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RESEARCH ARTICLE

PHENOLOGY OF BUSH-FORAGE SPECIES ESTABLISHED IN A SILVOPASTORAL SYSTEM IN TWO SOIL TYPES IN YUCATÁN, MÉXICO

Zavaleta-Córdova Carmen¹, Sosa-Rubio Edgar Enrique¹, Rivera-Lorca Juan Antonio² and Herrera-Cool Gilbert José¹

1. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Campo Experimental Chetumal, Km 3.5, Carretera Xulha - Bacalar, Chetumal, Quintana Roo, México.
2. Tecnológico Nacional de México. Campus Conkal, Yucatán. Departamento de Posgraduados de Investigación.

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Abstract

Silvopastoral systems represent a sustainable alternative for livestock production. Such systems are part of agroforestry and represent an agroecosystem which can be designed chronological and topological by an arboreal and herbaceous component. It has been demonstrated that silvopastoral systems can improve the forage production, add firewood and reduce temperature in grassland what generating animal wellness. However, to obtain the benefits of a silvopastoral system, it is important to know the phenology of forage bushes in a multi-associated system. The objective of this work was to evaluate a multi-associated silvopastoral system accord of the phenological behavior of four bushes with forage potential in two types of soil (Leptosol and Lithosol). The study was carried out in a plot of 130 x 25 m. Around the plot was intercalated *Hibiscus rosa-sinensis* (Tulipan) species at 25 cm between plant, *Gliricidia sepium* (Cocoite) and *Guazuma ulmifolia* (Pixoy) at 2 m, and inside of the plot *Leucaena leucocephala* (Huaxin) at 50 cm between plants and 3 m between rows. Evaluated treatments were Leptosol or Lithosol soils, the variables measured were plant height, basal diameter, diameter at 35 cm, branches number, flowering date and pods number, growth rate and surviving. The analysis of variance and Duncan test were carried out to detect differences between treatments in plant age. The 100% of surviving was observed in Huaxin, Pixoy and Tulipan species in both soil types at 10, 7 and 10 months of age respectively, furthermore, Cocoite showed 69 and 81 % of surviving in Leptosol and Lithosol soil respectively at the 6 months of transplant. Plant height of Huaxin at ten months of age was ($P < 0.05$) 145.5 ± 38.70 cm with growth rate (GR) of 0.66 ± 0.19 cm d⁻¹ in Leptosol soil and 138.2 ± 46.71 cm for Lithosol with GR of 0.62 ± 0.16 cm d⁻¹. Flowering was in winter at 5 age months. Pods productions differences ($P < 0.05$) were observed in Leptosol with 56.3 ± 49.41 pods and in Lithosol with 45 ± 43.74 pods. The growth rate of Pixoy at seven months of age was ($P < 0.05$) 133.0 ± 29.00 cm in Leptosol with 0.68 ± 0.14 cm d⁻¹ and 101.0 ± 27.33 cm in Lithosol soil with 0.52 ± 0.13 cm d⁻¹. The highest Tulipan plants at ten months of age were ($P < 0.05$) 163 ± 36.10 cm with 0.68 ± 0.12 cm d⁻¹ of GR in Leptosol soil and 147.7 ± 20.38 cm with

Corresponding Author:- Zavaleta-Córdova Carmen

Address:- Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Campo Experimental Chetumal, Km 3.5, Carretera Xulha - Bacalar, Chetumal, Quintana Roo, México.

0.62±0.07 cm d⁻¹ of GR in Lithosol soil. For all variables in soil treatment were detected differences (P<0.05), in which, Leptosol showed be the best soil for growth. Furthermore, this type soil showed positive influence in forage bushes growth due to plants showed the best growth, except Cocoite which the surviving rate was higher in Lithosol soil.

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Introduction:-

Livestock production systems in Mexico are determined by a marked seasonality of precipitation which control forage and grass abundance or shortage (Stephenson *et al.*, 2019; Cháirez and Ruiz, 2013) and usually, those forage or grass are of low nutritional quality and productivity (Beraueret *et al.*, 2020; Cain *et al.*, 2017). This problem is a challenge due to the necessity to have grass and forage of quality to obtain a sustainable livestock system (Jose and Dollinger, 2019), furthermore, seasonality, big extensions of native grasslands and low nutritional quality have originated the establishment of artificial grasses (Cui *et al.*, 2019).

The grasses are usually of extractive types, destroy big extensions of forest and cause ecosystem damage. On the other hand, sustainable strategies in livestock production have been designed to face the climate change (Rojas-Downing *et al.*, 2017). In this sense, silvopastoral systems (SPS) offer an option to improve and to optimize the production in sustainable way (Yadavet *et al.*, 2019; Broom, 2017), likewise, the presence of trees benefits the nutrients recycling and absorption, like so the increasing of organic matter to soil (Ortega *et al.*, 2020; Calilet *et al.*, 2016). In a SPS can be considered cultivation in alleys, trees in paddocks, live fences, windbreak curtains and fodder banks (Vandermeulen *et al.*, 2018). The SPS can contribute in monoculture reduction, improve the ecology benefits and achieve sustainable livestock systems (Yadavet *et al.*, 2019; Lima *et al.*, 2018; Calilet *et al.*, 2016; Fassbender, 1993), furthermore, it improves the animal diet, decreases the capacity of methane emission, improves degraded areas and permits the natural regeneration, moreover it can be considered as carbon sinks and habitat of organisms and rodents to connect stable ecosystems (Ávila-Ramírez *et al.*, 2019; Cárdenas-Velásquez, 2018).

There are different species that can be used to these goals, for example: Cocoite (*G. sepium*), Pixoy (*G. ulmifolia*), Tulipán (*H. rosa-sinensis*) and Leucaena (*L. leucocephala*), this last is a native legume from Yucatan which is usually used in SPS in different countries due to its capacity to improve the soil fertility (Azuara-Morales *et al.*, 2020; Sarabia-Salgado *et al.*, 2020; Bottini-Luzardo *et al.*, 2016). These arboreous species have great potential to stay in paddocks during drought season, furthermore, it is recommendable to carry out combinations between *G. sepium*, *G. ulmifolia*, *L. leucocephala*, *Sesbania* spp. and *Erythrina berteroana* (Sánchez, 1996) which can be intercalated with high nutritive quality foliage plants such as *H. rosa-sinensis*, *Malvaviscus arboreus* and *Trichanthera gigantea*.

It has been demonstrated that forage bushes intercalated with grams improve productivity (Broom *et al.*, 2013), for instance: Huaxin in grasslands of *C. nlemfuensis* (star grass) showed be an alternative to a grazing system in the Cattle Breeding and Rearing Enterprise “Manuel Fajardo”, Granma province, in Cuba (Delia *et al.*, 2016). other studies have demonstrated similar results in those silvopastoral systems (Cadavidet *et al.*, 2019; Bottini-Luzardo *et al.*, 2016; Cairo-Cairo *et al.*, 2017).

Because of the importance of forage species and the necessity to know about its development and behavior in Yucatan center-north conditions, the objective of this research was to evaluate the phenology of forage bushes in two types of soil for establishment in a silvopastoral system.

Materials and methods:-

Area of study and edaphoclimatic conditions:

The present study was carried out in forage areas of Centro de Selección y Reproducción Ovina (CeSyRO) of Instituto Tecnológico Agropecuario de Conkal, located in municipality of Conkal, Yucatan at 21° 05' North and 89° 32' West with an elevation of 9 masl. In the zone predominates the Aw_o climate classification accord Köppen, modified by García (1988), this climate is the driest of warm sub-humid climates with summer rains. Temperature average is 26°C with 35°C maximum and 17°C minimum. Annual precipitation average is 900 mm, it exists two seasons defined: rains from June to November and droughts from December to May. Soils are calcareous, shallow,

highly stony and 7-8 of pH. Types of soils found in plots were: Tzek'el (Lithosols) and Pus-lu'um with Ch'och'ollu'um (Leptosol) (Duch, 1988).

Establishment and management of experimental plots:

The distribution of plants in field was in two types of soil, Leptosol and Lithosol, in plots of 130 x 25 m, each plot was covered with Africa Star Grass (*Cynodon nlenfuensis*). In the same plots were established four forage species with different typological arrangement. The Tulipan (*H. rosa-sinesis*), Cocoite (*Gliricidia sepium*) and Pixoy (*Guazuma ulminifolia*) were planted intercalate as live fence to delimit all perimeter of plot. The Huaxin (*Leucaena leucocephala*) was established as alley cropping. Each species was evaluated independently. The experimental plots were manually cleaned once a month in order to avoid competition from the African star grass (*Cynodon nlenfuensis*), undergrowth and established forage bushes. Sprinkler irrigation was performed once a week for 2 hours during establishment and during the dry season. The irrigation sheet was approximately 8 mm.

Management and establishment of Huaxin:

Huaxin plants var. Cunningham were culture in green house for 75 days, then were transplanted in experimental plot when they had 11.6 ± 1.08 cm of height, 2.0 ± 0.36 mm of basal diameter and 4.4 ± 0.80 branches. Plants were sown at 8 cm of deep, distribution was alley cropping at 0.50 cm between plants and 3 m between rows. The experimental unity was 10 plants with four replicates in each soil type (Leptosol and Lithosol).

Management and establishment of Pixoy:

Plants of 90 days with 9.7 ± 0.80 cm of height, 2.4 ± 0.28 mm basal diameter and 1.4 branches were sown in plots. The plants were sown at 8 cm of deep and 2 m between plants. The experimental unity was three plants and four replicates per treatment.

Management and establishment of Tulipan:

This species was established through vegetative material. Plants with 38.85 ± 3.27 cm of height and 7.14 ± 1.46 mm of basal diameter were sown at 25 cm of deep around the plot as live fence at 0.25 cm between plants. Each experimental unity was constituted by 6 plants and four replicates per treatment.

Management and establishment of Cocoite:

The Cocoite was established through vegetative material at two meters between plants intercalated with Tulipan around the plot. Each plant was sown at 25 cm of deep. Each experimental unity was constituted by four plant stakes of 19.97 ± 2.62 cm of height with four replicates per treatment.

Experimental design:

A random complete design was carried out for each species in which the treatments were the two soil types (Leptosol and Lithosol). Data were recorded monthly, the variables evaluated in all species were surviving percentage, plant height (measured with measure tape), basal diameter (measured at two cm above root neck with digital vernier caliper H-7352, ULINE), number of branches, age of flowering, number of pods and growth index, this last is defined as the growth difference of the species between the growth months number. In addition to the variables afore mentioned, stem diameter was evaluated in Tulipan at 35 cm of height, (measured with digital vernier caliper H-73252, ULINE), the number of flowers and crown diameter in Huaxin, and diameter of two branches per each plant (determination of the development of the plant per stake) for Cocoite. Finally, height growth average rates (HGAR) were calculated for all species.

Plots were evaluated by species and data were analyzed separately. An analysis of variance was carried out for plant age (between months) to define plant growth and for soil type. Medias were compared by Duncan test and correlation between variables were carried out.

Results:-

Huaxin phenology:

Surviving average in Huaxin plants was 100% in evaluation at 10 months, both in Leptosol and Lithosol soils. Statistical differences ($P < 0.05$) were detected for the growth rate in plant height variable at five months of age in January. The highest values obtained were 18.92 ± 1.52 cm in Leptosol soil and 8.10 ± 1.23 cm in Lithosol soil. Regarding the basal diameter, statistical differences ($P < 0.05$) were detected at the six months of age in February. The highest values obtained were 3.76 ± 0.23 mm in Leptosol soil and 2.53 ± 0.19 mm in Lithosol soil, furthermore

at 10 months of age in May with 2.86 ± 0.34 and 2.00 ± 0.22 mm in Leptosol and Lithosol soils respectively. In the other months of evaluation, there were not significant statistical differences due to all growth rates were similar in both soil types. In respect with branches number, significant statistical differences ($P < 0.05$) were detected at 2 months of age in October with 7.80 ± 0.48 and 9.27 ± 0.34 branches, also at 3 months of age with 7.80 ± 0.48 and 9.27 ± 0.34 branches in Leptosol and Lithosol soils respectively. In the other months of evaluation, no significant statistical differences were detected both between treatments and between months. Flowering started at 5 months of age in January in both soil types without finding significant statistical differences ($P > 0.05$), however, at 6, 7 and 8 months of age in February, March and April respectively were detected greater flowering in Leptosol soil. Regarding the number of pods, no significant statistical differences ($P > 0.05$) were detected between months, however, differences were detected between soil types. In Table 1 can be observed the data obtained in variables evaluated in Huaxin. The total data correspond to 10 months of age per soil type.

Table 1: Phenology of Huaxin in two soil types at ten months of age.

Variable	Leptosol		Lithosol	
	Media	SD	Media	SD
Height(cm)	145.53 ^a	38.70	138.16 ^b	46.71
Basal diameter (mm)	26.74 ^a	5.54	23.80 ^a	5.02
Branches number	8.70 ^a	5.23	10.80 ^a	6.74
Flowers number	13.80 ^b	15.32	17.30 ^a	17.35
Pods number	56.25 ^a	49.41	45.07 ^b	47.74
Tree top diameter (cm)	44.83 ^a	19.99	44.95 ^a	18.41

SD = Standard deviation, Similar letters correspond to treatments statistically equal according to Duncan test ($P \leq 0.05$).

Pixoy phenology:

It was obtained 100% of surviving in establishment at 7 months of age in both soil types. Significant statistical differences ($p < 0.05$) were detected in growth rate of plant height between months. The highest values obtained were at 7 months of age with 19.75 ± 2.09 and 12.58 ± 2.04 cm for Leptosol and Lithosol soils respectively. This tendency was observed at 5 months of age in April with 16.08 ± 2.16 and 8.91 ± 2.05 cm and at 6 months of age in May with 39.50 ± 2.96 and 26.00 ± 2.07 cm in Leptosol and Lithosol respectively. No significant statistical differences were detected in basal diameter of Pixoy between months. This data suggest that this species had similar behavior in basal diameter without consider the month of evaluation, however, in branches number, no significant statistical differences were detected at 6 months of age in May with 14.33 ± 0.73 and 11.16 ± 0.97 branches, also at 7 months of age in June with 17.08 ± 1.40 and 12.50 ± 0.18 branches in Leptosol and Lithosol soils respectively. In Tree top diameter, no statistical differences were observed in both soil types in the first two months, moreover, at 6 and 7 months of age, Leptosol soil showed higher values ($P < 0.05$). In Table 2, can be observed the response of variables in two soil types at 7 months of age with growth rate of 0.68 ± 14 and 0.52 ± 14 cm d⁻¹ in Leptosol and Lithosol soils respectively.

Table 2: Phenology of Pixoy in two soil types at seven months of age.

Variable	Leptosol		Lithosol	
	Media	SD	Media	SD
Height (cm)	133.0 ^a	29.00	101.0 ^b	27.33
Basal diameter (mm)	24.2 ^a	4.55	21.0 ^b	5.22
Branches number	14.8 ^a	4.89	10.6 ^b	4.4
Tree top diameter (cm)	68.0 ^a	12.15	46.8 ^b	11.00

SD = Standard deviation, Similar letters correspond to treatments statistically equal according to Duncan test ($P \leq 0.05$).

Positive correlation between plant height with basal diameter was obtained in variables studied of Pixoy. On the other hand, a significant correlation in respect with plant height with branches, basal diameter with branches and plant height with tree top diameter was observed. Data obtained suggest that growth and development for this species is highly proportional, that is, as the tree grows, its basal diameter and branches grow simultaneously.

Tulipan phenology:

Surviving of Tulipan in both soil types was 100%. Data analysis showed statistical differences ($P < 0.05$) between months and soil types. Growth rates in the first month of evaluation for plant height were 30.00 ± 2.66 and 23.87 ± 1.57 cm in Leptosol and Lithosol respectively. Furthermore, at 10 months of age in May, growth rates were 15.33 ± 1.48 for Leptosol and 11.08 ± 1.40 cm for Lithosol. Differences ($P < 0.05$) in basal diameter growth were observed at 3 months of age in October with 4.94 ± 0.56 mm in Leptosol soil and 3.4 ± 0.57 mm in Lithosol soil, including at 9 months of age in April with 4.34 ± 0.50 and 3.0 ± 0.39 mm in Leptosol and Lithosol respectively. In the other months, no statistical differences were detected.

In diameter at 35 cm evaluated, statistical differences were observed ($P < 0.05$) at 4 months of age in November, observing values of 2.09 ± 0.34 in leptosol soils and 1.15 ± 0.20 cm in lithosol soils, this difference was observed again after 6 months of evaluation in January with 2.09 ± 0.29 in Leptosol soil and 1.15 ± 0.20 cm in Lithosol soil. Likewise, at 9 months the same behavior was observed with 1.90 ± 0.27 and 1.05 ± 0.21 cm in Leptosol and Lithosol respectively.

Regarding the number of branches, the differences ($P < 0.05$) were obtained after three months of evaluation in October with averages of 17.25 ± 0.78 branches in Leptosol soil and 14.12 ± 1.32 branches in Lithosol soil. It was also observed that at 5, 8 and 9 months the difference in the number of branches was greater in Leptosol, this data coincides with dry season. Table 3 shows the Tulipan response in two types of soil. The final plant height obtained was 163.8 ± 36.10 cm at 10 months of age in Leptosol soil and the growth rate was 0.68 ± 0.121 cm d⁻¹. On the other hand, the final plant height in Lithosol soil was 147.7 ± 20.38 cm with growth rate of 62 ± 0.07 cm d⁻¹.

Table 3: Phenology of Tulipan in two soil types at ten age months.

Variable	Leptosol		Lithosol	
	Media	SD	Media	SD
Height (cm)	163.8 ^a	36.10	147.7 ^b	20.38
Basal diameter (mm)	31.3 ^a	7.11	28.6 ^b	6.34
Diameter at 35 cm	20.5 ^a	5.25	18.0 ^b	3.72
Branches number	10.7 ^a	4.03	9.6 ^b	3.16

SD = Standard deviation, Similar letters correspond to treatments statistically equal according to Duncan test ($P < 0.05$).

Positive correlation was observed between the variables plant height with basal diameter, also in basal diameter with diameter at 35 cm. Differently, correlation obtained between plant height with number of branches and basal diameter with number of branches was null, these data suggest that tall plants with many branches, as well as with few branches, could develop in different types of soil, also it would develop thick stem plants with many branches or thin stem plants with few branches. Therefore, there is a strong positive correlation in plant phenology with soil type.

Cocoite phenology:

Surviving rate in this species was different in 6 months of evaluation. The best surviving rate was observed in Lithosol soil. The total mortality was 31% in Leptosol soil and 19% in Lithosol soil. Differences ($P < 0.05$) were detected in basal diameter at two months of age in January with 11.94 ± 0.89 in Leptosol soil and 15.82 ± 0.81 cm in Lithosol soil. These data suggest that this species could have better adaptation in Lithosol soil, however, in consecutive months of evaluation, significative differences ($P > 0.05$) were no detected. In branches number and growth rate of basal diameter, data showed positive correlation in plant height with basal diameter, like so in plant height with branches and basal diameter of branches. On the other hand, correlation null was observed between branches with plant height.

Discussion:-

Leucaena leucocephala (Huaxin) is native from Mexico and Central America. This species has been widely distributed and adopted in all Latin American. It is usually used as protein banks, alley cultivation and feeding for cattle and sheep (Pachaset *al.*, 2019). Another important characteristic of this plant is that can be used as soil fertility improvement through nitrogen biological fixation. Banegas *et al.* (2019) mentioned that establishment of Huaxin improved 7.6% of the nitrogen concentration (from 0.31 to 0.141%) in the top layer of soil (0~ 20 cm). This

nitrogen was associated with an increase of labile form (particulate organic nitrogen) due to the foliar residues, animal manure and plant nodules. To achieve a silvopastoral system and improve the soil characteristics, the Huaxin was established as alley crop with spaces to permit the animal transit.

To establish Huaxin by seed is necessary the seed scarification to soften the seed-coat, to eliminate the dormancy and to achieve high percentage in germination. Koobonyet *et al.* (2018) used immersion in water at 80°C for 5 minutes and obtained 84.3% of germination, while in our studies we obtained 80% of germination with 91% of surviving rate when the seeds were immersed in water at 100°C for 5 seconds and then soaked for 24 hours. On the other hand, when plants were transplanted in field, we obtained 100% of rate surviving of plants in both types of soil at 10 months of age. These values were higher than Sánchez and Viveros (2002) reported. They mention 84% with a population of 1,075 plants ha⁻¹ in the establishment of a silvopastoral system of Huaxin with grasslands of *Bothriochloa pertuosa*. Huaxin had better development in Leptosol soil with final value of 154.53 ± 38.70 cm. These values are similar to obtained by Ssenkuet *et al.* (2014) who obtained 141.20 ± 26.84 cm of height, contrary to the reported by Rodríguez Fernández and Roncallo Fandiño (2013) who reported values of 214 cm at ten months of age in plants developed in loamy clay soils.

Positive correlation between height and basal diameter was obtained, these data suggest when the plant grows, the diameter increases. The same type of correlation was observed in plant height with branches and basal diameter with branches, so it can be expected that a plant has the possibility of having a greater number of branches while it is higher and more robust. Regarding the plant height with diameter variables of the crown, a weak correlation was obtained. The correlation between flowering with pods was positive, this data shows that all flowers reached maturity.

Flowering in Huaxin was similar with reported by González *et al.* (2005) who mentioned that Huaxin is heterogeneous flowering and seeds do not mature at same time, nevertheless, flowering can be massive in February, March, August and September, it means that harvest can be carried out from October to December accord to the cultivar used. In respect with plant height and branches of Huaxin, Hernández and Seguí (1998) reported heights of 1.60 m with 23 branches at 14 months of age in cv. Cunningham.

Regarding the growth rate of Pixoy, CATIE (1991) reported between 75 and 100 % of surviving in a range from 6 to 9 months, in another study, Sánchez (1996) obtained 100 % of surviving when he established this species as live fence, these reports are accord with our results. The other variables showed better development and behavior in Leptosol soil. Dincaet *et al.* (2012) and Juráni and Balkovič (2007) mentioned that Leptosols belong to carbon rich forest soils, furthermore Owing to their potential to support important ecological processes, Leptosols are represented in many biodiversity hot-spot areas, biosphere reserves, and in elements of some World Natural Heritage sites (Homoláket *et al.*, 2017; UNESCO, 2011).

Tulipan is a native species from Mexico southeast, the Antilles and Northeast South America (Meléndez, 2001). Tulipan is used in Mexico as ornamental plant, however, their leaves are better used for forage (Benavides, 2001). In recent years has been used as animal feeding due to its high protein percentage of 18% (Meléndez, 2001). It has been observed that this species can develop in soil with better fertility without prolonged floods. In this study, the growth rate was high in Leptosol soil respect with Lithosol soil. The growth rate was significative in November with 30.00 ± 0.27 and 23.87 ± 1.57 cm and in January with 15.33 ± 1.48 and 11.08 ± 1.40 cm in Leptosol and Lithosol respectively. Final height observed was 163.8 ± 36.10 cm in Leptosol soil and 147.67 ± 20.38 cm in Lithosol soil, these values were similar that Oséset *et al.* (2006) reported in planting density and cutting interval in the yield and quality of forage of Tulipan (*Hibiscus rosa-sinensis*).

Pixoy is widely distributed through Caribe, Mexico and Central American and South America. It is an important resource of forage for cattle, particularly in the best precipitation season (Little and Wadsworth, 1964). The Pixoy forage can contain between 13.7 (Lópezet *et al.*, 2008) and 21.3 % of crude protein per kilogram of dry matter (Meléndez, 2001). The Pixoy seed do not require scarification, however, this method can increase the germination percentage. Villarruelet *et al.* (2007) suggest to soak the seeds in water at 80°C from 8 to 10 minutes and then maintain in water at room temperature from 24 to 36 hours. With this method they obtained 95% of germination. We obtained 80% of germination applying the method suggested by Sánchez *et al.* (2004) in which the seed were submerged in water at 100°C per 5 seconds and then soaked in room temperature water for 24 hours. The rate surviving was 100% in field.

The growth was higher in Leptosol than Lithosol soil, the averages were 133.0 ± 29.0 cm and 101.0 ± 27.3 at the 7 months of age, these values were upper than obtained by Fernández and Fandiño (2013) who reported 97 cm at 9 months of age, those differences could be to the direct sowing to the soil that they applied, furthermore, the soil used in their experiments was medium compaction soil what could influence to the bushy growing.

Cocoite is a tree from Central America and South America North which is distributed in Tropical America, Caribbean, Africa, Asia and Pacific islands (Elevitch and Francis, 2006). This species is widely known in Mexico because of its nutritive properties which are used as feed supplement in grazing or cut and haul for ruminants (Oyedele et al., 2016). In the south of Mexico, it has been obtained crude protein values up to 19.3% (Ku-Vera et al., 1999). This plant can be used as perimeter fence, shade, green manure and erosion control (González-Jiménez and Velarde-Hermida, 2007). Furthermore, it has medicinal uses and can be used as firewood and human feeding (Pinto et al., 2002). We sowed this plant as life fence to delimit the study area.

The Cocoite establishment could be by seeds in greenhouse or direct sowing in field by plant stakes (Gómez et al., 2002). Seeds sowed in field do not need any special treatment because of their capacity of easy germination which can be from three to five days. This plant develops an excellent radicular system (Aldana, 2009). In the present study we used plant stakes to sow directly on field, the growth was observed in Lithosol soil which are considered as stony soils. This response was because of the low demand of the plant in nutrients and soil.

Aldana (2009) mentioned that Cocoite is a plant that can easily adapt both dry and wet soils with pH between 4.5 and 7.0 and with properties of sandy and clay loam soils, furthermore, they hold out acid soils with medium fertility but with good soil drainage.

In our study, the adaptation to soil type was observed as Cocoite mortality. We had 31% of mortality in Lithosol and 19% in Leptosol soil. This can indicate that low fertility of soils could be favorable for growing of this species. The basal diameter of sprouts was better in Lithosol soil which confirms the preference and the capacity of Cocoite to grow in this soil type.

Conclusion:-

Leptosol soils showed to be the best condition for Tulipan, Huaxin and Pixoy while Cocoite had better development in Lithosol soil, however, differences did not show that bushy species cannot be established in another soil types. Better response to the species in Leptosol soil could be to the great retention of humidity which permits to bushy plants to take the water in a long period.

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