 100-seed weight of lablab was significantly heavier when a cutting height of 20cm was adopted as opposed to the 10cm cutting height.

4.2.9 Seed yield

The response of lablab's seed yield to phosphorus application, cutting height and cutting age in 2006-2008 and the combined data is presented in Table 37.Phosphorus application and cutting height did not cause significant differences in seed yield of lablab either across the years of study or in the combined data.

Cutting age exerted significant differences in seed yield in all years and in the combined analysis. The lablab that was cut at 18 weeks did not produce viable seeds, throughout the period of experimentation (2006-2008). In 2006 and 2007 seed yield of lablab cut at 6 and 12 weeks were at par with maturity. However, in 2008 maturity produced significantly more seeds (by 42.8%) than cutting at 6 weeks. Furthermore, cutting lablab at 6 weeks also resulted in significantly higher seed yield than cutting at 12 weeks. When the data were combined, it was evident that seed yield of lablab cut at 6 weeks was similar to that of maturity and this parity was in turn significantly higher (by 53.9%) than seed yield of lablab cut at the 12-week growth stage.

4.3 Quality Parameters

4.3.1 Dry matter yield

The data on dry matter yield of lablab as affected by phosphorus application, cutting height and cutting age at the 1st and 2nd cuttings in 2007, 2008 and the combined analysis of both years are presented in Table 38. At the 1st cutting, dry matter yield was not influenced by phosphorus application or by cutting height in both years and in the combined analysis.

At the 1st cutting, the differences in dry matter yield of lablab due to cutting age were significant in both years (2007-2008) and in the combined analysis. Generally, cutting lablab at maturity favoured dry matter production over the other cutting ages except in 2008 when cutting at maturity produced similar dry matter yield as cutting at 12 weeks. The earlier cutting ages (i.e. 6 and 12 weeks) produced similar dry matter yields that were statistically superior to the dry matter yield of lablab produced at 18 weeks, except in 2008 when dry matter accumulated at the cutting ages of 6, 12 and 18 weeks were at par. The interaction between phosphorus and cutting age for dry matter yield in 2008 and in the combined analysis was significant.

At the 2nd cutting, phosphorus application exerted a significant influence on dry matter yield of lablab in 2007. The phosphorus application rate of 24 kg P ha^{-1} produced significantly higher dry matter yield than the control. However, dry matter yields for the phosphorus rates of 0, 12 and 36 kg P ha^{-1} were similar as were for those for the phosphorus rates of 12 and 24 kg P ha^{-1}.

Cutting height effect on dry matter yield of lablab was not significant at any period of sampling. Similarly, cutting age did not significantly influence the dry matter accumulation of lablab except in 2008 when the cuttings at 6, 12 and 18 weeks produced similar dry matter yields that were significantly lower than that produced at maturity.

The interactions between phosphorus and cutting height for dry matter yield in 2007 and in the combined analysis (2007-2008), and between phosphorus and cutting age in the combined analysis (2007-2008) were significant. Table 39 shows the phosphorus x cutting height interaction combined between 2007 and 2008. At a constant cutting height of 10cm, 24 kg P ha^{-1} produced significantly more dry matter than the control, whereas at a 20cm cutting height the dry matter yields produced at all phosphorus application rates were similar. At a constant rate of phosphorus application and with variable cutting heights, dry matter yield of lablab was similar except in the

control, where a cutting height of 20cm produced higher dry matter yield than a cutting height of 10cm. Table 40 shows the phosphorus x cutting age interaction for dry matter production by lablab. At a constant cutting age with varying levels of phosphorus, dry matter production differed significantly when lablab was cut at 6 and 18 weeks. At 6 weeks, the highest rate of phosphorus fertilization (36 kg P ha^{-1}) produced the highest dry matter yield, whereas at 18 weeks the highest dry matter yield of lablab was achieved with an application rate of 24 kg P ha^{-1}. At a constant rate of phosphorus fertilization in combination with varying ages of cutting, it was observed that dry matter accumulation was similar at the P application rate of 24 kg P ha^{-1} , but different when the other phosphorus rates (0, 12 and 36 kg P ha^{-1}) were applied. In the same vein, dry matter produced at maturity cutting was significantly higher than those produced at the other cutting ages when either 0 or 12 kg P ha^{-1} was applied. However, when the highest P rate of 36 kg P ha^{-1} was applied, dry matter production of lablab was lowest when cutting was carried out at 18 weeks.

4.3.2 Nitrogen-free-extract concentration

Table 41 shows the data on nitrogen-free-extract (NFE) of lablab as affected by phosphorus application, cutting height and cutting age at the 1st and 2nd cuttings in 2007, 2008 and the combined analysis data for both years. Phosphorus application and cutting height did not affect nitrogen-free-extract significantly at any period of sampling in either of the two cuttings.

The differences due to cutting age were however significant at both cuttings in both years (2007-2008) and in the combined analysis. At the 1st cutting, the nitrogen-free-extract concentration of lablab was generally significantly highest when cutting was carried out at 12 weeks. In 2007 and 2008 nitrogen-free-extract accumulated by lablab at the other cutting ages (6,18WAS and maturity) did not follow a consistent pattern, unlike in the combined data where cutting at these ages

produced similar nitrogen-free-extract. In 2007 and 2008 the lowest values for NFE were recorded for the 6- and 18-week cutting ages respectively.

At the 2nd cutting, the trend was consistent. Lablab cut at the younger ages of 6, 12 and 18 weeks accumulated similar nitrogen-free-extract values that were significantly higher than what was accumulated by plants cut at maturity. That was also true in the case of the combined data for both years. The phosphorus x cutting height interaction for NFE at the 1st cutting in 2007 was significant but is not presented.

4.3.3 Crude protein concentration

Effects of phosphorus application, cutting height and cutting age on crude protein concentration of lablab at the 1st and 2nd cuttings in 2007, 2008 and the combined data for both years are presented in Table 42. The differences in crude protein (CP) due to phosphorus application and cutting height at the 1st and 2nd cuttings in both years and in the combined analysis were not significant.

Crude protein concentration in lablab differed significantly between cutting ages at all sampling periods (Table 42). Generally, crude protein concentration decreased as the cutting age increased during the 1st cutting. In each of the two years, crude protein concentration of lablab was significantly lower when cut at maturity compared to the other cutting ages. In the combined analysis, crude protein values for plants cut at 6 and 12 weeks were at par and significantly higher than crude protein for plants cut at 18 weeks.

At the 2nd cutting, lablab cut at 6, 12 or 18 weeks had similar crude protein concentrations that were significantly higher than that for plants cut at maturity. However, in 2007 only the plants cut at

12 weeks were statistically superior to those plants cut at maturity, in terms of crude protein concentration.

The interaction between phosphorus and cutting age for crude protein at the 1st cutting in 2008 was significant (Table 43). At a constant cutting age but varying rates of phosphorus application, it was evident that when cutting at 18 weeks, 36 kg P ha^{-1} application rate produced significantly higher crude protein concentration than 24 kg P ha^{-1} application rate, while when cutting lablab at maturity, 24 kg P ha^{-1} rate of application was significantly higher than the 0 kg P ha^{-1} rate of application in terms of lablab's crude protein concentration. At a constant rate of P fertilization in association with varying cutting ages, it was observed that lablab's crude protein concentration differed significantly depending on the rate of phosphorus applied. At 0 and 12 kg P ha^{-1}, crude protein concentration of lablab was similar at the cutting ages of 6, 12 and 18 weeks which were significantly higher than the crude protein value obtained at maturity cutting. However, at 24 kg P ha^{-1} cutting at 6 weeks produced significantly higher crude protein concentration in lablab than cutting at 18 weeks while at 36 kg P ha^{-1}, cutting at 18 weeks produced significantly higher crude protein than cutting at 12 weeks or at maturity. However, cutting lablab at either 18 weeks or at 6 weeks produced similar crude protein concentrations when 36 kg P ha^{-1} rate of application was considered.

4.3.4 Crude fibre concentration

Data on the effects of phosphorus application, cutting height and cutting age on crude fibre (CF) concentration of lablab at the 1st and 2nd cuttings in 2007, 2008 and in the combined means for both years are presented in Table 44. At the 1st and 2nd cuttings for both years and in their combined analysis, phosphorus and cutting height effects were not significant whereas, cutting age caused significant differences in the crude fibre concentration of lablab.

At the 1st cutting, the plots cut at 18 weeks and maturity produced significantly higher crude fibre than those cut at 6 and 12 weeks. However, in 2007 and in the combined data, crude fibre of lablab was significantly higher at 6 weeks than at 12 weeks. The highest crude fibre concentration was recorded when lablab herbage was cut at 18 weeks and at maturity. In 2008 and the combined data, crude fibre concentration for 18-week cutting age was 35.5 and 50.6% higher than that for the 12-week cut respectively.

At the 2nd cutting, the crude fibre values of lablab cut at 6, 12 and 18 weeks were at par but were significantly lower than the crude fibre of lablab obtained when cutting was done at maturity. The crude fibre concentration for the 6 week cut was 21.8, 31.2 and 26.6% lower than that for maturity in 2007, 2008 and for the combined data respectively.

The interaction between phosphorus and cutting age on crude fibre concentration at the 1st cutting in 2008 was significant (Table 45).Holding cutting age constant and varying rates of P fertilization, differences in crude fibre concentration were found when lablab was cut at either 12 weeks or at maturity. At 12 weeks, crude fibre concentration was significantly higher when 12 rather than 0 kg P ha^{-1} was applied, whereas when cutting was done at maturity, lablab accumulated more crude fibre at 0 rather than 24 kg P ha^{-1} application rate. In holding P constant, and varying cutting ages, at 0 kg P ha^{-1} crude fibre produced at maturity was significantly higher than that produced at 6 and 12 weeks of cutting while at 24 kg P ha^{-1} crude fibre obtained at 18-week cutting was significantly higher than the CF concentration obtained when lablab was cut at 12 weeks.

4.3.5 Ether extract concentration

Table 46 shows the effects of phosphorus application, cutting height and cutting age on ether extract concentration of lablab at the 1st and 2nd cuttings in 2007, 2008 and in the combined means for both years. Phosphorus application affected ether extract concentration significantly in

2008 and in the combined analysis at the 1st cutting. A phosphorus application rate of 12 kg P ha^{-1} produced significantly more ether extract in lablab than the application rate 24 kg P ha^{-1} at both sampling periods, being higher by 66.2 and 27.8% respectively.

The differences in ether extract concentration in lablab due to cutting height was not significant; whereas cutting age affected ether extract concentration significantly at the 1st cutting in 2007, 2008 and in the combined analysis. Generally, the youngest cutting (6 weeks) favoured ether extract concentration over the later cuttings, with value for 6-week age being higher than that for the 12- or 18-week age and maturity by 58.7 and 120.4% respectively. In the combined analysis, the ether extract concentrations of lablab cut at 12 and 18 weeks were at par but significantly higher than for the lablab cut at maturity. At the 2nd cutting, the lablab cut at 6, 12 and 18 weeks yielded similar ether extract concentrations that were significantly higher by 28.6-48.6% than what was produced when cutting was at maturity.

The phosphorus x cutting age interaction for ether extract combined over 2007 and 2008 was significant (Table 47). At a constant cutting age with varying rates of phosphorus application, significant differences in ether extract concentration of lablab were observed at the cutting ages of 6, 18 weeks and maturity. At the 6-week cutting, 12 kg P ha^{-1} produced significantly more ether extract (by 44.4%) than 36 kg P ha^{-1}. At the 18-week cutting, 12 kg P ha^{-1} was statistically superior to 24 kg P ha^{-1} while at maturity, 24 and 36 kg P ha^{-1} were at par but statistically superior to 0 kg P ha^{-1} in ether extract of lablab When phosphorus application was held constant and cutting age was varied, differences in ether extract occurred when 0, 12 or 24 kg P ha^{-1} application rate was adopted. Generally, at these rates of P application, ether extract in lablab was significantly higher when cutting was carried out at 6 weeks compared to the other cutting ages (Table 47).

4.3.6 Ash concentration

Table 48 shows the effects of phosphorus application, cutting height and cutting age on lablab ash concentration at the 1st and 2nd cuttings in 2007, 2008 and the combined means for both years. Phosphorus application and cutting height did not affect ash concentration at any period of sampling (Table 48).

With respect to cutting age, ash concentration in lablab was affected significantly only at the 1st cutting in 2008 and in the combined analysis. In 2008, cutting at 18 weeks produced the highest ash concentration that was significantly more than that for the other cutting ages that were all at par. However, in the combined analysis, the lower ash concentration was obtained when lablab was cut at 12 weeks while the other cutting ages produced similar ash concentrations that were at par.

The phosphorus x cutting age interaction of the combined data (2007-2008) for ash concentration at the 2nd cutting was significant (Table 49). When cutting age is held constant and phosphorus levels are varied, at the 6-week cutting age lablab's ash concentration was similar for all P levels. At 12-week cutting age, a phosphorus application rate of 12 kg P ha^{-1} produced significantly higher ash concentration than the control, while it was at par with the two higher P rates. At 18 weeks, the control (0 kg P ha^{-1}) produced significantly higher ash concentration in lablab than 24 kg P ha^{-1} application rate, while at maturity cutting 36 kg P ha^{-1} produced more ash concentration than the 12 kg P ha^{-1} rate of application. When phosphorus application rate is held constant, at varying cutting ages, it was observed that at the 0 kg P ha^{-1} rate of application, ash concentrations were similar for all the cutting ages. When an application rate of 12 kg P ha^{-1} was considered, cutting at 12 weeks produced more ash than cutting at maturity; whereas at 24 kg P ha^{-1} the lablab's ash concentration at the 6-week cutting age was significantly higher than what was obtained from

cutting lablab at 18 weeks. Finally, at 36 kg P ha^{-1} the lablab cut at maturity was significantly more concentrated in ash than those cut at 6 weeks.

4.3.7 Calcium concentration

Table 50 shows the effects of phosphorus application, cutting height and cutting age on calcium concentration in lablab at the 1st and 2nd cuttings in 2006, 2007 and the means of the two years. Phosphorus application significantly affected calcium concentration at the 2nd cutting in 2006. At this sampling period, lablab accumulated significantly more calcium in its tissue when 36 kg P ha^{-1} was applied compared to the application rates of 0 and 24 kg P ha^{-1}. Cutting height effect on calcium concentration of lablab was significant in the combined analysis. Lablab cut to a height of 10cm accumulated more calcium compared to lablab cut to a height of 20cm.

Cutting age caused significant differences in calcium concentration at each of the sampling dates. However, the patterns of response were not consistent. In 2006, lablab cut at 12 weeks produced significantly more calcium than those cut at the other cutting ages which were at par. In 2007, cutting at 18-week age favoured calcium concentration over cutting at 6 or 12 weeks whereas in the combined analysis cutting at 18 weeks produced more calcium in lablab than cutting at either 6 weeks or at maturity.

At the 2nd cutting, the differences in calcium concentration of lablab due to cutting age were significant in both years and in the combined analysis. In 2006 cutting at 12 weeks produced calcium concentration that was statistically superior to lablab cut at 6WAS or at maturity. In 2007, lablab cut at maturity contained significantly more calcium than lablab cut at either 6 or 12 weeks. However, in the combined analysis, the calcium concentrations of lablab cut at either 12, 18 weeks or at maturity were similar but significantly higher than the calcium concentration of lablab cut at 6 weeks. The

cutting height x cutting age interaction for calcium concentration at the 2nd cutting in 2006 was statistically significant but is not presented.

4.3.8 Phosphorus concentration

Table 51 shows the effects of phosphorus application, cutting height and cutting age on phosphorus concentration of lablab at the 1st and 2nd cuttings in 2006, 2007 and their combined data. Phosphorus application did not affect phosphorus concentration in either year or cutting stage. Cutting height however influenced phosphorus concentration in the combined data of the 2nd cutting. The lower cutting height (10cm) produced significantly greater phosphorus concentration in the dry herbage than the higher cutting height of 20cm (Table 51).

Cutting age significantly influenced phosphorus concentration of lablab in the 1st cutting in 2007 and in the combined data of the same cutting stage as well as at the 2nd cutting in 2006 and in the combined data of that cutting stage. Generally, the P concentration of lablab cut at the 1st stage was 109.1% greater than that cut at the 2nd stage. At the 1st cutting in 2007, phosphorus concentration of lablab cut at 6 weeks was significantly higher than that of lablab cut at the 12- and 18-week cutting ages both of which were at par and significantly higher than the phosphorus concentration produced when lablab was cut at maturity. In the combined data of the 1st cutting stage, phosphorus concentration of lablab cut at 6-,12-and 18 weeks was similar and significantly higher than the P concentration of lablab cut at maturity.

At the 2nd cutting in 2006, cutting lablab at 6-, 12- and 18-week ages produced similar phosphorus concentrations which were significantly lower than the phosphorus concentration of lablab cut at maturity. Similarly, in the combined data of the 2nd stage of cutting, phosphorus concentration of lablab cut at maturity was significantly higher than those obtained from the 6-, 12-

and 18-week cutting ages which produced similar phosphorus concentration. However, the P concentration of lablab cut at 18 weeks was also at par with that cut at maturity.

The interaction between phosphorus and cutting height for phosphorus concentration in the combined analysis at the 2nd cutting was significant (Table 52). Holding cutting height constant and varying phosphorus application rates, at 10cm the control (0 kg P ha^{-1}) was significantly higher than the other P rates of application except for the 36 kg P ha^{-1} rate which had a similar phosphorus concentration as the control. At 20cm all rates of P application were at par in the phosphorus concentration of lablab. Holding P constant and varying cutting height, at the control (0 kg P ha^{-1}), the 10cm cutting height produced a statistically higher phosphorus concentration than the 20cm cutting height while the other P rates produced similar tissue phosphorus concentration irrespective of the cutting height of lablab.

4.3.9 Calcium: phosphorus ratio

Table 53 presents the effects of phosphorus application, cutting height and cutting age on the calcium: phosphorus ratio of lablab at the 1st and 2nd cuttings in 2006, 2007 and their combined data. At the 1st cutting, phosphorus affected calcium: phosphorus ratio in 2007 and in the combined analysis in the same manner. Phosphorus application rates of 0 and 12 kg P ha^{-1} favoured the calcium: phosphorus ratio of lablab over the highest phosphorus rate of 36 kg P ha^{-1},with enhancement in Ca:P ratio being within the range of 37.1-42.9% for 2007 and 26.7-30% for the combined data.

Cutting age affected the calcium: phosphorus ratio of lablab significantly in both years at the 1st cutting, but only in 2006 at the 2nd cutting. Generally, lablab cut at maturity had significantly higher calcium: phosphorus ratio than lablab cut at the earlier cutting ages and in addition, the

calcium: phosphorus ratio of lablab increased as cutting age increased. The older the cutting age the higher was the Ca: P ratio.

4.4 Correlation Analysis

The relationships between the cumulative dry herbage yield and some growth parameters of lablab at 12WAS and stand count at 3WAS combined between 2006 and 2007 is shown in the correlation matrix in Table 54. There was positive and highly significant correlation between cumulative dry herbage yield and stand count (r=0.299**), sward height(r=0.287**), number of root nodules(r=0.336**), and nodule dry weight(r=0.381**). However, ground cover score had positive but significant(r=0.151*) relationship with cumulative dry herbage yield of lablab. On the other hand, the relationships between mean NAR (0.083), mean RGR (0.093), mean CGR (0.103), number of primary branches (-0.131), leaf area per plant (-0.131) and leaf area index (-0.171) and cumulative dry herbage yield of lablab were not significant.

The coefficients of correlation between stand count at 3WAS, some growth parameters at 12WAS and cumulative dry herbage yield of lablab combined over the three years of study (2006-2008) are presented in Table 55. Stand count (0.272**), sward height (0.319**), ground cover score (0.236**), number of root nodules (0.407**), nodule dry weight (0.443**) and leaf area per plant (0.156**) had positive and highly significant correlation with cumulative dry herbage yield of lablab. Leaf area index (0.081) had a weakly positive relationship while number of primary branches (-0.013), mean NAR (-0.044), mean RGR (-0.022) and mean CGR (-0.031) had non-significant relationships with cumulative dry herbage yield of lablab.

4.5 Path Coefficient Analysis

The direct and indirect contributions of different growth parameters to cumulative dry matter of lablab combined over 2006 and 2007 cropping seasons at Samaru, Nigeria are presented in Table 56 and Figure 1.The greatest direct contribution to cumulative dry herbage yield of lablab was from nodule dry weight (0.482) while the least was ground cover score (-0.014).

With respect to nodule dry weight, the indirect contributions through stand count and sward height were weakly positive (0.078 and 0.045 respectively); whereas through ground cover score and number of root nodules indirect contributions were weakly negative (-0.0003 and -0.224 respectively). The total contribution of nodule dry weight (0.381) was the highest among the correlated parameters. The direct contribution of stand count to cumulative dry herbage yield of lablab was 0.161, while its indirect contributions were 0.0003, 0.003, -0.099, and 0.234 through sward height, ground cover score, number of root nodules and nodule dry weight respectively, making the total contribution of stand count to cumulative dry herbage of lablab 0.299. In the case of sward height, which had a total contribution of 0.286, the direct contribution was 0.275 while indirect contributions were stand count(0.0002), ground cover score(-0.010), number of root nodules(-0.057) and nodule dry weight(0.078). Ground cover score had a weak negative direct (-0.014) but a positive total (0.162) contribution. The associated indirect contributions of -0.027, 0.211, -0.019 and 0.011 were for stand count, sward height, number of root nodules and nodule dry weight respectively. The direct contribution of number of root nodules (-0.001) and indirect contribution through stand count (-0.241), sward height (0.066), ground cover score (0.065) and nodule dry weight (0.447) amounted to a total contribution of 0.336

When the direct effect was further expressed in percentage (Table 57), it was observed that the highest individual contribution to cumulative dry herbage was from nodule dry weight (23%). All the other parameters contributed less than 10%, while ground cover score was exceptionally low

(<1%). The combined contributions of stand count and nodule dry weight (7.5%), sward height and nodule dry weight (4.3%) to cumulative dry matter of lablab represented the highest since the other combined contributions were below 1%.The residual or unexplained contribution to cumulative dry herbage in lablab was 77%

The direct and indirect contributions of some growth parameters to cumulative dry herbage yield of lablab combined over 2006-2008 cropping seasons at Samaru, Nigeria are presented in Table 58 and in Figure 2. The direct contributions to cumulative dry herbage yield of lablab in the highest to lowest order were nodule dry weight (0.352), sward height (0.261), stand count (0.170), ground cover score (-0.026) and number of root nodules (-0.026)

Nodule dry weight had a total contribution of 0.444 with indirect contributions of 0.054, 0.067, -0.005 and -0.024 through stand count, sward height, ground cover score and number of root nodules respectively. In the case of sward height, the indirect contributions were by stand count (-0.003), ground cover score (-0.021), number of root nodules (-0.006) and nodule dry weight (0.090) in addition to the direct (0.261) gave a total contribution of 0.321. The direct contribution of stand count (0.170), and indirectly through sward height (-0.005), ground cover score (0.003), number of root nodules (-0.007) and nodule dry weight (0.111) added up to a total contribution of 0.272. Ground cover score had a negative direct contribution (-0.026) and indirect contributions through stand count (-0.020), sward height (0.215), number of root nodules (-0.005) and nodule dry weight (0.073) for a total contribution of 0.237. Number of root nodules had a total contribution of 0.407, a direct contribution of -0.026 and indirect contributions through stand count(0.048), sward height(0.065), ground cover score(-0.005) and nodule dry weight(0.325).

When the direct effect was further expressed in percentage to get over the problems of different entities and units (Table 59), it was revealed that nodule dry weight had the highest direct

contribution of 13% while sward height had 7% and stand count 3%. Ground cover score and number of root nodules were less than 1%. The combined contribution of sward height and nodule dry weight (4.902) was the highest. All other double contributions were less than 1%. The unexplained (residual) contribution was 76%.

4.6 Polynomial Response

To determine the polynomial response of cumulative dry herbage yield to cutting age, the sum of squares due to cutting age were apportioned into various levels of response variances, along with their respective degrees of freedom. It was then observed that none of the responses (linear and quadratic) was found to be statistically significant in all three years (2006-2008) and in the combined analysis for cutting age (Appendices V and VI). It was further noted that the cubic response cannot be tested in these experiments as there is no variance for deviation and degrees of freedom available to test it.

When no response was singled out to be statistically better than the others using analysis of variance, the data were further investigated using chi-square (Ψ^2) test of significance and calculating the square of deviations between observed and expected yields. The regression equations (Appendix VII) were used to predict the expected linear and quadratic cumulative dry herbage yields. In all cases, it was observed that the linear and quadratic responses had a similar fit to the data in all years and the combined means for the years (Appendices VIII, IX, X and XI).

To get out of the contradictory results, that emanated from chi-square test, in obtaining the best fitting curve for the data, line graphs were drawn for all the years and the combined means for the years (Figures 3, 4, 5 and 6). It was observed from the graphical depictions, that the quadratic response in 2007 was the nearest fit to the data (Figure 4).

CHAPTER FIVE

5.0 DISCUSSION

5.1 General

This study has shown that lablab growth, herbage and seed yield vary more with years than the lablab quality parameters of crude protein and crude fibre which did not differ significantly between the years. The highest number of root nodules, nodule dry weight, cumulative fresh herbage yield, cumulative dry herbage yield, initial dry herbage yield and seed yield of lablab were recorded in 2008, the highest rainfall year. This underscores the relative importance of adequate precipitation to lablab growth and yield. The productivity of crops per unit of water differs widely (Majumdar, 2004) and Muir (2002) reported that yearly warm season legume dry matter yields were dependent on rainfall and that lablab yields ranged from 78 to 2,739 kg ha^{-1} under dryland conditions in north central Texas. However, under irrigation, Muir *et al*. (2001) reported that lablab produced more than 9000 kg ha^{-1} yr^{-1}. In New South Wales Australia, lablab produced from around 500 to over 5000 kg DM ha^{-1}, with irrigated areas recording yields of up to 14,000 kg DM ha^{-1} (Anonymous, 2000). This is almost similar to the cumulative dry herbage yield of lablab obtained in this study at the 18-week cutting age in 2008 which was 14.8 tonnes ha^{-1}.

The productivity of lablab could be reduced by pests and diseases as evident by the disease outbreak on the crop in 2007, which was not observed in 2006 but controlled in 2008.The major disease in the complex was web blight of beans, which is caused by the fungus *Rhizoctonia solani* Kuhn (Imperfect state) (Thurston,1984). Web blight caused defoliation and a noticeable drop in the ground cover score, number of primary branches, leaf area per plant and leaf area index in 2007 compared to 2006. Invariably, this study supports the suggestion that early canopy cover or life mulch may prevent web blight attack. Infection by web blight follows splash inoculum from infested

soil and cultural practices, such as mulching, can be very effective in suppressing web blight (Allen *et al*., 1996). The high humidity in the later years (i.e. 2007 and 2008) which probably militated against an early canopy cover increased splashing by raindrops directly hitting the soil surface, unlike in 2006 when an early canopy cover provided mulch which reduced splashing. At 12WAS in 2006, lablab ground cover score at 6 weeks of age was 4.8 compared to 2.7 and 1.9 in 2007 and 2008 respectively.

Lablab requires protection from insect pests in order to enhance seed production. Although not determined, the seed yield of lablab in the present study was probably reduced by insect pests such as *Mylabris bifasciata* (Deger), a flower-feeder, *Clavigralla tomentosicollis* (Stal) and *Clavigralla shadabi* (Dolling) which are pod-suckers and the larvae of *Maruca* spp., which is a pod-borer that were present during flowering and pod formation throughout the experimental years(2006-2008). Larvae of legume pod-borer damage flowers and flower buds and also feed on young tender shoots and peduncles causing up to 60% yield loss (Singh and Rachie, 1985). However, these insect pests were controlled by repeated applications of either cypermethrin or dimethoate insecticides to limit their visible damage on the crop throughout the years of study.

5.2 Response to Phosphorus

In this study, the response of lablab growth, yield and quality parameters to phosphorus application was not consistent. This was probably due to the fact that the native soil available phosphorus of the experimental fields was sufficient for the lablab crop, given the high soil test levels obtained (5.3-17.5 mg kg^{-1}) (Table 1). However, the application rate of 12 kg P ha^{-1} increased lablab sward height and ground cover score slightly(4%) while 24 kg P ha^{-1} increased leaf area per plant (18%), leaf area index(10%), sward height (4%), number of root nodules (42%) and nodule dry weight (50%) over the control. Among the yield parameters, 12 kg P ha^{-1} increased lablab 100-seed

weight (4%) and 36 kg P ha^{-1} increased cumulative dry herbage yield (13%) above the zero P control. These favourable responses of lablab to phosphorus application, especially in the case of number of root nodules and nodule dry weight, could be attributed to the role of phosphorus in forage growth. Phosphorus is involved in energy-transfer processes which synthesize and degrade starch and transport nutrients from the soil through the roots to the plants tops and P also enhances cell division, fat formation, flowering, fruiting, seed formation, and development of lateral and fibrous roots; it may improve disease resistance and forage quality (Follett and Wilkinson, 1985). Phosphorus fertilized plants develop more roots than plants not fertilized with phosphorus (Mitchell, 1970).

The results obtained are in general agreement with those of other researchers. In India, the application of 35 kg P ha^{-1} gave further dry matter and seed yield increases in lablab that was considered uneconomical (Verma, 1975). Phosphorus application of 26.4 kg ha^{-1} at Samaru, Nigeria increased soybean LAI by 38% compared with plots on which no P was applied (Chiezey *et al*.,2004), while soybean nodulation was significantly increased (13.8-22.5%) by the application of 26.4 kg P ha^{-1} compared with the control (Chiezey *et al*., 1992).

High rainfall may hamper the effectiveness of phosphorus application on lablab. Lablab response to phosphorus application was highest (48%) in 2007 followed by

2006 (38%) and lowest in 2008 (14%). This trend shows that phosphorus response was lowest in the highest rainfall year (2008) and highest in the lowest rainfall year (2007). However, the residual phosphorus from the previous cowpea-cotton intercrop in 2006 may have contributed to the high response observed in 2007. Phosphorus utilization in the year of application can be rather low while residual effects are considerable (Hague *et al*., 2008). On the other hand, waterlogging which was evident for a short period in some main plots may have prevented lablab from maximal root

extension for phosphorus uptake to take place in 2008, which may have retarded crop growth. Field observation showed that sward height of lablab followed a gradient, being higher in the replications with less surface water. In addition, some quantity of phosphorus could have been lost through runoff as well. Phosphorus losses from agricultural landscapes arise from the interaction of hydrologic, edaphic and management factors (Buda *et al*., 2009).

The low response of lablab to phosphorus application with reference to several parameters in the present study may be interpreted in several ways. The edaphic factors of the experimental fields such as the medium rating of soil available phosphorus (8.4-17.5 mg kg^{-1}), the strongly to very strongly acidic soils (pH 4.6-5.2) and the medium soil calcium concentration (2.2 -2.8 cmol kg^{-1}) may have acted in concert with reduced lablab response to phosphorus. The significant responses of soybean to a phosphorus application rate of 26 kg P ha^{-1} for high grain yield observed by Chiezey *et al*. (1991) was recorded when soil P levels were in the range of 2.7-3.5mg kg^{-1} while response of green gram (*Vigna radiata*) to P application was attributed by Mahmud *et al*. (1996) to low soil test P levels (2.49-3.01mg kg^{-1}). In studying the response of legumes to phosphorus fertilizers in Queensland, Australia, soil analysis indicated a low P content wherever a response occurred (Crowder and Chheda, 1982). Furthermore, the availability of phosphorus in soils is influenced by soil pH and the magnitude of Ca^{2+}, Mg^{2+}, Fe^{+},Fe^{2+} and Al^{3+} present in the soil (Hague *et al*., 2008). At soil pH below 6.0, Fe and Al phosphates of low solubility predominate (Follett and Wilkinson, 1985). Phosphorus was therefore probably less readily available in the acidic soils such as those used in this study.

Lablab tissue P concentration in the current study is sufficient for ruminant nutrition .This is because the range of lablab tissue P concentration obtained (4.0-5.0 g P kg^{-1}) was within the range of the National Research Council (NRC) recommendation (1.2-4.8 g kg^{-1}) for some classes of

ruminants as reported by Cullison (1979). Total phosphorus in plant tissue ranges from about 0.1 to 1% and a typical plant might contain approximately 0.004% P as deoxyribonucleic acid (DNA), 0.04% P as ribonucleic acid (RNA), 0.03% as lipid P, 0.02% as ester P and 0.13% as inorganic P (Sanchez,2007). Follett and Wilkinson (1985) noted that the critical P concentration in forages may range from 0.14 to over 0.3% which is below the range obtained for lablab in the present study. However, Mupangwa, *et al*. (2006) obtained phosphorus concentration of 1.2, 1.4 and 1.1 g kg^{-1} DM at 8, 14 and 20 weeks respectively. This variation may be ascribed to differences in the factors such as cutting age (i.e.2 weeks earlier in the current study), altitude (i.e. 686m in Samaru vs. 1,500m in Zimbabwe) rainfall (which is slightly higher in Samaru), soil pH (i.e.4.9 vs. 5.5) and the analytical procedures for P determination (i.e. optical density (OD) in spectrophotometer vs. inductively coupled plasma (ICP) emission spectrometer) utilized at Samaru vs. Zimbabwe respectively. Moreover, the lack of response of lablab tissue P concentration to phosphorus application is an indication that lablab is able to extract soil phosphorus to achieve equal tissue phosphorus concentration sufficient for ruminant requirement irrespective of the phosphorus application rates, especially in soils that contain medium to high soil P levels. According to Griffith (1974), legumes are able to extract phosphorus in low soil available concentrations, especially in low production situations. This implies that resource-poor farmers may grow lablab with little or no phosphorus fertilizer and still meet the P requirement of ruminants.

Although not studied, the probable presence of mycorrhizal fungi in these fields may also have enhanced phosphorus uptake. The uptake of nutrients particularly phosphorus is increased markedly as a result of mycorrhizal association (Brady, 1974). Phosphorus uptake averaged 25 times greater in mycorrhizal- than in non-mycorrhizal-infected plants and mycorrhizal associations with legumes in low-P soils have increased nodulation and nitrogen fixation (Follett and Wilkinson, 1985).

5.3 Response to Cutting Height

This study has shown that for cutting or grazing, a higher cutting height is desirable for lablab productivity. Although not presented in the results, statistical analysis revealed that significantly more lablab stands died in the lower cutting (10cm) treatment and in addition there were significantly more active lablab buds following cutting at 20cm compared to the 10cm cutting height. Dalzell *et al*. (1977) found that with increasing severity of cutting, lablab top-growth yield declined compared with those of *Macroptilium bracteatum* (CPI 27404) and *Macroptilium daltonii*.

Although the 10cm cutting height produced higher fresh and dry herbage yields that did not differ significantly from those produced with the 20cm cutting height, it is noteworthy that 20cm cutting height produced significantly higher sward height, ground cover score, pod length and 100-seed weight of lablab in the current study. This implies that lablab cut at 20cm had faster regrowth and translocated more assimilates for seed production than lablab cut at 10cm, probably because the plants cut to a higher stubble height utilized less energy in recovering compared to those cut to the lower stubble height. This is in agreement with the report of Stockdale (2005) that aboveground total seed numbers and seed weights were generally greater at the higher defoliation height (7.0 vs. 2.8cm) of subterranean clover (*Trifolium subterraneum* L.).

The results of the present study also suggest that both the amount of stored reserves in lablab root and LAI following defoliation may determine lablab response to cutting or grazing heights. Root total non-structural carbohydrates (TNC) which comprise sugars and starches provide energy for plant regrowth after each harvest (Herbert, 2009). According to Fulkerson *et al*. (1999), defoliation height influenced non-structural carbohydrates (NSC) concentration of kikuyu grass (*Pennisetum clandestinum*). In this vein, TNC or NSC may have been less for lablab cut at 10cm compared to that cut at a 20cm height and hence the difference in response in favour of 20cm. In

Florida, Trujillo *et al*.(1996) reported that stubble heights of 25 and 100cm following defoliation provided higher TNC levels and a greater number of active buds, in the legume *Desmanthus virgatus*, than did clipping to a 5-cm stubble. Adeyemo *et al*. (1987) reported that a higher cutting height of 23cm produced more nodes and larger economic branches in *Amaranthus hybidus* L. relative to a lower cutting height of 15cm. In the present study there were more active buds in lablab plants cut at 20cm height (data not presented), however the level of root TNC was not measured.

Furthermore, lablab cut to a height of 10cm might have had another obvious disadvantage with respect to assimilate production and regrowth. According to Caddel *et al*. (2009), if nearly all legume plants are consumed (grazed or otherwise harvested) nitrogen fixation stops until they have sufficient regrowth for fixation to proceed, a scenario that was observed in the current study. At the 10cm stubble height, most of the functional lablab leaves were lost and the plants had to start new leaf growth, a process which took some time before photosynthesis could begin to fully support respiration and growth. This situation could have negatively impacted on the rate of lablab regrowth. Experiments with the grass *Panicum maximum* showed that the amount of leaf surface remaining after defoliation was a greater influence on the rate of regrowth than the carbohydrate status at the time of defoliation (Humphreys, 1987).Consequently, the level of lablab LAI following defoliation to a 20cm stubble height in addition to a probably higher TNC level at this cutting height may have informed the observed favorable responses obtained compared to the lower cutting height of 10cm which visually had a lower LAI value. Ward and Blazer (1961) postulated that organic reserves and leaf area interact and complement each other in regrowth after defoliation.

However, the lower cutting height (10cm) produced significantly higher calcium and phosphorus in the current study. This condition may have resulted because of the slower regrowth

rate of lablab, a condition which enabled these elements to accumulate over time, in addition to fewer leaves compared to stems in this cutting treatment (10cm), which may have skewed the P analysis.

5.4 Response to Cutting Age

Cutting age had an overwhelming influence on lablab, having had significant impact on growth, yield and quality parameters. A sigmoid growth pattern was evident for lablab parameters such as cumulative dry herbage yield, initial dry herbage yield and sward height. These parameters increased with length of cutting age and peaked at 18WAS, before dropping off. This finding underscores the fact that lablab herbage should be utilized for either cut-and-carry or grazing by 18 weeks after sowing to maximize the return in investment in producing the crop. In the present study, cumulative fresh herbage yield of lablab ranged from 1.0 to 62.1 tonnes ha^{-1}, cumulative dry herbage yield of lablab ranged from 4.7 to 10.2 tonnes ha^{-1} while the initial dry herbage yield ranged from 1.0 to 9.0 tonnes ha^{-1}. This observed wide range of lablab herbage yields suggests that lablab can provide adequate quantity forage for ruminant livestock nutrition in sub-Saharan Africa. In addition, these values fell within the range for lablab dry herbage yields obtained by various earlier workers. Jingura *et al*. (2001) obtained a dry matter yield of 5.9 tonnes ha^{-1} for "Highworth" lablab in Zimbabwe. Rongai lablab varieties in Nigeria can produce forage yield of 0.64-4.62 tonnes ha^{-1} (Anonymous, 2008). Muir (2002) obtained dry matter yield of 1.7 tonnes ha^{-1} yr^{-1} for "Tecomate" lablab while Rongai lablab produced dry matter yields of 3.7-4.1 tonnes ha^{-1} (Muir *et al*.,2008) in Texas, USA.

It was evident from the study, that sward height (at 12- and 18 WAS), mean net assimilation rate (at 12-18WAS), and crop growth rate (at 12-18WAS), can be negatively affected by defoliating diseases, depending on the stage of lablab growth. Between the 6 and 12 weeks cutting ages these

parameters had significant drops in their respective values due to web blight attack. This supports the need for adequate crop protection during this period of growth if livestock are to benefit from the highest accumulated fresh and dry herbage yields of lablab which were attained at 18WAS in this study. In warm and humid tropics, web blight (*Thanatephorus cucumeris*) can cause rapid defoliation and sometimes complete crop failure of beans (Thurston, 1984).

This study revealed that with good management and favourable growth conditions, lablab can attain the highest sward height by 18WAS. Mean minimum and maximum temperatures during the three years of study were 19.1 and 34.3^{o}C respectively. Optimum growth takes place between 28 and 33^{o}C (Pandey and Sinha,1972) and there was sufficient supply of food, water, oxygen, light and probably growth hormones before 18WAS based on visual field observations. Generally, sward height of lablab in this study fell within the range of 44.2-87.2 cm and followed a sigmoid growth pattern. According to Gardner *et al*. (1985), if plant dry matter, volume, leaf area, height or accumulation of chemical substances is plotted against time, a line fitted to the data will normally be sigmoid.

The number of root nodules and nodule dry weight of lablab in the current study ranged between 15-39 and 91-288 mg respectively. It is possible that not all lablab root nodules were extracted from the soil because of the obvious practical difficulty under field conditions. However, the number of root nodules (14.9-58.3) obtained in the current study was within the range obtained (23.5-54.3) for soybean by Chiezey *et al*. (1992). The difference between the values for these parameters at 6 and 12 weeks of age at 12WAS sampling period was significant. This implies that farmers should incorporate their slow release phosphorus fertilizers at sowing where possible or by 4 weeks after sowing, to support lablab root growth, which could enhance nodulation. In trials conducted at Samaru, delaying phosphorus application until 4-5 weeks did not negatively affect

cowpea and groundnut yields compared with application at sowing (Olufajo, 2011). Phosphorus-fertilized plants develop more roots than plants not fertilized with phosphorus (Mitchell, 1970).

The mean value for CGR at the 6-12WAS in this study fell within a range of 0.23-1.19 $g.m^{-2}.wk^{-1}$. The only significant difference occurred between the 6 and 12 weeks cutting ages. Beyond 12 weeks up to maturity, there was no statistically significant difference in the CGR values. This implies that intensive management of lablab growth should be carried out within 12 weeks of sowing for an overall benefit of the crop.

This study has shown that lablab LAI is sufficient for maximum dry matter production. According to Brown and Blaser (1968), where dry matter production vs. time curve of a crop is sigmoid, an optimum LAI of intermediate value is presupposed. Lablab may therefore operate with an optimum LAI which is prone to shading of the lower leaves such that respiration exceeds photosynthesis thereby creating parasitism of the shaded leaves. This is another reason in favour of cutting or grazing lablab at 12 weeks after sowing for increased crop productivity.

The LAI values at 6 and 18WAS were in the range of 9.3-11.5, whereas measurement at 12WAS showed LAI values in the range of 13.4-21.0. These values which fell within the acceptable range of LAI presented by plant physiologists suggest that lablab is a crop suited to cutting or grazing. A leaf area index of 3-5 is necessary for maximum dry matter production of most cultivated crops. However, forage grasses may require a LAI of 8-10 while higher LAI is required in forage crops when total biomass and not economic yield fraction is the objective (Gardner *et al.*, 1985). The higher LAI values obtained at 12WAS may be due to the high sward height, which translated into more leaves per unit area. Seasonal growth and sward LAI values fluctuate widely and LAI values in excess of those needed to intercept 95% of incident light is required in swards cut for hay or subjected to heavy rotational grazing (Brown and Blaser, 1968).

The results of this study suggest that in order to enhance regrowth, lablab should be cut or grazed when conditions that favour regeneration are best. The relative regeneration rates (0.31,0.49,0.15 and 0.32 in 2006,2007,2008 and combined respectively) of lablab at 18 weeks was the highest recorded among the cutting ages. This could be due to the better established root system and the higher amount of total non-structural carbohydrates (TNC) both of which favoured lablab regrowth when cutting was done at this sampling stage. The practical implication of this finding is that where it is desirable to grow lablab as a short season perennial with supplementary irrigation, the best interval of cutting lablab before irrigation is 18WAS when its RRR is fastest. The grazing or cutting management system used for irrigated pastures should be designed to optimize the physiological capabilities of the forage being grazed or cut (Nichols and Clanton, 1985).

The RRR values obtained in this study, were considerably lower than those values reported by Odion and Singh(2005a) for cowpea varieties .This variation may be associated with differences in both crop species (lablab vs. cowpea), cutting height(10 and 20cm for lablab vs. 15 and 25cm for cowpea) and environment(Samaru vs. Kano) utilized in these studies. At the lablab cutting heights (10 and 20cm), LAI was reduced considerably and most bud sites required for speedy regeneration were eliminated. This also suggests that a more lenient defoliation height for lablab may be desirable to promote regrowth.

The number of days to 50% flowering of lablab was significantly affected by cutting age. The results of the present study indicated that cutting at 6 weeks or at harvest produced similar number of days to 50% flowering, whereas cutting at 12 or 18 WAS increased the number of days to 50% flowering. The implication of this finding is that appropriate cutting or grazing may prolong the vegetative growth of lablab, which is desirable in livestock husbandry, since legume quality drops at the onset of flowering. Once alfalfa buds appear, feeding value will decline about 0.2% in crude

protein per day (Bragg, 2003). Farmers may deliberately cut or graze their lablab crop to prolong the vegetative phase.

The implication of the results of this study in terms of seed production is that appropriate cutting or grazing lablab, such as 6 and 12 weeks in the current study, will not prevent seed production as most lablab producers believe. The seed yield of lablab from plots cut at 6 weeks and maturity were similar (822 vs. 926 kg ha^{-1} respectively). These values were also similar to lablab seed yield values quoted in the literature. In Nigeria, Rongai and Highworth lablab varieties can produce seed yields of 1.0-1.2 tonnes ha^{-1}(Anonymous, 2008). Ewansiha *et al*. (2007) obtained lablab seed yields of 0.6-2.4 tonnes ha^{-1} with some lablab accessions tested at Samaru, Nigeria. The seed yield of lablab cut at 12 weeks was 35% lower than those of lablab cut at either 6 weeks or at maturity. This may have been due to slower regrowth rate which significantly delayed the time at which lablab cut at 12 weeks reached 50% flowering. This finding should not deter producers from cutting or grazing lablab at this stage of growth since some seed production for continuity is still possible. However, cutting lablab at 18 weeks inhibited seed production, which implies that when seed production is required, lablab should not be cut or grazed at or after 18 weeks. The inability of lablab cut at 18 weeks to produce seed could be attributed to moisture stress, which prevented adequate regrowth and other physiological processes. The stress triggered flowering 15 days after cutting when sufficient re-growth and assimilate production had not occurred. In all the three years of study, cutting at 18WAS fell into November, a time when no rain was received. Chiezey *et al.* (1992) and Mahmud *et al*. (1996) reported that the abrupt cessation of rainfall at Samaru in 1990 resulted in small, incompletely filled pods of soybean (*Glycine max* (L) Merrill) and green gram (*Vigna radiata* (L) Wilezek) respectively. El-Shatnawi *et al*. (2003) on the other hand attributed the lack of seed production in late-cut wall barley in Jordan to rapid reduction in soil moisture. Inadequate soil moisture causes a decrease in the water status of plant tissues which affects cell division and cell

enlargement (Smith and Nelson, 1985). Water provides a reaction solution for cellular activity, cell turgidity necessary for cell enlargement which enhances photosynthetic processes (Mitchell, 1970).

The results of this study indicated that timely consumption of lablab herbage will ensure quality nutrition for ruminants. Generally, at the first cutting, lablab crude protein concentration reduced significantly as cutting age increased. This decline may be attributed to an increase in cell wall accumulation while cell contents decline (Buxton, 1989). Generally, there was a 20% drop in crude protein between 12 and 18 weeks and a 26% drop between 18 weeks and maturity at the first cutting. These drops in CP content with older cutting age were indicative of decreasing forage quality with crop age. Short delays in cutting result in significantly lower forage quality and once alfalfa buds appear, feeding value will decline about 0.2% in crude protein per day (Bragg, 2003). The relatively high lablab crude protein content of 134.4 g kg^{-1} even at 18 weeks, is above that proposed as the minimum requirements for lactation (120g CP kg^{-1} DM) and growth (113 g CP kg^{-1} DM) in ruminants (ARC,1984). This implies that a reduction in protein concentrate usage is possible if lablab herbage is conserved at this stage for the dry season feeding of dairy animals.

At the 1st cutting, crude protein of lablab ranged between 99.5 and 168 g kg^{-1}.This is in agreement with the findings of some researchers. Under low soil moisture conditions in Mississippi, USA, Brink and Fairbrother (1988) measured 128 and 204 g CP kg^{-1} in new growth lablab and whole plant lablab respectively. In Zimbabwe, Jingura *et al*. (2001) reported 159 g CP kg^{-1}, whereas Mupangwa *et al*. (2006) reported a range of 162 to 254 g kg^{-1} for "Highworth" lablab. Evans (2002) reported a range of 12.7-14.1% CP while Aganga and Autlwetse (2000) working in Botswana reported a CP content of 16.4% for whole plant lablab hay. Muldoon (1985), Mupangwa *et al*. (1997), and Dalzell *et al*. (1997) measured 248, 251 and 218 g CP kg^{-1} in lablab leaves respectively in moist tropical climates. However, Karachi (1997) reported lablab CP content as 25% for leaves and

11.88% for stems. In the present study, whole plant (leaves plus stems) lablab CP was measured. Cutting lablab improved the CP concentration by 21 %(97.2 vs. 122.4 g kg^{-1} CP for the 1st and mean of 2nd cuttings respectively), which is consistent with Adjei and Gentry (1996) who reported that clipping management improved crude protein of lablab in the semi-arid tropics.

This study has revealed that delaying of lablab herbage consumption until after seed harvest (crop residue) as generally practiced will reduce quality significantly. However, this reduction in lablab quality is primarily due to an increase in CF rather than a drop in CP. Even when cut at harvest, lablab CP content of 99.5 and 97.2 g kg^{-1} at the 1st and 2nd cuttings respectively, is higher than the generally suggested critical CP (i.e. 6 to 7 %) level of forages needed to maintain efficient rumen function (Otsyina *et al*.,1987). Therefore, to utilize lablab herbage at a good quality, timely cutting or grazing is required to prevent an undesirable increase in CF content. According to Van Soest(1985), despite its greater lignification, legume fiber offers more buffering capacity and better fermentation rates, than does fiber in grasses and the level required to maintain optimum efficiency is about 36% neutral-detergent fiber(NDF) in the complete diet although different fiber sources differ in efficiency. The mean NDF values of lablab in a study conducted in Zimbabwe were 352,464 and 544 g kg^{-1} DM at 8, 14 and 20 weeks of growth respectively (Mupangwa *et al*., 2006). Consequently, earlier utilization of lablab as proposed is desirable.

Crude fibre of lablab which ranged between 172.8 and 276.7 g kg^{-1}, increased with cutting age. This could be associated with an increase in stem growth, leaf senescence and abscission (Albrecht *et al*., 1987). Upon evaluating three annual forage legumes in Ethiopia, Gebrehiwot *et al.* (1996) found that in all species, crude fibre increased with maturity in total herbage and stem fractions. In their study, Adjei and Fianu (1985) found a significant progressive increase in crude fibre content of both stems and leaves for all legumes with older cutting age. Cutting age improved

lablab quality through a crude protein concentration increase of 26 % (122.4 vs. 97.2 g CP kg^{-1}) and a crude fibre concentration decrease of 24 % (277.6 vs. 210.0 g CF kg^{-1}) from the 1st and 2nd cuttings respectively. This decline in crude fibre due to cutting could have positive implications on the intake and digestibility of lablab since these factors may be influenced by fibre content of forages according to Van Soest (1985).

In the current study, cutting did not favour lablab ether extract content as it did in the case of crude protein and crude fibre. Rather, there was a marked decrease (by 46%) in the ether extract concentration of lablab within the 12-week period between the 1st and 2nd cuttings (i.e. 8.1 vs.4.4 g kg^{-1}).This is probably because components of ether extract such as galactolipids, triglycerides, waxes, pigments, organic acids, essential oils that occur in plants as steam-volatile lipids including fat-soluble vitamins(carotenes, D, E, and K) as enumerated by Van Soest(1985) may have declined or been lost with lablab maturity. Ether extract concentration of lablab decreased as cutting age increased and was highest at the youngest cutting age of 6 weeks while the lowest ether extract concentration was recorded at maturity. However, Adjei and Fianu (1985) did not get a consistent pattern in the response of either the leaf or stem ether extract to cutting age in some legumes, none of which was lablab.

It was found that the calcium concentration of lablab fell within the range of 9.4 to 15.5 g kg^{-1} which is similar to the values(9.0 to 19.8 g kg^{-1} DM) reported by Gohl (1981). Calcium concentration increased with maturity, but decreased between 18 weeks and harvest at the first cutting stage. Mupangwa *et al*. (2006) associated a similar calcium increase in the forage legumes they studied (lablab inclusive) with increased calcium accumulation in plant tissues associated with plant support. However, lablab can adequately cater for the recommended (1.9 to 4.0 g kg^{-1} DM)

calcium requirements of livestock, since the values obtained in the present study are much higher than the recommended Agricultural Research Council (ARC) (1984) values.

Generally, the values for Ca: P ratios recorded for lablab are adequate for various species of ruminants The Ca: P ratio of lablab in the current study ranged between 2.7 and 5.5 at the 1st cutting and from 6.1 to 7.1 at the 2nd cutting. The recommended Ca: P ratio in ruminant feeds is 2:1(Buxton, 2008).The Ca: P ratio of lablab was more favourable at the shorter cutting ages (6, 12 and 18 weeks) compared to maturity. However, the trend at which the Ca: P ratio changed between the 1st and 2nd cuttings was similar to results obtained in an earlier study. Collins (1989) reported that the Ca: P ratio of alfalfa increased from 5.3 at the first sampling date for alfalfa to 7.5 on the last date while that of birdsfoot trefoil had Ca: P ratios of 3.5 and 4.7 on the first and last sampling dates respectively.

5.5 Phosphorus x Cutting Height Interaction

The interaction between phosphorus and cutting height was significant for sward height, number of root nodules, 100-seed weight, dry matter and phosphorus concentration. A combination of application rate of 36 kg P ha^{-1} and 20cm cutting height produced the highest sward. Lablab 100-seed weight was heaviest when 12 kg P ha^{-1} was supplied along with a 20cm cutting height. These observations were probably due to the sufficient soil phosphorus, which enhanced root growth at the 12 and 36 kg P ha^{-1} application rates as well as a more functional foliage for photosynthesis left after cutting lablab to a 20cm stubble height, which could have enhanced regrowth and assimilate translocation. According to Mitchell (1970), phosphorus fertilization increases top growth, more carbohydrate is photosynthesized, and this in turn increases root growth and probably number of root nodules.

A combination of 24 kg P ha^{-1} and 10cm cutting height produced the highest number of root nodules. This result is similar to the one obtained by Chiezey *et al*.(1992), who found that soybean nodulation increased by 13.8 - 22.5% above the zero P control with an application rate of 26.4 kg P ha^{-1}. However, this combination involving a lower cutting height (10cm) and "sufficient" phosphorus level may have triggered the production of new root nodules. In legumes, root nodules are one of the first organs to be affected by defoliation. Drastic defoliation can cause the premature senescence of nodules and their eventually shedding from roots (Humphreys, 1987).However, Whiteman (1970) provided evidence in support of the idea that changes in nodule dry weight which were induced by defoliation were related to a loss of part of the original nodule population and the initiation of new nodules.

Phosphorus concentration of lablab herbage was highest when no P was applied along with a cutting height of 10cm.This treatment combination probably reduced the growth rate of lablab thereby lowering the dilution effect (i.e. lower mineral content relative to increased dry matter production). In addition, an increase in root surface area occasioned by search for phosphorus in the soil profile may have ensued at the expense of shoot growth, which in turn enhanced phosphorus uptake.

5.6 Phosphorus x Cutting Age Interaction

In 2008, there was a significant interaction between phosphorus rate and cutting age for crude protein and crude fibre concentrations of lablab. Crude protein was highest at the 0 kg P ha^{-1} coupled with 6 weeks cutting age. Nitrogen fixation and assimilate production at the early stages of lablab growth may have enhanced crude protein concentration. Expectedly, since CF increases with maturity, the crude fibre concentration of lablab was highest at maturity, when an application rate

of 0 kg P ha^{-1} was utilized. This implies that early utilization of lablab will reduce crude fibre thereby improving herbage quality and by implication digestibility.

Phosphorus rate x cutting age interaction was significant for number of primary branches, ether extract and ash at the 1st cutting and dry matter at the 2nd cutting. An application rate of 12 kg P ha^{-1} produced the highest number of primary branches (at 18 weeks), ether extract (at 6 weeks), ash concentration (at 12 weeks) and dry matter concentration (at maturity). A 12 kg P ha^{-1} application rate favoured several lablab parameters, which is an indication that lablab cut or grazed at different ages can perform optimally with a 12 kg P ha^{-1} rate of application, a condition which resource-poor farmers would find attractive. With respect to ash, the results obtained (i.e. 91 to 111 g kg^{-1} DM) in the current study were generally similar to those reported (i.e. 77 to 114 g kg^{-1} DM) by Mupangwa *et al*. (2006).

5.7 Cutting Height x Cutting Age Interaction

The interaction between cutting height and cutting age for cumulative dry herbage in 2008 was significant. The highest cumulative dry herbage was obtained at 18 weeks cutting age irrespective of cutting height. This suggests that at 18 weeks, which coincided with full bloom in alfalfa or 50% flowering in lablab, the amount of root labile carbohydrates rather than LAI of lablab determined the rate of regrowth. Generally, energy reserves are highest when legume plants are in the full bloom and lowest a short time after cutting, when the plant is growing rapidly (Anonymous, 2009).Usually, the closer to maturity that cutting or grazing occurs, the higher the stored food reserves will be and the easier it is to maintain vigour for productivity(Smith and Nelson,1985)

On the other hand, the lowest cumulative dry herbage yield of lablab was obtained when a cutting height of 10cm was used along with the youngest cutting age of 6 weeks. This cutting management, was detrimental to lablab probably because the quantity of labile carbohydrates was

very low at that stage of growth and with most lablab leaves removed (near zero LAI) at that lower cutting height (10cm), assimilate production was partially halted, which together affected dry herbage accumulation. Both competition and defoliation (which were at play in the plant communities of this study) cause less per plant root development due to reduced carbohydrate synthesized per plant and hence the reduced quantity of food available for root growth (Mitchell, 1970), this scenario may have affected dry herbage accumulation indirectly.

According to Humphreys (1987), "critical" LAI is defined as the amount of leaf area necessary to reduce the light value at ground level to 0.05 daylight. After cutting lablab to a 10cm stubble height, the LAI would have fallen below the critical range of 3-5 causing a reduction in growth rate because of inadequate light interceptions (Humphreys, 1987). In addition, Smith and Nelson (1985) stated that to intercept 95% of the radiation, flat-leafed plants like clovers require a LAI of about 3, alfalfa or orchardgrass require 4 to 5 whereas perennial ryegrass requires 7 to 11. "Until these LAIs are achieved by the canopy following cutting or grazing, the growth rate is more related to radiation interception than to photosynthetic activity per unit of leaf area" (Smith and Nelson, 1985).

5.8 Correlation

The positive and significant correlation observed between most of the growth parameters of lablab indicates inter-dependency within these characters. Similarly positive and significant association was observed between cumulative dry herbage yield and stand count, sward height, ground cover score, number of root nodules and nodule dry weight. This revealed the importance of these parameters as yield contributing factors with a direct bearing on herbage production in lablab.

The positive correlation between sward height and cumulative dry herbage yield is noteworthy. Since the lowest substantive P application rate (12 kg P ha^{-1}) significantly increased

sward height above the zero P control at 12WAS, farmers could produce high forage yields for livestock with this relatively low rate of phosphorus application.

5.9 Path Analysis

The path analysis showed that nodule dry weight, sward height and stand count had positive direct contributions while ground cover score and number of root nodules had negative direct contributions to cumulative dry herbage yield of lablab. The direct positive contribution indicates the relative importance of these parameters to cumulative dry herbage yield of lablab. On the other hand, the observed negative direct contribution of number of root nodules may support the understanding that nodule dry weight instead of number of root nodules is more important in legume productivity as suggested by Whiteman (1970).

Although ground cover score and number of root nodules in lablab had negative direct contributions, their total contributions in association with the other growth parameters were positive. This underscores the importance of several variables working together to achieve maximum cumulative dry herbage yield in lablab.

5.10 Percentage Contribution

In terms of percentage contributions, nodule dry weight was the highest individual contributor to cumulative dry herbage of lablab followed by sward height and number of root nodules. This observation is an indication that these growth parameters are strong contributors to lablab herbage yield.

When the combined contribution is considered, sward height and nodule dry weight were consistently the highest contributing pair to cumulative dry herbage yield of lablab. This may be due to the fact that nodule dry weight which enhanced nitrogen fixation could have promoted sward height and thereby higher photosynthetic surface for greater photosynthesis and higher herbage yield. However, the residual percentage contribution, which is the remaining portion of yield not accounted for by the five independent variables evaluated, was 77 percent. According to Ahmed (1997), this implies that there are other factors affecting the cumulative dry herbage yield of lablab which were not included in the current analysis.

5.11 Polynomial Response

There was no conclusive evidence to determine the best fitting curve when cumulative dry herbage yield was regressed against cutting age despite the methods of ANOVA, Chi square and graphing employed. This discrepancy may be explained by the low coefficient of determination (R^2) values obtained for the regression analysis except in 2008. From these R^2 values, 0.0015(in 2006), 0.3439 (in 2007), 0.7990 (in 2008) and 0.2753(in 2006-2008), it can be observed that the proportion of cumulative dry herbage of lablab which is unexplained (coefficient of alienation or $1-r^2$) by the regression analysis is much larger than the proportion explained. This is an indication that there are other variables beside those evaluated in the current study that have greater effect on cumulative dry herbage yield of lablab. This observation is in line with the high residual value (77%) obtained in the percentage contribution analysis in the present study.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

6.1 Summary

Field trials were conducted during the 2006, 2007 and 2008 cropping seasons at the Institute for Agricultural Research (IAR) Experimental Farm, Samaru (lat. $11^0 11'N$, long. $7^0 38'E$, 686m above sea level) in the northern Guinea savanna zone of Nigeria, to study the response of lablab (*Lablab purpureus*(L.) Sweet), to phosphorus application rates, cutting height and cutting age. The experiment was a split plot design with three replications and the treatments were composed of factorial combinations of four levels of phosphorus fertilizer (0,12,24 and 36 kg P ha^{-1}), two cutting heights (10 and 20cm) and four cutting ages (6,12,18 weeks and maturity).

The results of the study revealed that a phosphorus application rate of 12kg P ha^{-1} significantly increased sward height, leaf area per plant, leaf area index, number of root nodules and nodule dry weight above the no-P control. In addition, cutting lablab to a 20cm stubble height produced significantly higher sward height, ground cover score, mean pod length and 100-seed weight whereas a cutting height of 10cm produced significantly higher calcium and phosphorus concentrations. Furthermore, the highest sward height, cumulative fresh, dry and initial herbage yields were obtained at the 18-week cutting age. Cutting lablab at 6 weeks did not depress seed yield compared with the cutting at maturity. The highest crude protein and crude fibre concentrations of lablab were obtained at the 12-week and maturity cutting ages respectively, while the quality of both parameters improved at the 2nd cutting. Lablab ether extract concentration in dry

herbage decreased while Ca: P ratio increased as cutting age increased at the 1st cutting while the concentrations of both parameters decreased at the 2nd cutting.

A combination involving 36 kg P ha^{-1} and 20cm cutting height produced the highest sward. The highest number of root nodules was obtained when lablab was supplied with 24 kg P ha^{-1} and cut to a height of 10cm. However, the heaviest 100-seed weight was produced from a combination of 12 kg P ha^{-1} application rate and a 20cm cutting height. The phosphorus application rate of 12 kg P ha^{-1} produced the highest ether extract, ash, number of primary branches, and proximate dry matter concentration in lablab when cutting ages were at 6, 12,18 weeks, and maturity respectively. The highest phosphorus concentration of lablab was obtained when an application rate of 0 kg P ha^{-1} and a cutting height of 10cm interacted significantly in this study. Application rate of 0 kg P ha^{-1} combined with a cutting age of 6 weeks produced the highest crude protein concentration of lablab while the crude fibre concentration was highest when lablab given an application rate of 0 kg P ha^{-1} was cut at harvest. The highest cumulative dry herbage yield was obtained at 18 weeks irrespective of cutting height.

A positive and significant correlation was observed between cumulative dry herbage yield and stand count, sward height, ground cover score, number of root nodules and nodule dry weight of lablab. The path analysis showed that nodule dry weight, sward height and stand count had positive direct contributions. However, nodule dry weight was the highest individual contributor to the cumulative dry herbage yield of lablab in this study. The polynomial response analysis did not produce a best fitting curve when cumulative dry herbage yield was regressed on cutting ages.

6.2 Conclusion

In conclusion, an application rate of either 12 or 24 kg P ha^{-1} was favourable to many parameters of lablab including nodule dry weight. Cutting lablab at 18 weeks produced the highest fresh and dry herbage yields but at the expense of seed production. Overall, the highest quality and quantity of lablab herbage was produced at the 12 week cutting age whereas cutting lablab at harvest or maturity reduced the herbage quality, and quantity and even the seed yield of lablab relative to the earlier cutting ages.

Based on the results of this study, it is suggested that lablab should be developed into a ley (temporary) pasture in the farming systems of the northern Guinea savanna zone of Nigeria and utilized for ruminant livestock feeding pre- rather than post- harvest maturity. This role will be more suitable for lablab because after 18 weeks of growth, lablab loses 67.3% and 40.2% of its cumulative fresh and dry herbage yields respectively, and 35.1% of its crude protein content while its crude fibre content increases by 6.3%.Moreover, for livestock producers in this zone who wish to feed lablab and yet require seed for subsequent pasture, cutting before or at 12 weeks ensures a harvest of at least 37.1% of the seed yield at maturity, whereas for those producers with alternative seed supply, feeding at 18 weeks ensures that 60% of the accumulated dry herbage and 65% of the crude protein content is utilized by livestock.

REFERENCES

Acunapommiezi, H. (2007). Effect of phosphorus, potassium and sulphur application on productivity of *Lotus spp*. in two big groups of Chilean soils. *Lotus newsletter* 37(1):39.

Adeoye, K.B and Onifade, O.S. (2000). Cover crops adoption and forage seed production in Nigeria: Report for the sub-humid zone. *In:* Carsky, R.J., Eteka, A.C., Keatunge J.D.H. and Manyong V.M. (Eds) Cover crops for natural resources management in West Africa. Proceedings of a Workshop, IITA – Cotonou, Benin Republic, 26-29 October 1999, pp 280-289. International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria.

Adeyemo, M.O., Fakorede, M.A.B. and Edema, A.O. (1987). Effects of poultry manure and cutting height on the performance of *Amaranthus hybridus* L. *Nigerian Journal of Agronomy* 2(1):21-26.

Adjei, M.B. and Fianu, F.K. (1985). The effect of cutting interval on the yield and nutritive value of some tropical legumes on the coastal grassland of Ghana. *Tropical Grasslands* 19(4):164-171.

Adjei, M.B. and Gentry, T.J. (1996). Forage characteristics of lablab beans in semi-arid tropics. *Agronomy Abstract.* pp 42.

Aganga, A.A. and Autlwetse, M.N. (2000). Utilization of sorghum forage, millet forage, veldt grass and buffel grass by Tswana sheep and goats when fed *Lablab purpureus* L. as a protein supplement. *Asian-Australian Journal of Animal Science* 13:1035-1188.

Ahmadi, A.H.A., Chaichi, M.R., and Mirabzade, M. (2009). Effects of nitrogen fertilizing system and harvest frequencies on forage dry matter yield and quality of snail medic (*Medicago scutellata* var. Robinson). *Asian Journal of Plant Sciences* 8(2):160-156.

Ahmed,M.K.(1997). Yield analysis via path coefficients: 1.Direct and indirect contributions of components to yield.II.Direct and combined contributions (percent) of yield components to yield and their residual effect. Special seminar in statistics. Department of Agronomy. Ahmadu Bello University, Zaria. pp 2.

Aina, A.B.J. and Onwukwe, S..C. (2002). Estimation of nutrient contents of some selected grasses as affected by age of cuttings. 212 – 214 Proc. 7th Ann. Conf. Anim. Sci. Ass. of Nig. (ASAN) Sept. 16 – 19. Univ. of Agric. Abeokuta, Nigeria. pp 212-214.

Akinola, J.O. and Onifade, S.O. (1984). Yield responses of soyabean (*Glycine max*. L. Merrill) to two different sources and varying levels of phosphorus. NAPRI Annual Report, National Animal Production Research Institute,Shika, Nigeria. pp 73-75.

Akinola, J.O., Onifade, O.S. and Kera, B.S. (1985). Direct and residual effects of fertilizer phosphorus sources and levels on dry matter and seed yields of four soyabean genotypes. NAPRI Annual Report, National Animal Production Research Institute,Shika, Nigeria. pp 92-94.

Albrecht,K.A.,Wedin,W.F. and Buxton, D.R..(1987). Cell wall composition and digestibility of alfalfa stems and leaves. *Crop Science* 27:735-741.

Allen,D.J., Ampofo, J.K.O. and Wortmann, C.S.(1996). Pests, diseases and nutritional disorders of the common bean in Africa: A field guide.. Cali, Colombia: International Center for Tropical Agriculture; Wageningen, The Netherlands .Technical Centre for Agricultural and Rural Cooperation 1996. 132 pp. (CIAT Publication, No. 260).

Al-Masri, M.R. (1998). Yield and nutritive value of vetch (*Vicia sativa*) barley (*Hordeum vulgare*) forage under different harvesting regimes. *Tropical Grasslands* 32:201-206.

Amodu, J.T., Onifade, O.S, Kallah, M.S., Adeyinka, I.A. and Alawa, J.P. (2003). Sowing date and spacing influence on fodder and seed yields of lablab in northern Guinea savanna of Nigeria. *ASSET Series A* 3(1): 53 – 58.

Andrae, J. and Pinkerton, B. (2009). Forage quality as affected by soil fertility. Pasture fertility Internet In-service training. *Clemson Extension Service*. 5pp.

Anonymous (2000). Summer legume forage crops:cowpeas,lablab,soybeans.http:

//aciar.gov.nsw. May 10th 2007.

Anonymous (2008). Production of lablab in Nigeria.Extension Bulletin No 206, Livestock Series No. 23 National Agricultural Extension and Research Liason Services.Ahmadu Bello University, Zaria, Nigeria. 5pp.

Anonymous (2009). Cutting management of alfalfa, red clover and birdsfoot trefoil.http:

www.pennstate.edu. June 1st 2009.

ARC (Agricultural Research Council) (1984).The nutrient requirements of ruminant

livestock. Supplement No.1. Commonwealth Agricultural Bureaux.

Slough,UK.

Ariba, O.O. Agishi, E.C., Kera, E.S. and Olorunju, S.A.S. (1988). The effect of different levels of phosphorus fertilizer and time of planting on seed yield. NAPRI Annual Report, National Animal Production Research Institute,Shika, Nigeria. pp 57-58.

Association of Official Analytical Chemists (1990).AOAC.Official Methods of Analysis. Vol 1, 15th edition.Washington,DC.

Bhilare, R.L. (2003). Effect of phosphorus levels on forage yield of cowpea varieties. *Madras Agricultural Journal* 90(4-6): 355-356.

Black, C.A. (1965). Methods of Soil Analysis II. Chemical and Microbiological Properties. American Society of Agronomy Madison, Wisconsin.

Bolland, M.D.A., Sweetingham, M.W., and Jarvis, R.J. (2000). Effect of applied phosphorus on the growth of *Lupinus luteus*, *L. angustifolius* and *L. albus* in acidic soils in the south-west of Western Australia. *Australian Journal of Experimental Agriculture*. 40:79-92.

Bolland, M.D.A., Reithmuller, G.P., Siddique, K.H.M and Loss, S.P. (2001). Method of phosphorus fertilizer application and row spacing on grain yield of faba bean (*Vicia faba* L.). *Australian Journal of Experimental Agriculture* 41, 227-234.

Brady, N.C. (1974). The nature and properties of soils.8th edition. Macmillan publishing company, Incorporated. New-York. 639pp.

Bragg, J., (2003). Cutting management of Alfalfa. *http:www.ag.pennstate.edu.* June 20th 2009.

Brennan, R.F. and Bolland, M.D.A. (2007). Effects of fertilizer phosphorus and nitrogen on the concentrations of oil and protein in grain and the grain yield of canola (*Brassica napus* L.) grown in south-western Australia. *Australian Journal of Experimental Agriculture* 47:984-991.

Brink, G.E. (1995). White clover growth and morphology under contrasting cutting regimes. *Crop Science* 35: 1100 – 1103.

Brink G.E. and Fairbrother, T.E. (1988). Cool-and warm-season forage legume potential for the southeastern USA. *Tropical Grasslands*.22:116-125.

Brown,R.H. and Blaser, R.E.(1968). Leaf area index in pasture growth. *Herbage Abstracts* 38(1):1-9.

Buda, A.R., Kleinman, P.J.A., Srinivasan, M.S., Bryant, R.B. and Feyereisen, G.W. (2009). Effects of hydrology and field management on phosphorus transport in surface runoff. *Journal of Environmental Quality* 38:35-40.

Buxton, D.R. (1989). In vitro digestion kinetics of temperate perennial forge legumes and grass stems. *Crop Science* 29:213-219.

Buxton, D.R. (2008). Growing quality forages under variable environmental conditions.*http:/www.rrd.org/buxt/9012.htm.* May 15th 2009.

Caballero, R., Alzueta, C., Ortiz, L.T., Rodriguez, M.L., Barro, C. and Rebole, A. (2001). Carbohydrate and protein fractions of fresh and dried common vetch at three maturity stages. *Agronomy Journal* 93:1006-1013.

Caddel, J., Redfearn, D., Zhang, H., Edwards, J., and Deng, S. (2009). Forage legumes and nitrogen production. *http:www. 11054 facts Oklahoma State. Edu.* May 15th 2009.

Carsky, R.J., Oyewole, B. and Tian, G. (2001). Effect of phosphorus application in legume cover crop rotation on subsequent maize in savanna zone of West Africa. *Nutrient Cycling in Agroecosystems.* 59:151-159.

Chiezey,U.F.,Yayock, J.Y. and Ahmed, M.K.(1991). Effect of phosphorus and plant density on the yield and yield components of soybean (*Glycine max* L. Merrill). *Crop Research* 4(1):11-18

Chiezey,U.F., Yayock,J.Y. and Shebayan,J.A.Y(1992). Response of soybean(*Glycine max* L. Merrill) to nitrogen and phosphorus fertilizer levels. *Tropical Science* 32:361-368.

Chiezey,U.F., Haruna, I.M. and Odion, E.C.(2004). Growth and development of sorghum/soybean mixture with nitrogen, phosphorus and plant arrangement in the northern Guinea Savanna ecological zone of Nigeria. *Crop Research* 28(1, 2&3):1-14.

Collins, M. (1989). Mineral concentrations in whole crop and pressed forage of three forage legumes. *Agronomy Journal* 81: 901-906.

Crowder, L.V. and Chheda, H.R.(1982). Tropical grassland husbandry.Longman Inc.,

New York. 562pp.

Cullison, A.E. (1979). Feeds and feeding. Reston Publishing Company, Inc. Reston, Virginia.595pp.

Dalzell, S.A., Brandon, N.J. and Jones, R.M. (1997). Response of *Lablab purpureus* cv. High-worth, *Macroptilium bracteatum* and *Macrotyloma daltonii* to different intensities and frequencies of cutting. *Tropical Grasslands* 31:107-113.

Das, L.D.V. (1990). Performance of forage accessions of *Dolichos lablab* (L.) *Madras Agricultural Journal* 77:555-556.

De-Geus, J.G. (1977). Production potentialities of pastures in the tropics and sub tropics. Conzett and Huber AG Press. Zurich. 450pp.

Devkota, N.R., and Rerkasem, B. (2000). Effects of cutting on the nitrogen economy and dry matter yield of lablab grown under monoculture and inter-cropped with maize in northern. *Thailand Experimental Agriculture* 36:459-468.

Duke, J.A., Kretschner, A.E., Jr, Read, C.F. and Weder, J.K.P (1981). *Lablab purpureus* L. Sweet. In: *Handbook of Legumes of World Economic Importance*. Plenum Press, New York. 102 – 106 pp.

Duncan, D.B. (1955). Multiple range and multiple F-tests*; Biometrics* 11:1-42.

El-Shatnawi, M.J., Al-Qurran, L.Z.,Ereifej,K.I. and Turk,M. (2003). Defoliation of wall barley under sub-humid Mediterranean conditions. *Australian Journal of Agricultural Research* 54:53-58.

Evans, D.O. (2002). Sustainable agriculture in Hawaii. Green manures: lablab. *http://www2.ctahr,Hawaii.edu/systainag/sustainableAg/Green Manures/lablab asp.* July 13th 2007.

Evans, P.M., Trigg, P.J., Kearney, G.A. and Byron, A.H. (2004). Effect of cutting regime on the agronomic performance of two contrasting lines of *Melilotus albus*. *Australian Journal of Experimental Agriculture* 44:1177-1183.

Ewansiha, S.U., Chiezey, U.F., Tarawali, S.A., and Iwuafor, E.N.O (2007). Potential of *Lablab purpureus* accessions for crop-livestock production in the West African savanna. *Journal of Agricultural Science* (*Cambridge)* 145: 229-238.

Falade, J.A. (2006). Effect of phosphorus on the growth and mineral composition of four tropical forage legumes. *Journal of the Science of Food and Agriculture* 24(7):795-802.

Follett,R.F. and Wilkinson,S.R.(1985). Soil fertility and fertilization of forages. pp: 304-317 *In*: *Forages: The science of grassland agriculture*. 4th edition. Edited by, Heath M.E., Barnes R.F. and Metcalfe D.S. The Iowa State University Press, Ames, Iowa.

Fribourg, H.A., Overton, J.R, McNeill, W.E.., Culverhouse, E.W., Montgomery, M.J., Smith, M., Carlisle, R.J. and Robinson, W.W. (1984). Evaluation of the potential of hyacinth bean as an annual warm-season forage in the mid-south. *Agronomy Journal* 76(6): 905 – 910.

Fulkerson, W.J., Slack, K. and Havilah, E. (1999). The effect of defoliation interval and height on growth and herbage quality of kikuyu grass *(Pennisetum clandestinum*). *Tropical Grasslands* 33:138-145.

Gardner,F.P., Pearce,R.B. and Mitchell,R.L.(1985). *Physiology of crop plants*. The Iowa State University Press. Ames, Iowa.

Gebrehiwot, L., McGraw, R.L. and Assefa, G.(1996). Forage yield and quality profile of three annual legumes in the tropical highlands of Ethiopia. *Tropical Agriculture* 73(2): 83-89.

Gohl, B. (1981). (Ed) Tropical feeds. FAO Animal Production and Health Series No. 12, FAO, Rome. 186pp.

Griffith, W.K. (1974). Satisfying the nutritional requirements of established legumes. In D.A. Mays (Ed). *Forage Fertilization*. ASA, Madison, WI.

Hague, I. and Lupwayi, N.Z (1999). Landform and phosphorus effects on nitrogen fixed by annual clovers and its contribution to succeeding cereals in the Ethiopian highlands. *Australian Journal of Agricultural Research* 50:1393-1398.

Hague, I., Nnadi, L.A and Mohamed–Saleem, M.A., (2008). Phosphorus management with special reference to forage legumes in sub-Saharan Africa. *http:www.fao.org.* January 20th 2009.

Hague, I., Lupwayi, N.Z., and Ssali, H. (1999). Agronomic effectiveness of unacidulated and partially acidulated Minjingu rock phosphates on *Stylosanthes guianensis. Tropical Grasslands* 33:159-164.

Hare, M.D., Saengkham, M., Kaewkunya, C, Tudsri, S, Suriyjantratong, W, Thummasaeng, K. and Wongpichet, K. (2001). Effect of cutting on yield and quality of *Paspalum atratum* in Thailand. *Tropical Grasslands* 35:144-150.

Harricharan, H, Morris, J and Devers, C. (1987). Mineral content of some tropical forage legumes. *Tropical Agriculture* (*Trinidad*) 65(2):132-135.

Hart, A.L. and Jessop, D. (2006). Leaf phosphorus fractionation and growth responses to phosphorus of the forage legumes *Trifolium repens, T. dubium* and *Lotus pedunculatus. Physoilogia Plantarum* 61(3):435-440.

Hena, S.W., Agishi E.C., Olorunju S.A.S. and Mohammed I.R. (1990). The effect of time of cut on the productivity and nutritive values of lablab varieties. NAPRI Annual Report.National Animal Production Research Institute,Shika,Nigeria. pp 75-78.

Hendricksen, R.E. and Minson, O.J. (1985a). *Lablab purpureus* – A Review. *Herbage Abstracts*. 55(8): 215 – 228.

Hendricksen, R.E. and Minson, D.J. (1985b). Growth, canopy structure and chemical composition of *Lablab purpureus* cv. Rongai at Samford, South East Queensland. *Tropical Grasslands* 19: 81 – 87.

Herbert,S.J. (2009). Harvest management for high quality Alfalfa hay.

http://redalyc.uaemex.mx/pdf/939/93960104.pdf. July 15th 2009.

Humphreys, L.R., (1987). Tropical pastures and fodder crops. Intermediate Tropical Agriculture Series. Longman Scientific and Technical, UK.155pp.

Idris, M., Mahmood, T., and Malik, K (1989). Response of field grown chick pea (*Cicer arietinum* L.) to phosphorus fertilization, for yield and nitrogen fixation. *Plant and Soil*. 114: 135-138.

IITA (1975). International Institute for Tropical Agriculture Ibadan, Nigerian. Annual Report. 150pp.

Iwuafor, E.N.O and Odunze, A.C. (1999). Performance of selected legume cover crops in an arid zone of Nigeria. pp 209 – 213. *In*: Carsky, R.J., Elepo A.C., Keating J.D.H. and Manyong V.M. (eds). Cover Crops for Natural Resource Management in West Africa. Proceedings of a workshop, International Institute of Tropical Agriculutre (IITA), Ibadan. Nigeria.

Jibrin, J.M., Chude, V.O., Daudu, C.K. and Miko, S. (2003). The effect of phosphate application to cover crops on the yields of succeeding maize (*Zea mays* L.) on a Kanhaplic Haplustalf in northern Guinea savanna of Nigeria. *Nigerian Journal of Soil Research*. 4: 25 – 34.

Jingura, R.M.,Sibanda, S. and Hamudikuwanda, H(2001). Yield and nutritive value of

tropical forage legumes grown in semi-arid parts of Zimbabwe. *Tropical*

Grasslands.35:168-174.

Jones, R.J. (1973). The effect of frequency and severity of cutting on yield and persistence of *Desmodium intortum* cv. Green leaf in a subtropical environment. *Australian Journal of Experimental Agriculture and Animal Husbandry.* 13(61):171-177.

Jung, G.A., Shaffer, J.A., and Everhart, J.R. (1996). Harvest frequency and cultivar influence on yield and protein of alfalfa-ryegrass mixtures. *Agronomy Journal* 88:817-822.

Kallenbach, R.L., Nelson, C.J., and Coutts, J.H. (2002). Yield, quality and persistence of grazing and hay-type alfalfa under three harvest frequencies. *Agronomy Journal* 94:1094-1103.

Karachi, M.(1997). Growth and nutritive value of *Lablab purpureus* accessions in semi-arid Kenya. *Tropical Grasslands*.31:214-218.

Kathiravan, M., Vijayakumar, A. and Vanitha, C. (2008). Influence of mother crop nutrition on seed yield and quality characteristics in lablab (*Lablab purpureus* L.). *Legume Research* 31(1):13-15.

Kitalyi, A.J., Mtenga, L.A., and Owen, E. (2008). Lablab forage for supplementation of crop residue based diets in smallholder dairy production systems. *http://aciar.gov.nsw.* July 15th 2009.

Knight, R. (1970). The effect of plant density and frequency of cutting on the growth of cocksfoot (*Dactylis glomerata* L.) I. The production of vegetative and reproductive tillers. *Australian Journal of Agricultural Research*. 21(1):9-17.

Kowal,J.M. and Knabe,D.T.(1972). An Agroclimatological Atlas of the Northern States of Nigeria. Ahmadu Bello University Press, Zaria, Nigeria.111pp.

Kvet, J and Svoboda,J(1971). Development of vertical structure and growth analysis in a stand of *Phragmites communis* Trin. In: *Plant Photosynthetic Production: Manual of Methods.* Dr W. Junk N.V. Publisher. The Hague. 650pp.

Lamidi, O.S., Abdullahi, B and Omokanye, A.T. (1997). Effect of plant spacing, phosphorus level and time of harvest on forage yield of lablab. (*Lablab purpureus*) c.v. Highworth. *Nigerian Journal of Animal Production* 24: 161 – 164.

Larson, A. (1965). Growth analytic studies on three beet strains. *Tidsskr. Planteavl* 69:1-37.

Leach, G.J. (1968). The growth of lucerne plant after cutting. I. The effects of cutting at different stages of maturity and at different intensities. *Australian Journal of Agricultural Research* 19(4):517-530.

Little,T.M.and Hills,F.J.(1978)..*Agricultural Experimentation*. John Wiley and Sons, New York.340pp.

Loi,A., Howieson,J.G., Nutt,B.J. and Carr, S.J.(2005).A second generation of annual pasture legumes and their potential for inclusion in Mediterranean-type farming systems. *Australian Journal of Experimental Agriculture* 45:289-299.

Lowe,K.F.,Bowdler,T.M.and Schrodter,G.N.(1985). Effect of cutting height on lucerne(*Medicago sativa*)cultivars. *Tropical grasslands* 19(1): 24-28.

Luck, P.E. (1965). *Dolichos lablab* – A valuable grazing crop. *Queensland Agricultural Journal* 91: 308 – 309.

Maasdorp, B.V. and Titterton, M. (1997). Nutritional improvement of maize silage for dairying: mixed-crop silages from sole and intercropped legumes and a long-season variety of maize. I. Biomass yield and nutritive value. *Feed Science Technology* 69: 241 – 261

Mahmud, M., Falaki, A.M., Abubakar, I.U. and Miko, S.(1996). Effects of different levels of phosphorus fertilizer and plant density on yield and yield components of green gram (*Vigna Radiata* L. Wilezek).*Journal of Agricultural Technology* 4(1):26-32.

Majumdar, D.K. (2004). *Irrigation Water Management-Principles and Practice*. Prentice-Hall of India, New-Delhi.487pp.

Mero, R.N. and Uden, P. (1997). Promising tropical grasses and legumes as feed resources in Central Tanzania I. Effect of different cutting patterns on production and nutritive value of six grasses and six legumes. *Tropical Grasslands* 31:549-555.

Minson, D.J. (1990). Forage in Ruminant Nutrition. Academic Press. Inc: New York. USA.450pp.

Mitchell, R.L.(1970). *Crop Growth and Culture*. The Iowa State University Press. Ames, Iowa. 349pp.

Muhammed, I.R. and Abubakar, S.A. (2004). Establishment and management of sown pastures. pp. 11-17. *In*: *Forage Production and Management in Nigeria – A Training Manual.* Shereef Salam Press, Zaria, Nigeria.

Muir, J.P., and Abrao, L. (1999). Productivity of 12 stylosanthes in semi-arid Mozambique. *Tropical Grasslands* 33:40-45.

Muir, J.P., Pitman, W.D. and Coombs, D.F. (2001). Seeding rate, phosphorus fertilization and location effects on 'Armadillo' Burr Medic. *Agronomy Journal* 93:1269-1275.

Muir, J.P. (2002). Hand-picked forage yield and quality and seed production from annual and short-lived perennial warm season legumes fertilized with composed manure. *Crop Science* 42:897-904 pp 897-904.

Muir, J.P., Butter, T.J., Wolfe, R.M and Bow, J.R (2008). Harvest techniques change annual warm season legume forage yield and nutritive value. *Agronomy Journal* 100(3):765-770.

Muldoon, D.K. (1985). The growth and mineral composition of forage legumes. *Australian Journal of Experimental Agriculture* 25:417-423.

Mullen, R.W., Johnson, G.V., Stritzke, J.F., Caddel, J.L., Phillips, S.B., and Raun, W.R. (2000). Alfalfa yield response to method and rate of applied phosphorus. *Better Crops* 84(3): 18-19 and 23.

Mupangwa,J.F., Ngongoni, N.T.,Topps, J.H. and Ndlovu, P.(1997). Chemical composition and dry matter degradability profiles of forage legumes *Cassia rotundifolia* cv. Wynn, *Lablab purpureus* cv. Highworth and *Macroptilium atropurpurreum* cv. Siratro at 8 weeks growth(pre-anthesis). *Animal Feed Science Technology*.69:167-178.

Mupangwa, J.F.,Ngongoni, N.T. and Hamudikuwanda, H.(2006). The effect of stage of growth and method of drying fresh herbage on chemical composition of three tropical herbaceous forage legumes. *Tropical and Subtropical Agroecosystems* 6:23-30.

Mureithi, J.G., Njunie, M.N., Muinga, R.W., Ali, R., Thorpe, W., and Mwatate, C.D. (1998). Adoption of planted forages by small holder dairy farmers in coastal low land Kenya. *Tropical Grasslands* 32:221-229.

Murungweni, C., Mabuku, O. and Mangawu, G.J. (2004). Mucuna, lablab and paprika calyx as substitutes for commercial protein sources used in dairy and pen-fattening diets by smallholder farmers of Zimbabwe. In: *Tropical legumes for suitable farming system in southern Africa and Australia. ACIAR Proceedings* No. 115.108pp.

NAS (1979). Lablab bean In: *Tropical Legumes: Resources for the Future*. National Academy of Sciences, Washington D.C. 59 – 67 pp.

Nichols,J.T. and Clanton,D.C.(1985).Irrigated Pastures. pp 507-516. In: *Forages: The science of grassland agriculture.* 4th edition. Edited by, Heath M.E., Barnes R.F. and Metcalfe D.S. The Iowa State University Press, Ames, Iowa.

NRCS (2007). National resources conservation service bulletin. USA.15pp.

Odion, E.C. and Singh, B.B. (2005a). Production of dual purpose cowpea varieties at two clipping heights in the Sudan savanna of Nigeria.1.Fodder production in pure stand. *Journal of Arid Agriculture* 15:9-14.

Odion, E.C. and Singh, B.B. (2005b). Production of dual purpose cowpea varieties at two clipping heights in the Sudan savanna of Nigeria.2.Pod and grain production in pure stand. *Journal of Arid Agriculture* 15: 15-19.

Odion, E.C., Asiribo, O.E., Ogunlela, V.B., Singh, B.B., and Tarawali, S.A. (2007). Strategies to improve and sustain food production capacity in the savanna: The role of leguminous fodder crops in maintaining soil fertility and health. *Journal of Food, Agriculture and Environment*. 5(2):338-344.

Odunze, A.C., Tarawali, S.A., de Hann, N.C., Akoueguon, E., Amadji, A.F., Schultze-kraft, R. and Bawa, G.S. (2004). Forage legumes for soil productivity enhancement and quality fodder production. *Journal of Food, Agriculture and Environment*. 2(2):201-209.

O'Hara, G.W. (2001). Nutritive constraints on root nodule bacteria affecting symbiotic nitrogen fixation: a review. *Australian Journal of Experimental Agriculture* 41:417-433.

Olufajo,O.O.(2011).Personal communication.

Omokanye, A.T. (2001). Research note: Forage yield and chemical composition of centro (*Centrosema pubescens*) in the year of establishment at Shika, Nigeria. *Tropical Grasslands* 35:53-57.

Omokanye, A.T., Amodu, J.T. and Onifade, O.S. (2004). Influence of intra-row plant spacing, phosphorus application and growth stage on the forage, seed yield and quality of

Phasey bean (*Macroptilium lathyroides*) in a sub-humid area of Nigeria. *Nigerian Journal of Animal Production* 32(1): 45 – 50.

Otsyina, R.M., von Kaufmann, R.R., Mohamed Saleem, M.A. and Suleimann, H (1987).

Manual on fodder bank establishment and management Sub-humid zone

programme, International Livestock Centre for Africa .ILCA press. Addis-Ababa, Ethiopia. 27pp.

Oyenuga, V.A. (1960). Effect of stages of growth and frequency of cutting on the yield and chemical composition of some Nigeria fodder grasses *Journal of Agricultural Science, (Cambridge*) 55: 350 – 399.

Pandey,S.N. and Sinha,B.K. (1972). *Plant physiology*. Vikas Publishing House, PVT Ltd, New Delhi, India. 682pp.

Patil, V.S., Kale P.B., Wankhade, R.N., and Nagdere, M.B. (1995). Effect of fertilizer levels and spacing, on growth and green pod yield of Dolichos bean var 'konkan bhushan'. *Vegetable Science* 22:9-12.

Peters, M., Tarawali, S.A., and Alkamper, J. (1997). Dry season performance of four tropical pasture legumes in sub-humid West Africa as influenced by superphosphate application and weed control. *Tropical Grasslands* 31:201-213.

Philpotts, H. (1969). 'Rongai' *Dolichos lablab*, a drought hardy forage legume for the northern wheat belt of New South Wales. *Agricultural Gazette of New South Wales* 80: 541 – 543.

Radford, P.J.(1967). Growth analysis formulae, their uses and abuse. *Crop Science* 7:171-175.

Redfearn, D.D., Venuto, B.C., and Pitman, W.D. (2001). Nutritive value responses of Rhizoma peanut to nitrogen and harvest frequency. *Agronomy Journal* 93:107-112.

Romero, F., Vanllorn, H.H., Prine, G.M., and French, E.C (1987). Effect of cutting interval upon yield, composition and digestibility of Florida 77 alfalfa and Florigraze rhizoma peanut. *Journal of Animal Science* 65:786-796.

Sanchez, C.A.(2007). Phosphorus. In: *Handbook of Plant Nutrition*. Baker, A.V. and Philbeam, D.J. eds. CRC Press. Taylor and Francis Group. New York. 613pp.

Scott, B.J., Carpenter, D.J., Braysher, B.D., Cullis, B.R., and Evans, C.M., (2003). Phosphorus fertilizer placement for lupins in southern New South Wales. *Australian Journal of Experimental Agriculture.* 43: 79-86.

Shehu, Y., Alhassan, W.S., Pal, U.R., and Philips, C.J.C. (2001). Yield and chemical composition responses of *Lablab purpureus* to nitrogen, phosphorus and potassium fertilizers. *Tropical Grasslands* 35:180-185.

Shehu, Y., Alhassan W.S., Pal U.R., and Phillips C.J.C. (2008). The effects of timing of an interim harvest on the yield and composition of *Lablab purpureus. Journal of Agronomy and Crop Science* 186(1):31-36.

Singh, D. Alsemgeest, V., Cooper, D., Routley, R and Sale, P. (2004). Managing economic and environmental sustainability with better phosphorus nutrition and summer forage legume in rotation with wheat in southern Queensland. *In Proceedings of the 4th International Crop Science Congress* held in Brisbane, Australia. 26th September. -1st October.

Singh,S.R. and Rachie,K.O. eds.(1985). Cowpea: Research, Production and Utilization. John Wiley and Sons Ltd. New York. 460pp.

Slarke,R.H. and Mason,W.K.(1987). Effect of growth stage at cutting on yield and quality of lucerne cultivars from different dormancy groups in northern Victoria. *Australian Journal of Experimental Agriculture* 27: 55-58.

Smith, D and Nelson, C.J. (1967). Growth of birdsfoot trefoil and alfalfa I. Responses to height and frequency of cutting. *Crop Science* 7:130-133.

Smith,D. and Nelson, C.J.(1985). Physiological considerations in forage management. pp

326-337 In*: Forages: The science of grassland agriculture*. . 4th edition.

Edited by, Heath M.E., Barnes R.F. and Metcalfe D.S. The Iowa State

University Press, Ames, Iowa.

Snedecor, G.W. and Cochran, W.G. (1967). *Statistical Methods*. 6th edition Iowa State University Press, Ames, Iowa U.S.A. 456pp.

Stockdale, C.R (2005). The productivity of irrigated legumes in northern Victoria.3. Frequency and intensity of defoliation of subterranean clover. *Australian Journal of Experimental Agriculture* 45: 1587-1594.

Swift, R.W. and Sullivan, H.W. (1962). The effect of differential cutting on the yield, persistence, protein and mineral content of birdsfoot trefoil. *Agronomy Journal* 49:318-319.

Tarawali,S.A., Peters,M., and Schultze-Kraft,R.(1999). Forage Legumes for Sustainable Agriculture and Livestock Production in Sub-humid West Africa. International Livestock Research Institute (ILRI). Project Report. ILRI, Nairobi, Kenya.132pp.

Tag El Din, S.S., and Assaeed, A.M. (1995). Effect of phosphorus fertilizer and irrigation frequency on yield and protein content of alfalfa. *Journal of King Saud University* (*Agricultural Science*) 7(1):49-60.

Teutsch, C.D., Sulc, R.M., and Barta, A.L (2000). Banded phosphorus effects on alfalfa seedling growth and productivity after temporary water-logging. *Agronomy Journal* 92:48-54.

Thomas, D. and Sumberg, J.E. (1995). A review of the evaluation and use of tropical forage legumes in sub-Saharan Africa. *Agriculture, Ecosystems and Environment* 54: 151 – 163.

Thurston, H.D. (1984). Tropical plant diseases. The American Phytopathological Society. St. Paul, Minnesota.208pp.

Tongel, O. and Albayrak, S. (2006). Effect of different levels of phosphorus on forage yield and quality of white clover (*Trifolium repens* L). *Asian Journal of Plant Science.* 5(2):201-206.

Trujillo, W., Pitman, W.D., Chambliss, C.G., and Williams, K. (1996). Effects of height and frequency of cutting on yield, quality and persistence of *Desmanthus virgatus. Tropical Grasslands* 30:367-373.

Turk, M.A., Tawaha, A.R.M., and Samara, N. (2003). Effects of seeding rate and date and phosphorus application on growth and yield of narbon vetch (*Vicia narbonensis) Agronomie*. 23:355-358.

Twamley, B.E. (2006). A management study of a Birdsfoot trefoil strain trial. *Grass and Forage Science*. 23(4):322-325.

Valenzuela, H and Smith, J. (2002). Lablab. Cooperative Extension Service publication. *University of Hawaii at Manoa*. 3pp.

Van Hiep, N., Wiktorsson, H and Van Man, N. (2008). The effect of cutting interval on foliage yield and chemical composition of tropical kudzu (*Pueraria phaseoloides)* cultivated as cover-crop in rubber plantation. *Livestock Research for Rural Development* 20:15-20.

Van Soest, P.J. (1985). Composition, fiber quality, and nutritive value of forages. pp 412-421. In: *Forages: The science of grassland agriculture*. 4th edition. Edited by, Heath M.E., Barnes, R.F. and Metcalfe, D.S. The Iowa State University Press, Ames, Iowa.

Verma, C.M. (1975). Effect of spacing and phosphorus fertilizer on forage and seed yield of lablab (*Dolichos lablab* c.v. Lignosus). *Annals of Arid Zones* 14: 235 – 240.

Ward,C.Y. and Blaser,R.E.(1961). Carbohydrate food reserves and leaf area in regrowth of orchard grass. *Crop Science* 1:366-370.

Watkins, J.M, and Lewy–vanSeveren, M. (1951). Effect of frequency and height of cutting on the yield, stand and protein content of some forages in El-Salvador. *Agronomy Journal* 43: 291 – 296

Watson, D.J. (1958). The dependence of net assimilate on leaf area index. *Annals of Botany* 23:37-supp.

Whiteman, P.C. (1970). Seasonal changes in growth and nodulation of perennial tropical pasture legumes in the field. II. Effects of controlled defoliation levels on nodulation of *Desmodium uncinatum* and *Phaseolus atropurpureus*. *Australian Journal of Agricultural Research*. 21(2):207-214.

Wood, I.M. (1983). Lablab bean (*Lablab purpureus*) for grain and forage production in the old irrigation area. *Australian Journal of Experimental Agriculture and Animal Husbandry* 23(121): 162 – 171.

Yilmaz, S. (2008). Effects of increased phosphorus rates and plant densities on yield and yield-related traits of Narbon vetch lines. *Turk Journal of Agriculture.* 32:49-56.

Yu, J., Bingcheng, X., Fengmin, L and Xiaoling, W. (2007). Availability and contributions of soil phosphorus to forage production of seeded alfalfa in semi-arid Loess plateau. *Acta Ecologica Sinica* 27(1):42-47.

Zaman, O.U. and Malik, M.A. (1999). Growth, seed yield and protein contents of rice bean (*Vigna umbellata*) in relation to nitrogen and phosphorus nutrition. *International Journal of Agriculture and Biology* 1(4):290-292.

Zaroug, M.G., and Munns, D.N. (1980). Influence of phosphorus and sulfur nutrition on composition of *Clitoria ternatea* L. *Plant and Soil* 55(2):251-259.

Appendix I: Six-year cropping history of experimental field (T15)

Field	Preceding crop year	Experimental crop year
T15	Cotton/Sunflower (2002)	-
T15	Cowpea (2003)	-
T15	Fallow (2004)	-
T15	Cotton/Maize (2005)	Lablab (2006)
T15	Cowpea/Cotton (2006)	Lablab (2007)
T15	Sorghum (2007)	Lablab (2008)

Appendix II: Samaru Meteorological Observation in 2006

Month	Rainfall (mm)	Temperature (^{o}C)		Relative humidity (%)	
		Min	Max	10.00H	16.00H
January	-	15.7	34.8	15.5	14.4
February	-	18.3	37.2	20.4	14.5
March	-	28.3	58.7	27.9	21.3
April	1.8	21.4	38.5	25.0	16.3
May	121.9	21.6	33.6	71.0	49.5
June	126.5	21.1	32.2	72.3	56.8
July	232.2	20.8	30.8	78.8	66.6
August	215.5	20.4	29.9	81.5	69.1
September	281.5	20.2	30.9	80.1	70.5
October	28.5	20.7	32.3	68.0	55.5
November	-	13.6	31.1	22.2	22.3
December	-	12.5	30.6	18.2	14.5
Total	1007.9	234.6	420.6	580.9	471.3
Mean	84.0	19.6	35.1	48.4	39.9

Source: Meteorological Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Appendix III: Samaru Meteorological Observation in 2007

Month	Rainfall (mm)	Temperature (^{o}C)		Relative humidity (%)	
		Min	Max	10.00H	16.00H
January	-	12.9	28.8	18.4	12.4
February	-	16.3	34.9	13.0	9.8
March	-	19.0	37.1	19.2	9.2
April	-	22.8	37.8	48.4	30.2
May	194.8	21.8	34.0	68.0	53.6
June	109.0	20.4	31.2	76.9	62.7
July	228.6	20.8	29.8	79.6	66.9
August	328.0	21.3	28.8	77.0	74.3
September	31.9	20.2	31.5	76.2	59.1
October	8.3	18.2	34.9	59.0	38.5
November	-	15.2	35.3	22.8	18.0
December	-	13.5	32.9	17.6	16.1
Total	900.6	222.4	397.0	576.1	450.8
Mean	75.1	18.5	33.1	48.0	37.6

Source: Meteorological Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Appendix IV: Samaru Meteorological Observation in 2008.

Month	Rainfall (mm)	Temperature (^{o}C)		Relative humidity (%)	
		Min	Max	10.00H	16.00H
January	-	13.6	29.0	19.7	15.1
February	-	15.7	32.0	12.7	9.4
March	-	19.9	38.6	19.5	13.8
April	72.6	29.1	57.2	34.0	23.9
May	95.0	21.9	35.0	63.0	46.2
June	111.7	20.9	33.1	72.3	55.1
July	201.3	20.0	30.5	79.6	68.0
August	352.6	19.5	29.7	82.0	73.2
September	217.5	25.5	31.4	77.1	66.0
October	89.0	18.2	33.2	58.8	51.8
November	-	12.8	33.8	21.2	23.1
December	-	14.6	32.1	20.8	17.8
Total	1140.0	231.7	415.6	560.7	463.4
Mean	95.0	19.3	34.6	46.7	38.6

Source: Meteorological Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.