AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Yield, intercepted radiation, and morphology of crotalaria (*Crotalaria juncea* L.) at different densities

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ABSTRACT

Objective: The objective of this study was to evaluate the yield, intercepted radiation, and morphology of crotalaria (*Crotalaria juncea* L.) at different planting densities, in the dry tropics of the state of Guerrero, Mexico.

Design/Methodology/Approach: The treatments were four planting densities: 400,000, 200,000, 100,000 plants ha^{-1} and overseed. Additionally, a growth analysis was carried out at 30, 38, 45, 52, 60, 68, and 75 days of growth, after the pod was fully developed. The following variables were evaluated: dry matter yield, intercepted radiation, and morphology composition.

Results: Regardless of the cutting age, the dry matter was recorded in the following descending order: 400,000 > overseed > 200,000 > 100,000 plants ha^{-1} planting densities, with 19,837, 17,918, 8,786, and 4,074 kg DM ha^{-1}, respectively.

Study Limitations/Implications: In order to improve livestock feeding in the tropics, the perspective of the producers about the use of pulses as forage must be broadened.

Findings/Conclusions: A 400,000 crotalaria plants ha^{-1} planting density and cuts after 45 days of growth are recommended. During this period, the meadow reaches its optimal structural characteristics, while the intercepted radiation reaches 95%.

Keywords: Pulses, intercepted radiation, yield, plant density.

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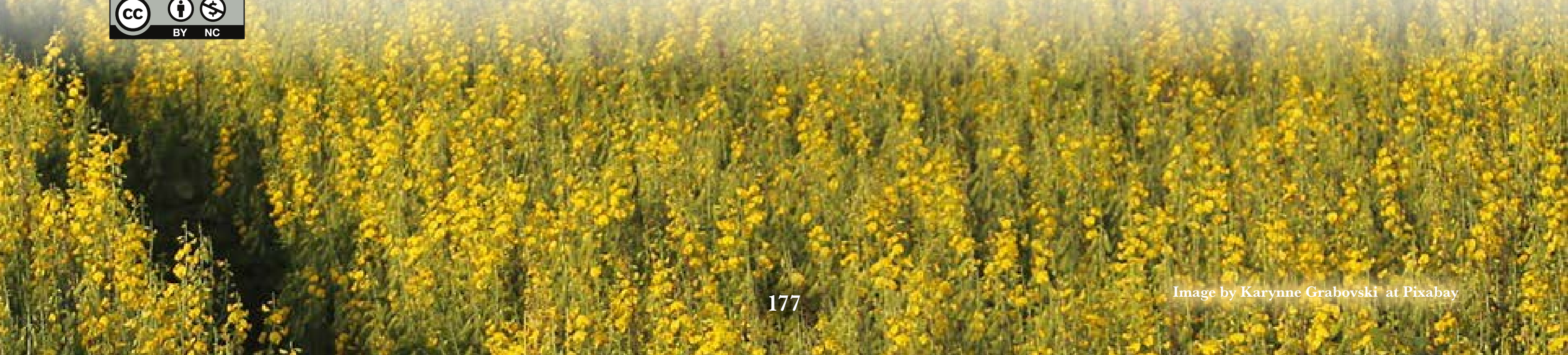
INTRODUCTION

In the livestock-raising regions of the state of Guerrero, ruminant production is carried out under an extensive system and feeding is based on stubble and native grasses with little nutrient content. This type of feeding reduces the weight and number of animals and, consequently, the profits of the producers. In view of this situation, the option is to use cutting and annual species, which can be transformed into flour or silage and can be used as supplement during the dry season (Tui *et al.*, 2015; Castro *et al.*, 2017). Including pulses in the ruminant diets increases the nutrition value of the feed; additionally, this



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type of plants has been proven to be beneficial to the environment (Douxchamps *et al.*, 2014). For instance, they are used in the recovery of degraded soil (as coverage, green manure, or environmental nitrogen fixators), reducing greenhouse gasses (McSorley, 2001; Prudhomme *et al.*, 2017).

Crotolaria (*Crotalaria juncea* L.) is an annual species, native to India, which belongs to the family Fabaceae. Genus *Crotalaria* is made up of 350 species; they develop and grow in humid and dry tropics (Santana and Ascencio, 2011). Several studies about the production condition of this species mention that it produces high dry matter yields (5.0-12.5 t ha^{-1}) (Akanvou *et al.*, 2001; Jiménez *et al.*, 2005; Li and Stoffellia, 2002). Additionally, this pulse is an excellent green manure and vegetal coverage (Almeida-Santos *et al.*, 2019). Its presence in the soil increases the nutrient content and yield of different species (mainly grasses) which grow in association or rotation (Lemaire *et al.*, 2014; Muraoka *et al.*, 2002). There is a relationship between the phenological state and the physical quality and nutrition parameters in vegetable species. If they produce a large quantity of leaves, they have a higher quality. However, when the size and number of stems increase, the quality diminishes (Lemaire, 2001). Yield can be the opposite of quality. In late stages, yield is higher, but quality is lower. Determining the seasonal distribution of yield involves a search for balance between quantity and quality of forage species (Castro *et al.*, 2012; Matthew *et al.*, 2001). Therefore, the objective of this study was to evaluate the yield, intercepted radiation, and morphology of crotalaria (*Crotalaria juncea* L.) at different planting densities and age of the plant, in the dry tropics of the state of Guerrero, Mexico.

MATERIALS AND METHODS

Experimental plot location

The study was carried out from July to October 2020, in an experimental plot in Tecuescontitlán, Tepecuacuilco de Trujano, Guerrero, Mexico (18° 08' N and −99° 33' W, a 782 m.a.s.l). The climate is subhumid warm with summer rains (790 mm annual average rainfall) and a 26 °C average temperature (García, 2004). The soil has a 7.3 pH, 0.3 dS m^{-1}, and 2.1 % organic matter. Figure 1 shows the maximum, medium, and minimum temperatures, as well as the weekly rainfall accumulation during the study period. The data were obtained from the weather station 12,092, located in Tonalapa del Sur, 51 km away from the experimental plot.

Plot management

The experimental plot was established on July 30, 2020, during the rainy season. The land was prepared with traditional techniques (fallow, two harrows, and furrow). Sixteen experimental units made up of 5×5 m plots —randomly distributed and with 3 repetitions— were used. Four planting densities (treatments) were evaluated. The seeds were sown by hand, placing them in the furrows, at a depth that doubled the size of the seed. The distance between furrows was 50 cm and the distance between plants was 5, 10, and 20 cm, resulting in 400,000, 200,000, 100,000 plants ha^{-1} per each distance. For its part, control was overseed (approximately 380,000 plants ha^{-1}). No irrigation or fertilizers were used, and weed was controlled by hand. From the 30 days after the emergence,

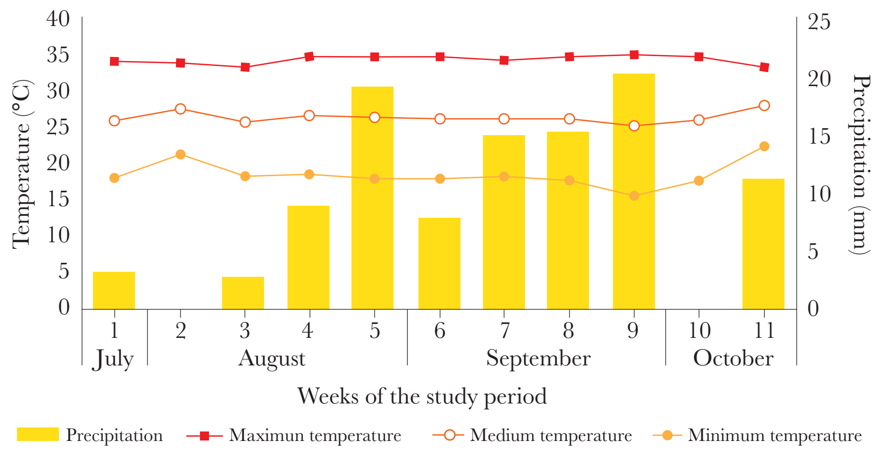

Figure 1. Maximum, medium, and minimum temperatures and weekly rainfall accumulation recorded during the experiment.

samplings were carried out at 8-day intervals, until the plants reached their reproductive stage and had fully developed seeds.

Evaluated variables

Dry matter yield

The 1-m linear method was used to carry out randomly destructive samplings on the experimental units and control in order to establish dry matter (DM) forage (kg ha^{-1}) yield. Forage was harvested 10 cm above ground level. Subsequently, it was weighted and put in paper bags. It was dried at 60 °C in a forced-air electrical stove until it reached a constant weight.

Intercepted radiation

In order to measure intercepted radiation, a day before the cutting, five random instant readings of each repetition were made. The length (cm) of shadow cast by the canopy were measured using a 100 cm rule. It was placed on the surface of the soil, between the furrows (under the canopy), at approximately 1:00 pm.

Morphology composition

In order to determine the morphology composition, a ≈20% subsample was taken from the forage yield sample. This subsample was divided into its morphology components: stem, leaf, flower, and pods (leaflet + seeds). Each component was weighted, put in paper bags, and dried in an electric stove at 60 °C, until they reached a constant weight.

Statistical analysis

The data was analyzed using a completely randomized design with an arrangement comprised of divided plots and four repetitions. The PROC GLM of SAS 9.2 (2009) procedure was used and the means comparison was carried out with a Tukey test (α=0.05). Simple polynomic regressions were carried out in order to compare intercepted radiation and the leaf component. The significance correlation coefficients ($p<0.05$) were calculated, and an analysis of variance and a means comparison test (Tukey $p<0.05$) were also carried out.

RESULTS AND DISCUSSION

Dry matter yield

Table 1 shows the dry matter yield of crotalaria when the planting density and the cutting age change. Regardless of the cutting age, the average behavior of this variable was recorded in the following descending order: 400,000 > overseed > 200,000 > 100,000 plants ha^{-1} planting densities, with 19,837, 17,918, 8,786, and 4,074 kg DM ha^{-1}, respectively ($p<0.05$). Regarding the cutting age, the highest dry matter yield (28,363 kg ha^{-1}) was obtained at 75 days, while the lowest was obtained at 30 days (527 kg ha^{-1}); planting densities ($p<0.05$) were not considered.

In this and other studies, dry matter (DM) yield varies at different planting densities and depends on the interspecific competition (mainly for nutrients and light). Santos *et al.* (2011) and Mosjidis *et al.* (2013) determined that crotalaria has a 15,831-10,000 kg ha^{-1} yield. Jiménez *et al.* (2005) pointed out that the yield depends on the sowing season, the management, the planting densities, and climatic conditions (mainly rainfall and temperature).

Intercepted radiation

Intercepted radiation is a measure studied in grasses and pulses, which establishes the optimal harvest time when a 95% radiation is obtained. Therefore, during the evaluation of pulses (specifically crotalaria), the highest values of intercepted radiation (>93%) were observed at 45 days in the 400,000, 200,000 plants ha^{-1}, and overseed planting densities ($p<0.05$) (Table 2). A lower intercepted radiation ($p<0.05$) was obtained at the ages of 30, 38, 52, 60, 68, and 75, in all the planting densities evaluated.

Maldonado-Peralta *et al.* (2019) and Rojas-García *et al.* (2018) pointed out that the optimal harvesting moment is when the meadow has a 95% intercepted radiation. Rojas-García *et al.* (2017) and Rojas *et al.* (2016) confirmed that this is the appropriate value for harvesting or grazing pulses by themselves or associated pulses, respectively. This is the result of the quality and quantity attributes of the forage. The development of crotalaria

Table 1. Forage yield (kg ha^{-1}) of crotalaria, at different planting densities and cutting age.

Density (plants ha^{-1})	Age at cut (days after the emergency)							Average
	30	38	45	52	60	68	75	
400,000	680 ^{Ag}	3,424 ^{Af}	7,762 ^{Be}	16,411 ^{Ad}	29,497 ^{Ac}	37,810 ^{Ab}	43,278 ^{Aa}	19,837 ^{A}
200,000	482 ^{BCf}	2,016 ^{Bef}	3,551 ^{Ce}	7,448 ^{Bd}	11,603 ^{Cc}	16,086 ^{Cb}	20,317 ^{Ba}	8,786 ^{C}
100,000	399 ^{Ce}	1,052 ^{Cde}	2,162 ^{Dcd}	3,354 ^{Cc}	4,982 ^{Db}	7,718 ^{Da}	8,856 ^{Ca}	4,074 ^{D}
Overseed	549 ^{Bg}	3,686 ^{Af}	8,992 ^{Ae}	16,354 ^{Ad}	22,449 ^{Bc}	32,393 ^{Bb}	41,004 ^{Aa}	17,918 ^{B}
Average	527 ^{g}	2,544 ^{f}	5,616 ^{e}	10,871 ^{d}	17,132 ^{c}	23,501 ^{b}	28,363 ^{a}	

Means with the same lower-case letter in the same row (^{abcd}) and capital letters (^{ABCD}) in the same column are not statistically different (Tukey: $\alpha=0.05$).

Table 2. Intercepted radiation (%) of crotalaria, at different planting densities and cutting age.

Density (plants ha^{-1})	Age at cut (days after the emergency)							Average
	30	38	45	52	60	68	75	
400,000	24^{Be}	55^{Ad}	95^{Aa}	82^{Ab}	69^{Ac}	58^{Ad}	58^{ABd}	63^{A}
200,000	29^{Af}	49^{Be}	93^{Aa}	76^{ABb}	69^{Ac}	60^{Ad}	58^{ABd}	62^{B}
100,000	27^{ABe}	49^{Bd}	88^{Ba}	74^{Bb}	69^{Ab}	59^{Ac}	59^{Ac}	60^{D}
Overseed	24^{Be}	53^{ABd}	93^{Aa}	80^{ABb}	70^{Ac}	53^{Bd}	54^{Bd}	61^{C}
Average	26^{e}	52^{d}	92^{a}	78^{b}	69^{c}	58^{d}	57^{d}	

Means with the same lower-case letter in the same row (^{abcd}) and capital letters (^{ABCD}) in the same column are not statistically different (Tukey: α=0.05).

crops at 45 days had a better coverage. This was an efficient crop, because it spreads its canopy during the initial growth, increasing the coverage and the interception of light. In this study, the 400,000, 200,000 plants ha^{-1} and overseed planting densities obtained 95, 93, and 93% radiation, respectively. However, this was not the case with the 100,000 plants ha^{-1} density, which only reached 88% radiation. These results do not match the results of Jiménez *et al.* (2005), who evaluated a 172,000 plants ha^{-1} planting density and found 97% intercepted radiation.

Morphology composition

Table 3 shows the morphology composition of crotalaria in different planting densities and cutting age. A higher proportion of leaves was found during the first days of the evaluation. Regardless of the planting density, the proportion was higher at day 30 (62%) and lower at day 75 (15%) after the emergence ($p>0.05$). At day 30, 100,000 and 200,000 plants ha^{-1} planting densities recorded the highest number of leaves at the beginning of the research (66% and 62%, respectively). However, at day 75, both planting densities also had the lowest number of leaves during the last cut (10% and 14%, respectively). Regardless of the densities, the highest stem percentage was recorded at day 52, obtaining a 75% average. The lowest percentage was recorded at day 30 of their development, obtaining a 37% stem average ($p<0.05$). Flowers appeared after 52 days, in the 200,000 plants ha^{-1} (3.1%) and the overseed (0.6%) planting densities; these percentages increased up to day 75 (4.8 and 3.9%, respectively). However, the 400,000 and 100,000 plants ha^{-1} planting densities recorded the highest flower percentage ($p<0.05$) (7.2 and 6.6%, respectively) at the cutting (75 days). Meanwhile, crotalaria pods appeared 14 days after the flowers (day 68). The highest percentage of pods (22.1%) was recorded at day 75 ($p<0.05$) in the 200,000 plants ha^{-1} density. On this regard, Oliveira *et al.* (2020) mentioned that planting density is a determining factor of the morphology composition of crotalaria. They also pointed out that if density increases, the biomass increases, but pod production diminishes. This phenomenon was not observed in this research, because pod production started 75 days after the emergence. Therefore, statistical differences between the highest and the lowest evaluated densities were not recorded. In this regard, Abdul-Baki *et al.* (2001) pointed out that the morphology composition is determined by the vegetative development cycle, because, at the beginning of the development, leaves have a higher percentage. This percentage diminishes over time, as stems, flowers, and pods start to grow, as we reported in this research.

Intercepted radiation regression (%) of leaves (%)

Figure 2 shows the regression coefficients (R^2) between the intercepted radiation (%) and the leaves (%), when the different planting densities change. Overall, all the regressions had a polynomial trend and a high relationship. The highest relationship took place in the 400,000 plants ha^{-1} density with a 0.898 ($p<0.001$) R^2, obtaining 95% of intercepted radiation, 45 days after the emergence, with 32% of leaves. However, overseed planting density recorded the lowest relationship with a 0.629 ($p<0.05$) R^2, reaching a maximum intercepted radiation of 93%, 45 days after the emergence, with 28% of leaves. Meanwhile, in a research about alfalfa, Teixeira *et al.* (2007) evaluated the frequency and intensity of grazing and reported a 95% maximum intercepted radiation, as a result of a greater leaf area (3.6).

Table 3. Morphology composition (%) of crotalaria, at different planting densities and cutting age.

Density (plants ha^{-1})	Age at cut (days after the emergency)							Average
	30	38	45	52	60	68	75	
				Leaf				
400,000	56 ^{Ba}	45 ^{Ab}	32 ^{ABc}	30 ^{Ac}	21 ^{Bd}	20 ^{Bd}	18 ^{Ad}	32 ^{B}
200,000	62 ^{ABa}	44 ^{Ab}	30 ^{ABc}	25 ^{Bc}	24 ^{Ac}	23 ^{Ac}	14 ^{ABd}	32 ^{B}
100,000	66 ^{Aa}	42 ^{ABb}	40 ^{Abc}	31 ^{Acd}	23 ^{ABde}	20 ^{Be}	10 ^{Bf}	33 ^{A}
Overseed	64 ^{Aa}	40 ^{Bb}	28 ^{Bc}	26 ^{Bcd}	24 ^{Acd}	23 ^{Acd}	18 ^{Ad}	32 ^{B}
Average	62 ^{a}	43 ^{b}	33 ^{c}	28 ^{d}	23 ^{e}	22 ^{e}	15 ^{f}	
				Stem				
400,000	43 ^{Ad}	54 ^{Bc}	67 ^{ABb}	76 ^{Aa}	76 ^{Aa}	75 ^{Aa}	68 ^{Aab}	65 ^{A}
200,000	37 ^{ABc}	55 ^{Bb}	69 ^{ABa}	74 ^{Ba}	74 ^{Ba}	71 ^{Ba}	58 ^{Bb}	62 ^{B}
100,000	33 ^{Be}	57 ^{ABd}	59 ^{Bcd}	75 ^{Aab}	75 ^{Aab}	77 ^{Aa}	76 ^{Aa}	64 ^{AB}
Overseed	35 ^{Bc}	59 ^{Ab}	71 ^{Aa}	74 ^{Ba}	74 ^{Ba}	72 ^{Ba}	68 ^{Aab}	65 ^{A}
Average	37 ^{d}	56 ^{c}	67 ^{b}	75 ^{a}	75 ^{a}	74 ^{a}	68 ^{b}	
				Flower				
400,000	--	--	--	1.4 ^{Bc}	1.4 ^{Bc}	3.3 ^{Bb}	7.2 ^{Aa}	4.0 ^{A}
200,000	--	--	--	1.0 ^{Cc}	1.0 ^{Cc}	5.2 ^{Aa}	4.8 ^{BCab}	3.5 ^{B}
100,000	--	--	--	1.8 ^{Ab}	1.8 ^{Ab}	1.6 ^{Cb}	6.6 ^{Aba}	3.3 ^{B}
Overseed	--	--	--	0.9 ^{Cb}	0.9 ^{Cb}	3.7 ^{Ba}	3.9 ^{Ca}	2.3 ^{C}
Average	--	--	--	1.4 ^{c}	1.4 ^{c}	3.5 ^{b}	5.6 ^{a}	
				Sheath				
400,000	--	--	--	--	--	0.2 ^{Ab}	5.3 ^{Ba}	2.8 ^{D}
200,000	--	--	--	--	--	0.1 ^{Ab}	22.1 ^{Aa}	11.1 ^{A}
100,000	--	--	--	--	--	--	6.3 ^{Ba}	6.3 ^{B}
Overseed	--	--	--	--	--	0.1 ^{Ab}	8.8 ^{Ba}	4.5 ^{C}
Average	--	--	--	--	--	0.1 ^{b}	10.6 ^{a}	

Means with the same lower-case letter in the same row (^{abcd}) and capital letters (^{ABCD}) in the same column are not statistically different (Tukey: $\alpha=0.05$).

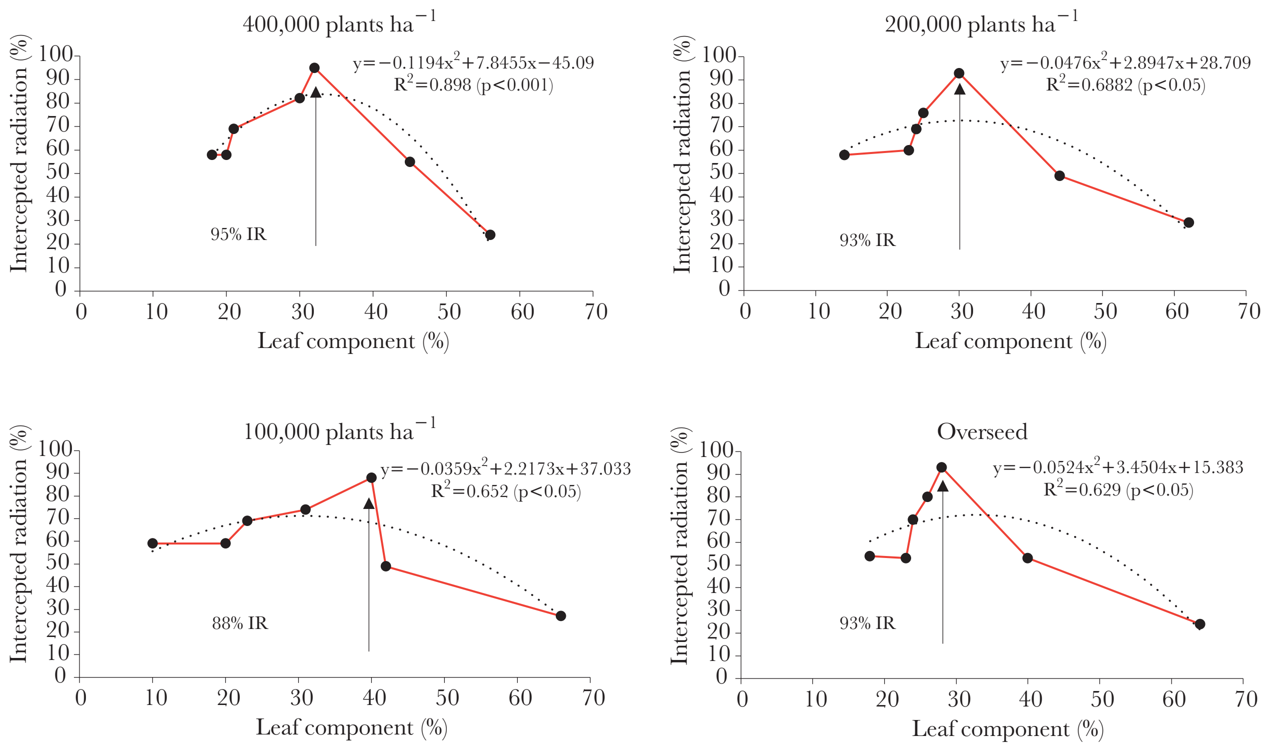

Figure 2. Regression coefficient between intercepted radiation (%) and leaves (%) of crotalaria, at different planting densities and cutting age.

Finally, in their research about white clover pulse, associated to orchard grass and perennial ryegrass, Rojas *et al.* (2016) found a high relationship between the intercepted radiation and the growth rate in all the associations, with 0.87 ($p<0.001$) R^2 in average. They also pointed out that a higher growth rate is linked with a higher intercepted radiation rate and *vice versa*.

CONCLUSION

Crotalaria obtained a higher yield with a 400,000 plants ha^{-1} planting density. The best structural characteristics of the meadow and 95% of intercepted radiation can be obtained 45 days after the emergence. However, a 200,000 plants ha^{-1} planting density is more conducive to a higher pod production.

REFERENCES

Abdul-Baki, A.A., Bryan, H.H., Zinati, G.M., Klassen, W., Codallo, M., Heckert, N. (2001). Biomass yield and flower production in Sunn Hemp: Effect of Cutting the main stem. *Journal of Vegetable Crop Production 7*(1), 83-104. Doi: 10.1300/J068v07n01_10

Akanvou, R., Bastiaans, L., Kropff, MJ., Goudriaas, J., Becker, M. (2001). Characterization of growth, nitrogen accumulation and competitive ability of six tropical legumes for potential use in intercropping systems. *Journal of Agronomy and Crop Science 187*(2), 111-120. Doi: 10.1046/j.1439-037X.2001.00503.x

Almeida-Santos, L.E., Obrador-Olán, J.J., García-López, E., Castelán-Estrada, M., Carrillo-Ávila, E. (2019). Cultivation and incorporation of *Crotalaria juncea* L. in a sugarcane culture soil in the Chontalpa, Tabasco, Mexico. *Agroproductividad 12*(7), 87-93. Doi: 10.32854/agrop.v0i0.1475

Castro, R.E., Sierra-Alarcón, A., Mojica, J.E., Carulla, J., Lascano, C.E. (2017). Efecto de especies y manejo de abonos verdes de leguminosas en la producción y calidad de un cultivo forrajero utilizado en sistemas ganaderos del trópico seco. *Archivos de Zootecnia 66*(253), 99-106. Doi: 10.21071/az.v66i253.2131

Castro, R.R., Hernández, G.A., Vaquera, H.H., Hernández, G.J.P., Quero, C.A.R., Enríquez, Q.J.F., Martínez, H.P.A. (2012). Comportamiento productivo de asociaciones de gramíneas con leguminosas en pastoreo. *Revista Fitotecnia Mexicana 35*(1), 87-95.

Douxchamps, S., Rao, I.M., Peters, M., Van-Der-Hoek, R., Schmidt, A., Martens, S., Polania, J., Mena, M., Binder, C.R., Schöll, R., Quintero, M., Kreuzer, M., Frossard, E., Oberson. A. (2014). Farm-scale tradeoffs between legume use as forage versus green manure: The case of *Canavalia brasiliensis*. *Agroecology and Sustainable Food Systems 38*(1). 25-45. Doi: 10.1080/21683565.2013.828667

García, E. (2004). Modificaciones al sistema de clasificación climática de Köppen. 5ª. (Ed.). Instituto de Geografia. Universidad Nacional Autónoma de México (UNAM). México, DF. 217 p.

Jiménez, S.A.M., Farfán, V.F., Morales-Londoño, C.S. (2005). Biomasa seca y contenido de nutrientes de *Cajanus cajan*, *Crotalaria juncea* y *Tephrosia candida*, empleadas como abonos verdes en cafetales. *Cenicafé 56*(2), 93-109.

Lemaire, G. (2001). *Ecophysiology of grasslands: dynamics aspects of forage plant populations in grazed swards*. *In*: International Grassland Congress. Proc. XIX International Grassland Congress. Brazilian Society of Animal Husbandry, 1a ed. Sociedade Brasileira de Zootecnia (eds). São Pedro, São Paulo. Brazil. 29-37 p.

Lemaire, G., Franzluebbers, A., Carvalho, P.C.F., y Dedieu, B. (2014). Integrated crop-livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. *Agriculture, Ecosystems and Environment 190*(1),4-8. Doi: 10.1016/j.agee.2013.08.009

Maldonado-Peralta, M.A., Rojas-García, A.R., Sánchez-Santillán, P., Bottini-Luzardo, M. B., Torres-Salado, N., Ventura-Ríos, J., Joaquín-Cancino, S., Luna-Guerrero, M. J. (2019). Growth analysis of Cuba grass OM-22 (*Pennisetum purpureum* × *Pennisetum glaucum*) in the dry tropics. *Agroproductividad 12*(8), 17-22. Doi: 10.32854/agrop.v0i0.1445

Matthew, C.G., Val Loo, E.N., Tom, E.R., Dawson, L.A. and Care, D.A. (2001). *Understanding shoot and root development*. *In*: Proc. XIX International Grassland Congress. Brazilian Society of Animal Husbandry, Sociedade Brasileira de Zootecnia (eds). 1ª ed. São Pedro, São Paulo. Brazil. 19-27 p.

McSorley, R. (2001). Multiple cropping systems for nematode management: A review. *Soil and Crop Science Society of Florida Proceedings. 60*(1), 132-142.

Mosjidis, A.J., Balkcom, K.S., Burke, J.M., Casey, P., Hess, J.B., Wehtje, G. (2013). Production of the Sunn Hemp Cultivars "AU Golden" and "AU Durbin" Developed by Auburn University. General information on biomass, forage and seed production. *Alabama Agricultural Experiment Station* 1-7. Doi: 10.13140/2.1.5187.0402

Muraoka, T., Ambrosano, E., Zapata, F., Bortoletto, N., Martins, A.L.M., Trivelin, P.C.O., Boaretto, A.E. y Scivittaro, W.B. (2002). Eficiencia de abonos verdes (*Crotalaria* y *Mucuna*) y urea, aplicados solos o juntamente, como fuentes de n para el cultivo de arroz. *Terra 20*(1), 17-23.

Oliveira de, M.N., Morais, de S.V.G.M., Costa, M.I.G., Bezerra de G.G. (2020). Biomass of *Crotalaria juncea* as a function of plant densities in the semiarid region of Northeastern Brazil. *Agronomía Colombiana 38*(1), 148-155. Doi: 10.15446/agron.colomb.v38n1.78957

Prudhomme, R., Brunelle, T., Dumas, P., zhang, X. (2017). Legumes production in europe to mitigate agricultural emissions in a global pers- pective. *4ème Conférence annuelle de la FAERE*. Nancy, France: LeF, BeTA. 1-16 p.

Rojas, G.A.R., Hernández, G.A., Quero, C.A.R., Guerrero, R.J.D., Ayala, W., Zaragoza, R.J.L. Trejo, L.C. (2016). Persistencia de *Dactylis glomerata* L. solo y asociado con *Lolium perenne* L. y *Trifolium repens* L. *Revista Mexicana de Ciencias Agrícolas 7*(4), 885-895.

Rojas-García, A.R., Torres-Salado, N., Joaquín-Cancino, S., Hernández-Garay, A., Maldonado-Peralta, M.A. y Sánchez-Santillán, P. (2017). Componentes del rendimiento en variedades de alfalfa (*Medicago sativa* L.). *Agrociencia 51*(7), 697-708.

Rojas-García, A.R., Torres-Salado, N., Maldonado-Peralta, M.A., Sánchez-Santillán, P., García-Balbuena, A., Mendoza-Pérez, S.I., Álvarez-Vázquez, P., Herrera-Pérez, J. y Hernández-Garay, A. (2018). Curva de crecimiento y calidad del pasto cobra (*Brachiaria* Hibrido BR02/1794) a dos densidades de corte. *Agroproductividad 11*(5),34-38

Santana, M.G. y Ascencio, J. (2011). Capacidad de crecimiento de *Crotalaria juncea* L. en condiciones de deficiencia de Fósforo. *Agronomía Tropical 61*(3-4), 221-230.

Santos, A., Valencia, E., Román-Paoli, E., Ramos-Santana, R. (2011). Época de siembra y fecha de corte y su efecto en la producción de biomasa y la contribución de nitrógeno de *Crotalaria juncea* L. "Tropic Sin" en el suroeste de Puerto Rico. *J. Agric. Univ. P.R., 95*(3-4), 169-178.

SAS. (2009). SAS/STAT® 9.2. Use's guide release. Cary, NC: SAS InstituteIcn. USA. 360 p.

Teixeira, E.I., Moot, D.J., Brown, H.E., Pollock, K.M. (2007). How does defoliation management impact on yield, canopy forming processes and light interception of lucerne (*Medicago sativa* L.) crops? *European Journal of Agronomy 27*(1), 154-164. Doi: 10.1016/j.eja.2007.03.001

Tui, S.H., Valbuena, D., Masikati, P., Descheemaeker, K., Nyamangara, J., Claessens, L., Erenstein, O., Van-Rooyen, A., Nkomboni, D. (2015). Economic trade-offs of biomass use in crop-livestock systems: Exploring more sustainable options in semi-arid Zimbabwe. *Agricultural Systems* 134, 48-60. Doi: 10.1016/j.agsy.2014.06.009