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ARTICLE

Productivity of *Tithonia diversifolia* under Edaphoclimatic Conditions of Eastern Cuba

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ABSTRACT

Livestock in the tropics is characterized by the use of production systems based on low quality pastures, *Tithonia diversifolia*; due to its productive potential and adequate nutritional value, stands as an alternative for the supplementation of grazing animals. With the objective of evaluating the productive behavior of *T. diversifolia* according to the climate and soil conditions of the eastern region of Cuba. For which, an experimental design was used in randomized blocks, where the cutoff moments (60, 90, 120, 150 and 180 days) were established as treatments. Total, edible and dry matter biomass were determined; the effect of plant age on these indicators was taken into account. For the statistical processing, the influence of the cutting times on the yields was taken into account, for this regression, equations were obtained (linear, quadratic, cubic, logarithmic and gompertz) and where the descending method was taken into account for its selection. The results showed that the productive indicators increased with forage maturity, with the highest values at 180 days (46.18 $t.ha^{-1}$ of green forage; 10.96 $t.ha^{-1}$ of dry forage), for the period of least rainfall. Total forage and dry forage production; in the case of edible biomass, it was better in the dry period (16.20 $t.ha^{-1}$), and linear, quadratic and cubic functions were fitted with R2 values greater than 0.90 in both climatic phases. Foliage maturity has a marked effect on its productivity, but with a similar response in each seasonal period but different specific values.

1. Introduction

In the Latin American region there is a greater number of tree and shrub species at the international level. Hence, it is expresses in a greater number of plant species in surface area. Therefore, although this variety of species

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exists, production systems have tended to use a reduced number of trees and legumes. What is accentuate in forage trees, which are not useD correctly in livestock production. The animal production methods used in the tropics, the sustainability of these is largely due to the use of different local biological resources as an alternative for feeding non-ruminant species [1].

This concept calls for expanding the use of the diversity of species as providers of large volumes of food for the animal. Given the diversity of forage species, there is an urgent need to study and recommend promising species for sustainable livestock ecosystems and for biomass production [2].

Among the strategies to increase production efficiency, reduce dependence on external inputs, and improve the profitability of livestock systems, methods have been investigate to improve the use of available forage resources, as well as evaluations and validations of materials with high forage potential, usable on farms, with adequate nutritional value and low production costs [3]. These efforts are aligned with objective number 12 of sustainable development; propose by the United Nations Organization, which establishes that sustainable consumption and production are based on the efficient use of resources and the promotion of lifestyles sustainable living [4].

The Tithonia diversifolia known as buttercup is recognized as a useful plant to incorporate nutrients into the soil, mainly for its use incorporated directly into the soil in the form of organic matter. Plant that helps to improve and protect the land from loss of the arable layer due to runoff [5].

These have adequate adaptation to a wide variety of edaphoclimatic conditions and tolerate acid conditions. It is also a species with good biomass production capacity, fast growing with low demand for inputs, and does not require a considerable amount of cultural activities for its management. It has important nutritional characteristics that allow it to be considered as a species with potential in animal feed. There are also reports on its use in other countries to attract beneficial insects to crops, as an antiparasitic for animals, and as straw for bedding in livestock and green manure in crops; this last use is the most widespread [6].

In livestock it is used for fencing, for its flowers for honey production, for some diseases and in systems with trees for cattle. In addition, it is used for cutting and carrying, in the form of meal and pellet in the feeding of non-ruminant species. It has nutritional characteristics to be used in the production system [6].

Due to its high yield in biomass and dry matter, this shrub is classified as a prominent species for silvopastoral systems, hence the need to deepen the knowledge and scientific results of its adaptability and productive response in Cuba [7].

Given the above, the objective of this study is to determine the correspondence between the cutting period and the yield components under climate and soil conditions in Granma province, Cuba.

2. Materials and Methods

2.1 Study Site and Edaphoclimatic Conditions

The research was carried out in areas of the University of Granma dedicated to investigative studies, it is located southeast in Cuba, in Bayamo, 17.5 km away from the city of Manzanillo in Granma Province. The tests were made in the periods of 2014-2015, in the seasons of the year, rainy (May-October) and dry (November-April).

In a brown carbonate soil [8], the study was carried out, which presented in terms of nutrients (P_2O_5, K_2O and N) 2.4 mg.100g^{-1}, 33.42 mg.100g^{-1} and 3 mg.100g^{-1} of soil and pH of 6.2. As well as, with 3.6% OM.

During the rainy period, the climate behaved as follows: rainfall (731.4 mm); average, minimum and maximum temperature and relative humidity (26.73 °C, 22.31 °C and 33.92 °C and 80.78%, 51.02% and 96.22%). For the dry: rainfall (270 mm); 24.05 °C, 18.29 °C and 31.58 °C (average, minimum and maximum temperature) and 76.21%, 44.16% and 97.03% (mean, minimum and maximum relative humidity).

2.2 Experimental Design and Treatments

The treatments were cutting ages of 60, 90, 120, 150 and 180 days, for which a randomized block design and four repetitions were followed.

2.3 Area Management and Sampling

With two years of establishment and 98% coverage of the area of the plots, at the beginning of each season (rainy and dry); an equalization cut was made at a height of 15 cm. For the sampling, 10 plants were taken by rows, discarding the first and the last; to counteract the edge effect. The collected plant material was mixed to obtain a homogeneous sample. Then proceeded to separate for each treatment whole plant and its fractions (leaves, stems with dimensions less than 2 mm). With which, by weighing this material, the productions in total foliage, edible, dry matter were established. To determine the percentages of dry matter, for each treatment and repetition of which 2 kg^{-1} were selected. Irrigation and fertilization were not used in the study period.

2.4 Statistical Analyzes

To establish the dependency of forage production on the cutting periods, regression analysis (linear, quadratic, cubic, logarithmic and Gompertz) was performed to select the expression with the best fit, the following criteria were followed (high coefficients of regression, high significance of the expression and the parameters, analysis of variance of the regression and the lowest standard error [9–11]. The statistical program SPSS version 22 was used.

3. Results

Total foliage production increased up to 180 days in *Tithonia diversifolia* (in 46.18 t.ha^{-1} and 44.20 t.ha^{-1} of green matter at 180 days, in the rainy and dry seasons. Quadratic and cubic models were obtains for each climatic period (Figure 1).

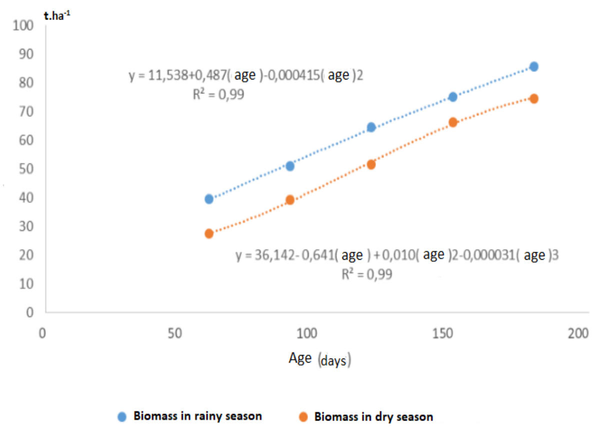

Figure 1. Total foliage production of *Tithonia diversifolia* in the rainy and dry season

The production of edible green foliage in Tithonia diversifolia (Figure 2) in the rain increased by 2.94 t.ha^{-1} of green matter at 120 days, during the dry it rose by 10.96 t.ha^{-1} up to 180 days, where for quadratic equations were selected for both climatic seasons.

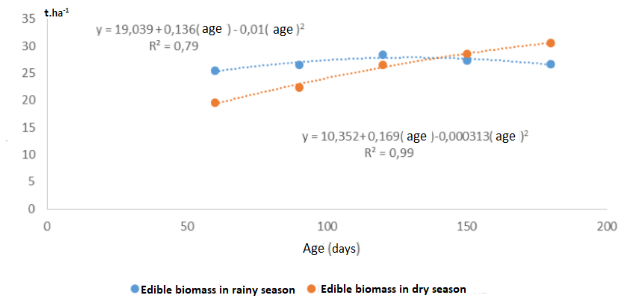

Figure 2. Production of edible green foliage of *Tithonia diversifolia* in the rainy and dry seasons

There were significant differences for P<0.001, with increases of 16.09 t.ha^{-1} and 15.93 t.ha^{-1} for the production of matter, at 180 days after the homogeneity cut and reporting linear models for rainy and dry (Figure 3).

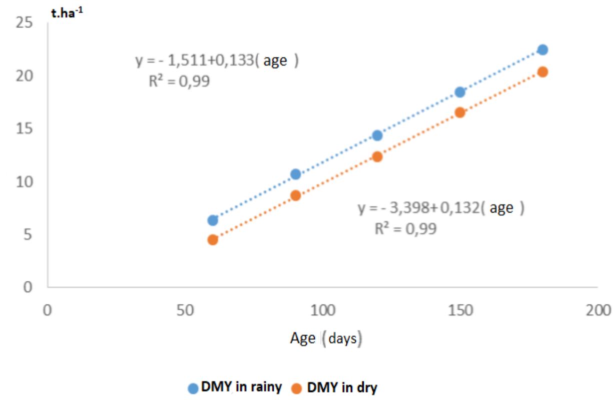

Figure 3. Dry matter production of *Tithonia diversifolia* in the rainy and dry season

4. Discussion

Yield indicators (integral green forage, usable and dry matter) experienced increases with foliage maturity (Figures 1, 2 and 3). Response attributable to the effect exerted on the plant by the management of the meadow, climate and soil conditions, aspects that allow increases in growth and development and greater accumulation of dry matter; product to greater deposition of structural carbohydrates. More accentuated behavior during the rainy season [12].

The forage dry matter production increased with the maturity of the forage material and the appearance of a greater number of stems. When evaluating the production potential of *T. diversifolia* [13], they reported that climate factors have an effect on the amount of biomass in tree species where high temperatures and rainfall make it possible to increase it, while the decrease in these climatological indicators favors low yields and poor plant growth.

The values reached in the current investigation are similar to those obtained [7,14]; who when studying the effect of forage maturity on yield found a direct relationship between both. Behavior that is due to the fact that, with age there is an appearance of a greater amount of support tissue and an increase in the woody fraction in the edible foliage. This has repercussions on the widening of the cell wall of the plant and consequently a decrease in the soluble content of nutrients in the cell, changes that are more notable during the period of greatest rainfall. Hence in studies on the productivity of *T. diversifolia* in the context of soil and climate of the eastern region of Cuba, which obtained a decrease in edible green forage of 0.5

$t.ha^{-1}$ in the rain in 60 days. In the present investigation there was a decrease of 1.77 $t.ha^{-1}$, the marked decrease is due to the variable and adverse climate and soil conditions of the Valle of Cauto in Cuba [15].

In Tithonia diversifolia [16], when using different amounts of plants per square meter and cutting heights and their effect on yields, where with 2.66 $plants.m^2$, no marked differences were found and 82 $t.ha^{-1}$, 57 $t.ha^{-1}$ and 46 $t.ha^{-1}$ were reported.. They reported the highest productions of usable forage in Leucaena from 3808 $kg.ha^{-1}$ to 3885 $kg.ha^{-1}$ at 90 days of regrowth. Therefore, this is an indicator of great importance for the management of this and other species; since the edible biomass (non-lignified leaves-stem) in the forage trees with maturity shows a tendency to decrease [17].

In studies of the influence of the cutting period obtained the best productions at 84 days with 2 $t.ha^{-1}$ and 0.90 $t.ha^{-1}$ of dry matter for the rainy and dry seasons. What is attributed to the soil effect and the prevailing climate in each region, hence the differences found between this study and the current one, since the higher yields were 10 $t.ha^{-1}$ and 7 $t.ha^{-1}$ of dry matter in each one of the times [18].

In study reported 138.3 $t.ha.year^{-1}$ of total biomass (17.7 $t.ha.cut^{-1}$, 8.20 $t.ha.cut^{-1}$ and 8.87 $t.ha.cut^{-1}$, for whole plant, leaves and stems) and 25.5 $t.ha.year^{-1}$ of dry matter (3.15 $t.ha.cut^{-1}$, 1.55 $t.ha.cut^{-1}$ and 1.88 $t.ha.cut^{-1}$, for integral plant, leaves and stems). Those who stated that forage production is determined by multiple factors, such as; climatic conditions prior to cutting, planting density, fertilization, physicochemical conditions of the soil and the recovery time of the bushes where production per cut is higher the larger. There is a recovery time; but the production per year tends to be lower with longer recovery times, because the plants have fewer cuts per year. Likewise, digestible biomass is reduced by the lignification suffered by plants, affecting the material that can be used by animals. They concluded that, despite water restriction and high temperatures, *T. diversifolia* produced forage under these extreme conditions, showing potential to improve feeding systems in critical periods, where grass species tend to be more vulnerable to climatic conditions extreme [19] .

The plantation framework is one of the aspects that determine the productivity of this species, since its behavior during establishment, as well as the characteristics that the propagation material must have in order to achieve rapid and effective development, can cause yields to fluctuate. In this sense when evaluating the influence of the planting frame on the productivity of Tithonia, found yield increases as the planting frame was extend with the highest results for 1 m^2 (13.52 $t.ha^{-1}$); this is due to the fact that in the smaller plantation frames stems of the plants grow vertically and only develop foliage in the crown; unlike the 1x1 m; in which the plants had a greater number of stems and they present leaves from base, behavior in response to competition for vital space, light and water; which is establish between plant [20].

In studies where the estimated production per $ha.year^{-1}$, productions were reached that went from 31.075 kg^{-1} of fresh matter to 147.408 kg^{-1}, show the importance of fertilization in crop management, which found correlation values between biomass production on a fresh basis and fertilization levels of N, P_2O_5 and K_2O of 90.3%, 90.5% and 90.9%, respectively; demonstrating the impact of each of the elements on biomass production [21].

When studying the combination during sowing of the stem section and the way of depositing the seed in the furrow of *T. diversifolia*. They found that the best results for yields were for the middle part of the stem, either deposited horizontally or vertical in the rainy and dry seasons, with 10.49 t/ha^{-1} and 3.04 t/ha^{-1} of dry matter; respectively. Those who attribute this result to the fact that the cuttings in the center of the stem have a greater number of buds than the basal cuttings, that aspects, that influence and increase the possibilities of sprouting. Since the reserve substances present in these, together with those of the new shoots and leaves in formation and growth, increase photosynthetic activity, as well as the production of endogenous auxins that enable the formation of calluses and their radical differentiation. This suggests that the sections of the stems at the base have greater lignification and a lower number of leaves and buds, which limits the obtaining of better results [22].

For his part, states that the foregoing, together with the effect of the physiological age of stem sections, could contribute to the difference between treatments. As *Tithonia diversifolia* is an erect-growing species, most of the plant material old is located in the lower strata (basal), where the metabolic activity of the plant and the synthesis of enzymes and proteins is lower, which could influence the mobilization of reserve substances. During the aging process, different biochemical and physiological changes occur, among which a significant reduction in the contents of chlorophylls, proteins and starch stand out. This fact could have negatively influenced the germination of the stem buds and, therefore, the development of the basal section was less than that of the middle [23].

This species is a forager par excellence and the biomass produced by *Tithonia diversifolia* varies between 30 $t.ha^{-1}$ and 70 $t.ha^{-1}$ of green forage depending on planting density, soil type, vegetative state and environmental conditions. In crops established on soils with phosphorus deficiency, fertilization with 50 kg^{-1} of this element per hectare increases the dry matter produced from stems and leaves from 7.4 $t.ha^{-1}$ to 9.3 $t.ha^{-1}$ and from 1 $t.ha^{-1}$ to 12 $t.ha^{-1}$ [24].

The biomass productivity of *Tithonia diversifolia*, observed that for the first cut of the harvest 120 days after sowing, an average of 3.4 kg^{-1} of leaves, stems and flowers is reached per plant. Yields in fresh forage in good humidity and fertility conditions are 2.6 $kg.plant^{-1}$ every 60 days. In plantations cultivated at a distance of 50 × 75 cm, 1.3 kg^{-1} of forage per plant were obtained every 49 days. At a distance of 0.75 × 1 m, the yield increases up to tow $kg.plant^{-1}$ in the same cutting periods mentioned above. This response is due to the fact that due to its characteristics and its high degree of plasticity ecological. Being able to be found from sea level to 2500 meters above sea level, with annual rainfall between 800 mm to 5000 mm and in different types of soil; it tolerates conditions of acidity, of low fertility and grows spontaneously on the banks of paths, rivers and highways. Its forage potential is directly linked to its tolerance to pruning and its ability to regrow, an effect that allows a large amount of biomass to be obtained per unit area [25].

When evaluating the usefulness of *Tithonia diversifolia* in increasing biomass production and the effect on soil fertility in 3 treatments: 1) cultivation of Tithonia diversifolia, 2) cultivation of Tithonia diversifolia + guinea grass, 3) cultivation of guinea grass. It was found that soil fertility measured through the Bio-test method was higher in treatment 2, presenting a higher biomass production for corn grown in the soil taken from the plots planted only with Tithonia diversifolia and improving the composition soil chemistry 6 months after establishment. Additionally, Tithonia diversifolia reduces the effects of animal trampling on the soil, offers high biomass production and is reported as an ideal forage to be used in cut-and-carry systems for dairy production [26].

When evaluating the effect of fertilization, on biomass production, they observed that a significant increase was shown with the increase in fertilization levels, going from average productions of 79.9 g^{-1} of dry matter (DM) in plants without fertilization at 50 days up to productions of 304.5 g^{-1} in plants with urea application. In the estimated production per hectare/year, productions were obtained that went from 31.075 kg^{-1} of fresh matter to 147.408 kg^{-1}. Here the importance of fertilization in crop management is evidenced, correlation values were found between biomass production on a fresh basis and fertilization levels of N, P_2O_5 and K_2O of 90.3%, 90.5% and 90.9%; respectively demonstrating the impact of each of the elements on biomass production for its importance in animal production [21].

5. Conclusions

Foliage maturity has a marked effect on its productivity, but with a similar response in each seasonal period but different specific values.

Author contributions

M. Paumier-Zayas (20%), R.C. Herrera-Herrera (15%), E.O. Toapamta-Mendoza (15%), D.A. González-Aguilera (15%), D.M. Verdecia-Acosta (15%), R.S. Herrera (10%), J.L. Ramírez-de la Ribera (10%).

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Verdecia, D.M., Herrera, R.S., Ramírez, J.L., et al., 2018. Yield components, chemical characterization and polyphenolic profile of *Tithonia diversifolia* in Valle of Cauto, Cuba. Cuban Journal of Agricultural Science. 52(4), 457-471.

[2] Herrera, R.S., Verdecia, D.M., Ramírez, J.L., et al., 2017. Relation between some climatic factors and the chemical composition of *Tithonia diversifolia*. Cuban Journal of Agricultural Science. 51(2), 271-279.

[3] Canu, F.A., Audia, I., Tobar, D., et al., 2018. Low Carbon Development Strategy (LCDS) for the livestock sector in Nicaragua. Copenhague: UNEP DTU Partnership.

[4] Meira-Cartea, P.Á., 2015. From the millennium development goals to the goals for sustainable development: the socially controversial role of environmental education. Social education. Journal of Socio-educational Intervention. 61, 58-73.

[5] Crespo, G., Ruiz, T.E., Alvarez, J., 2011. Effect of green manure from Tithonia (*T. diversifolia*) on the establishment and forage production of *P. purpureum* cv. CT–169 and some soil properties. Cuban Journal of Agricultural Science. 45(1), 79-82. http://cjascience.com/index.php/CJAS/article/view/191.

[6] Mahecha, E., Rosales, M., 2005. Nutritional value of buttercup foliage (*Tithonia diversifolia* (Helmsl.)

Gray, in animal production in the tropics. Livestock Research for Rural Development. 17. http://www.lrrd.org/lrrd17/9/mahe17100.htm.

[7] Ruiz, T.E., Febles, G.J., Galindo, J.L., et al., 2014. Tithonia diversifolia, its possibilities in livestock systems. Cuban Journal of Agricultural Sciences. 48(1), 79-82. http://cjascience.com/index.php/CJAS/issue/view/26.

[8] Soil Survey Staff, 2014. Keys to soil taxonomy, 12th ed. United States Department of Agriculture Natural Resources Conservation Service, Washington, United States. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/taxonomy/?cid=nrcs142p2_053580.

[9] Keviste, A., Álvarez, J.G., Rojo, A., et al., 2002. Application growth functions in the forestry field. Ministry of Science and Technology. Institute of Agricultural and Food Research and Technology. Madrid. Spain. INIA Monographs. http://cat.inist.fr/?aModele=afficheN&cpsidt=14522559.

[10] Guerra, C., Cabrera, A., Fernández, L., 2003. Criteria for the selection of statistical models in scientific research. Cuban Journal Agricultural Sciences. 37(1), 3–10. https://www.redalyc.org/pdf/1930/193018072001.pdf.

[11] Torres, V., Ortiz, J., 2005. Application of modelling and simulation to the production and feeding of farm animals. Cuban Journal of Agricultural Science. 39, 397-405. https://www.redalyc.org/pdf/613/61346406.pdf.

[12] Verdecia, D.M., Ramirez, J.L., Bodas, R., et al., 2011. Productive yield and chemical composition of the forage shrub Tithonia diversifolia in an area of the Cauto Valley, Cuba. In: Pastures, cultural landscapes between tradition and new paradigms of the 21st century (eds. C. López, M.P. Rodríguez, A. San Miguel, F. Fernández and S. Roig), Spanish Society for the Study of Pastures, Madrid. Spain. pp. 613-618.

[13] Ríos, C.I., 1999. *Tithonia diversifolia* (Hemsl.) Gray, a plant with potential for sustainable production in the tropics. Sánchez MD, Rosales M. (Eds.) Agroforestry for Animal Production in Latin America. FAO Animal Production and Health Study No. 143. FAO, Rome. Italy. 311-325.

[14] Mahecha, L., Escobar, J.P., Suárez, J.F., et al., 2007. *Tithonia diversifolia* (hemsl.) Gray (golden button) as a forage supplement for F1 cows (Holstein for Zebu). Livestock Research for Rural Development. 19. http://www.lrrd.org/lrrd19/2/mahe19016.

[15] Sanchez, T., Lamela, L., Lopez, O., 2007. Characterization of the plant community in an association of improved grasses and *Leucaena leucocephala* cv. Cunningham. Pasture and Forage. 30(4), 455-467. http://scielo.sld.cu/pdf/pyf/v30n4/pyf05407.pdf.

[16] Mendoza, H., Tzec, G.S., Solario, F., 2000. Effect of regrowth frequencies on the production and quality of the foliage of the “Ramón” tree (*Brosimum alicastrum* Swartz). Livestock Research for Rural Development. 12(4), 1–12. https://www.feedipedia.org/sites/default/files/public/mendoza-castillo_2000.pdf.

[17] Simon, L., Hernández, I., Ojeda, F., 1998. Role of trees in silvopastoral systems. In: Trees in livestock. Volume I. Silvopastoralism. Simon L (Ed.). EEPF “Indio Hatuey”. Matanzas, Cuba. pp. 28.

[18] Sosa, E.E., Cabrera, E., Pérez, D., et al., 2008. Seasonal production of dry matter of forage grasses and legumes with cutting in the state of Quintana Roo. Téc Pecu Méx. 46(4), 413-426. https://www.redalyc.org/pdf/613/61346406.pdf.

[19] Navas, A., Montaña, V., 2019. Behavior of *Tithonia diversifolia* under tropical humid forest conditions. Revista De Investigaciones Veterinarias Del Peru. 30(2), 721-732.
DOI: http://dx.doi.org/10.15381/rivep.v30i2.15066

[20] Carrillo-Mestre, R., Betancourt-Bagué, T., Toral-Pérez, O.C., et al., 2016. Influence of different plantation frameworks on the establishment and production of *Tithonia diversifolia*. Pasture and Forage. 39(2), 89-93.

[21] Botero-Lodoño, J.M., Gómez-Carabalí, A., Botero-Lodoño, M.A., 2019. Yield, agronomic parameters and nutritional quality of *Tithonia diversifolia* based on different levels of fertilization. Revista Mexicana de Ciencias Pecuarias. 10(3), 789-800.
DOI: https://doi.org/10.22319/rmcp.v10i3.4667

[22] González, D., Ruiz, T.E., Díaz, H., 2013. Stem section and planting method: its effect on the biomass production of *Tithonia diversifolia.* Cuban Journal of Agricultural Science. 47(4), 425-429. https://www.redalyc.org/pdf/1930/193029815017.pdf.

[23] Gómez-Gurrola, A., Del Sol-García, G., Sanginés-García, A., et al., 2017. Carcass yield of hair lambs fed different proportions of *Tithonia diversifolia* and *Pennisetum spp.* Veterinary Fan. 7(2), 34-42.

http://www.scielo.org.mx/pdf/av/v7n2/2448-6132-av-7-02-00034.pdf.

[24] González-Castillo, Habm von-Hesberg, C.M., Narváez-Solarte, W., 2014. Botanical characteristics of *Tithonia diversifolia* (Asterales: Asteraceae) and its use in animal feed. Boletín Científico Centro de Museos Museode Historian. 18(2), 45-58. http://www.scielo.org.co/pdf/bccm/v18n2/v18n2a04.pdf.

[25] Polo, E.A., Medina, L.T., 2021. Effect of cutting frequency on yield and forage quality of buttercup (*Tithonia diversifolia*). Eastern Seed Journal. 2(1), 59-69. https://revistas.up.ac.pa/index.php/semilla_este/article/download/2467/2252/.

[26] Londoño, J., Mahecha, L., Angulo, J., 2019. Agronomic performance and nutritional value of *Tithonia diversifolia* (Hemsl.) A Gray for cattle feeding. Colombian Journal of Animal Science. 11(1), 1–14. DOI: https://doi.org/10.24188/recia.v0.n0.2019.693ç