Genetic and morphological diversity of *Tithonia diversifolia* (Hemsl.) A. Gray for use in silvopastoral systems of Latin America

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Introduction

Tithonia diversifolia, a tropical shrub native to Mexico and Central America, presents characteristics of great interest for ruminant production systems (Mauricio *et al.,* 2017). This species, a shrub of the Asteraceae family, is considered a forage species of great importance due to its chemical composition, productive performance, and adaptation (Tendonkeng *et al.,* 2014).

In plant species, genetic and morphological variability are considered the basis for their adaptation and ability to respond to challenges and threats (Govindaraj *et al*., 2015). The study of genetic diversity in plants allows the selection of the best ecotypes in terms of productivity and forage quality (Ruiz *et al.,* 2013).

Objective

To determine the phenotypic diversity of *Tithonia diversifolia* in Colombia and Mexico, and recognize its productivity and socio-economic potential in cattle systems.

Materials and Methods

Genetic diversity

Localization

Five eco-regions in Colombia.
25 collection sites in Colombia.
Six collection sites in Mexico.

Figure 1. Collection sites of *T. diversifolia*

- Molecular markers: Cytochrome P450 and ISSRs (Yamanaka *et al.,* 2003), and amplification of the ITS region of ribosomal DNA using the oligos ITS1 5 '-3' and ITS4 5 '-3').
- Conglomerate analysis (Yeh *et al.,* 1999) and genetic structure evaluation (Pritchard et al., 2000). Analysis in R-Studio software (POPGEN; R-Studio Team, 2018).
- Multivariate statistical analysis in chemical and morphological evaluations (PCA).

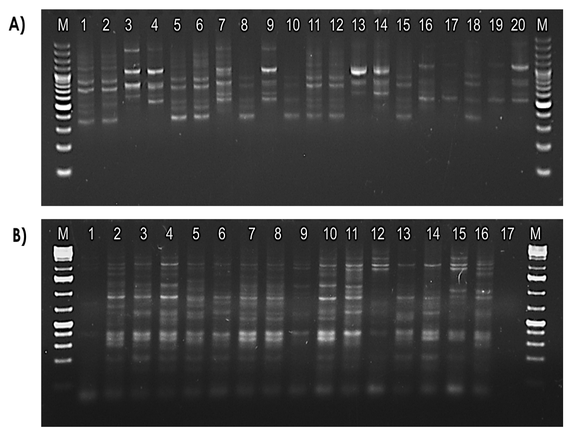


Figure 2. Agarose gel showing the amplification products for the molecular markers of *T. diversifolia*. A) ISSR (GA) 8YT, B) Cytochrome P450 CYP1A1F / heme2B6.

Productive and socio- economic impact of *T. diversifolia* in cattle systems

28 farms with traditional and *T. diversifolia* systems were evaluated.

Productivity impact

Completely random statistical design. – Stocking rate, milk production, and compositional quality milk.

Socio-economic impact

Non-parametric statistics analysis (Kruskal-Wallis test). – Internal rate of return, benefit/cost ratio, and employment generation.

Results and discussion

Genetic diversity

The Shannon information index (I) was 0.130 to 0.67, with a mean genetic diversity of 0.4320 ± 0.2267 indicating the high polymorphism through the loci.

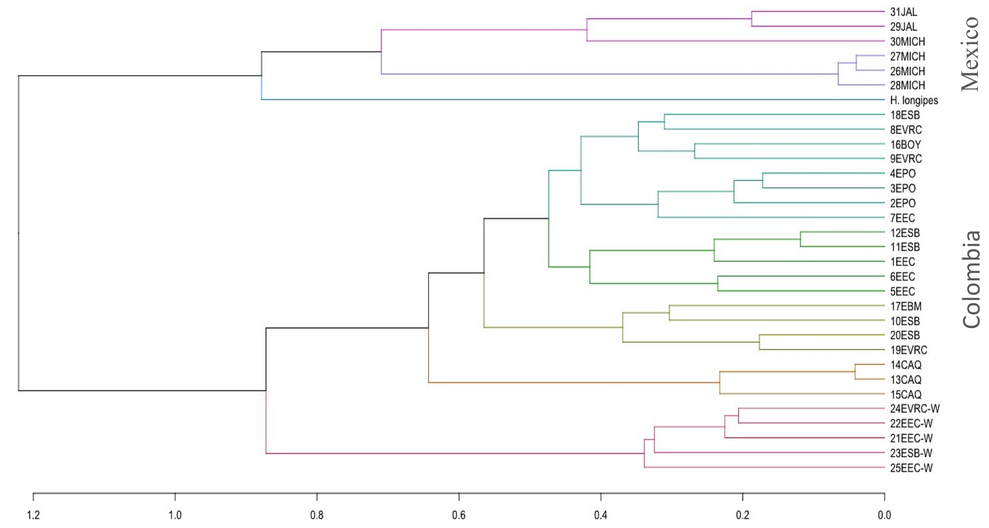


Figure 3. UPGMA dendrogram for the 31 collections of *T. diversi*folia from Mexico and Colombia (index of dissimilarity of Dice, high correlation coefficient (0.87) and agglomeration coefficient (0.8)).

Morphological and chemical characteristics in collections of *T. diversifolia*

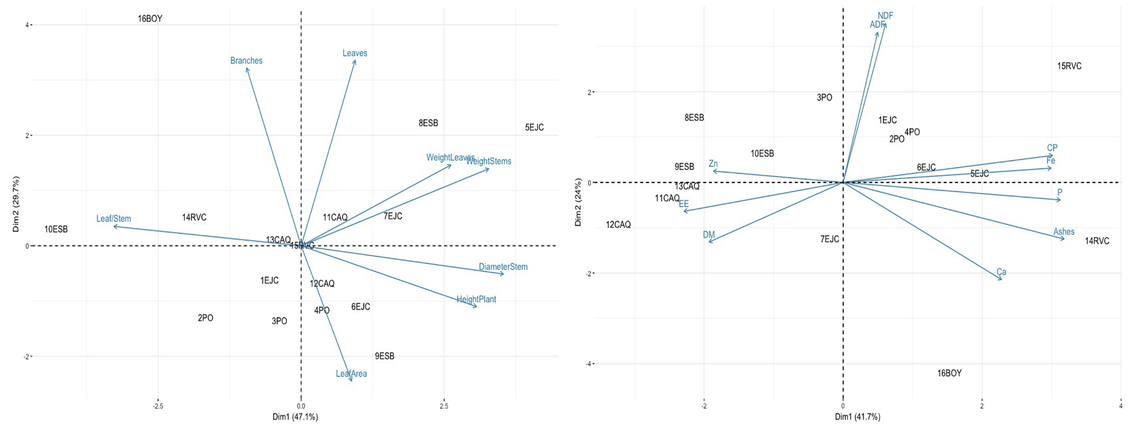


Figure 4. Variability and correlation of morphological and chemical characteristics in collections of *T. diversifolia* in Colombia (DM: dry matter; EE: extract ether; ADF: Acid detergent fiber; NDF: neutral detergent fiber; CP: Crude protein; P: Phosphorus; Ca: Calcium; Zn: Zinc; Fe: Iron).

Table 1. Morphological characteristics of *T. diversifolia* collected in Colombia (45 days growth).

	Leaf weight (g)	Stems weight (g)	Branches (#)	Height (cm)	Stem diameter (mm)	Leaf area (cm²)
Average	803±364	1354±855	26.8±20.9	139±46.2	11.9±2.7	178±62.2
Coef. of var. (%)	45.3	63.2	78.1	33.2	22.5	34.7

Table 2. Chemical composition of *T. diversifolia* collected in Colombia (45 days growth).

	DM	Ash	EE	ADF	NDF	CP	P	Ca	Zn	Fe
					%				ppm	
Average	16.4±1.5	15.4±3.2	1.57±0.67	44.9±9.4	46.8±12.5	29.3±3.3	0.63±0.14	2.43±0.9	136.7±71.9	120±34.3
Coef. of var. (%)	9.2	21.09	42.42	20.96	26.75	11.22	21.82	37.16	52.63	28.57

DM: dry matter; EE: extract ether; ADF: Acid detergent fiber; NDF: neutral detergent fiber; CP: Crude protein; P: Phosphorus; Ca: Calcium; Zn: Zinc; Fe: Iron.

Productive impact of *T. diversifolia* in cattle systems

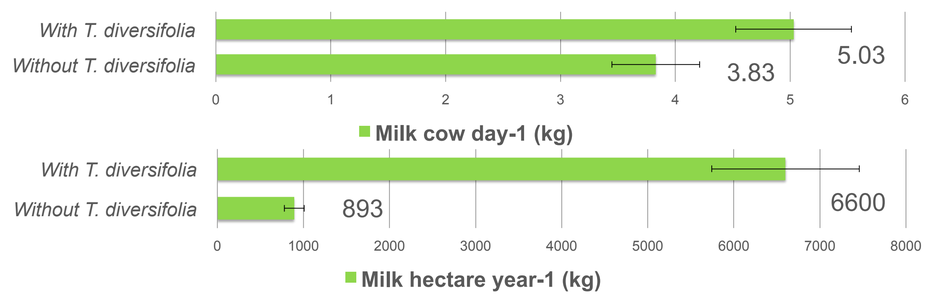


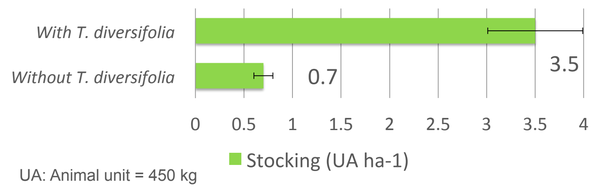
Figure 5. Milk productivity in systems with and without use of *T. diversifolia*

Table 3. Effect of the offer of *T. diversifolia* on the production of bovine milk solids (g).

	Without *T. diversifolia*	With *T. diversifolia*	Diff.
Fat cow day^{-1}	17.2^{b}	**21.1^{a}**	18.8%
P cow day^{-1}	13.6^{b}	**17.3^{a}**	21.6%
SNF cow day^{-1}	35.7^{b}	**45.8^{a}**	21.9%
Min cow day^{-1}	2.68^{b}	**3.4^{a}**	21.6%
TS cow day^{-1}	52.9^{b}	**66.9^{a}**	20.9%

P: protein; SNF: solids not fat; TS: total solids; Min: minerals. $P<0.05$

Systems with *T. diversifolia* can partially replace commercial feeds, approximately 15% of dry matter, in a total diet to dairy cows without any change in milk yield and composition, and intake (Ribeiro *et al.,* 2016).



UA: Animal unit = 450 kg

Figure 6. Stocking rate (animal per hectare) with and without the use of *T. diversifolia*.

Silvopastoral system *with T. diversifolia*

Socio-economic impact of *T. diversifolia* in cattle systems

The increase of the production and solids in milk is due to the offer of nutrients such as protein and soluble carbohydrates, as well as the low fiber that increases the intake of dry matter and its degradability (Gallego-Castro *et al.,* 2017).

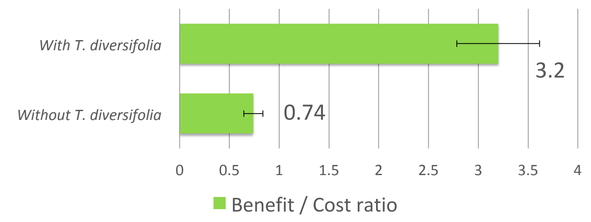


Figure 7. Cost-benefit ratio in milk production in systems with and without *T. diversifolia*

Internal rate of return, had values of 3.40 and -0.10 with a benefit/cost ratio of 3.20 and 0.74 (p <0.05), favoring a higher level of employment generation (4.3 and 0.6 per ha per year, respectively), and 9% more of gross profit in systems with Tithonia (40 vs. 49%).

Conclusion

T. diversifolia has a wide phenotypic diversity and adaptation to different agro-ecological conditions, including high-quality ecotypes that offer greater nutrients in cattle systems and great potential to contribute to the income and welfare of livestock producers.

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