ASSESSMENT OF BIOMASS PRODUCTION FROM *Tithonia diversifolia* AND *Sapium ellipticum*

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ABSTRACT
The amount and quality of fodder crops, such as Napier grass drastically declines during dry season. This reduces feed availability and impacts severe effects on livestock performance, in terms of growth, milk and meat production. Fodder trees and shrubs have been proportionately overlooked in terms of the research effort devoted to agricultural cropland, pasture grasses and fruit trees crops. Although they are the most visible plant forms in arid lands, shrubs have been neglected in most scientific research and land management policies. There is need, therefore, to explore the potential of indigenous fodder species as an alternative to introduction of exotic ones. Data on many indigenous fodder trees and shrubs biomass production is lacking. The objective of this study was, therefore, to assess the potential of biomass production from *Tithonia* and *Sapium* forages for use as possible substitutes to napier grass so as to widen the choice of forages and reduce risk of single species, such as napier grass and or *Leucaena leucocephala*, dependence. Biomass assessment for *Tithonia* and *Sapium* at KARI Embu involved selection of site, plot identification, plot demarcation, herbage harvesting, yield and dry matter determination. The herbage stems under shade were taller and slender than those under sun. The yield of Napier grass compared to both *Tithonia* and *Sapium* forages was much less because *Tithonia* was more aggressive in growth and *Sapium* had a deeper rooting system than Napier grass.
Keywords: Napier grass, *Leucaena leucocephala,* Dry matter

INTRODUCTION
The amount and quality of fodder crops, such as napier grass drastically declines during dry season. This reduces feed availability and hence severe effects on livestock performance, in terms of growth, milk and meat production. Fodder trees and shrubs have been proportionately overlooked in terms of the research effort devoted to agricultural cropland, pasture grasses and fruit trees crops. Although they are the most visible plant forms in arid lands, shrubs have been neglected in most of scientific research and land management policies. There is need, therefore, to explore the potential of indigenous fodder species as an alternative to introduction of exotic ones. In the eastern province districts of Meru and Embu, a shrub known as *Tithonia (Tithonia diversifolia)* and a tree referred to as *Sapium* (*Sapium ellipticum*) are reportedly used to supplement fodder during the dry season. However, as with many indigenous fodder trees and shrubs, data on their biomass production is lacking. The objective of this study was, therefore, to assess the potential biomass production of *Tithonia* and *Sapium* forages for use as possible substitute to napier grass so as to widen the choice of forages and thus reduce risk of single species dependence, such as napier grass, and or *Leucaena leucocephala.*

MATERIALS AND METHODS
Experimental Site
The data was collected at the Kenya Agricultural Research Institute (K.A.R.I) Regional Research Centre, Embu, and the neighboring areas. The centre is located in the Central highlands of Kenya, on the south eastern slopes of Mt. Kenya at an altitude of 1480 m above sea level. The soils are mainly humic Nitosols derived from basic volcanic rocks and classified by USDA under humic palehumult. Rainfall is moderate at an average of 1200 – 1500 mm and bimodal with the long rains (LR) coming between mid March and June amounting to an average of 750mm and the short rains (SR) from mid-October to December and averaging 350mm. Monthly temperature range between the averages of 18-21^{o}C.

The study fodder species
The experimental test shrub and tree were *Tithonia diversifolia* and *Sapium ellipticum*. Because of their difference in stature and growth period, the biomass yield for the two species was assessed separately.
Assessment of biomass production by *Tithonia*

Tithonia common name is Mexican sunflower and a native of Mexico or Central America. *Tithonia* belongs to the family compositae of *Asteraceae* of *Aster* family.It produces large quantities of biomass and tolerates regular pruning.

Selection of site

To assess its dry matter yield, four (4) plots measuring $8m^2$ each were randomly chosen from an area of bush land already entirely occupied by *Tithonia*. The piece of land, from which the four plots were chosen, at the Embu Research Centre, is in an area popularly known as, 'The Agroforestry Farm'. Two of the plots were on an open ground while the other two were under trees shade. The distance between the plots was twenty meters.

Identification of the plot

The four main plots were marked alphabetically, A, B, C, and D. Plots B and D were under the trees while plots A and C were in the open ground. Each of the main plots was subdivided into four Subplots of $2m^2$. These 16 sub-plots were randomly marked with numbers from one (1) to sixteen (16). Using a table of random numbers the 16 subplots were grouped for the purpose of consecutive cutting.

Demarcation of plots

A measuring tape, a panga and a meter and two-meter measuring sticks were used to demarcate the four plots and the sixteen subplots. The panga was used to clear vegetation from around the sites to pave way for erecting plot boundary sticks. Four border sticks were erected to mark the external perimeter of the plots and five other sticks were erected to mark the length of the subplots within the main plot.

Harvesting procedure and yield determination

The existing herbage of *Tithonia* in the four plots was cut down at the ground level (harvested) on day zero (0) of the experiment and then left to re-grow. The height of the stems was taken in centimeters using a measuring tape and recorded before each cut. The three shortest and the three longest stems were cut from every sub-plot, the length between the bottom and the apex of the stem measured and the average height calculated for each subplot. Both the stems and the leaves were harvested together by cutting all the stems from the ground level and collecting the herbage into gunny bags. The amount of herbage harvested from every plot was weighed using a spring balance and recorded. The first cutting of the first four subplots was done four weeks after clearing of the plots. Subsequent harvesting of the *Tithonia* herbage for the remaining subplots was done at fortnightly intervals, i.e. after six, eight and ten weeks of growth. Four subplots, one from each main plot were harvested at each time period.

Dry Matter Determination.

Samples from the four subplots were collected into four marked paper bags. The fresh samples were taken to the analytical laboratory and dried in ovens set at 105^oC for dry matter determination.

Assessment of biomass production by *Sapium ellipticum*

Sixteen trees having similar characteristics in terms of height and the crown cover were selected randomly from the 54 in the orchard. The selected trees were in a uniform stand. The trees were randomly marked with numbers (1-16) on the stem and grouped into groups of four for the purpose of herbage production estimation. The ground cover for each tree was estimated by marking the shade cover on the ground at twelve noon and estimating the irregular shade shape area through best lines approximately retaining similar space as that covered by shade.

Harvesting procedure and yield determination

At day zero (0) all the sixteen trees were harvested by stripping the leaves and twigs from the trees. This was done in order to allow sprouting of new herbage for uniform estimation of fodder dry matter yield. The second harvesting after the initial harvesting was done after seven weeks of re-growth. Subsequent, stripping was done after weeks nine, eleven and thirteen re-growth. The herbage was then put in marked gunny bags; the weight was determined and recorded. The shortest and the longest twigs were selected, and their length determined and recorded. A sample of the harvest was taken for dry matter determination. After the drying the dry matter weight was determined. The leaves and the twigs were then separated, their weights determined and recorded.

Dry matter determination

Samples of *Sapium* for each harvesting were analyzed for dry matter.

Data management and analysis

The data recorded for sapium and tithonia was entered into the Microsoft Excel® spreadsheet for management, and calculation of descriptive statistics. *Tithonia* dry matter data yields was subjected to the main plot and sub-plot analysis of variance with the week of growth as a covariate (Steel and Torrie, 1980). Only the effect of growth period time on dry matter yields and twig length was assessed statistically for *Sapium*.

RESULTS AND DISCUSSION

Stem height and dry matter yield of *Tithonia*

Stem height determination is important because it demonstrates how herbage responds to differences in growth period and environment. Stem heights for cuts 1-4, representing 4, 6, 8 and 10 weeks of growth were 13.4, 47.6, and 63.1 and 80.6 meters respectively (Table 1). In this study, half the plots were under tree shade while the other two were in open ground fully exposed to the sunrays. The stems of the herbage under the shade were taller and slender compared to the stem of the herbage growing under the sun (Table 2a**).** The stem mean heights for both plots under the shade and sun increased with the growth period in weeks. During the fourth week the stem mean heights for the plots under the shade and the sun was 12.5cm and 14.3cm respectively, while at the sixth week the stem mean heights was 53.5cm and 42.3cm respectively. The biggest mean stem-heights for the plots under the shade and under the sun were 83 cm and 78.3 cm at the tenth week of growth.

Table 1: Average stem height, amount of cut, dry matter of cut and dry matter yield of harvested *Tithonia* forage with the length of Growth period

Growth time (days/weeks)	Growth height (cm)	Dry Matter of cut (%)	Dry matter yield (kg/m2)	DMY Tonnes/ha	Leaf to stem ratio
4weeks	13.40	9.9	0.07	4.6	10
6weeks	47.63	10.3	0.48	31.1	3.41
8weeks	63.13	12.0	0.58	38.0	1.26
10weeks	80.63	16.5	1.13	73.7	0.27
L.S.D	12.56	1.899	0.1169		

The dry matterpercentage of the herbage both cut under the shade and the sun increased throughout the growth period. Overall dry matter of cut (%) was 9.9, 10.3, 12.0 and 16.5 for cuts 1-4 respectively. The dry matter of the harvested *Tithonia* increased from the 28th day to the 70th day. This increase is normal and is attributed to the fact that as the herbage matured the stems were becoming thicker, a reflection of increase in the stem dry biomass. Plants like *Tithonia, Sapium* and other indigenous fodder species such as *Gewia Similis* have a unique allocation of dry matter to different structures within its own system. Plants allocate the highest amounts of dry matter to the stem production and the lowest dry matter to the leaf production. Since the stem is made up of woody material the water content in this material is far much lower than in the leaves. Shade did not have a significant ($P>0.05$) effect on the dry matter proportion. However, cuts of herbage grown under shade had a consistent lower dry matterpercentage, with averagepercentage differences of 0.4, 0.3, 0.6 and 5.2 for herbage harvested at the cutting intervals of 1-4 respectively. Plants growing under shade should have less dry matter content because of reduction in photosynthetic capacity. Shading causes a reduction of the total soluble carbohydrates and an increase in lignin in the tissues.

Table 2a: Effect of shade and sun on *Tithonia* forage with changes in growth period (weeks) on the average of stem length, leaf to stem ratio, dry matter of cut, dry matter yield and extrapolated dry matter yields per ha per year

		4 weeks	**6 weeks**	**8 weeks**	**10 weeks**
Parameters	**Light effect**				
Stem length (cm)	Plots under shade	12.3	53.5	68.0	83.0
	Plots under sun	14.5	41.8	58.2	78.3
Leaf to stem ratio	Plots under shade	10.0	1.8	1.6	0.3
	Plots under sun	10.0	5.0	0.9	0.3
Dry matter of cut (%)	Plots under shade	9.8	10.2	11.7	13.9
	Plots under sun	10.2	10.5	12.3	19.1
Dry matter yield ($kg/2m^2$)	Plots under shade	0.09	0.66	0.66	0.91
	Plots under sun	0.05	0.3	0.5	1.4
Extrapolated DM yield per ha per year(tonnes)	Plots under shade	5.9	43.0	42.6	58.9
	Plots under sun	3.3	19.3	33.5	88.4

Table2b: Mean square values of analyses of variance for growth period and light effects on *Tithonia* forage production

Factor	Variable					
	DF	Stem height, cm	Leaf to stem ratio	Dry Matter (%)	DMY/m^2	Extrapolated DMY (t/ha)
Light	1	145	1.6	10.7	0.002	8.8
Growth time	1	9433*	197*	91.2*	2.2*	9175*
*(P<0.05)						

The amount of *Tithonia* herbage harvested increased from the fourth week through to the tenth ($P<0.05$). Longer growth period allowed for increase in stem thickness and height. The greatest amount of *Tithonia* harvest in $kg/2m^2$ was at the tenth week with 1.13kg per $2m^2$ plot. The dry matter yield ($kg/2m^2$) for leaves and stems increased from the initial harvest of the *Tithonia* herbage (28th day), through to the 70th day. The shade effect on dry matter yield was inconsistent. The amount of herbage produced under the sun was higher than that produced under the shade in the last harvest while the initial, second and the third harvest produced unexpected results. There was a sharp increase in the DM yield between the 4th and the 6th weeks for both plots under the shade and the sun. Thereafter, the increase was more gradual. The annual dry matter yields (tonnes/Ha) extra-polated for each of the growth periods, increased with the length growth period. This ranged from 5.9 to 58.9 and 3.3 to 88.4, for plots under the shade and the sun at the 4th and 10th weeks respectively. It can therefore be argued that the biomass produced from the plots under the shade was less (Table 2a) as a result of reduced light availability for carbon assimilation in the leaves. *Tithonia* propagates through seeds and cuttings. The density of plants in an area that is colonized by *Tithonia* can increase rapidly over a short time through tillering, germination of seeds and stems/cuttings taking hold on the ground. Although density of plants can cause great variation in herbage yield, stands of *Tithonia* that have lasted a few years are fairly uniform in density, as in this study.

Frequency of cutting influences the total annual herbage yield of plants that are capable of re-growing. Using vernal alfalfa grass, it was shown that forage harvested three or four times per season produced more total forage. Cutting frequency determines stem height at cutting with higher frequencies resulting in shorter stem heights. Dry matter yields and nutrients yields are higher for shorter cuttings heights as compared to leaving taller stubble. The cutting frequencies in this study were 13, 8.7, 6.5 and 5.2 weeks per year. An extreme cutting frequency may result, as in this study, with low annual herbage yields than expected. This study did not determine the optimal cutting frequency for *Tithonia* in Embu district.

Leaf to stem ratios

Leaf to stem ratio is an important factor affecting diet selection, quality and forage intake in ruminants' nutrition. In trees, shrubs and grass forages, leaf to stem ratio declines logarithmically over time. The leaf to stem ratios variation for plots under the shade and under the sun was 10.0, 1.8, 1.6, 0.3 and 10.0, 5.0, 0.9 and 0.3 at the 4th, 6th, 8th, and 10th weeks respectively**.** The ratio declined ($P<0.05$) from 10.0 kg/kg to 0.3 for both plots under the shade and the sun from the 4th and 10th weeks of growth respectively. The fiber component of leaves differs from that of stems. As the forage matures, leaf to stem ratio declines (more stems, fewer leaves) and as result (NDF) digestibility declines. This could consequently lead to a reduction in the voluntary feed intake. The separation of leaves from the twigs and stems increases the palatability and digestibility of a feed material.

Stripping Twig Length and Dry Matter Yield

The determination of stripping twigs length demonstrated how the *Sapium* forage responded with the increase in the cutting period. The twig and leaf height of the *Sapium* forage increased linearly with the consecutive increase in the length of the cutting period (7, 9, 11, and 13 weeks). This ranged from 42.8 to 86.5 cm at the 7th and 13th weeks respectively. The average twig length difference between the four cutting periods was 17.6cm, 6.1cm and 20cm. The increase in height of the twigs also corresponded with the increase in maturity of the *Sapium* forage. The DM yield of the *Sapium* forage increased throughout the growth period. The yield ranged from 1.1, 1.7, 1.9, and 7.3 kg/m^2 from the 7th, 9th, 11th and the 13th week respectively. Canopy coverpercentage reflected from the *Sapium* trees explain more about the variation in the difference of the dry matter yields than any other variable. The dry matter yield obtained in this study are significantly higher than that reported by Development and on farm evaluation of agro forestry livestock feeding systems of 0.3tonnes/ha.

Leaf to stem ratio in *Sapium* forage

As forage mature, stems, with their low forage quality, constitute a larger proportion of the total forage. Leaves typically are of higher quality than stems with higher CP and soluble sugar concentrations and higher digestibility. However crude protein concentration is usually greater in leaves and stem segments from the top of plant canopies than from the bottom. In the present study the leaf to stem ratio decreased from the seventh to the thirteenth week ranging from 1.6 to 0.8 from the seventh to the thirteenth week respectively (Table 3). The decrease in ratio became gradual after the 11th week of growth as the *sapium* forage matured.

Table 3: effect of time on growth of *sapium* on the average of stem height, leaf to stem ratio, dry matter of cut, dry matter yield per ha and dry matter annual yield

	Weeks of growth				
Parameters	7	9	11	13	Std Dev
Average tree ground cover, m^2	1.7	2.8	2.2	7.5	2.06
Stripping twig length, cm	42.8	60.4	66.5	86.5	6.75
Leaf to stem ratio, kg/kg	1.6	1.3	0.8	0.78	0.29
DM of strippings, %	22.3	30.2	33.8	40.1	3.02
Average tree DM YIELD, kg	1.1	1.7	1.9	7.3	1.83
Estimated annual DM yield, tonnes per ha	0.5	0.5	0.6	0.7	0.13

CONCLUSION

The amounts of yields of napier grass compared to both *Tithonia* and *Sapium* forages was much less because *Tithonia* is more aggressive in growth and *Sapium* has a more deeper rooting system than napier. Proportion of yields of *Tithonia* and *Sapium* forages to napier grass increases with consecutive period of cutting. To maximize the amount of annual dry matter yield (t/ha) by both *Tithonia* and *Sapium* their cutting intervals should be 10 and 13 weeks, respectively. This cutting interval will not only facilitate higher quantity of forage production but also greater and better ruminant nutrition and production.

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