Research Journal of Agronomy 5 (1): 10-19, 2011
ISSN: 1815-9354

Growth and Growth Attributes of Lablab (*Lablab purpureus* L. Sweet) as Influenced by Phosphorus Application, Cutting Height and Age of Cutting

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Abstract: With a view to studying the response growth and growth attributes of lablab (*Lablab purpureus* L. Sweet) to phosphorus application, cutting height and cutting age field trials were conducted during the 2006-2008 wet seasons at Samaru, Nigeria. The treatments were composed of factorial combinations of four rates of phosphorus application (0, 12, 24 and 36 kg P ha^{-1}), two cutting heights (10 and 20 cm) and four ages of cutting (6, 12, 18 weeks and at maturity) in a split plot design with three replications. Application of 12 kg P ha^{-1} increased lablab sward height slightly (4%) while applying 24 kg P ha^{-1} increased leaf area index by 10%, number of root nodules by 42% and nodule dry weight by 50% over the zero-P control. Cutting lablab to a 20 cm stubble produced significantly taller sward. The highest sward obtained by cutting fodder at 18 weeks, a treatment that also produced the fastest relative regeneration rate. A combination of 36 kg P ha^{-1} and 20 cm cutting height produced the highest sward. The highest number of root nodules was obtained when lablab was given 24 kg P ha^{-1} and cut to a stubble height of 10 cm. Intensive management of lablab growth should be carried out within 12 WAS for the overall benefit of the crop. Cutting or grazing treatment either of which may prolong the vegetative stage of lablab is also required to manage its leaf area index for better crop growth.

Key words: Cutting treatments, growth, growth attributes, *Lablab purpureus*, phosphorus nutrition, Nigeria

INTRODUCTION

Use of introduced forage legumes is a viable option for circumventing the perennial dry season livestock feed constraint in the Savanna zone. Fast-growing and high yielding forage legumes can either be grazed or cut and fed straight or conserved before feeding to the animals. 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 the Savanna, not enough plant biomass is available in the dry season to maintain the large stock of animals, partly accounting for the seasonal migration of animals (Odion *et al.*, 2007). 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). Among the many introduced forage legumes evaluated in Nigeria, lablab (*Lablab purpureus* L. Sweet) 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). Lablab accession ILRI 147 was selected for its good establishment and forage production in the sub humid zone of Nigeria (Ewansiha *et al.*, 2007).

Carsky *et al.* (2001) opined that merely introducing improved legume fallows is not sufficient to guarantee good herbage production where phosphorus in the soil is limiting. More so that phosphorus deficiency often limits establishment and persistence of legumes (Hague *et al.*, 2008). It is generally believed that the phosphorus demands of legumes are normally higher than those of other groups of crops because it is a nutrient that is necessary for both plant growth and rhizobial activity in nodulation and nitrogen fixation. Cutting treatment is known to affect the re-growth rate of pasture crops and their persistence (Odion *et al.*, 2007).

In the Northern Guinea Savanna where some research had been done on lablab, only lablab cultivars Rongai and Highworth have been subjected to scientific research. With the exception of research by Hena *et al.* (1990) and Lamidi *et al.* (1997) on Rongai and Highworth varieties, respectively, research information on the effect of cutting on the growth of any lablab accession is

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lacking. It is therefore, important to further evaluate lablab accession ILRI 147 in order to determine those factors which are likely to affect its growth for maximum productivity.

The objective of the present research was therefore to evaluate the effect of phosphorus application, cutting height and age of cutting on the growth and growth attributes of lablab.

MATERIALS AND METHODS

Field trials were conducted in the 2006-2008 wet seasons at the Institute for Agricultural Research (IAR) experimental farm, Samaru (lat. 11°11', long. 7°38'E 686 m above sea level) in the Northern Guinea Savanna zone of Nigeria.

The lablab accession ILRI 147 which is also known as Highworth, black-seeded was obtained from the International Livestock Research Institute (ILRI-Nigeria) and was evaluated in the study. A row spacing of 30×30 cm and seed rate of 24 kg ha^{-1} which are recommended for fodder production were used in the experiment. The gross plot size was 5×3 m (15 m^2). The treatments were factorial combinations of four rates of phosphorus application (0, 12, 24 and 36 kg P ha^{-1}) and two cutting height (10 and 20 cm above ground level) and four cutting ages (6, 12 and 18 Weeks After Sowing (WAS) and at maturity). The experiment was a split plot design where phosphorus application x cutting height represented the main plot while cutting age was the subplot. The treatments were replicated 3 times.

Lablab was cut at the specified heights at 6, 12 and 18 WAS and at maturity to determine Relative Regeneration Rate (RRR) whereas five plants were uprooted at each cutting age to determine the growth parameters measured.

In order to determine 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 plot using a metre rule and the mean values computed. Nodules were detached from the roots of the uprooted sampled plants and carefully cleaned of soil particles. The nodules were counted and the mean numbers recorded. After counting the detached nodules, they were dried to constant weight in a Gallenkamp oven (model ov-440) at a temperature of 70°C before weighing with a sensitive balance (Thelco (GCA) Precision Scientific).

The five randomly uprooted plants from each plot were striped of their leaves. The detached leaves and stems were oven dried separately to constant weight in a Gallenkamp oven (model ov-440) at a temperature of 70°C for plant growth analysis. The detached leaves 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 derived from the leaf disc samples by total dry leaf weight described by Watson (1958), Larson (1965).

The leaf area index, a dimensionless ratio of the leaf area over the area of land subtended by sampled plants was determined at 6, 12 and 18 WAS as described by Watson (1958). The ability of lablab to re-grow after clipping was determined using the Relative Regeneration Rate (RRR) according to Odion *et al*. (2007). Crop Growth Rate (CGR) was determined as described by Radford (1967). Number of days from sowing to the time when about 50% of the plants within the plot had flowered was recorded for each plot. The data collected were subjected to one-way analysis of variance using the SAS software (SAS, 2001) determine the significance of treatment effects as described by Snedecor and Cochran (1967) while the means were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1955; Steel *et al*., 1997).

RESULTS

Sward height: In 2006, lablab plants that were given 12 kg P ha^{-1} produced a sward at 12 WAS that was significantly taller than that produced by 36 kg P ha^{-1} application which was at par with the no-P control and the 24 kg P ha^{-1} rate (Table 1). In 2007, the heights of swards produced at 12 WAS with 24 and 36 kg P ha^{-1} rates were at par but significantly taller than those of the no-P control and 12 kg P ha^{-1}. In the combined data, application of 24 and 36 kg P ha^{-1} produced swards that were taller than that of the control which was at par with 12 kg P ha^{-1}. Phosphorus application did not influence sward height at 18 WAS in any year but in the combined data its effect was significant. A phosphorus application rate of 12 kg P ha^{-1} produced a taller 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 did not significantly influence lablab sward height in the individual years except that in the combined data where sward height at 12 WAS was higher when 20 cm cutting height was adopted relative to a 10 cm stubble (Table 1). Cutting height affected sward height at 18 WAS significantly in 2007, 2008 and in the combined data in a similar manner. A cutting height of 20 cm produced a taller sward than a cutting height

Table 1: Effect of phosphorus application, cutting height and age of cutting on lablab sward height (cm) at 6 and 12 Weeks After Sowing (WAS) in 2006-2008 and combined >2006-2008 wet seasons at Samaru, Nigeria

	12 WAS				18 WAS			
Treatments	2006	2007	2008	Combined	2006	2007	2008	Combined
Phosphorus (kg P ha^{-1})								
0	74.00^{ab}	66.05^{b}	68.20	69.50^{b}	73.10	60.90	67.40	67.10^{b}
12	77.40^{a}	69.05^{b}	67.20	71.40^{ab}	76.00	64.00	70.40	70.10^{a}
24	75.10^{ab}	74.04^{a}	68.10	72.50^{a}	74.50	62.10	66.40	67.70^{ab}
36	73.20^{b}	75.00^{a}	68.90	72.40^{a}	75.80	62.60	68.90	69.10^{ab}
±SE	1.19	1.19	0.97	0.68	1.44	1.46	1.80	0.91
Cutting height (cm)								
10	74.10	70.70	67.50	70.80^{b}	73.80	60.90^{b}	66.50^{b}	67.00^{b}
20	75.70	72.00	68.70	72.10^{a}	76.00	64.00^{a}	70.10^{a}	70.00^{a}
±SE	0.84	0.84	0.69	0.48	1.02	1.03	1.27	0.64
Age of cutting (WAS)								
6	70.10^{c}	49.00^{b}	38.00^{c}	52.40^{c}	82.50^{a}	69.00^{b}	65.60^{b}	72.40^{b}
12	79.30^{a}	79.80^{a}	78.90^{a}	79.30^{a}	54.60^{b}	30.10^{c}	33.30^{c}	39.30^{c}
18	74.30^{b}	79.80^{a}	79.70^{a}	77.90^{ab}	79.30^{a}	75.60^{a}	87.20^{a}	80.70^{a}
Maturity	76.00^{b}	76.80^{a}	75.80^{a}	76.20^{b}	83.10^{a}	74.90^{a}	86.90^{a}	81.70^{a}
±SE	1.19	1.19	0.97	0.68	1.44	1.46	1.79	0.91

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT)

of 10 cm. Age of cutting exerted significant influence on the sward height of lablab in each year and in the combined data. The later ages of cutting (12, 18 weeks and maturity) were at par and produced significantly taller swards than the 6 weeks cutting age by 62.9, 108.7 and 50.0% in 2007, 2008 and in the combined data, respectively. However, in 2006 the lablab sward at 12 weeks age of cutting was taller than those produced at 18 weeks and at maturity that were at par. In the combined data, the sward at the 12 weeks cutting interval was significantly higher than those at 6 weeks and at the control. However, 12 and 18 weeks age of cutting had statistically similar sward heights while the 18 weeks age and at maturity were also at par. At 18 WAS, the influence of age of cutting on sward height was consistent and significant across the years and in the combined data. The sward heights achieved when lablab was cut at either 18 weeks age or at maturity were at par and significantly higher than the sward from the 6 weeks age of cutting which was also significantly higher than the sward produced from cutting at 12 weeks. In 2006, however, the swards produced at 6, 18 weeks and at maturity were at par. The sward height produced by the 12 weeks age of cutting in 2007, 2008 and in the combined data was markedly lower than the other ages of cutting. When the combined data were considered, the mean sward height for the 18 weeks age of cutting and cutting at maturity was 106.6% while that for 6 weeks was 84.2% greater than the sward height produced at the 12 weeks cutting interval. The significant phosphorus rate x cutting height interaction for sward height at 12 WAS combined over 2006-2008 is shown in Table 2. Holding cutting height constant and varying phosphorus application rate, at 10 cm cutting height, the no-P control produced the shortest sward which was at par with the highest P application rate (36 kg P ha^{-1}). At 20 cm cutting height, however the higher P rates of 24 and 36 kg P ha^{-1} were at par and produced significantly taller swards than the no-P control and 12 kg P ha^{-1}. Holding P constant and varying cutting height, sward height of lablab was similar at all P application rates except at the highest rate (36 kg P ha^{-1}) where the higher cutting height (20 cm) produced a significantly taller lablab sward than the lower cutting height (10 cm).

Table 2: Interaction between phosphorus rate and cutting height on sward height (cm) in lablab at 12 WAS combined over 2006-2008 wet seasons at Samaru, Nigeria

	Cutting height (cm)	
Phosphorus (kg P ha^{-1})	10	20
0	68.8^{d}	70.3^{cd}
12	72.4^{abc}	70.4^{cd}
24	71.4^{bc}	73.7^{ab}
36	70.6^{cd}	74.1^{a}
±SE	0.91	-

Means followed by similar letter (s) within the same column or row are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

Number of root nodules: Table 3 shows the effects of phosphorus application, cutting height and age of cutting on the number of root nodules at 6 and 12 WAS in 2006-2008 including the combined data. Phosphorus application significantly affected the number of root nodules of lablab at 6 WAS in 2006, 12 WAS in 2006, 2007 and in the combined data at 12 WAS. At 6 WAS in 2006, 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 12 WAS in 2006, the substantive P application rates (i.e., 12, 24 and

Table 3: Effect of phosphorus application, cutting height and age of cutting on number of root nodules in lablab at 6 and 12 WAS in 2006-2008 and combined >2006-2008 wet seasons at Samaru, Nigeria

	6 WAS				12 WAS			
Treatments	2006	2007	2008	Combined	2006	2007	2008	Combined
Phosphorus (kg P ha^{-1})								
0	13.40^{b}	16.30	11.20	13.80	11.30^{b}	25.70^{b}	40.70	25.90^{b}
12	18.50^{a}	16.70	10.30	15.20	17.90^{a}	31.90^{ab}	46.50	32.10^{ab}
24	11.10^{b}	16.00	11.20	12.80	23.00^{a}	36.50^{a}	50.60	36.70^{a}
36	11.30^{b}	20.10	13.90	15.10	19.00^{a}	32.20^{ab}	45.90	32.40^{ab}
±SE	1.56	1.94	1.24	1.05	2.18	3.14	6.15	2.34
Cutting height (cm)								
10	13.10	18.10	11.10	14.10	19.20	33.30	47.90	33.50
20	14.10	16.50	12.30	14.30	16.40	29.90	43.90	30.10
±SE	1.10	1.37	0.87	0.74	1.54	2.22	4.35	1.66
Age of cutting (WAS)								
6	14.70	19.70	12.30	15.60^{a}	17.90	14.90^{b}	12.30^{b}	15.00^{b}
12	10.90	14.30	11.10	12.10^{b}	20.50	39.20^{a}	58.30^{a}	39.30^{a}
18	14.90	17.70	11.70	14.80^{ab}	16.40	35.20^{a}	54.70^{a}	35.40^{a}
Maturity	13.80	17.50	11.80	14.40^{ab}	16.50	37.20^{a}	58.30^{a}	37.40^{a}
±SE	1.56	1.94	1.24	1.05	2.18	3.14	6.15	2.34

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

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 12 WAS in 2007 and in the combined data in a similar manner (Table 3). Application 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}) which was also at par with 12 and 36 kg P ha^{-1} rates with respect to the number of root nodules produced.

Cutting height did not influence the number of root nodules at 6 or 12 WAS whereas age of cutting affected this parameter in the combined data for 6 WAS and also at 12 WAS in 2007, 2008 and in the combined data (2006-2008) of 12 WAS. The combined data at 6 WAS 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 and 18 weeks or the control or at 12 and 18 weeks or at maturity were similar. Age of cutting affected the number of root nodules produced by lablab at 12 WAS in 2007, 2008 and in the combined data in a similar manner. The later age of cutting (i.e., 12, 18 weeks and the control) were at par and produced significantly more root nodules than the earliest age of cutting of 6 weeks. The phosphorus rate x cutting height interaction for number of root nodules at 6 WAS in 2006 was statistically significant (Table 4). Holding cutting height constant at 10 cm, the P rates of 0, 12 and 24 kg P ha^{-1} were similar with respect to number of root nodules. However, 12 kg P ha^{-1} application rate produced statistically more root nodules than 36 kg P ha^{-1}. At 20 cm 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

Table 4: Interaction between phosphorus rate and cutting height for number of root nodules per plant in lablab at 6 WAS in 2006 and at 12 WAS combined over 2006-2008 wet seasons at Samaru, Nigeria

	Cutting heights (cm)	
Phosphorus (kg P ha^{-1})	10	20
6 WAS (2006)		
0	11.60^{bcd}	15.20^{abc}
12	16.30^{ab}	20.80^{a}
24	15.20^{abc}	7.10^{d}
36	9.50^{cd}	13.20^{bcd}
±SE	2.20	-
12 WAS combined over 2006-2008		
10		20.00
0	30.30^{bc}	21.50^{c}
12	27.90^{bc}	36.40^{ab}
24	40.50^{a}	33.10^{ab}
36	35.20^{ab}	29.60^{bc}
±SE	3.41	-

Means followed by similar letter (s) within the same column or row are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

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 (10 cm) produced statistically more root nodules than the 20 cm cutting height. The phosphorus rate x cutting height interaction for number of root nodules at 12 WAS combined over 2006-2008 was significant (Table 4).

At a constant cutting height of 10 cm, lablab produced the most root nodules when 24 kg P ha^{-1} was applied. However, number of root nodules obtained at this application rate was similar to the number produced with the application of 36 kg P ha^{-1}. At a 20 cm cutting height, the fewest root nodules were produced with 0 and 36 kg P ha^{-1} application rates. When P rate was held constant and the cutting height was being

Table 5: Effect of phosphorus application, cutting height and age of cutting on nodule dry weight (mg) in lablab at 6 and 12 WAS in 2006-2008 and combined over 2006-2008 wet seasons at Samaru, Nigeria

	6 WAS				12 WAS			
Treatments	2006	2007	2008	Combined	2006	2007	2008	Combined
Phosphorus (kg P ha⁻¹)								
0	105.0[b]	128.0	89.0	108.0	55.0[b]	203.0[b]	279.0	179.0[b]
12	145.0[a]	131.0	81.0	119.0	89.0[b]	251.0[ab]	346.0	229.0[ab]
24	88.0[b]	126.0	88.0	101.0	139.0[a]	287.0[a]	379.0	269.0[a]
36	89.0[b]	158.0	109.0	119.0	98.0[ab]	253.0[ab]	425.0	259.0[a]
±SE	12.1	15.0	9.8	8.2	15.6	24.4	60.3	22.0
Cutting height (cm)								
10	103.0	142.0	88.0	111.0	101.0	262.0	345.0	236.0
20	111.0	129.0	96.0	112.0	91.0	236.0	369.0	232.0
±SE	8.5	10.6	6.9	5.8	11.1	17.2	42.7	15.2
Age of cutting (WAS)								
6	115.0	154.0	96.0	122.0[a]	103.0	119.0[b]	52.0[b]	91.0[b]
12	87.0	113.0	86.0	95.0[b]	109.0	307.0[a]	430.0[a]	282.0[a]
18	117.0	139.0	92.0	116.0[ab]	88.0	277.0[a]	458.0[a]	274.0[a]
Maturity	109.0	137.0	93.0	113.0[ab]	82.0	292.0[a]	488.0[a]	288.0[a]
±SE	12.1	15.0	9.8	8.2	15.6	24.4	60.3	21.5

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

varied, the number of root nodules in lablab was similar for all rates of P application i.e., 0, 12, 24 and 36 kg P ha^{-1}.

Nodule dry weight: Table 5 shows the effects of phosphorus, cutting height and age of cutting on nodule dry weight at 6 and 12 WAS in 2006-2008 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 at 6 WAS significantly in 2006 and at 12 WAS in 2006, 2007 and in the combined data of this growth stage. At 6 WAS 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} was significantly higher than that produced with 0 and 12 kg P ha^{-1} at 12 WAS in 2006. At 12 WAS 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. In the combined analysis of 12 WAS the higher P application rates were at par and produced significantly heavier nodule dry weight than the control (0 kg P ha^{-1}).

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

Leaf area index: Table 6 shows the effects of phosphorus application, cutting height and cutting interval on Leaf Area Index (LAI) at 6 and 12 WAS in 2006-2008 and the combined data. Phosphorus application significantly influenced LAI at 6 WAS in 2007 and in the combined data. At 6 WAS in 2007, application 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. 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 although, 12 and 24 kg P ha^{-1} application rates also produced similar lablab LAI values. Cutting height did not affect leaf area index of lablab significantly at the 6 and 12 WAS sampling periods nor did the 6 WAS age of cutting in 2006 and 2008 and at 12 WAS in 2007. In 2007, cutting at 6 weeks produced a leaf area index at 6 WAS that was significantly higher than LAI values obtained for the 12 weeks cutting age (by 24.4%) and at maturity (by 17.9%) but was similar to the LAI value for the 18 weeks age of cutting. In the combined analysis, the ages of cutting of 6, 18 weeks and at maturity were at par with respect to LAI values. However, only the LAI values for the 6 and 18 weeks ages of cutting were significantly higher than the LAI for the 12 weeks interval which was at par with the LAI value obtained for cutting at maturity. The leaf area index at 12 WAS obtained for cutting at maturity was significantly higher than that obtained for the 6 weeks age of cutting

Table 6: Effect of phosphorus application, cutting height and age of cutting on leaf area index in lablab at 6 and 12 WAS in 2006-2008 and combined over 2006-2008 wet seasons at Samaru, Nigeria

	6 WAS				12 WAS			
Treatments	2006	2007	2008	Combined	2006	2007	2008	Combined
Phosphorus (kg P ha^{-1})								
0	6.40	8.40^{c}	13.00	9.200^{b}	22.10	10.20	24.40	19.00
12	7.10	9.40^{bc}	13.80	10.100^{ab}	21.60	9.30	26.70	19.20
24	7.60	11.20^{a}	14.20	11.100^{a}	25.00	7.70	27.50	20.10
36	5.80	10.60^{ab}	13.00	9.800^{b}	25.10	9.10	26.40	20.20
±SE	0.72	0.45	0.55	0.336	3.25	0.90	2.32	1.37
Cutting height (cm)								
10	6.70	9.70	13.30	9.900	25.00	9.20	24.50	19.60
20	6.70	10.10	13.70	10.200	22.00	8.90	28.00	19.60
±SE	0.51	0.32	0.39	0.238	2.30	0.64	1.64	0.97
Age of cutting (WAS)								
6	7.60	11.20^{a}	12.90	10.500^{a}	15.50^{b}	9.50	15.30^{c}	13.40^{c}
12	5.80	9.00^{b}	13.40	9.300^{b}	26.70^{a}	9.90	26.50^{b}	21.00^{ab}
18	7.40	10.10^{ab}	14.10	10.500^{a}	23.50^{ab}	9.20	27.00^{b}	19.90^{b}
Maturity	6.00	9.50^{b}	13.60	9.700^{ab}	28.10^{a}	7.70	36.30^{a}	24.00^{a}
±SE	0.72	0.45	0.55	0.336	3.25	0.90	2.32	1.37

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

Table 7: Effect of phosphorus application, cutting height and age of cutting on Relative Regeneration Rate (RRR) in lablab in 2006-2008 wet seasons and combined over 2006-2008 at Samaru, Nigeria

Treatments	2006	2007	2008	Combined
Phosphorus (kg P ha^{-1})				
0	0.1300	0.0500	-0.030	0.050
12	0.1200	0.0600	-0.090	0.030
24	0.0900	0.0200	-0.070	0.020
36	0.1100	0.0200	-0.090	0.010
±SE	0.0780	0.0960	0.114	0.055
Cutting height (cm)				
10	0.1400	0.1000	-0.060	0.060
20	0.0900	0.0300	-0.080	-0.010
±SE	0.0550	0.0680	0.080	0.039
Age of cutting (WAS)				
6	0.020^{b}	-0.4900^{c}	-0.240^{b}	-0.240^{c}
12	0.120^{ab}	0.1600^{b}	-0.190^{ab}	0.030^{b}
18	0.310^{a}	0.4900^{a}	0.150^{a}	0.320^{a}
Maturity	-0.010^{b}	0.0004^{b}	-0.003^{ab}	-0.004^{b}
±SE	0.078	0.0960	0.114	0.055

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

while those for 12 and 18 weeks ages of cutting were generally similar. The various interactions were not statistically significant.

Relative regeneration rate: The data on relative regeneration rate of lablab as influenced by phosphorus application, cutting height and age of cutting for each of the 3 years (2006-2008) and the combined data are shown in Table 7. Neither phosphorus nor cutting height influenced relative regeneration rate of lablab significantly.

However, age of herbage cutting affected relative regeneration rate significantly each year. As was the case with respect to dry matter accumulation, relative regeneration rate of lablab was highest when cutting was done at 18 weeks. In 2006 and 2008, cutting at 12 and 18 weeks had similar rates of relative regeneration. Furthermore, the relative regeneration rate of lablab was usually at par when cutting was done either at 12 weeks or at maturity. Relative regeneration rate was generally lowest when lablab was cut at 6 weeks.

Crop growth rate: Effect of phosphorus application, cutting height and age of cutting on Crop Growth Rate (CGR) at 6-12 and 12-18 WAS in 2006, 2007 and the combined data is shown in Table 8. Phosphorus application affected crop growth rate significantly at 6-12 WAS in 2007 with the no-P control producing significantly higher crop growth rate in lablab relative to the 24 kg P ha^{-1} rate. There was also some similarity in the crop growth rates of the 12, 24 and 36 kg ha^{-1} rates on one hand and 0, 12 and 36 kg ha^{-1} rates on the other. At 12-18 WAS, phosphorus application also exerted significant influence on crop growth rate in 2006 and in the combined data (Table 8). At this growth stage, the response of lablab CGR to phosphorus application was similar to that in 2006 and in the combined data. The no-P control produced significantly higher crop growth rate than the highest 36 kg P ha^{-1} application rate which produced the lowest CGR value. In addition, the no-P control had similar crop growth rate with plants on plots fertilized with 12 and 24 kg P ha^{-1} rates whereas plots that received 12, 24 and 36 kg P ha^{-1} were also at par with respect to CGR.

Cutting height did not influence crop growth rate of lablab at any sampling period in each of the 2 years. Contrarily however, age of cutting affected CGR at all sampling periods in both years (2006-2007). At 6-12 WAS, cutting at an interval of 6 weeks significantly reduced the crop growth rate of lablab compared to later cuttings

Table 8: Effect of phosphorus application, cutting height and cutting interval on mean crop growth rate (g^{-2}/week) in lablab at 6-12 and 12-18 WAS in 2006, 2007 and combined over 2006 and 2007 wet seasons at Samaru, Nigeria

	6-12WAS			12-18WAS		
Treatments	2006	2007	Combined	2006	2007	Combined
Phosphorus (kg P ha^{-1})						
0	1.330	0.500^{a}	0.910	1.710^{a}	1.930	1.820^{a}
12	1.340	0.300^{ab}	0.800	1.320^{ab}	1.860	1.590^{ab}
24	1.610	0.040^{b}	0.820	0.260^{ab}	2.470	1.370^{ab}
36	1.900	0.240^{ab}	1.060	-0.310^{b}	1.650	0.670^{b}
±SE	0.272	0.102	0.145	0.594	0.319	0.337
Cutting height (cm)						
10	1.620	0.300	0.960	0.680	2.090	1.390
20	1.500	0.210	0.840	0.810	1.870	1.340
±SE	0.192	0.072	0.103	0.420	0.226	0.239
Age of cutting (WAS)						
6	0.300^{b}	0.160^{b}	0.230^{b}	1.660^{a}	2.830^{a}	2.250^{a}
12	1.900^{a}	0.510^{a}	1.190^{a}	-0.510^{b}	-0.740^{b}	-0.620^{b}
18	1.900^{a}	0.240^{ab}	1.050^{a}	1.460^{a}	3.230^{a}	2.350^{a}
Maturity	2.140^{a}	0.120^{b}	1.130^{a}	0.380^{ab}	2.590^{a}	1.490^{a}
±SE	0.272	0.102	0.145	0.594	0.319	0.337

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

Table 9: Effect of phosphorus application, cutting height and age of cutting on number of days to 50% flowering in lablab in 2006-2008 wet seasons and combined over 2006-2008 at Samaru, Nigeria

Treatments	2006	2007	2008	Combined
Phosphorus (kg P ha^{-1})				
0	92.30	136.80	144.20	12.40
12	92.10	136.80	147.00	125.30
24	91.20	135.10	141.70	122.70
36	92.30	136.50	149.50	126.10
±SE	0.76	2.14	3.27	1.34
Cutting height (cm)				
10	91.80	138.80^{a}	142.20^{b}	124.20
20	92.20	133.80^{b}	149.10^{a}	125.00
±SE	0.54	1.51	2.31	0.95
Age of cutting (WAS)				
6	91.90^{ab}	121.40^{c}	133.30^{c}	115.50^{c}
12	94.00^{a}	135.40^{b}	148.00^{b}	125.80^{b}
18	91.00^{b}	168.60^{a}	163.50^{a}	141.00^{a}
Maturity	91.00^{b}	119.80^{c}	137.60^{c}	116.20^{c}
±SE	0.76	2.14	3.27	1.34

Means followed by similar letter(s) within the same column are not significantly different at 5% level of probability according to the Duncan's Multiple Range Test (DMRT). WAS = Weeks After Sowing

(12, 18 weeks and at maturity) which were at par. At 12-18 WAS, cutting at 12 weeks produced significantly lower crop growth rates than the other ages of cutting that were at par, except for 2006 when cutting at maturity was also at par with cutting at 12 weeks.

Days to 50% flowering: The effect of phosphorus application, cutting height and age of cutting on number of days to 50% flowering of lablab in 2006-2008 and the combined for the 3 years is shown in Table 9. Phosphorus application did not affect number of days to 50% flowering significantly in any of the years of study. Cutting height influenced number of days to 50% flowering of lablab in 2007 and 2008 but in a reverse manner. Whereas, the lower cutting height (10 cm) resulted in earlier 50% flowering in 2007, this cutting treatment delayed it in 2008. Opposite to this situation, 20 cm cutting height delayed flowering in 2007 but caused lablab to reach 50% flowering earlier than the 10 cm cutting height in 2008.

Age of cutting significantly influenced number of days to 50% flowering in the 3 years and in the combined data. The consistent trend was that cutting at 18 weeks interval delayed 50% flowering of lablab significantly relative to the other ages of cutting. However, cutting at 12 WAS also delayed 50% flowering of lablab compared to cutting at 6 weeks and maturity both of which were at par.

DISCUSSION

This study has shown that lablab growth differs significantly between the years. The highest number of root nodules and nodule dry weight of lablab were recorded in 2008, the year with the most favourable rainfall. This underscores the relative importance of adequate precipitation to lablab growth. The productivity of crops per unit of water consumed differs widely (Majumdar, 2004). The productivity of lablab in 2007 might have been reduced by pests and the disease outbreak that occurred on the crop that year. The major disease in the complex was web blight of beans caused by the fungus *Rhizoctonia solani* Kuhn (Imperfect state) (Thurston, 1984). Web blight caused partial defoliation and a noticeable reduction in leaf area index in 2007 relative to 2006.

Response to phosphorus: Response of lablab growth parameters to phosphorus application was generally inconsistent. However, application of 24 kg P ha^{-1}

increased leaf area index, sward height, number of root nodules and nodule dry weight over the no-P control. The observed favourable responses of lablab to phosphorus application, most especially in the case of number of root nodules and nodule dry weight could be attributed to the role of phosphorus nutrition in forage growth. Phosphorus is known to be involved in energy-transfer processes which synthesize and degrade starch and transport nutrients from the soil through the roots to plant tops and P also enhances cell division, fat formation, flowering, fruiting, seed formation, development of lateral and fibrous roots. Its availability may also improve disease resistance and forage quality (Follett and Wilkinson, 1985). The results obtained are in general agreement with those of some other researchers. 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). Similarly, soybean nodulation was significantly increased (13.8-22.5%) by the same application rate compared with the no-phosphorus control (Chiezey *et al*., 1992).

The inconsistent response of lablab to phosphorus application in the present study may be attributed to the soil factors of the experimental sites. These include the medium soil available phosphorus rating (8.4-17.5 mg kg^{-1}), the strong to very strongly soil acidity (pH 4.6-5.2) and the medium soil calcium concentration (2.2-2.8 cmol kg^{-1}) which may have acted in concert to cause reduced lablab response to phosphorus. Studying the response of legumes to phosphorus fertilizers in Queensland, Australia, soil analysis results indicated a low P content wherever a positive response to this nutrient occurred (Crowder and Chheda, 1982).

Response to cutting height: The result of the present investigation has shown that for proper cutting or grazing, a higher cutting height is desirable for lablab productivity. Although, statistical analysis revealed that significantly more lablab stands died in the lower cutting (10 cm) treatment and there were significantly more active lablab axillary buds developing following cutting at the 20 cm height compared to the 10 cm cutting height. A higher cutting height of 20 cm produced a significantly higher sward height. This implies that lablab cut at 20 cm had a faster regrowth than lablab cut at 10 cm, probably because the plants cut to a higher stubble height utilized relatively less energy for recovery compared to a lower cut stubble. Furthermore, lablab cut to a height of 10 cm may 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 such plants have sufficient regrowth for fixation to proceed, a scenario that was observed in the present study. At the 10 cm stubble height, most of the functional lablab leaves were lost and the plants had to start new leaf growth that took some time before photosynthesis could start to fully support respiration and growth. This situation must have negatively impacted on lablab's rate of regrowth.

Response to age of cutting: It was evident from the results of the study that sward height number of root nodules, nodule dry weight and crop growth rate can be negatively affected by defoliating diseases depending on the stage of lablab growth. Between the 6 and 12 weeks ages of cutting these parameters had significant declines in their respective values due to web blight attack. This supports the need for adequate crop protection during this period of growth if livestock is to benefit from the highest accumulated fresh and dry herbage yields of lablab which were attained at 18 WAS 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 12 WAS. Sward height of lablab in this study fell within the range of 45.9 and 80.7 cm and followed a sigmoid growth pattern over the season.

The number of root nodules and nodule dry weight of lablab ranged between 15-39 and 91-288 mg, respectively. The greatest increase in these parameters occurred between 6 and 12 weeks after sowing. This implies that farmers should where possible incorporate their slow release phosphorus fertilizers at sowing where possible or by 4 weeks after sowing to support lablab root growth and possibly enhance nodulation. Phosphorus-fertilized plants develop more roots than plants not fertilized with phosphorus (Mitchell, 1970). The value for CGR at the 6 weeks sampling interval in this study fell within a range of 0.23 and 1.19 g^{-2}/week. However, beyond 12 WAS 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 crop growth for an overall benefit of the crop. According to Gardner *et al*. (1995), a crop growth rate of 20 g^{-2}/day (200 kg/ha/day) is considered respectable for most crops, particularly C_3 types. Although, this value was not attained by lablab in this study, probably due to a complex of environmental, climatic, edaphic and procedural factors such as interval of sampling used in this study, it is noteworthy that lablab still accumulated a respectable fresh (33.0 ton ha^{-1}) and dry (8.8 ton ha^{-1})

herbage yields in this study. This study has shown that lablab LAI is adequate 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 for increased crop productivity. The LAI values at 6 and 18 WAS were in the range of 9.3-11.5 whereas measurement at 12 WAS showed LAI values in the range of 13.4-24.0. The higher LAI values obtained at 12 WAS may be due to the high sward height which translated into more leaves per unit of land 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 re-growth, lablab should be cut or grazed when conditions that favour regeneration are best. The relative re-generation rate (15.0-49.0) of lablab at 18 weeks was the highest recorded among the different ages of cutting. 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 perennial with supplementary irrigation, the best age for cutting lablab herbage before irrigation is 18 WAS, a time 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 number of days to 50% flowering of lablab was significantly affected by age of cutting. 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 cutting or grazing at the most appropriate time 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 for the purpose of prolonging the vegetative phase.

Phosphorus x cutting height interaction: The interaction between phosphorus rate and cutting height was significant for sward height and number of root nodules. A combination of application rate of 36 kg P ha^{-1} and 20 cm cutting height produced the highest sward. These observations were probably due to the adequate soil phosphorus which enhanced root growth at the 36 kg P ha^{-1} application rate as well as a more functional foliage that was for photosynthesis left after cutting lablab to a 20 cm stubble height which could have enhanced regrowth and assimilate translocation.

A combination of 24 kg P ha^{-1} and 10 cm cutting height produced the highest number of root nodules. This result is similar to that reported 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 (10 cm) and adequate 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 premature senescence of nodules and their eventual shedding from roots (Humphreys, 1987). However, Whiteman (1970) provided evidence in support of the idea that change 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.

CONCLUSION

Phosphorus application of 24 kg P ha^{-1} will increase lablab's nodule dry weight significantly above the zero-P control. Cutting at 20 cm stubble height will enhance sward height in lablab while highest sward and fastest relative regeneration rate would be obtained when herbage is cut at 18 weeks.

ACKNOWLEDGEMENTS

The postgraduate degree training of the principal researcher was made possible through a study leave granted by the management of the National Veterinary Research Institute, Vom, Plateau State, Nigeria. The research facilities provided by the Institute for Agricultural Research, Samaru and the Department of Agronomy, Ahmadu Bello University, Zaria, Nigeria for the research are gratefully acknowledged.

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