Tanzania Journal of Forestry and Nature Conservation, Vol 91, No. 2 (2022) pp 193-201

Napier (*Penisetum purpureum*) Agronomic Response Under Desmodium (*Desmodium intortum*) Influence at Ubiri village Lushoto District, Tanzania

[1]C.S. Lissu, [1]L.L. Lulandala, [2]*B.J. Manyanda, [3]T.B. Tsere and [4]I.B. Babili

[1]Department of Ecosystems and Conservation,
College of Forestry, Wildlife and Tourism
Sokoine University of Agriculture, Morogoro, Tanzania.

[2]Department of Forest Resources Assessment and Management,
College of Forestry, Wildlife and Tourism

Sokoine University of Agriculture, Morogoro, Tanzania.

[3]Tanzania Forest Services Agency,
Ministry of Natural Resources and Tourism, Arusha Tanzania

[4]Institute of Continuing Education,
Sokoine University of Agriculture, Morogoro, Tanzania

*Corresponding author: *bernardol.manyanda@sua.ac.tz*

ABSTRACT

The scarcity of high-quality forage to animals is one of the major limiting factors to dairy productivity improvement in Lushoto District. This is attributed to soil fertility losses due to soil erosion, deforestation and the decrease or abandonment of the use of mineral fertilizer. The objective of the present study was to assess the Napier Agronomic response under Desmodium influence for dairy producers in Ubiri Village, Lushoto District. Two treatments were used; Desmodium and number of harvests established using Randomized Complete Block Design with three replications. Data collected included counting the number of tillers per bunch, measuring the height of tillers (m), leaf area indices and biomass yield (tha^{-1}) in each treatment in their respective replications. Data were analyzed by two-way analysis of variance in R software. The results show that, during the third harvest (28 weeks) Desmodium significantly ($P<0.05$) increased the tiller number, leaf area index (LAI) and the biomass yield (tha^{-1}) of the grasses by 41%, 76%, and 73% respectively. It was concluded that, Desmodium had positive influence on the agronomic performance of hybrid Napier grass. For sustainable provision of benefits to livestock keepers, we recommend that, integration of forage crops and Desmodium should be promoted.

Key words: Biomass - Desmodium legume – Harvest - Leaf Area index - Napier grass - Tiller

INTRODUCTION

Declining soil fertility and low macro-nutrient levels are fundamental obstructions to agricultural development in sub-Saharan Africa (Vanlauwe and Giller 2006). Apart from the primary effects of declining per capita food production, poor soil fertility triggers other side effects on-farm such as lack of fodder for livestock production. Finding the scientific and developmental innovations that can lead to sustainable livelihoods provision while minimizing declines in environmental services that characterize much of the region remains the biggest challenges for stakeholders and policy makers (Ajayi *et al.* 2007; Foley *et al.* 2011).

Tanzania accounts for around 1.4 % of the total global cattle population and 11 % of the total African cattle population (FAO 2014). Tanzania has nearly 30.5 million cattle, 18.8 million goats and 5.3 million sheep. Other livestock include 38.2 million local chicken and 36.6 million improved chickens (URT 2017). For sustainable contribution of Tanzania to the global cattle production, quality of feeds especially the forages need to be available.

In most developing countries, ruminant livestock keeping is thwarted by prolonged feed shortage (Devendra and Leng 2011). Animal performance including milk production and growth rates depend on the quality of feeds especially the forages available to the animal (More and Sollenburg 2004). Unfortunately, Tanzania like other sub-Saharan Africa countries, her smallholder livestock keepers rely on the native pastures and crop residues that are poor in quality and provide inadequate nutrients to grazing livestock (Franzel and Wambugu 2007). To improve milk and growth performance of animals, it is necessary to introduce and cultivate high-quality forages with high yielding potential (Hintsa 2006). Some of such forages are Napier grass (*Pennisetum purpureum*), Brachiaria (*Brachiaria Mulato* II) and various legumes including Desmodium (*Desmodium intortum*) and lablab species (*Lablab purpureus*) (Cook *et al.* 2005).

Forage grasses are commonly intercropped with legumes to produce high quantity of forage with more balanced nutrition for livestock feeding (Koc *et al*. 2013). Legumes increase soil nitrogen through their nitrogen fixation ranging from 32 to 115 $kgha^{-1}$ in symbiosis with rhizobium bacteria (Iannetta *et al.* 2016). This can in turn decrease subsequent fertilizer use for crops grown thereafter, a nitrogen reduction between 23 and 31 $kgha^{-1}$ (Preissel *et al.* 2015). Therefore, legume intercropping with grasses allow lower inputs through reduced fertilizer and pesticide requirements, and it contributes to a greater uptake of water and nutrients, increased soil conservation, increased efficiency of land use, enhancing the capture and use of light, controlling weeds, high productivity and profitability compared to mono cropping systems (Coll *et al*. 2012, Akman *et al.* 2013).

Napier grasses belong to the family Poaceae that comprises the Carbon 4 plants (C4-plants) (Ben 2013). C4-plants geographically adapt well in the tropical and semi tropical high light intensity, high temperature and dry conditions (Simpson 2010). On the other hand, Desmodium belongs to the family Fabeacea or Leguminosae, which is one of the plant families comprising the Carbon 3 plants (C3-plants) (Ben 2013). C3- plants are geographically adapted in temperate regions (cold environment) (Moore, 2003).

Various studies (Njunie *et al.* 2000; Mwangi *et al*. 2002, Tessema and Bears 2006, Diriba and Diriba 2013; Tessema and Feleke 2018) have been conducted to document the effect of legumes on the performance of fodder plant species under lowland climatic conditions. However, there is limited information about the effect of legumes on the performance of fodder plant species in mountainous region of Lushoto District Tanzania. This study aimed at assessing the growth response of the hybrid Napier grasses as influenced by Desmodium under undifferentiated rocky terrain agro-ecological condition of Lushoto District, Tanzania. The findings would contribute in filling the gaps of the effect of legumes on the performance of fodder plant species in mountainous region. Additionally, outcomes from this study would be deemed essential for enhancing intensive livestock farming in particular smallholder dairy farming in the study area and elsewhere with related climatic conditions.

MATERIALS AND METHODS

Study area

The present study was conducted in Ubiri Village, Lushoto District (Fig.1) from mid-November 2014 to end of June 2015. The site is situated between $4^0$49.44’ and $4^0$49.51’ latitudes south of equator and between $38^0$18.99' and $38^0$19.33' longitudes east of Greenwich and the mean elevation of 1199 m above sea level. The climate in Lushoto District is oceanic with bimodal rainfall, partly determined by their proximity to the Indian Ocean and the equator. Rainfall peaks in April and November. The mean annual rainfall maximum is 2,000 mm in the wettest areas, falling to less than 600 mm in the rain shadow areas (Lovett 1996). Temperatures are higher on the lower parts (25-27° C mean monthly) and lower on the plateau (13-18°C mean monthly). The minimum and maximum temperatures are 13°C and 27°C, respectively. Extreme temperatures (7°C during cold seasons and 30°C during hot seasons) have been recorded (Msuya and Kideghesho 2009). Moreover, the soil texture and type are sand clay loam and chromic acrisols respectively (Mwango *et al.* 2014). The plant population for Napier and Desmodium are 2500 and 5000 plants/ha respectively.

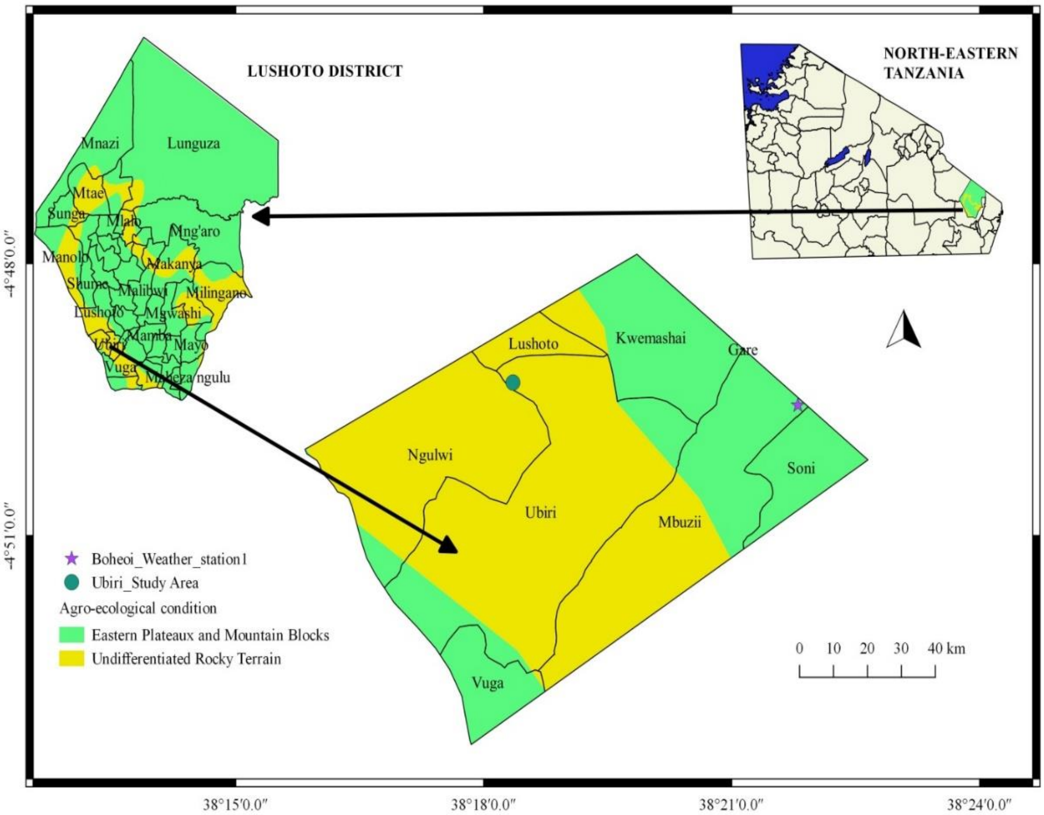

Figure 1: **The location of the study area in Ubiri ward, Lushoto District, Tanzania under respective agro-ecological condition. (Source: Own source)**

Data collection

After identifying the area where the experiment would be set, soil samples were taken using soil-sampling augur at a depth of 0-20 cm layer for its physical-chemical analysis. The physical properties of the area and their proportion in indicated in bracket were clay (60.094%), sand (27.8635%), silt (12.04048%), PH (6.52333), CEC (27.8229meq/100g) and bulk density (866kg/m^3). Likewise, the chemical properties and their amount in bracket were Bray P (3.81094mg/kg), Nitrogen (0.23189%) and Carbon (2.22411%).

The experiment was set from mid-November 2014 to end of June 2015. Before planting, the land was tilled by hand hoe followed by harrowing using a forked hoe. The first weed control was done three weeks after crop emergence. More weed controls were done to ensure that the field was weed-free. The data were collected during harvesting where the first harvest was done when the forage crops had the age of 16 weeks. The successive harvesting tasks were conducted at intervals of 6 weeks. The first and second harvesting phases involved Napier plants. Desmodium plants were harvested together with Napier grasses during the third harvest.

Samples were collected from the net plot (at the plot center) which consisted of eight bunches/clumps (had the area of 4 m x 2 m). Three bunches/clumps were randomly selected among the eight bunches in each plot and marked. Agronomic data were collected in the field trial which included tiller number, tiller height, leaf area index and dry matter yield. Additionally, height of the tallest, medium and the shortest tillers in three randomly selected bunches/ clumps were measured from the ground to the tip using tape measure (in cm). Furthermore, leaf area index parameters were measured by using an Accupar/Ceptometer. In each leaf, above photosynthetic active radiation reading was measured followed by five below successive (photosynthetic active radiations) readings diagonally in the five randomly selected bunches at the plot center. The measurements were repeated in each plot. All readings were taken when the sun was directly overhead (zero zenith angle).

On the other hand, all forage crops in the net plot (8 bunches) were harvested at the height of 10 cm from the ground level and tied together by using a rope and its bulk weight was measured using a beam balance. The forages were untied and the tillers were thoroughly mixed together. Five tillers were randomly selected, chopped and packed in the paper bags, and their fresh weights weighed using electronic weigh balance. All samples were then transported to laboratory of Tanzania Livestock Research Institute (TALIRI)-Tanga for laboratory work. In the laboratory, samples were introduced in the oven to obtain dry weight at 65 ^{0}C for 48 hours. The samples were removed from the oven and the weights of the dry samples in the paper bag were weighed by using the electronic weight balance.

Data analysis

Analyses were performed in R software (R. core team 2021). The average of the three tillers was calculated to get the bunch tiller height as follows.

$$\textit{The bunch tiller height } (m) = \frac{\textit{Tall tiller } (cm) + \textit{Medium tiller } (cm) + \textit{Short tiller } (cm)}{3*100} \quad (1)$$

The average tiller heights (in m) were calculated as:

$$\textit{The bunch tiller height} = \frac{\textit{1st bunch tiller} + \textit{2nd bunch tiller} + \textit{3rd bunch tiller}}{3} \quad (2)$$

Moreover, tiller numbers for the three randomly selected bunches in the net plot of each plot were counted. The average tiller number from three bunches was calculated to estimate the tiller number in the bunch of each forage variety.

$$\textit{Tiller number} = \frac{TN1 + TN2 + TN3}{3} \quad (3)$$

Where; TN1= Tiller no. for the 1st bunch, TN2= Tiller no. for the 2st bunch and TN3 = Tiller no. for the 3rd

On the other hand, fresh sample weights and dry sample weights were obtained by subtracting the paper bag weights as follows:

fsw = (fsw + pbw) – pbw (4)

dsw = (dsw + pbw) – pbw (5)

The dry matter (%) (DM) was then calculated by using the following formula

DM = (dsw/fsw) x 100 % (6)

Also, the Dry matter yield (DMY) was calculated by using the formula:

DMY = DM x bulk fresh weight (7)

Where; fsw = Fresh sample weight; dsw = Dry sample weight and pbw = Paper bag weight.

Differences in means were compared by using standard error of the mean. Data concerning the Desmodium and Harvest variables were subjected to analysis of variance according to the following statistical model:

$$Yijk = \mu + \tau i + \alpha j + (\alpha\tau)ij + \beta k + eijk \quad (8)$$

Where:

Yijk = A single observation from ith level of harvest; j[th] level of fertilizer and k[th] replications;
μ = Over all mean; τi = Effect of ith level of Harvest;
αj = effect of jth level of fertilizer;
(ατ)ij = Effect of ith level of harvest and jth level of fertilizer interaction;
Bk = Effect of kth replications and Eijk = Error

RESULTS AND DISCUSSION

The influence of Desmodium on the tiller heights of the hybrid Napier grass over the three successive harvests are shown in the Fig. 2. Results indicates that Desmodium integration had no significant effect (P>0.05) during the three growth cycles. Furthermore, the performance of the grass in terms of tiller heights reached the peak during the second harvest (22 weeks) but declined during the third harvest (28 weeks).

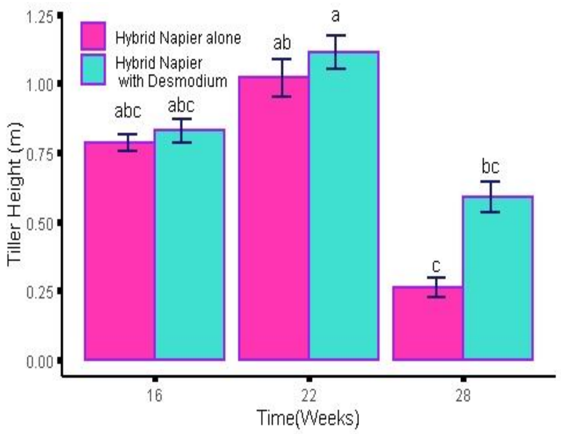

Figure 2: Tiller height of hybrid Napier grass as affected by Desmodium integration.

Note: Symbols with a combination of letters were significantly different (P<0.05) among treatments at each growth cycle by the LSD method at the 5% level.

Moreover, results on the influence of Desmodium on the tiller numbers of the hybrid Napier grass over the three successive harvests are shown in Fig. 3. The Desmodium integration had significantly improved the performance of tiller numbers by 41 % during the third harvest (28 weeks). However, the integration of Desmodium had no significant (P>0.05) increase in tiller numbers for the grass during the first and second harvests. The tiller numbers of the grass kept on increasing from the first harvest to the third harvest. The significant increase in tiller numbers per plant during the third harvest (22 weeks) was probably due to the nitrogen fixation of the root nodule of the legume which did not only favored the legumes but also the companion grass to increase tiller number per plant. These findings are consistent with the study of Menalu *et al.* 2019 who reported the significant increase in tiller numbers of Buffel grass when planted with Silver leaf Desmodium compared with the sole Buffel grass.

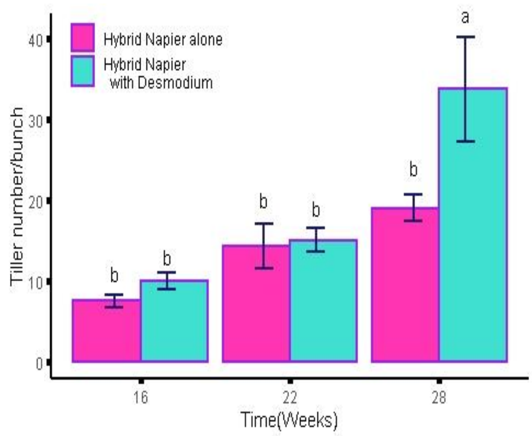

Figure 3: Tiller number of hybrid Napier grass as affected by Desmodium integration.

Note: Symbols with a single letter was not significantly different (P<0.05) among treatments at each growth cycle by the LSD method at the 5% level

On the other hand, Fig. 4 show results on the influence of Desmodium on the leaf area indices of the hybrid Napier grasses over the three successive harvests. Desmodium integration had significantly (P<0.05) improved the performance in terms of leaf area index by 76 % during the third harvest (28 weeks). However, the integration of

Desmodium had no significant increase in leaf area index for the grasses during the first (16 weeks) and second (22 weeks) harvests. LAI is mainly concerned with accumulation and partitioning of photosynthesis to the economic part of the plant. Additionally, it also has economic role in the final biomass yield of the crop (Afzal et al 2013). The significant upsurge in terms of LAI observed during the third harvest (22 weeks) was probably attributed by the sufficient soil moisture content that enhanced Desmodium root nodules exudation, nutrient release from dead roots, shade off plant leaves and the additive effect of the Desmodium biomass. The results from this experiment concur with those of (Arshad and Ranamukhaarachchi 2012 in Thailand who reported higher LAI in dry season when sweet sorghum was intercropped with Mung bean. However, (Ishiaku *et al.* 2016) reported the lower LAI for sorghum intercropped with lablab as compared to the sole cropping.

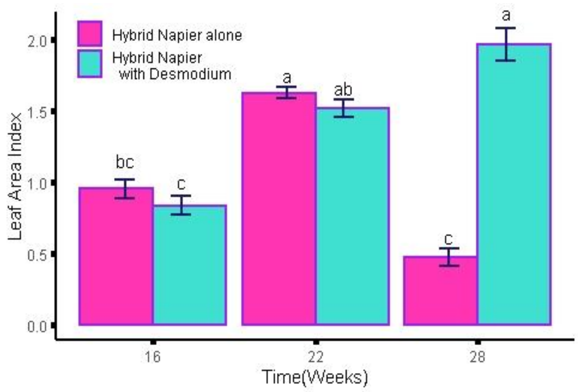

Figure 4: Leaf Area Index of hybrid Napier grass as affected by Desmodium integration.

Note: Symbols with combined letters were significantly different (P<0.05) among treatments at each growth cycle by the LSD method at the 5% level

In term of biomass yield (Fig. 5), Desmodium had significantly (P<0.05) increased the biomass yield of the hybrid Napier grasses by 73 % during the third harvest. However, the biomass yield of the grass was not affected by Desmodium integration during the first (16 weeks) and second (22 weeks) harvests. Moreover, the performance of the grass reached the peak during the second harvest and declined during the third harvest. The significant influence of Desmodium on the grass biomass during the third harvest (28 weeks) was probably due to sufficient soil moisture content which enhanced Desmodium root nodules exudation, nutrient release from dead roots, shade off plant leaves and the additive effect of the Desmodium biomass. These findings are in line with those of (Njunie *et al.* 2000) in a study of intercropping Cowpea with Napier grass in a coastal low land area of Kenya and found that the legumes benefited the grasses more when the rainfall was relatively high. Mwangi *et al.* 2002, cited in Rahman *et al.*, (2015) reported that the DM production increased from 20 to 25 and 27 $tha^{-1}yr^{-1}$ by integrating Axillaris (*Macrotyloma axillare*) and Greenleaf Desmodium (*Desmodium intortum* cv Greenleaf) respectively in Napier grass system in central Kenya. The results from the present study are in line with those of (Tessema and Bears 2006, Diriba and, Diriba 2013, Tessema and Feleke 2018) who reported that grass planted with the legume had higher dry matter yield than at the pure stand grass.

Furthermore, the influence of Desmodium on the agronomic performance of the hybrid Napier was not significant during the first (16 weeks) and second (22 weeks) harvests. However, during the third harvest (28 weeks) the Desmodium significantly improved the performance of hybrid Napier in dry matter yield. The delay of Desmodium to influence the performance of the grass might have been attributed to low soil moisture content that probably reduced the Desmodium root nodulation during the short rain season. Njunie *et al.* 2000 reported similar results when Cowpea was intercropped with Napier grass in a coastal low land area of Kenya. It was further found that the legumes benefited the grasses more when the rainfall was relatively high (Njunie *et al.* 2000). On the other hand, (Ndimbo *et al.* 2015) reported that the nodule numbers of beans were reduced with increase in moisture stress at all growth stages. was further found that the legumes benefited the grasses more when the rainfall was relatively high (Njunie *et al.*

2000). On the other hand, (Ndimbo *et al.* 2015) reported that the nodule numbers of beans were reduced with increase in moisture stress at all growth stages. However, the performance of the grass alone during the third harvest (28weeks) was observed to fall. This is probably due to unfavorably low temperature for the better agronomic performance of the grass (C4 plants). FAO (2015) reported that, the optimal temperatures for Napier growth are in the range 25 to 40^{oC} with annual rainfall of over 1500mm.

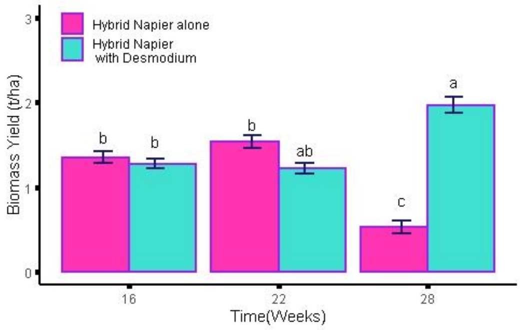

Figure 5: Biomass Yield of hybrid Napier grass as affected by Desmodium integration.

Note: Symbols with combined letters were significantly different (P<0.05) among treatments at each growth cycle by the LSD method at the 5 % level

On the other hand, (Duke 1983) reported that Napier grass stops growing below the temperature of 15^{oC} and is sensitive to frost, though it can regrow from the stolon if the soil is not frozen. The tall varieties cannot withstand frost, in contrast to the dwarf type that is frost tolerant (Legel 1990).

CONCLUSION AND RECOMMENDATIONS

The hybrid Napier grass performed better when in integration with Desmodium than when alone. Therefore, the integration with Desmodium improves the agronomic performance of grass. However, during the low temperature condition the agronomic performance of the grass fell. This study recommends the integrating of Desmodium and hybrid Napier grass by the smallholder livestock keepers of Lushoto District should be encouraged to maximize the production of the forages and therefore, the proper solution of animal feed shortage. Moreover, it recommends the new forage cultivars that are tolerant to low temperature condition for example dwarf Napier grass should be introduced to supplement animal feed shortage during cold weather condition. Additionally, it is recommended that hay or silage making technology should be synchronized to the weather condition.

REFERENCES

Afzal, M., Ahmad, A., Zamir, S., Khalid, F., Mohsin, A. & Gillani S. 2013. Performance of multicut forage sorghum under various sowing methods and nitrogen application rates. The Journal of Animal and Plant Sciences, 23(1): 232–239.

Ajayi O., Akinnifesi, F.K., Sileshi, G. & Chakeredza, S. 2007. Adoption of renewable soil fertility replenishment technologies in the southern African. Natural Resources Forum 31. 306–310.

Akman, H., Tamkoc, A. & Topal, A. 2013. Effects on yield, yellow berry and black point disease of fertilization applications in Hungarian vetch and durum wheat intercropping system. Digital Proceeding of the ICOEST' 2013, 18-21, June 2013, Turkey 839-847.

Arshad, M. & Ranamukhaarachchi, S. 2012. Effects of legume type, planting pattern and time of establishment on growth and yield of sweet sorghum-legume intercropping. Australian Journal of Crop Science, 6(8): 1265–1274.

Ben, B. 2013. Plant types: I. C3 plants, comparison with C4 and CAM plants. [http://www.cropsreview.com] accessed on 13rd May 2022.

Coll, L., Cerrudo, R., Rizzalli, J., Monzon, P. & Andrade, F.H. 2012. Capture and use of water and radiation in summer intercrops in the southeast Pampas of

Argentina. Field Crops Research, 134: 105–113.

Cook, B.G., Pengelly, B.C., Brown, S.D., Donnelly, J.L., Eagles, D.A., Franco, M.A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M. & Schultze-Kraft, R. 2005. Tropical forages. CSIRO, DPI&F (Qld), CIAT and ILRI, Brisbane, Australia, 120 - 125.

Devendra, C. & Leng, R. 2011. Feed resources for animals in Asia: issues, strategies for use, intensification and integration for increased productivity. Asian-Australasian Journal of Animal Science, 24: 303–321.

Diriba, D. & Diriba, G. 2013. Effects of seed proportion and planting pattern on dry matter yield, compatibility and nutritive value of Panicum coloratum and Stylosanthes guianensis mixtures under Bako Condition, Western Oromia, Ethiopia. Sci. Techn. Arts Res. J, 2(4): 56–61.

Duke, J.A. 1983. Handbook of Energy Crops. Purdue University, Center for New Crops and Plant Products. [www.hort.purdue.edu/newcrop/duke_energy/dukeindex.html] accessed on 1st April 2022.

FAO. 2014. Brachiaria ruziziensis - Germain and Everard. [http://www.fao.org/ag/agp/AGPC/doc/gbase/data/Pf000193.htm] accessed on 13rd April 2022

FAO. 2015. Grassland Index. A researchable catalogue of grass and forage legumes.

Foley, J., Ramankutty, N., Brauman, K.A., Cassidy E. & Gerber, J. 2011. Solutions for a cultivated planet. Nature, 478(5): 337 – 342.

Franzel, S. & Wambugu, C. 2007. The uptake of fodder shrubs among smallholders in East Africa: Key elements that facilitate widespread adoption. In: Hare, M.D. and Wongpichet, K (2007). (Editors). Proceedings of an International Symposium, Faculty of Agriculture. 9–12 May 2007, Ubon Ratchathani University, Thailand. pp 203 - 222.

Hintsa, H. 2006. The Effect of Improved Fodder Production on Livestock Productivity in Endamehoni District, Southern Tigray Ethiopia. MSc Thesis, Mekelle University, Ethiopia.201pp.

Iannetta, P., Young, M., Bachinger, J., Bergkvist, G., Doltra, J. & Lopez-Bellido, R. 2016. A comparative nitrogen balance and productivity analysis of legume and non-legume supported cropping systems: the potential role of biological nitrogen fixation. Plant Science 7:1700. Plant Science. https://doi.org/doi: 10.3389/fpls. 01700.

Ishiaku, Y., Hassan, M., Tanko, R., Amodu, J., Abdu, S., Ahmed, S.A. & Bello, S. 2016. Productivity of Columbus Grass (Sorghum almum) Intercrop with Lablab (Lablab purpureus) in Shika, Nigeria. Nigerian J. Anim. Sci 1, 215–229.

Koc, A., Erkovan, S., Erkovan, H., Birben, U. & Tunc, R. 2013. Competitive effects of plant species under different sowing ratios in some annual cereal and legume mixtures. Journal of Animal and Veterinary Advances, 12(4): 509-520.

Legel, S. 1990. Tropical forage legumes and grasses. Karl Max University, Berlin. 1990; 80p.

Lovett, J.C. 1996. Elevational and latitudinal changes in tree associations and diversity in the Eastern Arc Mountains of Tanzania. Journal of Tropical Ecology 2, 629-650.

Menalu, D., Awuk, B. & Asnakew, L. 2019. Evaluation of Agronomic performance and Biomass Yield of Buffel grass and Silver leaf desmodium Grown in Pure Stands and in Mixture At Different

Harvesting Times in Gozamen District, East Gojjam Zone, Ethiopia. Greener Journal of Agricultural Sciences, 9(4): 396–404.

Moore, R., Clark, W. & Vodopich, D. 2003. Botany (2nd ed). McGraw-Hill: Massachusetts:

More, J. E. & Sollenburg, L. 2004. Forage Quality. University of Florida 15–17

Msuya, T.S. & Kideghesho, J.R. 2009. The role of traditional management practices in enhancing sustainable use and conservation of medicinal plants in West Usambara Mountains, Tanzania. Tropical Conservation Science 2, 88- 105.

Mwangi, D. & Thorpe, W. 2002. The effect of establishing Desmodium intortum and Macrotyloma axillare from vines or seeds on dry matter yield of a Napier grass/legumes mixture. In: Mukisira, E. A., Kiriro, F. H., Wamuongo, J.W., Seresinhe, T. & Pathirana, K.K. (2000). Associate eff. Tropical Grasslands 34, 103–109.

Mwango, S.B., Msanya, B.M., Mtakwa, P.W., Kimaro, D.N., Deckers, J., Poesen, J., Massawe, V. & Bethuel, I. 2014. Root Properties of Plants Used for Soil Erosion Control in the Usambara Mountains, Tanzania. International Journal of Plant & Soil Science, 3(12): 1567-1580.

Ndimbo, M., Nchimbi-Msolla, S. & Semu, E. 2015. Effects of moisture stress levels at different growth stages on nodulation and nitrogen fixation in common bean (phaseolus vulgaris l.) Genotype. Asian Journal of Agriculture and Rural Development, 5(8): 187–201.

Njunie, M., Ramadhan, A. & Mureithi, J. 2000. Intercropping of forage legumes with maize and Napier grass for smallholder farmers in coastal Kenya. Participatory technology development for soil management by s (J. Mureithi, C. Mwendia, F. Muyekho, M. Onyango, and S. N. Maobe (Eds.). Publishing Company Inc.

Preissel, S., Reckling, M., Schläfke, N. & Zander, P. 2015. Magnitude and farm economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Research 175, 64–79.

R.Team core. 2021. R: A language and environment for statistical computing. R Founddation for Statistical Computing. http://www.r-project.org/.

Simpson, M. 2010. Plant Systematics (2nd ed). Elviser Inc.

Tessema, Z. & Bears, R. 2006. Chemical Composition and dry matter production and yield dynamics of tropical grasses mixed with perennial forage legumes. Trop. Grasslands 40, 150–156.

Tessema, Z. and Feleke, B. 2018. Yield, yield dynamics and nutritional quality of grass-legume mixed pasture. The J. Anim. Plant Sci, 28(1): 2018.

URT. 2017. Tanzania Livestock Master Plan 2017/2018-2021/2022.

Vanlauwe, B. & Giller, K.E. 2006. Popular myths around soil fertility management in sub-Saharan Africa. Agricultural Ecosystem and Environment 116, 34–46.