

Stem section and planting method: its effect on *Tithonia diversifolia* biomass production

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The effect of the stem section, basal or middle, as well as the way of placing the stick (standing or lying) within the furrow in the biomass production of *Tithonia diversifolia* in both weather seasons. A design of random blocks in factorial arrangement (2 x 2), with four copies, was used. The results showed an interaction between the evaluated factors of height during the rainy and dry seasons ($P < 0.05$, $P < 0.01$), respectively. When planting the middle part of the stem, either standing or lying, the height obtained was higher. In the case of the growing, weight/leaf and leaves percentage indicators there was interaction among factors only during the dry season. Growing showed differences ($P < 0.05$) and it was worst when planting the lying basal part. On the contrary, the leaves percentage was inferior ($P < 0.01$) when planting the standing middle part. For the weight/leaf the best values were achieved when planting the lying middle part. The stem section influenced ($P < 0.001$) in the growing/d of the plant during the rainy period, as well as in the number of leaves/plants during the dry period. The middle part was superior for both indicators. This factor also influenced in the annual ($P < 0.01$) and seasonal ($P < 0.05$, rainy period and $P < 0.001$, dry period) yield. Superior values were obtained in all the cases for the middle section. There was a higher population of stems/ha ($P < 0.01$) when planting the middle section for the first year of evaluation. During the second year the population showed interaction ($P < 0.05$), and the lowest result was found when planting the standing middle part. It can be concluded that the *Tithonia diversifolia* should be planted, preferably, lying the stick in the bottom of the furrow using the middle section of the stem.

Key words: *Tithonia*, plantation, biomass production

The animal diet in the tropical cattle raising is focused on the use of large food as a main source. The study and development of species capable of adapting to the less favorable conditions for the majority of crops and of reaching high biomass volumes as well as top-quality levels, represents the priority objectives of researches developed in the stockbreeding field.

Many species that does not belong to the grass and leguminous plants produce high volumes of biomass and accumulate high levels of nitrogen and phosphorous in their leaves. These characteristics turn them into possible alternatives for exploitation. *Tithonia diversifolia*, for instance, fulfills the previous features (Wanjau *et al.* 1998), and also has a great adaptability to soils with a wide range of pH and low fertility Calle and Murgueitio 2008.

Tithonia diversifolia, belonging to the Asteracea family, is located all over the world (Gómez and Rivera 1987). It is naturalized in Cuba with the common name of "margaritona", although it is also known as giant marguerite or island marguerite (Roig 1928). This plant is widely used by farmers for different purposes, like feeding of sheeps, goats, hens, cows, rabbits and pigs (Cairns 1997). It is also used with medical purposes, in living fences, as windshields, green fertilizer and soil improver (Ríos 1998).

According to Mahecha and Rosales (2005), its yield can vary between 30 and 70 t/ha of green forage. This value will be determined, like in the rest of crops, by the conditions for the development of this specie as well as the management it receives during its establishment and exploitation.

The plantation, as the first stage of the establishment, constitutes an activity of great importance for the further development of the plant. A proper work of sowing, taken into account every aspect regarding seeds and its sowing method, constitute important aspects to achieve a successful establishment and a good biomass production, capable of fulfilling the requirements for stockbreeding.

Therefore, the objective of this study was to evaluate the effect of the stem section (basal or middle) used in the plantation as well as the way of placing the stick (standing or lying) within the furrow in the biomass production of *Tithonia diversifolia* in both weather seasons.

Materials and Methods

Treatments and design. A random blocks design in factorial arrangement (2 x 2) was used. The evaluated factors were: a) stem section selected for the sowing (basal and middle) and b) method of placing the stick in the furrow (standing or lying). The treatments were: lying basal, standing basal, lying middle and standing middle. Four replication were taken for each treatment.

Characteristics of the experimental area. The study was carried out in the Experimental Station of Pasture and Forages "Miguel Sistachs Naya", belonging to the department of Pasture and Forages from the Institute of Animal Science, at 22°53' N and 82°02' W, 80 m a.s.l. The experiment was carried out in a typical red ferrallitic soil, full of clay and deep over limestone, with fast drying, average content of organic matter, neutral pH and acceptable values of P, K and Ca (Hernández *et al.* 2005).

The specie was planted during the rainy season, within furrows of 3 m long, separated from each other by 3.0 m and five furrows per plot. Fertilization or irrigation was not applied during the evaluated period. Rains reached accumulated values of 1125.2 mm and 284.2 mm during the rainy and dry seasons, respectively.

The *Tithonia diversifolia* ecotype 10 was used. Sticks with 80 d old and 50 cm long were used for the plantation, within furrows of 15 cm deep. Some sticks were planted with one of the tips buried until 20 cm deep and some others lying in the bottom of the furrow. The sticks used came from the middle and basal part of the stem. The same amount of sticks per furrow was used and the experimental area was always free of weeds.

Experimental procedure. The samplings were performed between July, 2009 and July 2011, with a cut frequency of two and three months during the rainy and dry periods, respectively.

The plant height (cm), number of stems/ha, yield (t of DM/ha), number of leaves/plant and percent of the leaf weight regarding the total weight were determined.

For the data analysis, the InfoStat, version 1.1. (2002) statistical package was used and for the number of stems/m and the number of green leaves/plant the data was transformed according to \sqrt{x} . An analysis of variance was used to process data and the test of Duncan (1955) was applied for the necessary cases.

Results and Discussion

There was an interaction between the evaluated factors for the plant height during the rainy and dry season ($P < 0.05$, $P < 0.01$, respectively). The highest values were obtained when planting the middle part of the stem, either lying or standing.

In the case of the growing, weight/leaf and leaves percentage indicators there was only interaction between factors during the dry season (table 1).

The growth (cm/d) showed differences ($P < 0.05$) and the results were worst when planting the lying basal part. On the other hand, the percentage of leaves was inferior ($P < 0.01$) when using the standing middle part. The best values of weight/leaf were achieved when planting the lying middle part.

Table 2 shows that the stem section used in the plantation influenced ($P < 0.001$) on the daily growth of the plant during the rainy period, providing better results when planting the middle part. During the dry season there were no significant differences.

The differences in the number of leaves/plant ($P < 0.001$) occurred during the dry season, in which the middle part of the stem generated higher results than the basal part.

The stem section had a significant influence on the yield reached by *Tithonia* during the course of the year ($P < 0.01$) during the rainy ($P < 0.05$) and dry ($P < 0.001$) seasons, independently. In all the cases the middle section of the stem had higher yield than the

basal part (table 3).

Regarding the stems population/ha (table 4), there were differences during the first year of evaluation. The middle part of the stem of *Tithonia* had the best results. However, there were no differences between both sections at the beginning because the homogeneity for each treatment was taken into account. During the second year, this indicator showed interaction ($P < 0.05$) between the evaluated factors. In this case, the worst behavior was reached when planting the standing middle part of the stem (table 5).

The results of this study show that, for most of the indicators, the best values were reached when

Table 1. Interaction of the factors sowing method and stem section to plant in productive indicators of *Tithonia diversifolia*

Sowing method	Height		Height (Dry season)		Growth (cm/d)		Leaves, % (Dry season)		Weight/leaf (Dry season)	
	Rainy season		Dry season		Dry season		Dry season		Dry season	
	Lying	Standing	Lying	Standing	Lying	Standing	Lying	Standing	Lying	Standing
Basal	147.00 ^b	158.00 ^b	66.00 ^c	72.00 ^b	0.60 ^c	0.80 ^b	45 ^a	45 ^a	19 ^b	20 ^b
Middle	173.00 ^a	168.00 ^a	96.00 ^a	93.00 ^a	1.03 ^a	0.99 ^a	40 ^b	38 ^c	24 ^a	21 ^b
±SE	2.61*		1.42**		0.05*		0.27**		0.85*	

^{a,b,c} values without common letters differ significantly for $P < 0.05$ (Duncan 1955)

* $P < 0.05$ ** $P < 0.01$

Table 2. Effect of the stem section to plant on the number of leaves and growth of *Tithonia diversifolia*

Factor	Growth(cm/d)		Number of leaves/plant	
	Season			
Stem section	Rainy	Dry	Rainy	Dry
Basal	4.84 ^b	0.70	3.62 (13)	3.02 ^b (9)
Middle	5.63 ^a	1.01	3.67 (13)	3.22 ^a (10)
±SE	0.09***	NS	NS	0.03***

^{a,b} Middle stem section without common letters within each column differ significantly for $P < 0.05$ (Duncan 1955). *** $P < 0.001$ NS: not significant, () Real value

Table 3. Effect of the stem section to plant on the yield of *Tithonia diversifolia*

Factor	Yield t DM/ha		
	Annual	Rainy Season	Dry season
Stem section			
Basal	10.36 ^b	8.08 ^b	2.31 ^b
Middle	13.61 ^a	10.49 ^a	3.04 ^a
±SE	0.71**	0.54*	0.09***

^{a,b} Middle stem section without common letters within each column differ significantly for $P < 0.05$ (Duncan 1955)

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

Table 4. Effect of the stem section to plant on the population of *Tithonia diversifolia* during the first evaluated year

Factor	Population stems/ha	
	Begining	First year
Stem section		
Basal	387.89(151666)	406.84 ^b (166249)
Middle	377.38(143333)	454.02 ^a (206249)
±SE	NS	8.27**

^{a,b} Middle stem section without common letters within each column differ significantly for $P < 0.05$ (Duncan 1955)

** $P < 0.01$ NS: not significant. () Real value

Table 5. Interactions of the factors sowing method and stem section to plant in the population of *Tithonia diversifolia* during the second evaluated year

Tratamientos	Población tallos/ha
	Segundo año
Basal lying	377.14 ^{ab} (142499)
Basal standing	397.33 ^{ab} (158333)
Middle lying	407.31 ^a (166666)
Middle lying	373.02 ^b (139166)
EE ± interaction	9.71*

^{a,b} Different letters indicate significant differences ($P < 0.05$) Duncan (1955). * $P < 0.05$ () Real value

planting the middle part of the stem. This coincides with the results obtained by Fanego *et al.* (2009), who achieved the highest percent of germination and rooting in the central part when evaluating the sticks from different stem sections of the *Bougainvillea glabra*, which has a direct influence on the productive factors, such as stem population/ha and the yield

calculated in t of DM/ha. These authors state that the central sticks have higher amounts of leaf buds than the basal sticks, which increases the possibilities of germination. Besides, the reserve substances of the sticks, together with the new buds and leaves, increase the photosynthetic activity as well as the production of endogenous auxins that stimulates callus formation

and its radical differentiation. Then, it is supposed that the basal sticks have higher lignification and lower number of leaves and buds which limit to obtain the best results.

Other authors, like Duarte and Suchini (2002), achieved similar results evaluating sticks of *Litchi chinensis*. They informed high percentages of rooting as well as high number of leaves when planting the stick from the middle part of the stem. The results were different when they planted the basal part.

There was a difference in some indicators like daily growth, percentage of leaves, weight/leaf and leaves/plants only during the dry season. This may be caused by the beneficial effect of the weather conditions during the rainy period, which facilitates the development of the specie and the expression of its potential. Both treatments can be developed with no difficulties because there are no limiting factors like drought and lack of light. However, the unfavorable weather conditions (low temperatures, solar radiation and the few rains) during the dry season, limit the development of most of plant species. Torres *et al.* (2000) confirmed this fact, who evaluated, during different periods, the effect of different patterns of sowing on the production of biomass of *Leucaena leucocephala*. They obtained differences ($P < 0.05$) during the rainy and dry seasons, with values of 4.519 and 1.856 kg/ha, respectively.

All the previous information, together with the effect of the physiological age of the stem sections, could contribute to the differences among treatments. As *Tithonia diversifolia* is an erect growth specie, the oldest plant material is located in the inferior strata (basal) where the metabolic activity of the plant and the synthesis of enzymes and proteins are inferior. This could influence on the mobilization of the reserve substances. Regarding this fact, Pérez and Martínez (1994) stated that during the aging process, different biochemical and physiological changes occurred, for instance, an important reduction of the contents of chlorophyll, proteins and starch. This fact could have had a negative influence on the germination of the buds from the stems and, consequently, the development of the basal section was lower than the middle section.

In the case of the factor plantation method, in some of the measures like weight/leaf and percent of leaves (both during dry season) and population of stems/ha (for the second evaluated year), there were superior results when planting the stick lying in the bottom of the furrow. This coincides with the results of Ruiz *et al.* (2009), who obtained, in a similar study, higher weight of green leaves of the same specie when planting the stick lying in the bottom of the furrow. These authors stated that, when planting the stems by one of the tips, the result showed weaker plants, with a lower number of leaves and less weight of the plant. They also

observed that these plants presented a lower amount of roots because, according to the authors, the contact between the soil and the stem surface is lower, contrary to what happens when planting the stem lying in the bottom of the furrow.

It can be concluded that the plantation of *Thitonia* should be performed, preferably, lying the stick in the bottom of the furrow using the middle section of the stem. This facilitates the obtaining of plants with superior volumes of biomass.

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