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RESEARCH ARTICLE

USE OF GREEN MANURES IN DWARF COCONUT PLANTATIONS (*COCOS NUCIFERA* L.) IN QUINTANA ROO, MEXICO

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Abstract

The objective of this study was to evaluate the agronomic behavior of species for green manures in coconut areas. The experiment was carried out in a Malay Dwarf Coconut tree plantation in INIFAP, Quintana Roo. Climate is subtropical wet Aw1 at 10 masl, the soil had low organic matter contain, nitrogen and phosphorus. The design was a completely randomized block experiment with 5 treatment (manure), T1: *Tithonia diversifolia* (Td), T2:*Clitoria ternatea* (Ct), T3:*Leucaena leucocephala* (Ll), T4:*Canavalia ensiformis* (Ce) and T5:*Gliricidia sepium* (Gs), each treatment had 4 replicates. Each species was sowed between coconut trees, using an arrangement of two rows per meter between them and one meter between plants. The measured variables were coverage percentage (CP), Weed Population (WP/m^2), Plant Height (PH), Dry Biomass Production (DBP) and Nitrogen Percentage (NP). The analysis of variance was carried out using SAS system and Tuckey test with $P \leq 0.05$ of significance. Significative differences statistical were detected in CP. The highest heights were in T2 and T1 with 96 and 93 % respectively. Equally in PH were detected differences ($P \leq 0.05$) for T1 and T3 with 1.92 and 1.34 cm respectively. In WP, the highest values were detected in T4 and T3 with 33 and 40 weed/m^2. The highest values obtained in DBP were in T1 and T4 with 5.2 and 2.3 ton/m/ha. The highest values in NP were observed in T3, T4 and T5 with 5.57,5.25 and 5.04 %. In respect with the agronomic behavior or evaluated species in this study, we can conclude that T1 and T4 represent an excellent option to be used as green manures.

Introduction:-

Continue uses in soil cause that certain elements generate new chemical combinations which are not harnessed by plants. Therefore, useful nutrients for plants decrease and can deplete. Soils that have the conditions mentioned should be renovate continuously, furthermore toestablish practices to increase the natural up taking of essential nutrients to improve and to maintain the productivity of crops. In Yucatan peninsula Located in Mexico southeast, soils suffer this loss of nutrients, especially in coconut tree crops where great quantity of nutrients are extracted and

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eliminated from 2000 Ha cultivated which go increasing.In the last five years has been observed nutritional disorders in coconut tree crops in Yucatan peninsula, especially in Quintana Roo, this problem, could be originated due to nutrient deficiency or poor soil fertilization which is common because of high costs of inorganic fertilization.Nitrogen (N) is the most important and limited element in agroecosystem due to its participation in multiple biochemical reactions, moreover this element is implied in physiological growing, development plant and crop production (Prager *et al*., 2012). Even though it exists inorganic fertilization to solve this deficiency, the inorganic contributions are expensive and implies environmental problems. Due to problems mentioned before, it is necessary to create new alternatives in fixation, contribution and recycling of nitrogen in agroecosystems (Sanclemente, 2013).Coconut is a species of agronomic importance because of employees that generates, is cultured by small farmer groups, furthermore can be obtained many environmentally friendly products and subproducts fromall plant. Coconut is internationally known because of industry diversification, agriculture, livestock, construction materials, medicine, ecology, tourism, handcraft products and many others (Serrano, 2000). In these circumstances, it is important to evaluate and to include sustainable alternatives to improve coconut nutrition. These alternatives could be implementation of cover plants, green manures and organic residues in the same plantation, moreover these alternatives will help to reduce dependence on external resources and maintaining and improving biodiversity in the system which are characteristics that small farmer groups could apply in their crop systems (Villanueva, 2002).

Green manure is one of the many alternatives that is cheaper and generate better results in short time. The application of these manures can be improving fertility conditions and time life of soil, furthermore dependency of inorganic fertilizers can be replaced. Another two important characteristics provided by the species used as green manures is that help to nitrogen fixation and vegetative material is transformed in organic matter which improve the physical, chemical and biological characteristics of soil (Ruiz and Molina, 2014). The practice of green manures consists in establishment of perennial and biennial legumes inside of plantation (Villanueva, 2002). Perennial legumes are used as cover plants and contribute nitrogen to the coconut tree, furthermore increase contain of organic matter. Those plants which are used as cover plants should be productive species with fast growing, adapted to the climate and to the soil conditions, good quality and protective against erosion (Barreto, 2005)

Many studies have showed that uses of green manures improve physical (Yang *et al*. 2014, Adekiya *et al*. 2019), chemicals (Naz *et al*. 2015) and biological properties of soils (Elfstrand *et al*. 2007), moreover it favors productivity. Green manures in agriculture have been an effective practice to improve yielding in many crops as in rice (Muñiz *et al*. 2012), tobacco (Bilalis *et al*. 2009) and corn (Tejada *et al*. 2008). The improving in crops isbecause the application of green manures has been related with increasing in nutrients availability (Muñiz *et al*. 2012, Piotrowska and Wilczewski 2012, Zotarelli *et al*. 2012, Yang *et al*. 2014), for example Espindola *et al*. (2006) evaluated the nutrients decomposition and liberation of*Pueraria phaseoiloides, Arachis pintoi, Macroptilium atropurpureum* and *Panicum maximum*as cover plants associated with banana tree crops. They found in dry season 25,3 g /kg of nitrogen in biomass of *P. phaseoloides*, contrary to what was found in *P. maximum* with 10,6 g/kg of nitrogen. In another study, Ovalle *et al*. (2007) found significative differences in soils with cover plant of legumes against soils without cover plants, moreover those differences were equally significative in legumes density, production of biomass and nitrogen contain in soil.Corley and Tinker (2003), reported that legumes have the capacity of fix the nitrogen and return it again to soil. In spite of be recommendable to use legume plants, it exists another species that may have similar functions, for instant Tree marigold (*Tithonia diversifolia*). This species accumulates enough nitrogen in their leaves like legume plants, it contains high levels of phosphorous, large root volume, ability to recover shortage nutrients from soil and it is a strong plant and can withstand pruning at ground level, also it is a fast growing plant with low demand of nutrients and undemanding in crop management (Medina *et al*., 2009).

To achieve a sustainable production, it is necessary to implement eco-efficient strategies to decrease production costs and to increase coconut tree plantation productivity to generate an efficient agronomic management with minimal environmental impact, furthermore to add conservation practices and fertility restauration of soils. To reduce the risk of lost plantation and to improve coconut productivity, the objective of this study was to evaluate to obtain the potential agronomic of biomass production and nutrient supply of four legumes (*Gliricidia sepium, Leucaena leucocephala, Canavalia ensiformis y Clitoria ternatea*) and one Asteraceae (*Tithonia diversifolia*) applying consecutive cutoffs in a year to be used as green manures.

Materials and Methods:-

Study localization, climate and soil conditions

The study was carried out from 2018 to 2020 in a Malayan Dwarf Yellow coconut plantation in temporal conditions. The plot is located in Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), campo experimental Chetumal, located in Othon P. Blanco, Quintana Roo at 3.5 km of Xul-Ha community with 21°30' N and 89°29' W coordinates. Climate conditions are 27.6° C and 62.3% of relative humidity on average, annual medium precipitation is 1300 mm. The coconut plants were sowed in the traditional pattern of quincunx each 8 meters, density of plantation was 142 plants per hectare. Soils are Vertisols with high contain of clay and low contain of organic matter. Period with the most precipitation was from June to November.

Establishment of treatment in experimental plot

The ground was prepared in a conventional way with a harrow pass and furrow. then in plot was established five cover plant species correspond to treatments T1: *Tithonia diversifolia* (Td), T2: *Clitoria ternatea* (Ct), T3: *Leucaena leucocephala* (Ll), T4: *Canavalia ensiformis* (Ce) and T5 *Gliricidia sepium* (Gs). For treatments T1 and T5 were used vegetative material from 18 to 24 months of age, plant growth regulator for rooting were add in a tip of each stake, then 8 cover plants were sowed between two coconut trees at 20 cm of deep and divided in two rows of four plants. The cover plants were sowed at 2.5 m from coconut tree stem and the first cutoff was at the three months for T1 and at the five months for T5 at 50 cm of height.In treatments T2, T3 and T4, botanic seeds were scarified with water at 100°C for four minutes, then were sowed in field. Sowing arrangement was equal to treatment T1 and T5 and the first cutoff was realized at three months of establishment.

Experimental design used and data analysis

Experimental unity was constituted by six coconut trees, distribution of treatments was established in a completely randomized block design with 5 replicates. Variable agronomics measured were cover percentage (%) of legumes at month ranges,weed population (plants/m^2), Dry matter yielding, height, green and dry biomass production (leaves dry weight, stem dry weight, whole plant dry weight, dry matter yield), nitrogen contribution (N) and total nutrients (NT). Evaluation of green matter production per plant was realized considered five samples per replicate, each of one replicate was constituted for five consecutive plants in the same treatment. Procedure to determine the nutrient contribution consisted in multiply the percentage of those nutrients times total production of dry matter then the result was divided between 100, excluding roots. Roots, stems and leaves samples were sent to laboratory to determine nitrogen contain and total nitrogen. Additionally, an agronomic evaluation of symbiotic association between legumes with *Rhizobium* bacteria was carried out as indicator of nitrogen biologic fixation. Variance analysis and Tukey test (P<0.05) was carried out with Statistical Analysis System (SAS) Software.

Results and Discussion:-

Nitrogen fixing in species evaluated

In direct evaluation of nitrogen fixing through legumes, it can be observed significant differences (P≤0.05) between treatments. In T2 can be observed high number of nodules comparing with other species (Table 1).

Table 1:- Evaluation of nodulation as indicator of nitrogen fixation in green manures used in coconut areas of Quintana Roo, Mexico.

Species	Nodules number average	Color	Form	Location
Clitoria ternatea	74^a ±5.2	Red	Round	Secondary and primary roots
Canavalia ensiformis	39^b ±3.7	Red	Round	Secondary root
Leucaena leucocephala	9^c ±.47	Red	Amorphous	Secondary root
Gliricidia sepium	11^c ±.26	Red	Round	Primary root

Similar letters correspond to treatments statistically equal according to Tukey test (P≤0.05).

This abundant nodulation is due to this species is promiscuous and has the characteristic of form nodules with any strain of *Rhizobium* in soil. Contrarily, Leucaena is a legume considered in semi-specific group because it only form nodules with certain *Rhizobium* strains in soil to fix nitrogen (Pérez *et al*., 2011), this is accord with observed by Salazar (2017) in tropical soils where exits diversity of native strains which promotes nodulation in different legumes, furthermore bacteria that realized the atmospheric fixation of N are specific guesses and many tropical legumes are highly specific in their association with *Rhizobium*. The principal presence of nodules was in primary and secondary roots; this characteristic is because effective nodules in nitrogen fixation are the closest to the root crown, that is to the carbohydrate font (Paredes, 2013).However, some symbiosis cannot be effective even if exits abundant nodulation (Salazar, 2017). Inner color of nodules was red, this is an indicator of effective nodules because of the presence of leghemoglobin. Green and white nodules were ineffective (Pérez *et al*., 2011). Nodules showed different forms like round, elongated or branched, furthermore sizes and various structures depending on host plant (Mayz-Figueroa, 2004).

Soil cover percentage and plant height

In soil cover percentage, significative differences (P≥0.05) were not found between T2 and T1 treatments, the values at 12 weeks of evaluation were 96 and 93 % respectively. On the other hand, T3, T4 and T5 treatments were detected differences (P≤ 0.05) with values of 84, 61 and 36 respectively. These values showed that T1 and T2 treatments are efficient species to establish as cover plants and protect the soil surface. Sánchez (2008) obtained the soil cover percentage at the 12 weeks in *Clitoria ternatea* with 80% and *Canavalia ensiformis* with 44%.These data are Accord with reported by Ramírez *et al*. (2001) for *Canavaliaensiformis*cover plant in association with corn where the plant covered the soil inan 80% at the 12 weeksafter sow. They showed that this species can control the weed growth and add dry matter to soil to improve the fertility.Significative differences (P≤ 0.05) were detected in plant height at 12 weeks, average values for T1, T3, T4, T5 y T2 were 1.94, 1.12, .91, .86 y .80 m respectively (Figure1).

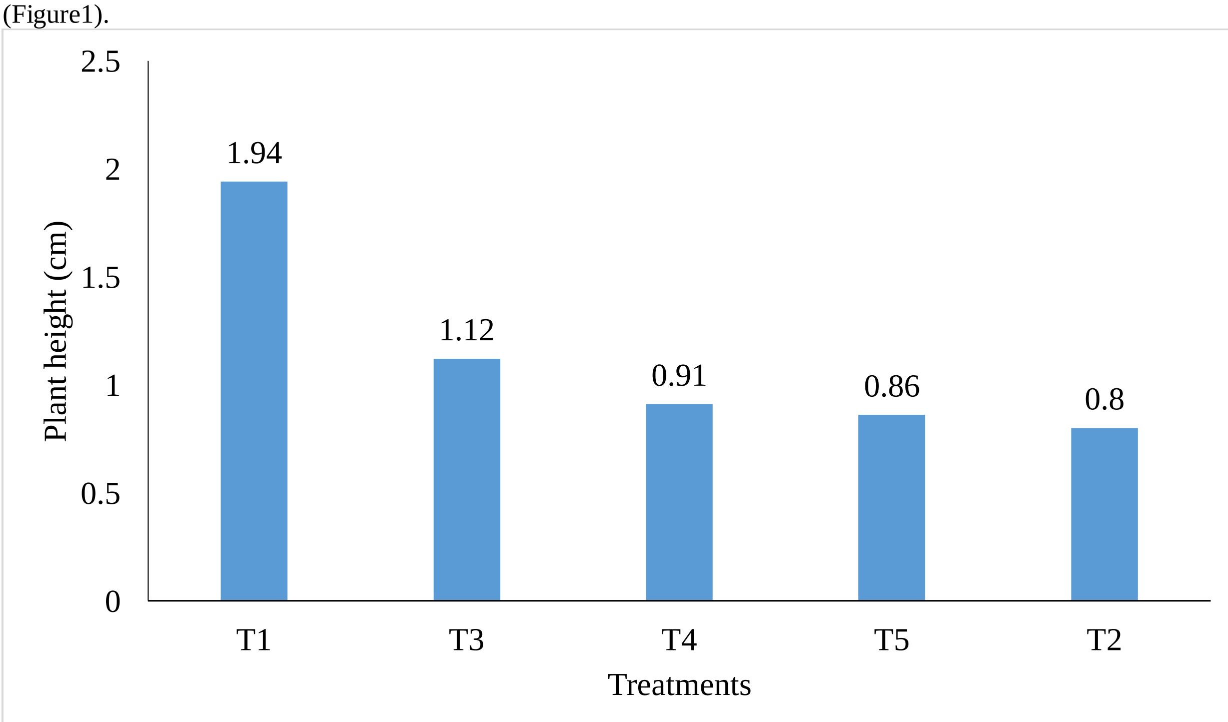

Figure 1:- Plant height average in species used as green manures in coconut plantations in Quintana Roo, Mexico.

Similar data in height were reported for *Clitoria ternatea* (Salazar, 2017) but in another report for *Canavalia ensiformis,* the heights were lower (González y Chow, 2008). Results obtained in T1: *Tithonia diversifolia* at the 12 weeks of established were higher than obtained by Ruiz *et al*. (2012) who reported heights between 71 and 125 cm at the 16 weeks of stablished. Lower values are also reported by Ríos and Salazar (1995) who reported heights between 45 and 48.5 cm in the same cutoff age but 176 and 190 cm at the 110 cutoff days.The growing of T1 in the first cutoff is accord with reported by Lugo *et al*. (2012), furthermore they mentioned that the initial regrowth is slow due to the small amount of leaf area and later there is a period with an increase in leaf production, a phase with an increase in height and finally the production of woody biomass in a more accelerated way. Fast growing is an important aspect in cover plant species due to they should to provide complete cover in soil, dense vegetation and fast growing (Ramírez *et al*., 2005).

Control of weed growth and biomass production

Regarding weed growth per square meter, significative differences (P≤ 0.05) were observed (Figure 2). The best control of weed was observed in T2 and T4 plots. These data are accord with reported by Ramírez *et al*. (2001) who reported the use of *Canavalia ensiformis* as cover plant in corn crops. They reported ten weeds per square meter, however in *Clitoria ternatea* showed serious problems because its development permitted weed invasion.

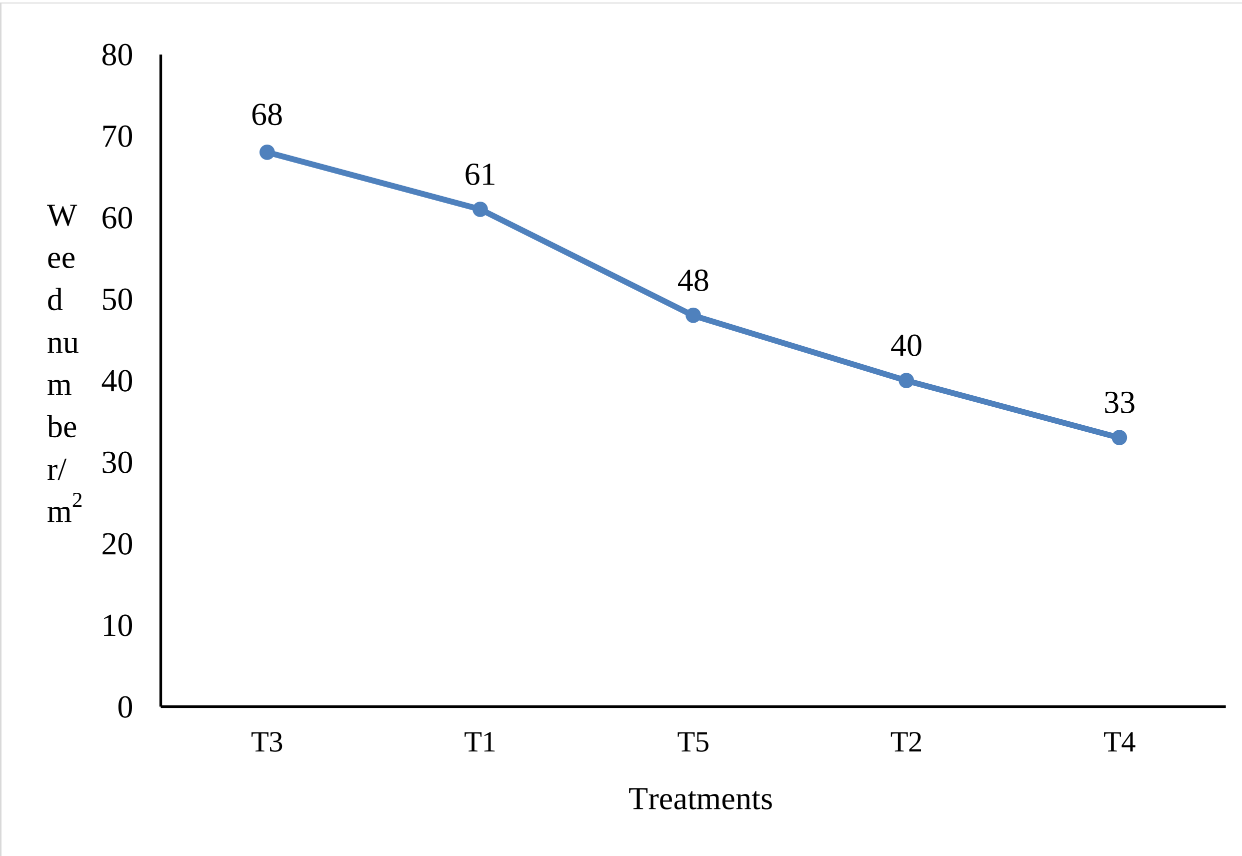

Figure 2:- weed control by species usedasgreen manuresin areas ofcoconut plantations in Quintana Roo, Mexico.

Values in dry matter production per hectare were lower, however those values were just considering the sowing density between rows in coconut plantation (2,272 plants per hectare). In Table 2 can be observed data of biomass (ton/ ha^{-1}) obtained in the four *Leguminosae* and one *Asteraceae* evaluated. Total dry matter yielding per hectare showed differences (P≤ 0.05)in treatments. The highest values were observed in T1 and T4 with 5.2 and 2.3 ton/DM/ha^{-1}. These results are accord with Ramirez *et al*. (2005) who mentioned that *Tithonia diversifolia* showed total biomass yielding of 5.4 ton/DM/ha^{-1} in plantations established in Yucatan, Mexico.

Table 2:- Dry matter production in leaves, stems and roots and total dry matter production in green manures established in coconut plantations in Quintana Roo, Mexico.

Species	leaves		Stems		Roots		TDMP Ton/DM/ha^{-1}
	%	DM	%	DM	%	DM	
T1: *Tithonia diversifolia*	42	2.1	47	2.4	11	.572	5.2[a]
T2: *Clitoria ternatea*	76	.418	12	.066	12	.066	.550[c]
T3: *Leucaena lecocephala*	30	.276	62	.570	8	.076	.920[c]
T4: *Canavalia ensiformis*	70	1.61	29	.667	1	.023	2.3[b]
T5: *Gliricidia sepium*	40	.480	45	.540	15	.180	1.2[c]

Similar letters correspond to treatments statistically equal according to Tukey test (P≤0.05). T1-T5: Treatments, DM: dry matter, TDMP: Total Dry Matter Production.

Medina *et al*. (2009) mention that biomass produced by *Tithonia diversifolia* is from 30 to 70 ton/ha^{-1} of green forage. This biomass production is due to the cut stage of plants without flowers which imply the use of leaves and stems up to two centimeters thick. On the other hand, if plant is for green fertilizer or composting manufacturing, it can be used all plant even flowers (Ríos, 1998). Another advantage of this species is the fast recover after the cutoff which depending of sow density, vegetative state and environmental conditions (Mahecha and Rosales 2005). Many authors confer to this species, high value as green fertilizer and improver to soil fertility (Jama *et al*. 2000; De Oliveira *et al*. 2007). In this sense, Ramirez (2005) highlighted the importance of this species, for instant: the elevate biomass production, high contain of nitrogen, phosphorous and potassium and fast capacity of decomposition in soil. Mosquera *et al*. (2012) mentioned that legumes species add the biomass in pre-flowering phonologic stage because that stage to generate the most quantity of nitrogen fixed and accumulated in its biomass. However, Bunch (2004) mentioned that some Latin-American farmers add green manures after flowering, even when vegetal tissue is mature.

Treatment T3 showed 0.920 ton/ha/year of dry matter due to the low sow density used. Anguiano *et al*. (2010) reported densities of 40, 60 and 80 thousand plants per hectare in coconut tree plantations and obtained 1.4, 2.1 and 4.3 ton/DM/year respectively.

Production in T5 treatment was lower in comparison to the reported by other authors who mentioned yielding from 2 ton/ha/year to 20 ton/ha/year. However, this speciesdepends on climate, soil, management, plant genetic and sow density between other factors (Elizondo-Salazar, 2018).

Dry matter production in T4 treatment was lower comparing by the reported in this legume in another studies in Quintana Roo, for example in corn production, Sosa (2005) reported 3ton/ha/year in milpa system and Ramirez *et al*. (2001) reported 4 ton/ha/year in mechanizable soils. Legumes need phosphorous to fix the nitrogen and the soil of coconut tree plantations evaluated are in clay soils, accord with Salazar (1986), low levels of phosphorous and soil type are the two principal factors that limit the growing of this species.

Nitrogen concentration obtained from biomass production

Concentration of nitrogen in dry biomass of leaves were similar in all treatments.Values can be observed in table 3.

Table 3:- Nitrogen contain and production of biomass in four species used as green manures.

Species	Nitrogen percentage (%)			Biomass (Ton/ha^{-1})		
	Leaf	Stem	Root	Leaf	Stem	Root
T1: *Tithonia diversifolia*	2.85	0.81	0.99	2.1	2.4	.572
T2: *Clitoria ternatea*	2.39	0.66	1.67	.418	.066	.066
T3: *Leucaena lecocephala*	2.93	1.37	1.27	.276	.570	.076
T4: *Canavalia ensiformis*	3.08	1.23	0.94	1.61	.667	.023
T5: *Gliricidia sepium*	3.0	1.2	0.84	.480	.540	.180

These data are accord with reported in *Gliricidia sepium* by Salazar (1986) and *Canavalia ensiformis* by Ramirez *et al*. (2001). They mentioned that these species showed high values of nutrients and can be used as green manures. In spite of T1 treatment is not a legume, it can accumulate high contain of nitrogen in their leaves as legumes (Medina *et al*., 2009). Nitrogen values obtained in *Leucaena leucocephala* and *Clitoria ternatea* were lower than reported by Carreon and Martínez (2010). In table 4 can be observed the total contain of nitrogen obtained in roots, stems and leaves in each of one species evaluated which can be compared with urea bags applied to soil, it can be observed that treatments T1 and T4 stand out again.

Table 4:- Nitrogen kilograms and Urea bags equivalent and disponible in soil through use of green manures species in coconut plantation in Quintana Roo, Mexico.

Species	**Kg/N/Ha**			**Total**	**Urea equivalent Bags***
	Leaves	**Stems**	**Roots**		
T1: Tithonia diversifolia	59.8	19.44	5.94	85.18	3.6

T2: Clitoria ternatea	9.2	.600	1.67	11.47	.5
T3: Leucaena leucocephala	17.4	6.85	1.27	25.52	1.0
T4: Canavalia ensiformis	48	8.61	0.21	56.82	2.0
T5: Gliricidia sepium	18	.720	0.08	18.8	.81

* bags of 50 kilograms of urea with 46% of nitrogen.

In T4 treatment, these values were lower to the reported by Ramírez *et al*. (2001). However, sow density used in their studies were greater than we used in this report so the dry matter production and total nitrogen were higher.

Conclusions:-

It can be concluded that T1, T4 and T5 can produce high biomass with high contain of nitrogen which can be considered as potential species to be used as cover plants and green manures in coconut tree plantations. In spite of treatment T1 is not a legume plant, it can accumulate high contain of nitrogen in their leaves as a legume and has high capacity of production of dry matter which permits to be considered as cover plant in coconut tree plantations.

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