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CHIPILÍN BIOMASS PRODUCTION OF *Crotalaria longirostrata* Hook & Arn UNDER DIFFERENT FORMULATIONS OF FERTILIZATION AND SOLAR RADIATION LEVELS

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ABSTRACT

Chipilín is a shrub species that grows wild in the tropical areas of Mexico and whose crude protein content is 31%. It is linked to food culture, mainly of the rural population. It is frequently found associated among tropical crops. Despite the fact that it is a plant genetic resource appreciated by rural families, its use continues to depend essentially on its natural reproduction and collection, perhaps because almost everything about the agronomic management of the plant is unknown. The objective of this work was to study the growth response and production of foliar biomass of *Crotalaria longirostrata* supplying different fertilization formulations (N, P and K) and different levels of solar radiation. A 3 x 3 factorial experiment was carried out, in a completely randomized design. The formulations were 45-30-26, 17-00-00 and 00-00-00, and the radiation levels were 50%, 65% and 100%, resulting in 9 treatments with 8 repetitions; and as an experimental unit a pot with a plant was considered. The results indicate significant differences ($p < 0.05$) between formulations, and solar radiation levels for all the variables considered, such as basal stem diameter, number of lateral branches, dry biomass of stem, leaf and root. In all cases the formulation 45-30-26 turned out to be better, for example at 100 days the amount of dry leaf biomass was 17.5 grams per plant, while with the formulations of 17-00-00 and 00-00 -00 was 6.0 and 3.5 grams per plant respectively. In the case of solar radiation, 15.0, 8.0 and 3.0 grams were obtained for 100%, 65% and 50% respectively. Therefore it is concluded that the best formulation and percentage of solar radiation for the production of Crotalaria longirostrata is 45-30-26 with 100% solar radiation, and that the amount of total fresh biomass that a plant can produce depends on the basal diameter of its stem.

Key words: *Phytogenetic resource, formulation, solar radiation, dry biomass*.

INTRODUCTION

Globally, plant genetic resources for food and agriculture are being lost at an unprecedented rate. Since the beginning of this century, around 75% of the genetic diversity of agricultural crops has been lost (FAO, 2016). Tropical forests are falling at a rate of just under 1% per year (Shelef *et al*, 2017) and only about 150 of an estimated 30,000 edible plant species are cultivated, and of these few species, genetic diversity has decreased even in the number of varieties marketed (Shelef *et al*, 2018; Sethi, 2015). At the same time, research is primarily focused on improving the productivity of some species of cash crops, rather than increasing crop diversity (Shand, 2000). This represents a serious loss of agrobiodiversity and the erosion of genetic diversity, leading to a food industry more susceptible to factors associated with global climate change (Sethi, 2015). Therefore, incorporating new local foods and species is a way to diversify food and income for local communities that depend on agriculture. In particular, adapting local communities to climate change will be essential for food security and poverty reduction (FAO, 2016).

Mexico is within the Mesoamerican region, considered one of the most important centers of origin and genetic diversity in the world (CONABIO, 2020; Jiménez *et al*, 2014), for which it has plant genetic resources with high nutritional and nutritional value, aspect that has been addressed by different investigations where it is shown that wild plants have a high content of nutritive elements compared to various commercial crops (Solís 2014). One of these species is the chipilín (*Crotalaria longirostrata*), which is a shrub plant that grows wild in the tropical areas of our country and whose crude protein content is 31%, high content of fiber, minerals and vitamins. (Laguna, 2016). Furthermore, it is an important food in the diet of the rural population that lives in the Mexican, Honduran and Salvadoran tropics. In the state of Tabasco and Chiapas, it is common to find the chipilín associated between tropical crops and the milpa because it is strongly linked to the culinary and food culture of the population (Maldonado, 2016; Mascorro, 2017) for being an accompaniment to food or dishes regional, such as: chipilín tamales, chipilín soup, stew with chipilín, “mondongo” and green pochitoque, to name a few. Currently, despite the fact that it is a plant genetic resource widely appreciated by rural families, its use continues to depend essentially on its natural reproduction and collection (Greenberg, 2015), the above, perhaps because almost everything is unknown in relation to management. agronomic of the plant. On the other hand, the productivity of the plants depends to a great extent on an adequate nutrition. When plant roots find nutrient availability and absorb in sufficient quantities the elements they need to perform their physiological functions, they can express their maximum potential for growth and production (Toledo, 2016). Soil is the main container of nutrients for plants; however, in most of the times, the nutrient contents are not sufficient, so it is necessary to apply fertilizers and other remedies that allow increasing soil fertility. It was considered to evaluate the effect of N, as a fundamental part of the formulations, because the high temperatures that occur in the area decrease the nitrogen content, due to the increase in the mineralization speed of organic matter, appearing simple compounds that are easily leached (Paredes, 2013). Also because the main purpose is to produce the largest amount of chipilin foliar biomass, since it is the usable part for feeding. Although legumes live in symbiosis with atmospheric nitrogen fixing bacteria, they are not enough in the case of Crotalaria longirostrata, because they only provide less than 50% of the nitrogen required by the plant, even when inoculation is carried out directly (Camarillo and Mangan 2020). Another essential element for plants to adequately carry out their physiological functions is solar radiation, since the process of photosynthesis through which it produces carbohydrates, a fundamental product for their growth and other functions, depends primarily on it. physiological. Possibly, by supplying the primary nutrients, it is possible to increase the biomass production of the chipilín, because its demand cannot be supplied by natural fertility, since tropical soils in general have low to low fertility (Molina and Meléndez, 2001). And due to its growth habit and since its requirement for solar radiation is unknown, it allows us to suppose that the management of radiation is a fundamental factor for the chipilín to have a good growth and therefore, a greater accumulation of foliar biomass. Therefore, the present study consisted of evaluating different fertilization doses and levels of solar radiation, in order to find the condition that allows obtaining good growth and the greatest accumulation of leaf biomass of the chipilin, thus contributing to the generation process of knowledge on the agronomic management of the plant, whose information will be useful for small producers who wish to adopt the technology and for its future use as a commercial crop.

MATERIAL AND METHODS

The research was carried out during the period from January to May 2015, in the Experimental Field of the UACh Southwest Regional University Unit, in Teapa, Tabasco Mexico. It is located between the coordinates 17 ° 15 ’and 17 ° 45’ north latitude, and 90 ° 38 ’and 93 ° 46’ west longitude. The predominant climate according to the Köppen classification modified by García (1988) is the Af (i ’) g; warm humid with rain all year. The total annual precipitation is 3,945 mm with an annual average temperature of 26°C.

Chipilín seeds were collected from the plots of small producers in the region. These were previously treated with hot water (98^{o}C) to promote germination and were then placed in Petri dishes with wet towels. Once germinated and with 1.0 cm of radicle, two seedlings per black nursery pot were deposited with a capacity of 10 liters of soil. According to the chemical analysis of the soil, this has a pH of 5.0, 7% of organic matter, high content of nitrogen (0.32%), low content of phosphorus and potassium with 5.34 mg kg-1 and 0.06 µmol kg-1 respectively.

A full 3 x 3 factorial experiment was established in a completely randomized design. The levels of solar radiation were 100, 65 and 50% and the fertilization formulations were 45-30-26, 17-00-00 and 00-00-00, resulting in 9 treatments with 8 repetitions; and as an experimental unit a pot with a plant was considered.

The maximum and minimum photosynthetically active radiation on a sunny day in March for the different percentages of solar radiation were: 100% =2145 and 494 $\mu mol \cdot m^{-2} \cdot s^{-1}$, 65%= 1245 and 281 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 50%= 825 and 192 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

To establish radiation levels, shade mesh covers with different shading percentages were constructed. Fertilization formulations were determined based on the rational methodology proposed by Rodríguez (1993), and using alfalfa (*Medicago sativa*) as a reference crop because it is a legume species with characteristics similar to *Crotalaria longirostrata*.

Statistical analysis was carried out with analysis of variance, Tukey's multiple comparisons test and simple linear regression.

RESULTS AND DISCUSSION

Table 1 shows the behavior over time of the production of dry and fresh leaf, stem and root biomass, as well as the basal diameter of the stem and the number of lateral branches of *Crotalaria longirostrata* subjected to different treatments. The results indicate significant differences ($p < 0.05$) between treatments for all the variables considered. In general, the best results were obtained with treatment 1 (100% solar radiation and fertilization formula 45-30-26) where the values of dry biomass at 110 days after sowing were 13.5, 26.4 and 15.3 g per plant for leaf, stem and root respectively, followed by treatment 4, with 9.9, 23.9 and 12.1 g per plant, while the worst treatments were 8 and 9, having a dry matter of 2.0, 2.6 and 1.0 g per plant for leaf, stem and root respectively. This is because, on the one hand, N is an essential element for the growth and development of plants, as it plays a fundamental role in the biochemical and physiological functions of the plant, participating in the production of chlorophyll, for the photosynthesis process, in addition to being part of several proteins that catalyze and regulate plant growth processes (Leghari et al 2016; Muñoz et al, 2013). For its part, P, helps cell division, as well as in the formation and development of roots and stems (Ocampo et al, 2012) and K, plays a role in load balance, osmotic adjustments and activation enzyme in plant cells (Wakeel et al, 2016).

In Figures 1 and 2, the effect of different levels of solar radiation and different fertilization formulations can be observed with greater precision, where the 45-30-26 formulation turned out to be better, for example at 100 days the amount of biomass Leaf dry was 17.5 grams per plant, while with the formulations of 17-00-00 and 00-00-00 it was 6.0 and 3.5 grams per plant respectively. For the percentages of solar radiation, 15.0, 8.0 and 3.0 grams were obtained for 100%, 65% and 50% respectively.

Table 1. Biomass production, basal stem diameter and number of lateral branches of *Crotalaria longirostrata*, at three levels of solar radiation and three fertilization formulations in the humid tropics of Mexico.

Factor A	Factor B	Dry leaf biomass (g)			Fresh leaf biomass (g)			Dry stem biomass (g)			Fresh stem biomass (g)		
		50	80	110	50	80	110	50	80	110	50	80	110
a1	b1	1.9 a	12.2 a	13.5 a	8. 0 a	56.8 a	76.8 a	1.0 a	11.2 a	26.4 a	5.6 a	68.0 a	87.1 a
	Sx̄	± 0.03	± 1.0	± 0.9	± 0.59	± 1.58	± 2.55	± 0.13	± 0.7	± 1.33	± 0.1	± 1.62	± 2.25
	b2	0.3 c	2.6 c	9.6 b	1.1 b	15.9 d	57.3 b	0.2 c	1.3 b	22.6 b	0.5 c	11.8 c	65.0 b
	Sx̄	± 0.02	± 0.3	± 1.0	± 0.05	± 1.16	± 4.11	± 0.01	± 0.1	± 0.99	± 0.04	± 0.67	± 2.23
	b3	0.1 d	0.4 d	4.6 c	0.6 b	24.7 c	29.7 c	0.1 c	0.4 b	8.1 c	0.2 cd	3.1 d	19.0 c
	Sx̄	± 0.03	± 0.02	± 0.25	± 0.12	± 0.55	± 1.325	± 0.01	± 0.04	± 0.7	± 0.03	± 0.5	± 1.97
a2	b1	1.4 b	9.1 b	9.9 b	6.6 a	46.3 b	56.2 b	0.6 b	10.0 a	23.9 ab	4.6 b	44.7 b	85.5 a
	Sx̄	± 0.05	± 0.55	± 1.03	± 1.07	± 1.93	± 1.86	± 0.11	± 0.72	± 1.11	± 0.1	± 4.38	± 4.11
	b2	0.1 d	0.4 d	1.8 d	0.6 b	7.8 e	10.6 de	0.1 c	0.5 b	3.8 d	0.2 cd	1.4 d	12.9 cd
	Sx̄	± 0.02	± 0.02	± 0.13	± 0.07	± 0.27	± 0.8	± 0.01	± 0.05	± 0.18	± 0.3	± 0.1	± 0.22
	b3	0.1 d	0.5 d	2.5 cd	0.4 b	3.5 ef	12.3 de	0.1 c	0.5 b	3.3 d	0.1 d	1.7 d	11.6 cd
	Sx̄	± 0.03	± 0.08	± 0.28	± 0.09	± 0.33	± 0.59	± 0.02	± 0.02	± 0.18	± 0.04	± 0.21	± 0.84
a3	b1	0.1 d	0.6 d	1.8 d	0.5 b	4.0 ef	14.6 d	0.1 c	0.5 b	3.3 d	0.2 cd	2.8 d	12.5 cd
	Sx̄	± 0.02	± 0.05	± 0.18	± 0.08	± 0.28	± 0.56	± 0.01	± 0.05	± 0.18	± 0.04	± 0.17	± 0.68
	b2	0.1 d	0.3 d	2.0 cd	0.3 b	1.8 f	10.6 de	0.1 c	0.4 b	2.6 d	0.1 d	0.9 d	10.0 cd
	Sx̄	± 0.02	± 0.05	± 0.15	± 0.13	± 0.05	± 0.65	± 0.01	± 0.04	± 0.23	± 0.15	± 0.12	± 1.17
	b3	0.1 d	0.4 d	1.2d	0.3 b	2.8 f	5.3 e	0.1 c	0.3 b	1.5 d	0.11 d	1.1 d	6.6 d
	Sx̄	± 0.03	± 0.02	± 0.3	± 0.11	± 0.43	± 0.5	± 0.01	± 0.06	± 0.22	± 0.05	± 0.15	± 0.76

Continuation……

Factor A	Factor B	Dry root biomass (g)	Fresh root biomass (g)	Basal diameter (mm)			Number of lateral branches		
		110	110	50	80	110	50	80	110
a1	b1	15.3 a	82.3 a	6.0 a	12.9 a	19.8 a	15.5 a	5.5 abc	6.0 b
	Sx̄	± 0.91	± 3.02	± 0.15	± 0.98	± 1.18	± 1.9	± 0.3	± 0
	b2	5.2 c	30.0 c	2.3 c	5.8 b	11.2 b	0 b	7.8 a	8.0 a
	Sx̄	± 0.36	± 0.5	± 0.15	± 0.3	± 0.6	± 0	± 0.3	± 0.4
	b3	2.4 d	15.8 d	2.1 c	3.6 bc	8.1 c	0 b	6.3 ab	7.3 ab
	Sx̄	± 0.21	± 1.58	± 0.12	± 0.32	± 0.65	± 0	± 1.0	± 0.6
a2	b1	12.1 b	50.0 b	5.2 b	11.4 a	13.6 b	12.3 a	6.0 ab	5.8 b
	Sx̄	± 0.86	± 1.9	± 0.16	± 0.91	± 0.88	± 1.9	± 0.4	± 0.5
	b2	0.8 d	4.7 ef	1.8 c	3.7 bc	7.3 c	0 b	5.3 bcd	6.5 ab
	Sx̄	± 0.06	± 0.36	± 0.11	± 0.08	± 0.42	± 0	± 0.3	± 0.3
	b3	0.6 d	2.7 f	1.9 c	3.6 bc	5.7 cd	0 b	5.8 ab	7.3 ab
	Sx̄	± 0.1	± 0.3	± 0.1	± 0.12	± 0.28	± 0	± 0.3	± 0.3
a3	b1	1.5 d	9.9 de	2.1 c	4.0 bc	5.7 cd	0 b	4.0 bcd	5.5 bc
	Sx̄	± 0.2	± 0.65	± 0.13	± 0.26	± 0.38	± 0	± 0.7	± 0.3
	b2	1.0 d	6.6 ef	1.8 c	3.2 c	5.4 cd	0 b	3.3 cd	3.8 cd
	Sx̄	± 0.18	± 1.05	± 0.14	± 0.32	± 0.35	± 0	± 0.3	± 0.5
	b3	0.8 d	5.9 ef	1.9 c	2.7 c	4.2 d	0 b	3.0 d	3.5 d
	Sx̄	± 0.14	± 0.63	± 0.19	±0.21	± 0.2	± 0	± 0.4	± 0.3

Mean values with different letter indicate statistical difference ($P < 0.05$) according to Tukey's multiple range test.
Factor A: Levels solar radiation (a1=100%, a2=65% and a3=50%)
Factor B: Fertilization formulaciones NPK (b1=45-30-26, b2=17-00-00 and b3=00-00-00)
Days after planting: 50, 80 and 100
Treatments: T1=a1b1, T2=a1b2, T3=a1b3, T4=a2b1, T5=a2b2, T6=a2b3, T7=aa3b1, T8=a3b2, T9=a3b3

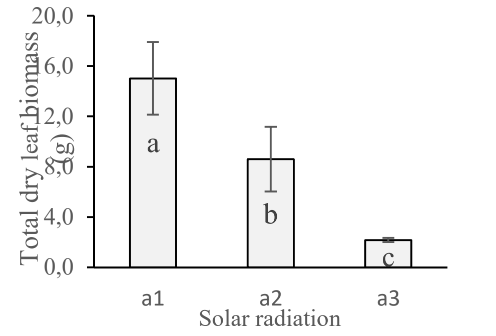

Figure 1. Total dry leaf biomass under different levels of solar radiation

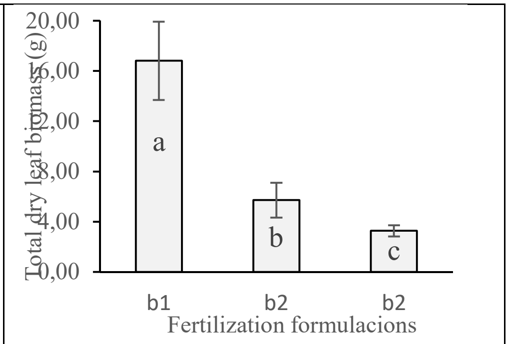

Figure 2. Total dry leaf biomass under different fertilization formulations

Figures 3 and 4 show the behavior of the interaction ($P < 0.05$) between the levels of solar radiation and the different fertilization formulations in the variables total fresh biomass of leaf and total fresh biomass of stem. What is observed is that under 100% solar radiation, the effect of the fertilization formulations is very different on the amount of total biomass that is produced, while at 50% solar radiation, the formulations have an almost similar in biomass production. Exactly the same is true for the production of total fresh stem biomass. This means that the effect of the fertilization formulations on the growth and productivity variables of *Crotalaria longirostrata* will depend on the percentage of solar radiation.

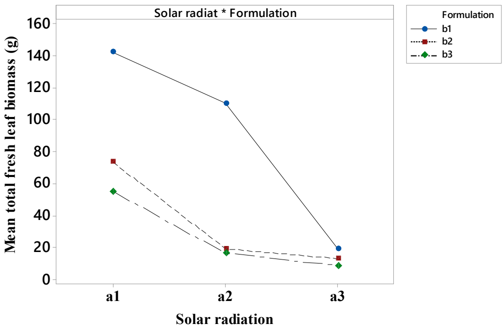

Figure 3. Interaction of solar radiation levels and fertilization formulations for the variable total fresh leaf biomass.

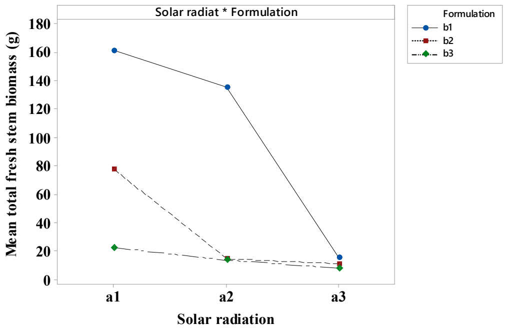

Figure 4. Interaction of solar radiation levels and fertilization formulations for the variable total fresh stem biomass.

In figure 5 a marked linear trend is observed since the dependent variable of fresh total leaf biomass increases as the variable basal stem diameter increases. This is confirmed by the regression equation, where the slope turns out to be 1.813, demonstrating that the basal stem diameter is a variable directly correlated with the biomass production of the aerial part of the *Crotalaria longirostrata* plant. The validation of the model is significant with $r^2 = 0.98$, which indicates an explained variation rate of 98%. This result will allow estimating the biomass productivity of the plant, knowing the basal diameter of the stem, without having to destroy the plant.

$$\hat{Y} = -7.422 + 1.813X \qquad r^2 = 0.98$$

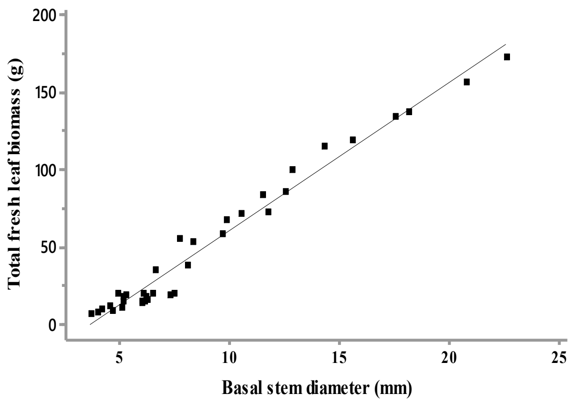

Figure 5. Linear regression line of the total fresh leaf biomass as a function of the basal stem diameter of *Crotalaria longirostrata.*

CONCLUSIONS

The *Crotalaria longirostrata* plant exposed to 100% solar radiation and a fertilization formula containing the three macronutrients turned out to be the best conditions for a greater production of dry and fresh biomass in leaf, stem and root. Similarly for the basal stem diameter and number of lateral branches. The amount of fresh leaf biomass depends on the basal stem diameter.

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