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ASSESSING THE BIOMASS PRODUCTION AND NUTRITIVE VALUE OF KENAF (*HIBISCUS CANNABINUS*) AT VARIOUS STAGES OF GROWTH

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Abstract

This study was carried out to evaluate the yield and chemical composition of Kenaf at different stages of growth. Nine (9) beds were constructed, each measuring 2 ×2m with a distance of 1m between them. Kenaf seeds were planted on the beds at 0.4 m between and within rows with a planting depth of 2.5 cm. Germination was observed three (3) days after planting and the following data were collected weekly for 9 weeks; plant heights, number of leaves and stem girth (diameter). Leaves, stems and roots were separated and dried in an oven at 65^{0} C for 48 hours until a constant weight was obtained for biomass determination. Both proximate (crude fibre, crude protein and carbohydrates) and elemental (N, P, K, Ca, Mg) analyses were carried out on Hibiscus cannabinus. Crude protein content decreased significantly from 5 week after planting (WAP) to 9 WAP (from 24.1 % to 17.6 %). Plant height was noted to have a perfect positive linear relationship (r= 0.991) with the number of leaves of the plant. The results also revealed that dry matter yield of Hibiscus cannabinus was 288.1 kg/ha at the end of the study. Conclusively, harvesting Hibiscus cannabinus at 5 WAP is the most appropriate stage for higher proportions of nutrients concentration. Specifically, for high crude protein concentration (24.1 %), Hibiscus cannabinus should be harvested at 5 WAP as fodder for animals.

Keywords: Kenaf, Forage, Elements, Proximate, Biomass

Introduction

Natural pastures are the main sources of feed for ruminants, and form the major feed component of domesticated livestock in Ghana. However, unfavourable rainfall pattern, uneven seasonal growth and unavailability of pasture during certain times of the year have been considered the major limitations to constant supply of forage for ruminants. The expansion of the livestock production in developing countries relied mainly on importation of feed grains rather than on the exploitation of the available local feed resources. Grain generally makes up between 55 – 85 % of most of the conventional compound feed, where protein is normally supplied from oil seed cake or meal and animal or fish by products (Machin, 1992). Intensification of livestock, particularly ruminant production in the tropical regions, should not rely solely on the intensive use of grains. Strategies for ruminant development should be based on the optimal utilization of local feed resources, to reduce feed cost as it makes up about 65 % of the production cost (Azizan and Eusof, 1996). Research outcomes have proven that it is possible to improve current ruminant production with the appropriate use of tropical feed resources such as legume and fodder. Protein fodders such as *Leucaena leucocephala*, *Gliricidia sepium* and *Calliondra calothyrsus* have received much attention in the tropics (Bosma and Bicabe, 1997; Nherera *et al*., 1998; Stewart *et al*., 1998).

Kenaf (*Hibiscus cannabinus L*., family Malvacae) is woody-herbaceous annual plant cultivated for fibre.

The interest in growing Kenaf throughout the world for its high biomass yield and elevated fibre content has been increased (Alexopoulou *et al*., 2000). Kenaf is a fast growing crop and has a high potential to be used as industrial crop globally since it contains higher fibre materials (Manzanares *et al*., 1996). Kenaf has received great attention as a multi-purpose crop for energy (Alexopoulou *et al*., 2004), pulp (Baldwin and Graham, 2006), thermal insulation boards and fibre-reinforced thermoplastic composites production (Ardente *et al*., 2008; Lips *et al*., 2009) in Mediterranean countries.

Kenaf has potential as a high quality feed for livestock. Throughout the growing season, Kenaf leaves contain a higher concentration of Nitrogen and digestible Dry Matter than the stalk, but the proportion of leaf in the total Dry Matter decreases dramatically at about 80 days after planting. To optimize forage quality and quantity, Kenaf should be harvested between 60 and 80 days after planting. Crude protein content at this time would be >15 % (Swingle *et al*., 1978).

Kenaf has been successfully used to replace Alfalfa as a crude protein supplement for lambs fed Bermuda grass or Fescue hay (Shorbert *et al*., 1997). In home gardens, people plant Kenaf and eat the scions and leaves either raw or cooked(Zhang, 2003).As an annual crop, Kenaf affords more flexibility than perennial crops to producers that manage integrated livestock-cropping enterprises. In an integrated livestock – cropping enterprise, annual crops afford more flexibility than perennial crops and producers could market Kenaf as either a source of fiber or as a livestock feed (Phillips *et al*., 2002a)Kenaf has substantial amount of minerals (Kobiasy *et al*., 2001) and could either be used to integrate with other food crops or as a sole crop. It could be harvested and used in the lean season. There is paucity of information on the nutritional value and the use of Kenaf as animal feed in this part of the world. This research is aimed at investigating and ascertaining the growth and nutritional content of *Hibiscus cannabinus* so as to recommend to livestock farmers the stage at which kenaf can be harvested for maximum nutritional benefit. The objectives of the study are to assess the growth performance of Kenaf, to determine the biomass production of Kenaf and to determine the elemental (N, P, K, Mg, Ca) and proximate (crude protein, crude fibre, and carbohydrates) composition of Kenaf at different stages of growth.

Materials and methods

Study Area

This study was conducted at the Nyankpala Campus of the University for Development Studies. Nyankpala is located in the Tolon district of the Northern Region of Ghana within the Guinea savannah Agro-ecological zone. Geographically, the district lies within latitude $9^0$25’ N and longitude $0^0$58’ W. Nyankpala is 16 km (10 miles) away from Tamale, the capital of the region with an altitude of 183m above sea level.

The study area has an annual rainfall of 1034 mm distributed fairly from April to late November with a mean monthly temperature of 22^0 C. The area has a unimodal rainfall regime that alternates with the dry season. Relative humidity in the study area is at its maximum during the rainy season with monthly value of 80 % and a sharp decrease to a minimum monthly value of 53 % during the dry season (SARI, 2005).

The vegetation of the study area is typically grassland. Common trees found include *Azadirachta indica*, *Parkia biglobosa*, *Adansonia digitata*, *Tectona grandis* and *Sena siamea*. Common grasses include *Pennisetum pedicellatum*, *Andropogon gayanus*, *sporobolus pyramidalis*, *Setaria pallid-fusca* and *Panicum maximum*. Inhabitants of the area are mostly farmers growing crops like maize, rice, sorghum, millet, yam, groundnut and soya beans. The farmers mainly practice the free range system of livestock farming. The terrain of the area is flat with the soil type being sandy-loam.

Materials

Field materials

The following materials and tools were used in the field for the study: Surveyors tape measure, Pegs, Callipers, Ruler, Hoe and Cutlass.

Laboratory Equipment

The following were the equipment for the laboratory test: Electronic Balance, Block digester, Spectrophotometer, Flame photometer, Oven, Micro-kjeldahl digesting apparatus, Air-tight sample container, Condenser, Electric furnace, Gooch crucible.

Methods

Experimental Layout and Data Collection

Nine (9) beds were constructed, each measuring 2.0× 2.0 m with a distance of 1m between them. Kenaf seeds were planted on the beds at 0.4 m between and within rows with a planting depth of 2.5 cm.

Germination was observed three (3) days after planting and the following data were collected at a week interval for 9 weeks; plant heights, number of leaves and stem girth (diameter).

Biomass measurements

Leaves, Stems and Roots were separated and dried in an oven at 65^{0}C for 48 hours until a constant weight was obtained. Plant components, dry matter and total dry matter yield was then determined.

Laboratory analysis

The crude protein and carbohydrate composition were carried out by the various methods described by AOAC procedure (2000).Total Nitrogen (N) was determined using the Vapodest (modified kjeldahl distillation unit). Total Phosphorous (P) was determined by using the Spectrophotometric vanadium phosphomolybdate method. Total Potassium (K) estimation was done on a flame photometer.

Calcium (Ca) and Magnesium (Mg) was determined by the Atomic Absorption Spectroscopy method.

Statistical Analysis

Data on nutrients concentration were subjected to one–way ANOVA using Genstat software and differences among treatments means were determined and Least Significant Difference (LSD) at 5%was used to separate means.

Results

Biomass of *Hibiscus cannabinus*

Figure 1 illustrates the average dry matter yield of the different parts of *Hibiscus cannabinus*.

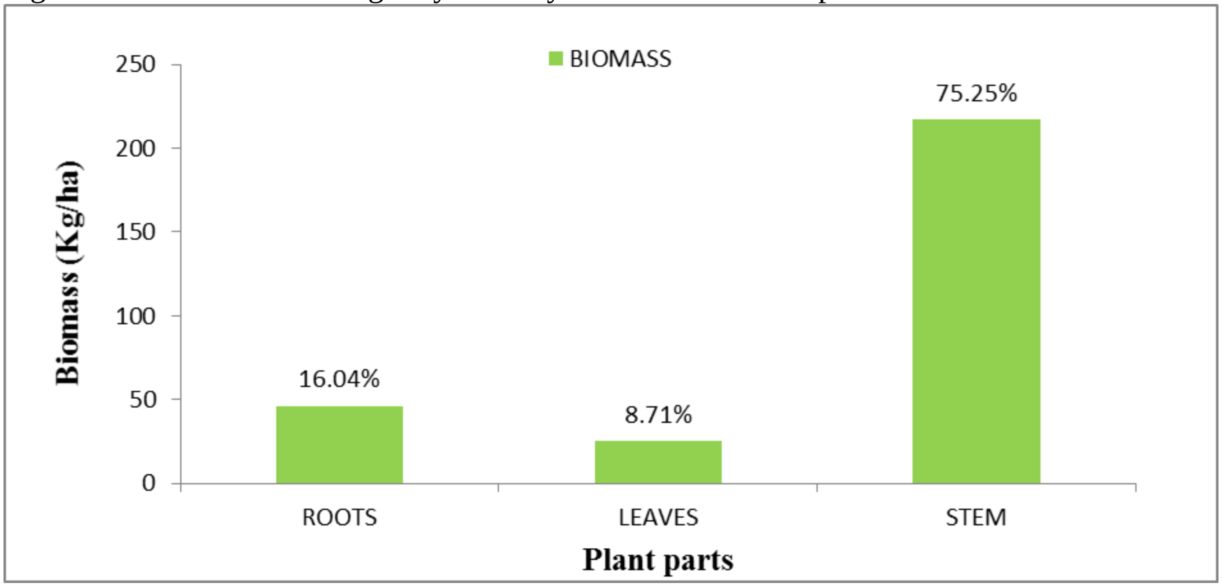

Figure 1: Average dry matter yield of different plant parts of *Hibiscus cannabinus* at 9 WAP.

Based on the average dry matter yield of different plant parts of *Hibiscus cannabinus*, the highest amount of the dry matter accumulation occurred in stems (216.8 kg/ha) followed by the dry matter accumulation in root (46.2 kg/ha) and the least being accumulated in the leaf (25.1 kg/ha) as indicated in figure 1. The total biomass of *Hibiscus cannabinus* was known to be 288.1 kg/ha.

Correlation of Plant Height and Number of leaves of *Hibiscus cannabinus*

Figure 2 depicts the correlation between plant heights and number of leaves from week one to week nine of the plant growth.

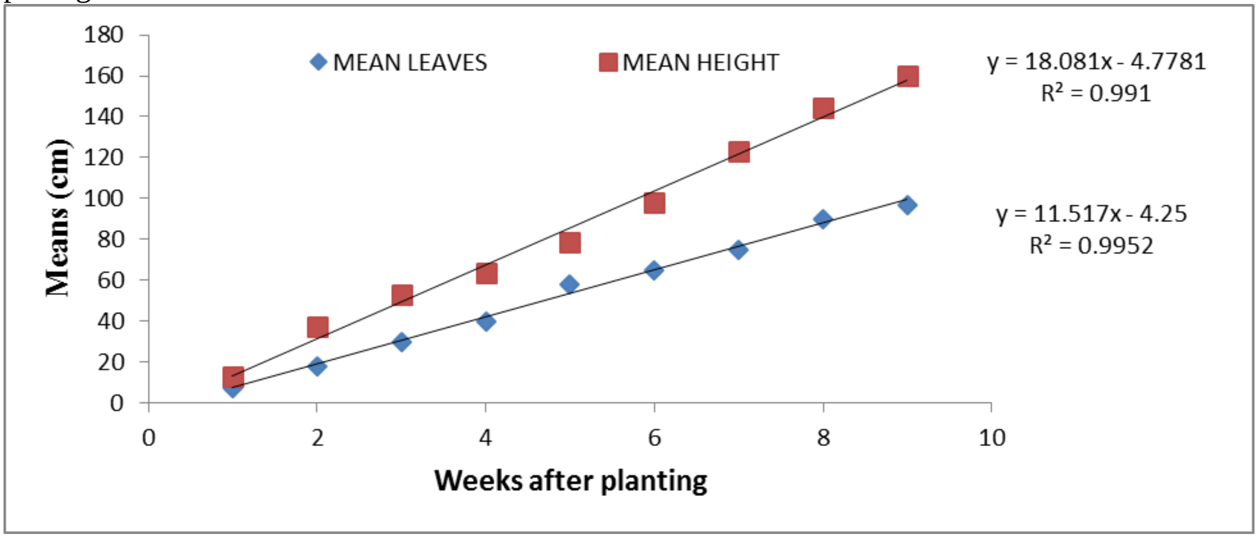

Figure 2: Correlation between plant height and number of leaves of *Hibiscus cannabinus* from week 1 – 9.

The correlation between the plant height and number of leaves indicated a positive linear relationship. As the weeks went by plant heights increased. The first week after planting recorded the least plant height (12.8 cm) whiles the ninth week after planting recorded the highest (160.2 cm).

Moreover, there was no significant difference ($p>0.05$) in the number of leaves between two successive weeks throughout the entire growth period. The highest number of leaves was recorded at 9 WAP (97 leaves/ plant) and the lowest recorded at 1 WAP (7 leaves/ plant).

Mean Stem Girth of *Hibiscus cannabinus*

Figure 3 illustrates the mean stem girth from week one to week nine after planting.

Figure 3: Stem girth of *Hibiscus cannabinus* from week 1 – 9. Bars represent means ±SE

There was no significant difference ($p>0.05$) in the stem girth between 1 and 2 WAP. However, there was significant differences ($p<0.05$) in mean stem girth at every two weeks with the exception of 6 and 8 WAP as well as 7 and 9 WAP.

Proximate composition of *Hibiscus cannabinus*

Figure 4 shows the concentrations of carbohydrates, crude protein and crude fibre of *Hibiscus cannabinus* at 5, 7, and 9 WAP.

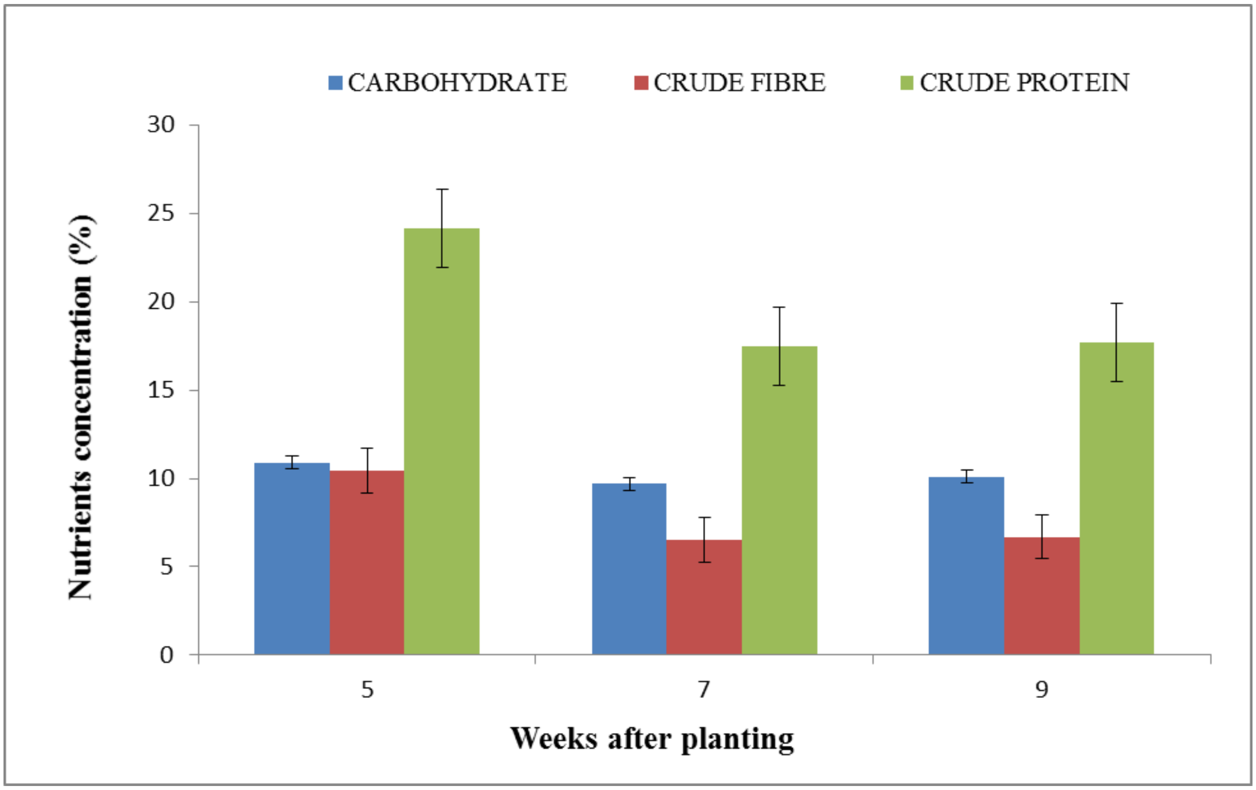

Figure 4: Concentrations of carbohydrates, crude fibre and crude protein at 5, 7 and 9 WAP. Bars represent means ±SE.

From the statistical analysis, the carbohydrates concentration showed no significant difference ($p>0.05$) at 5 WAP (10.9 %), 7 WAP (9.7 %) and 9 WAP (10.1 %). It was observed that the crude fibre concentration in *Hibiscus cannabinus* at 5 WAP (10.4 %) was significantly higher than 7 WAP (6.5 %) and 9 WAP (6.7 %). However, there was no significant difference ($p>0.05$) at 7 WAP (6.5 %) and 9 WAP (6.7 %).

Crude protein concentration at 5 WAP (24.1 %) was significantly higher than 7 WAP (17.4 %) and 9 WAP (17.6 %). It also revealed that, there was no significant difference ($p>0.05$) at 7 WAP (17.4 %) and 9 WAP (17.6 %).

Concentration of NPK in *Hibiscus cannabinus*
Figure 5 shows the concentrations of nitrogen (N), phosphorous (P) and potassium (K) of *Hibiscus cannabinus* at 5, 7 and 9 WAP.

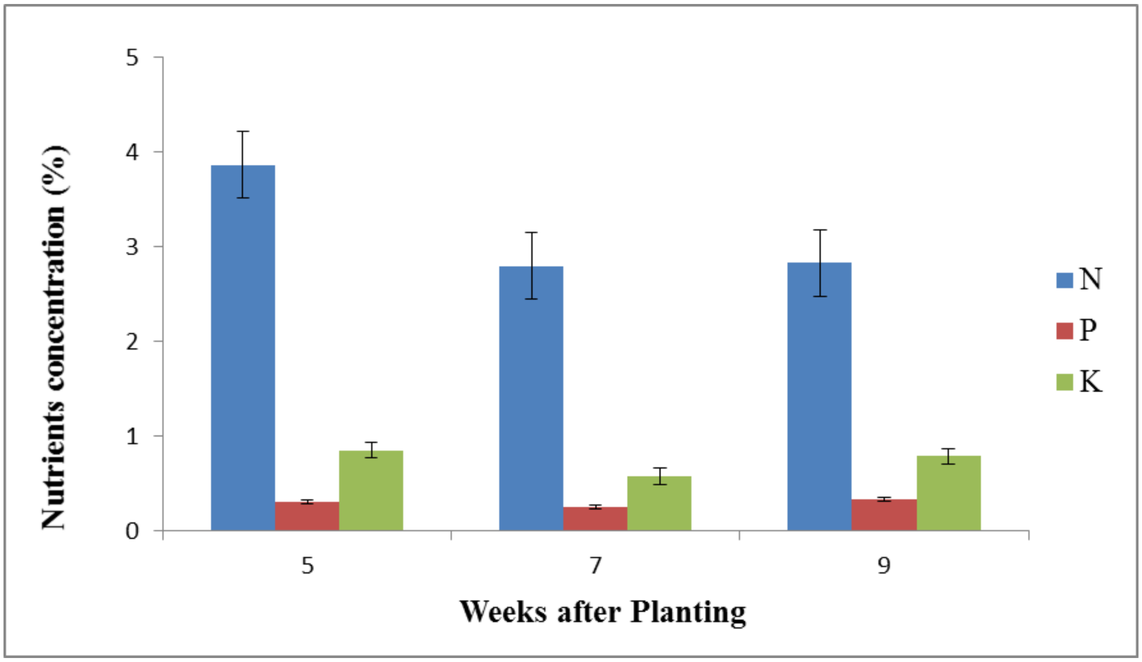

Figure 5: Concentrations of nitrogen, phosphorous and potassium at 5, 7 and 9 WAP. Bars represent means ±SE

There was no significant difference ($p>0.05$) between 7 WAP (2.7 %) and 9 WAP (2.8 %) in nitrogen concentration. Moreover, the concentration of nitrogen was significantly higher at 5 WAP (3.8 %) than 7 WAP (2.7 %) and 9 WAP (2.8 %).There was no significant difference ($p>0.05$) at 5 WAP (0.3 %) and 9 WAP (0.3 %) in the concentration of phosphorous. However, harvests at 9 WAP (0.3 %) and 5 WAP (0.3 %) were significantly higher than at 7 WAP (0.2 %).
It was observed that the potassium concentration of *Hibiscus cannabinus* was not significantly different ($p>0.05$) at 5 WAP (0.8%) and 9 WAP (0.7 %). It was also evident that there was significant difference ($p<0.05$) between 5 WAP (0.8%) and 7 WAP (0.5%). However, 5 WAP (0.8%) was noted to be significantly higher ($p<0.05$) than that of 7 WAP (0.5%) as shown in figure 2.

Figure 6 shows the concentrations of Calcium (Ca) and Magnesium (Mg) of *Hibiscus cannabinus* for harvests at 5, 7 and 9 WAP.

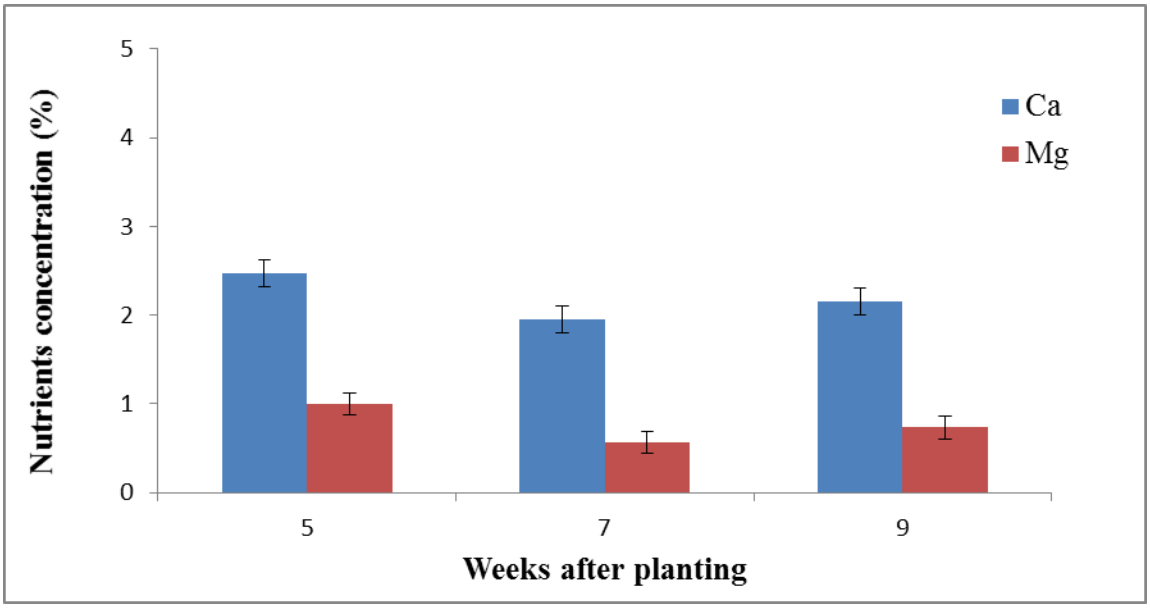

Figure 6: Concentrations of calcium and magnesium at 5, 7 and 9 WAP. Bars represent means ±SE

From the analysis there was no significant difference ($p>0.05$) in the concentration of calcium between 7 WAP (1.9 %) and 9 WAP (2.1 %). However, there was significant difference ($p<0.05$) between 5 WAP (2.4 %) and 7 WAP (1.9 %).

Magnesium concentration at 5 WAP (0.9 %) was significantly higher than at 7 WAP (0.5 %) but there was no significant difference ($p>0.05$) between 7 WAP (0.5 %) and 9 WAP (0.7 %).

Discussion

Biomass (dry weight) of *Hibiscus cannabinus*

Biomass of *Hibiscus cannabinus* was based on the leaves, stem and the roots. The stem dry matter obtained the highest value whilst the leaf dry matter recorded the lowest value (figure 6). The highest dry matter recorded by the stem could be attributed to the high amount of produce in the stem (Alexopoulou *et al*., 2000). *Hibiscus cannabinus* as an annual plant is cultivated mostly for fibre which is produced in its stem hence the high dry matter. Charles (2002) observed in an experiment that the stalk dry matter yield of kenaf increased with increase in plant height. This is consistent with Ching *et al*., (1993) who reported the same trend with full season kenaf for fibre production. Ejieji and Adeniran (2010) also observed that stem dry matter of grain Amaranth (*Amaranthus cruentus*) increased with the increase in plant height. Hasanuzzaman *et al*. (2008) also reported highest stem dry matter allocation in *Aloe vera*. Crowder and Chedda (1982) observed that stems yield more dry matter than leaf and this is because with advancing plant growth, the proportion of stem increases at the expense of leaf due to an increase in the proportion of lignified structural tissues.

Correlation of plant height and number of leaves of *Hibiscus cannabinus*

From the research plant height was noted to have a positive linear relationship with the number of leaves of the plant. This means that as the plant increased in heights, the number of leaves also increased.

Stem Girth of *Hibiscus cannabinus*

Stem girths recorded low values during the first four weeks after planting. However, the stem girths increased throughout the experimental period. This could be due to the low lignin accumulation in the stem during the early stages of the plant growth. However, as the plant ages the lignin accumulation increased thereby increasing the stem girth (Alexopoulou *et al*., 2000).

Proximate composition of *Hibiscus cannabinus*

According to the results crude protein concentration of the plant was highest at 5 WAP (24.1 %), decreased at 7 WAP (17.4 %) and later increased at 9 WAP (17.6 %) as shown in figure 1. The reduction in the crude protein content at 7 WAP could be due to rapid accumulation of fibrous component of the plant as reported by Suriyajantratong *et al*., (1973) and Wong and Vijasegaran (2001). Similar work by Krishna *et al*., (1985) reported a decrease in the crude protein concentration of sun hemp plant from 22.6 % at week 4 to 17.8 % at week 8. The crude protein value observed in this study was 24.1 %, which is higher than 3.3% recorded by the USDA Nutrient Database for Standard Reference (Hall, 1998). This makes the plant advantageous as a rich source of vegetable protein over some vegetables such as raw cocoyam leaf (3.4%), cooked cocoyam leaf (2.1%), *Amaranthus*(6.1%) and *Moringa oleifera* (4.2%) (Adepoju *et al*., 2006).

Crude fibre concentration of the plant was lowest at 7 WAP (6.5 %) and highest at 5 WAP (10.4 %). The decreased in the crude fibre concentration at 7 WAP could be attributed to the maturation of the plant. This means that as the plant matures, the crude fibre concentration reduces. This is in line with the findings of Chen *et al*., (1995) which stated that fibre length grow in the early part of the plant cycle and reduce as the plant matures.

The concentration of carbohydrates in *Hibiscus cannabinus* was highest at 5 WAP (10.9 %) and lowest at 7 WAP (6.5 %). The reduction in the concentration of carbohydrates at 7 WAP could be as a result of the formation of flowers at that stage. This means that more carbohydrates are required for the formation of flowers. However, the slight increase of the carbohydrates concentration at 9 WAP may be due to the fact that the plant had completed its flowering operation and therefore does not need much carbohydrate.

Mean mineral concentrations of *Hibiscus cannabinus*

From the study, the NPK concentrations varied significantly among the weeks after planting. Nitrogen showed the highest proportion (3.8 %) at 5 WAP and lowest of 2.7 % at 7 WAP (figure 2). The highest concentration of nitrogen at 5 WAP could be attributed to low lignin in the plant at 5 WAP. That means there is a relationship between the lignin content, nitrogen concentration and age of a plant. As the plant matures the lignin content increases whiles nitrogen concentration reduces (Gomide, 1978).

The reduction in phosphorous concentration at 7 WAP could be attributed to the aging of the plant. Generally, there is a rapid uptake of mineral during early growth and a gradual dilution as the plant matures (Berger, 1996). Report by Holechek *et al*., (1989) has it that phosphorous is generally associated with active growth and its content declines as forages approach maturity.

The results showed highest potassium concentration of 0.8 % at 5 WAP and lowest at 7 WAP (0.5 %). This means that there is a reduction in concentration of potassium from 5 WAP to 7 WAP. This reduction in potassium concentration could be as a result of the flower formation at 7 WAP. According to Baker and Reid (1977), potassium concentration in alfalfa was found to decline from 2.75 % to nearly 1.75 % from late vegetative growth to bloom. Similar work at University of Wisconsin Marshfield Research Station (2002) showed that from late vegetative growth to bloom, potassium content in alfalfa dropped from 3.21 to 2.08 %. Plants at flowering may have half the potassium concentration of immature forage earlier in the season.

The decreased in magnesium concentration of *Hibiscus cannabinus* at 7 WAP (0.5)as compared to 5 WAP (0.9) could be attributed to the fact that competing cations in the soil such as Ca^{2+}, H^{+}, NH_4^{2+}, Al^{3+} and Na^{+} prevented Magnesium intake by the plant. This is in conformity with Mengel and Kirkby (2001) and Shaul (2002), who reported that magnesium deficiency in plants can be induced, however, not only by direct lack of magnesium but also by the presence of competing cations that prevent Magnesium uptake by plants.

Concentration of Calcium in *Hibiscus cannabinus* was significantly higher at 5 WAP (2.4 %) than at 7 WAP (1.9 %). This means that the concentration of calcium in *Hibiscus cannabinus* decreases as the plant matures. This could be as a result of higher amount of nitrogen concentration in the plant at 5 WAP which facilitated the absorption of other nutrients including calcium. However, this finding disagrees with that of Perdomo *et al*. (1977) who revealed that calcium concentration in Guinea grass and Bermuda grass does not change with increasing maturity.

Conclusion

From the study, carbohydrate concentration of *Hibiscus cannabinus* was not statistically significant at 5, 7 and 9 WAP. It was also established per this study that crude fibre concentration at 5 WAP was significantly higher than 7 and 9 WAP. The research further revealed a higher concentration of crude protein in *Hibiscus cannabinus* at 5 WAP (24.1 %) than at 7 WAP (17.4 %) and 9 WAP (17.6 %) but there was no significant difference ($p>0.05$) between 7 and 9 WAP.

Mean concentration of nitrogen was significantly higher at 5 WAP than 7 and 9 WAP. Similarly magnesium concentration at 5 WAP was significantly higher than at 7 WAP.

The study also established a positive linear relationship ($r= 0.991$) between plant heights and the number of leaves. Biomass production of *Hibiscus cannabinus* was observed to be highest in the stem (75.3 %), followed by roots (16.0 %) and then the leaf (8.7 %). It can therefore be concluded per this study that harvesting *Hibiscus cannabinus* at 5 WAP is the most appropriate stage for higher proportions of nutrients concentration. For high crude protein concentration, *Hibiscus cannabinus* should be harvested at 5 WAP. It is therefore recommended to livestock farmers and Pasture growers to harvest *Hibiscus cannabinus* before 7 WAP.

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