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Plant growth evaluation of *Cajanus cajan* (L.) Millsp., *Canavalia ensiformis* (L.) DC. and *Cratylia argentea* (Desvaux) O. Kuntze., in soils degraded by sand and gravel extraction

Evaluación del crecimiento de *Cajanus cajan* (L.) Millsp, *Canavalia ensiformis* (L.) DC. y *Cratylia argentea* (Desvaux) O. Kuntze., en suelos degradados por la extracción de arena y grava

Mateo Vargas Zapata*, Juan Guillermo López Isaza, Luis Fernando Restrepo Betancur[1], Silvio Ayala Lopera and Marisol Medina Sierra

Facultad de Ciencias Agrarias, Escuela de Producción Agropecuaria. Universidad de Antioquia UdeA, sede Robledo. Medellín-Antioquia, Colombia. Author for correspondence: mateo.vargasz@udea.edu.co

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Abstract

In this research, the adaptability of pigeon pea (*Cajanus cajan* (L.) Millsp., canavalia (*Canavalia ensiformis* (L.) DC.) and veranera (*Cratylia argentea* (Desvaux) O. Kuntze) species, was evaluated in soils degraded by sand and gravel extraction. The three species were planted in bags as follows: 20 x 10cm, each with 3 seeds, with a substrate 2:1 soil and sand, respectively. The plants were grown under shadow conditions with 50% for 60 days, and received irrigation according to climate conditions. Therefore, were transplanted at field conditions, plant height (PH), fully developed leaves (FDL) and stem diameter (SD) variables, were measured every week for 10 weeks. A randomized block design was used with a fixed balanced effect. The number of replicates per treatment was four, the multivariate technique MANOVA variance with orthogonal type was included and the method of maximum likelihood was used to establish the dimensionality of the contrast. In fact, one-dimensional comparisons were carried out using Tukey method, which had achieved type I error of 5% statistical significance. Significant difference among plants for PH ($p<0.05$) variable was obtained. In addition, SD variable showed differences from the third week for all evaluated plants ($p<0.05$). A highly significant and directly proportional relationship among HP, FDL and SD variables ($p<0.0001$), was found. MANOVA Multivariate Analysis showed a highly significant difference among evaluated species ($p<0.0001$), which confirms the hypothesis. It was expected that species were developing and growing despite having contrasting conditions in the study area.

Keywords: Adaptability, erosion, legumes, losses from soil, organic matter, soil physicochemical properties.

Resumen

El presente estudio evaluó la adaptabilidad de las especies guandul (*Cajanus cajan* (L.) Millsp), canavalia (*Canavalia ensiformis* (L.) DC. y veranera (*Cratylia argentea* (Desvaux) O. Kuntze); a suelos degradados por la extracción de arena y grava. Las tres especies se sembraron en bolsas de 20cm x 10cm cada una con tres semillas, en un sustrato de suelo y arena en una relación 2:1 respectivamente. Las plantas se mantuvieron bajo polisombra del 50% durante 60 días, con una frecuencia de riego dependiendo de las condiciones climáticas. Posteriormente se trasplantaron a campo, allí se realizaron mediciones de las variables altura de la planta (ALP), hojas completamente desarrolladas (HCD) y diámetro del tallo (D) cada semana durante 10 semanas. El análisis se realizó mediante un diseño en bloques aleatorizados efecto fijo balanceado. Por medio de cuatro repeticiones para cada especie, se incluyó la técnica MANOVA con contraste ortogonal, el método de la máxima verosimilitud para establecer la dimensionalidad del contraste y las comparaciones unidimensionales se realizaron por método de Tukey teniendo como error tipo I un 5% de significancia estadística. Se obtuvo diferencia significativa entre las especies para la variable ALP ($p<0.05$). La variable diámetro presentó diferencias a partir de la tercera semana para las tres especies evaluadas ($p<0.05$). Se encontró una relación altamente significativa y directamente proporcional entre las variables ALP, HCD y D ($p<0.0001$). El análisis multivariado MANOVA mostró una diferencia altamente significativa entre las tres especies ($p<0.0001$) lo cual confirma la hipótesis de que las especies se desarrollaran y crecieran a pesar de las condiciones del área de estudio.

Palabras clave: Adaptabilidad, erosión, leguminosas, materia orgánica, perdida de suelo, propiedades físico-químicas del suelo.

Introduction

Population growth together with construction materials demand for the roads development and buildings is in increasing. Therefore, sand and gravel extraction is inevitable for cities development and expansion. This exploitation is carried out worldwide, according to Garcia (2013), from 47-59 billion tons of materials extracted per year; this represents 68-85%. Degraded soils are plentiful all over the world and their agricultural use is very difficult, uneconomical or directly impracticable (Ferrari & Wall 2004; García, 2013), as a consequence of sand extraction, where is carried out, the effects on the immediate neighboring ecosystem are devastating (Martínez, Zorrilla, Palma & González , 2002).

In this sense, biodiversity, water turbidity, groundwater levels and CO_2 emissions generated in transport, compared to the above factors, forests contain about 90% of terrestrial biodiversity. In addition to the excess of clays or other particles, which could contribute to a decreasing photosynthesis, an essential process to have achieved optimum oxygen levels for the life of aquaculture species. Therefore, there is a need to implement plantings of species, which can be adapted to these specific conditions without the use of chemical or organic fertilizers (Hu, Liu & Song, 2016).

Most of the materials have low porosity and low water retention, where Lavelle (2010), points out that it is possible that only local or highly adaptable species are adapted to degraded soils. Given these concerns, is considered that some legume species may be included under these conditions, because of their ease in adapting to arid environments or with low availability of nutrients, soil anchoring ability and as expressed by Aedo (1991), and the use of nitrogen present in the air.

Taking into account the mentioned characteristics, three types of shrub legumes were chosen as follows: pigeon pea (*Cajanus cajan* (L.) Millsp), canavalia (*Canavalia ensiformis* (L.) DC.) and veranera (*Cratylia argentea* (Desvaux) O. Kuntze), with the aim to evaluate the plant growth with respect to the variables: Plant height (PH), fully developed leaves (FDL) and stem diameter (SD), in soils degraded by mining in Bello-Antioquia, Colombia.

Materials and methods

Planting location

The research was carried out at Arenera San Antonio in Potrerito, which is part of the occidental mining zone of the Bello municipality, Antioquia-Colombia, bordering on the east by urban perimeter, at west by the Falles Calles, at north by Tierradentro ravine and at south by Hato ravine. The approximate altitude is 1650 m.a.s.l. and its average temperature is 18°C. The morphology is abrupt characterized by long, flat-convex surfaces with slopes between 30 and 75°, predominating slopes of 67° in the most abrupt part and 30° in the lower parts.

Nursery establishment

For nursery establishment was built a greenhouse close to planting location, the structure was covered with a polyshadow of 50% in order that, as expressed by Reyes & Rodríguez (2005), it would not reach the whole of the solar radiation to newly germinated seeds to avoid possible losses by direct exposure and promote plant growth with an average Darkness level. Three legume species were planted as follows: *Cajanus cajan*, *Canavalia ensiformis* and *Cratylia argentea,* respectively, as suggest Trujilo (2014), for this process were filled thousand bags under pressure, in fact, at the time of planting the root would not remain uncovered and more easily support the passage to field conditions. The seeds of the three species were sown at the rate of three seeds per bag to guarantee at least one plant per each bag as recommended by the same author. The ratio used to fill the bags was 2: 1 (two parts of soil per one of sand) and thus, favor the consistency and ease of water passage at the time of irrigation.

Subsequently, as Trujilo (2014), indicates, the substrate was moistened and irrigated during the following week every day in the morning, to guarantee the seed imbibition process, as in legumes, the amount of water, which penetrates and reach up to 180% of the seed weight depending on the type of endosperm (proteic or amilaceous). Therefore, relevant revisions were made daily in order to manually eliminate other species than those planted, since the bag density is minimal. A manual irrigation system was used to allow an uniform sheet of water distribution in all bags.

Blocks preparation

The planting density was adjusted according to what supports each species, being reported as Lobo, Higuera, Pabón & Sandoval (1996), in general, for *C. cajan* is 1m between rows and 50cm between plants. Marín (1984), cited by Cáceres, González & Delgado (1995), suggest for *C. ensiformis*, 80cm between rows and 25cm between plants and up 50000 plants.ha^{-1}, for *C. argentea,* Argel & Lascano (1998), propose a plant density of 6000-13000 plants.ha^{-1}. Based on this, a plant density of 10000 plants.ha^{-1}, was considered for this research, which is equivalent to 1m between plants x 1m between rows for all species for ease of handling. Therefore, the sites were selected to establish experimental blocks of $126m^2$, with replicates of $54m^2$, to obtain 126 total plants per block and 54 plants per replicate. In fact, the plant density was chosen in this way to facilitate the displacement in the moment of respective variable measurements and take advantage of the space allocated for the work without altering the plant densities that each one of them supports.

Soil sampling

The materials which were sampled, had achieved a mixture of different strata, from clayey silt (organic layer) to silty sand, in which there is also the presence of granoliorite saprolite or parental material 1-4 inches in diameter. As a result, it has long been thought that is the result of previous sand extraction. For soil sampling, a *zig-zag* method (Osorio & Ruiz (2001), was used and approximately 15 subsamples were taken in each block, with changes in direction or vertices being preferred; each sampling point had an approximate area of 35x35x35cm, which were pooled for subsequent analyses.

Sowing in field conditions

The species were transplanted when they presented two fully developed leaves (FDL); this factor guarantees a partial photosynthetic ability and the seedling development in field conditions (which took an average of 60 days). In addition, was planted in the place previously prepared without fertilizer use and applied irrigation depending on the rainfall frequency.

Measurements

One week after sowing in the field conditions, the respective measurements of plant height (PH), fully developed leaves (FDL) and stem diameter (SD) variables were started. In order to determine nursery seedlings, was carried out from the root neck to terminal bud, as Rodríguez (2010), states in the nursery practices manual. This same concept was applied for PH variable measurement under field conditions, since the plant is evaluated from its first stages until the end of the measurement, arranging the plants at the foot with a ruler (100cm metal) forcing the curvatures present in each one, to better determine the plant height.

The stem diameter (SD) variable, was measured with a vernier caliper, 1 cm from the stem base, which is where the stem has a higher growth rate.

To obtain the Number of fully developed leaves (FDL) variable, each leaf was counted per plant having a complete maturity stage.

Data analysis

A balanced randomized block design was used, where the number of replicates per species was four in total. The multivariate MANOVA variance technique, with canonical contrast of the orthogonal type, was incorporated into the experimental classification design, the contrasting dimensionality was established by the maximum likelihood method. The unidimensional comparisons were made by Tukey method, having as type I error a 5% of statistical significance. The analysis was complemented by means of descriptive statistics, whose objective was to establish arithmetic mean, standard deviation and coefficient of variation. In fact, SAS ® statistical package was used. It should be noted that the number of fully developed leaves (FDL) variable was transformed by means of the BOX-COX ™ family, determining the optimum lambda viability. The species were randomly assigned within each block.

Longitudinal model

The model was established according to the equation 1.

$$Y_{ijsr} = \mu + P_i + B_j + S_s + PS_{is} + E_r(_{ijs}) \quad \text{Equation 1}$$

Where:

$Y_{ijsr:}$ Corresponds to each of the response variables.

μ: Average effect of the experiment.

$P_{i:}$ Corresponds to the effect of each plants, which is fixed.

$B_{j:}$ Is defined as the blocking effect.

$S_{s:}$ Effect of the week, which is of random type.

PS_{is}: Corresponds to the interaction of the plant and timing effect.

$E_r(_{ijs})$: Is the experimental error term, which is of random type.

Model for each week

The model was established according to the equation 2.

$$Y_{ijsr} = \mu + P_i + B_j + E_r(_{ij}) \quad \text{Equation 2}$$

$Y_{ijr:}$ Corresponds to each of the response variables.

μ: Average effect of the experiment.

$P_{i:}$ Corresponds to the effect of each plants, which is fixed effect.

$B_{j:}$ Is defined as the blocking effect.

$E_r(_{ij})$: Is the term of experimental error.

Results

In Table 1, means, standard deviations and coefficient of variation for each plants in each week of observation can be observed, where a greater homogeneity was performed for the SD variable, related to *C. ensiformis*. In addition, is possible to be appreciated that *C. cajan,* presented a higher average plant growth dynamics over time, other case of *C. argentea*.

Table 1. Descriptive analysis of each species for PH, FDL and SD variables

Week	PH		FDL		SD	
	Mean± SD	CV	Mean± SD	CV	Mean± SD	CV
			C. argentea			
1	4.4±1.93	43.4	1.9±0.67	35.4	1.9±0.60	31.9
2	6.2±2.3	37.4	2.2±0.70	30.7	2.6±0.68	26.3
3	8.8±2.73	31.1	2.3±0.72	30.6	2.6±0.47	17.9
4	9.1±2.95	32.2	2.5±0.73	29.4	2.7±0.44	16.4
5	9.5±3.17	33.0	2.6±0.76	28.8	2.7±0.51	18.5
6	10.3±3.4	32.8	3.0±0.95	31.8	2.8±0.57	19.8
7	10.7±3.65	34.0	3.4±1.02	29.9	3.0±0.60	20.3
8	10.7±3.65	34.0	3.4±1.02	29.9	3.0±0.60	20.3
9	10.7±3.65	34.0	3.4±1.02	29.9	3.0±0.60	20.3
10	11.2±3.99	35.5	4.0±1.15	28.7	3.3±0.68	20.8
			C. cajan			
1	20.8±5.21	25.0	4.1±1.18	28.3	1.6±0.41	24.7
2	24.1±5.77	23.9	5.2±1.40	26.6	2.5±0.59	22.9
3	26.7±6.25	23.3	6.4±1.31	20.5	3.0±0.47	15.9
4	30.0±6.09	20.2	7.9±1.71	21.5	3.1±0.42	13.5
5	34.4±7.41	21.5	9.4±2.3	25.3	3.6±0.63	17.5
6	40.3±0.71	21.6	12.4±4.6	36.9	4.0±0.83	20.3
7	47.0±10.8	22.9	15.4±6.72	43.4	4.5±1.02	22.3
8	53.3±12.7	23.8	18.9±8.17	43.0	5.5±1.30	23.8
9	59.7±14.8	24.7	27.9±14.1	50.5	6.2±1.86	30.0
10	71.2±16.8	23.6	41.0±21.8	53.1	7.7±2.4	32.1
			C. ensiformis			
1	14.3±3.53	24.6	1.0±0.28	25.8	4.3±0.76	17.7
2	15.4±4.40	28.5	1.1±0.37	32.3	4.7±0.75	16.1
3	17.0±5.15	30.1	1.6±0.46	27.5	5.1±0.80	15.5
4	19.9±6.61	33.1	2.1±0.46	21.2	5.4±0.67	12.2
5	22.9±7.89	34.3	2.7±0.76	27.9	6.1±0.91	14.9
6	27.2±7.86	28.9	3.8±1.32	34.1	6.6±0.95	14.3
7	30.9±8.98	29.0	5.2±1.74	33.3	7.0±0.96	13.6
8	32.4±9.85	30.3	5.8±2.20	37.6	7.1±1.63	22.7
9	36.4±11.13	30.5	6.8±2.63	38.2	7.5±1.78	23.5
10	43.4±10.58	24.3	10.2±3.98	38.8	8.7±1.42	16.3

CV: Coefficient of variation; SD: Standard deviation. PH: Plant height: FDL: Fully developed leaves; SD: Stem diameter.

SOM contents, exchangeable AL and available P, ranged from 0.11-0.28% and are listed in Table 2.

Table 2. Comparative analysis among plants for each analyzed variable

Week	*C. argentea*	*C. cajan*	*C. ensiformis*
		PH	
1	c	a	b
2	c	a	b
3	c	a	b
4	c	a	b
5	c	a	b
6	c	a	b
7	c	a	b
8	c	a	b
9	c	a	b
10	c	a	b
		FDL	
1	b	a	c
2	b	a	c
3	b	a	c
4	b	a	b
5	b	a	b
6	b	a	b
7	c	a	b
8	c	a	b
9	c	a	b
10	c	a	b
		SD	
1	b	b	a
2	b	b	a
3	c	b	a
4	c	b	a
5	c	b	a
6	c	b	a
7	c	b	a
8	c	b	a
9	c	b	a
10	c	b	a

Different letters indicate significant statistical difference ($p<0.05$). PH: Plant height: FDL: Fully developed leaves; SD: Stem diameter.

It was observed that for SD variable, we obtained measurements of 3 cm. One of the possible factors that affect this parameter is the plant density. In this sense, for *C. ensiformis* at days 10, 20, 30 and 40 (approximately), measures of 14.5±3.5cm, 17±5cm, 19.9±6,6cm y 27.2±7.8cm, respectively, were established. One of the reasons, which can give this difference, is the OM percentage that in the present evaluation ranged from 0.11% to 0.28% according to the plant density used (10000 plants.ha^{-1}). As for SD variable, soil density and fertility did not affect the development of this variable since it was the most homogeneous during the weeks.

Conversely, Figure 1 shows that *C. argentea* has a very different plant growth dynamics with respect to the other evaluated plants; for instance, from the seventh week, tended to stabilize its plant growth and at tenth week, was evident an increasing in the stem diameter (SD) and the fully developed leaves (FDL).

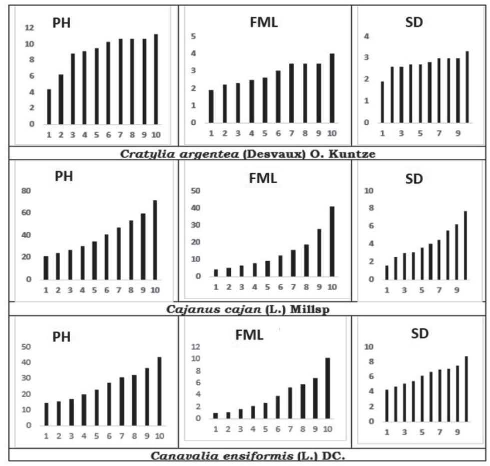

Figure 1. Plant growth dynamics over time of *C. argentea*, *C. cajan* and *C. ensiformis* species

PH: Plant height: FDL: Fully developed leaves; SD: Stem diameter.

A significant difference was detected among plants for the plant height variable throughout the evaluation period ($p <0.05$). At the weeks 4, 5 and 6, *C. argentea* and *C. ensiformis* were not statistically different ($p> 0.05$). The number of emitted leaves showed a statistical difference among plants at weeks 1, 2, 3, 7, 8, 9 and 10, respectively. In relation to stem diameter variable from the third week, all the plants were not statistically equal ($p <0.05$) (Table 2).

As expected, the plants show a significant difference among them, due to their own factors (species, plant growth dynamics) and external factors such as the amount of nutrients present in the soil and the climate. A highly significant and directly proportional relationship between plant height (PH), fully developed leaves (FDL) and stem diameter (SD) ($P <0.0001$) was found. (Table 3).

Table 3. Correlation analysis for each of the species

	C. argentea			*C. cajan*			*C. ensiformis*		
	PH	**FDL**	**SD**	**PH**	**FDL**	**SD**	**PH**	**FDL**	**SD**
PH	1.0	0.54	0.68	1.0	0.96	0.93	1.0	0.84	0.76
FDL		1.0	0.62		1.0	0.94		1.0	0.86
SD			1.0			1.0			1.0

All relationships were declared highly significant ($p<0.0001$) and direct The Spearman correlation method was applied PH: Plant height: FDL: Fully developed leaves; SD: Stem diameter.

This results provides more accurate and reliable estimates of plant growth dynamics of the evaluated species, slow (*C. argentea*) or rapid (*C.*

ensiformis and *C. cajan*), it can be observed that the evaluated variables are directly proportional to the plant development. In fact, MANOVA multivariate analysis of the variance, which simultaneously takes into account all response variables (PH, FDL and SD), showed a highly significant difference among evaluated species (Tables 4, 5).

Table 4. MANOVA analysis for the evaluated species

	PH	FDL	SD
C. argentea	c	c	c
C. cajan	a	a	b
C. ensiformis	b	b	a
		MANOVA	
	Value	**F**	**p Value**
Wilks' Lambda	0.03	1658.3	<0.0001
Pillai's Trace	1.61	1466.6	<0.0001
Hotelling-L-T	10.7	1871.1	<0.0001
Roy's Greatest	8.11	2824.9	<0.0001

Different letters indicate significant statistical difference (p<0.05). PH: Plant height: FDL: Fully developed leaves; SD: Stem diameter.

Table 5. Bromatological composition of the evaluated species at the end of the evaluation

	Evaluated species		
Parameter	***C. cajan***	***C. ensiformis***	***C. argentea***
DM (%)	37.50	31.37	34.87
CP (%)	9.66	9.58	13.88
NDF (%)	52.82	30.97	58.53
FAD (%)	36.48	15.55	30.71
Ca (%)	1.17	1.34	0.38
P (%)	0.20	0.15	0.22
EE (Kcal Kg $^{-1}$)	4541	3800	4063

Integrated Laboratory of Animal Nutrition, Biochemistry, Pastures and Forages of the Universidad de Antioquia, Colombia.

DM: Dry matter; CP: Crude protein; NDF: Neutral detergent fiber; FDA: Fiber acid detergent. Ca: Calcium; P: phosphorus.

The rehabilitation or reclamation works of degraded soils by mining activities, where the soil condition is almost completely lost due to soil physical properties alteration, a decreasing in the biota, the washing of nutrients, the loss of the soil organic matter (SOM) among others, are listed in Table 6. This information is useful and indispensable to reduce the environmental impact generated by sand and other materials extraction in soils degraded by mining activities.

Table 6. Soil analysis at the initial and final stage of each block with statistical analysis

Variable	Soil unity	Method	Block 1		Block 2		Block 3		Block 4		Statistic Analysis	
			Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
pH		Potentiometric	6.89	6.34	5.61	5.8	6.2	6.25	6.08	6.19	6.19a	6.14a
EC	ds.m^{-1}	Conductivitymeter (soil: water 1:5)	0.09	0.15	0.02	0.07	0.04	0.12	0.05	0.04	0.05a	0.09a
SOM	%	Walkey & Black	0.28	0.26	0.11	0.21	0.19	0.24	0.18	0.13	0.19a	0.21a
p	mg.kg^{-1}	Bray II	15.23	13.2	9.54	7.9	17.21	14.5	12.59	9.87	13.6a	11.4a
S	mg.kg^{-1}	Monobasic calcium phosphate	3.75	2	2.57	1.25	3.6	2.15	2.2	2.3	3.0a	1.9b
Al+H	cmol(+).kg^{-1}	KCL	0	nd	nd	nd	nd	nd	nd	nd	nd	nd
Al	cmol(+).kg^{-1}	KCL	0	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ca	cmol(+).kg^{-1}	Ammonium acetate 1N pH 7.0	6.24	5.78	2.19	1.58	4.5	4.8	4.15	2.72	4.3a	3.7a
Mg	cmol(+).kg^{-1}	Ammonium acetate 1N pH 7.0	2.43	1.93	1.25	1.01	2.08	1.77	1.7	1.8	1.9a	1.6a
K	cmol(+).kg^{-1}	Ammonium acetate 1N pH 7.0	0.05	0.05	0.02	0.01	0.06	0.09	0.02	0.04	0.03a	0.04a
Na	cmol(+).kg^{-1}	Ammonium acetate 1N pH 7.0	0.16	0.11	0.07	0.11	0.12	0.15	0.12	0.06	0.11a	0.10a
ECC	cmol(+).kg^{-1}	Sum of cations	8.87		3.53		6.76		5.99		nd	nd
Fe	mg.kg^{-1}	Olsen modified	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	16.7	nd	nd
Mn	mg.kg^{-1}	Olsen modified	2.31	1.58	2.12	2.04	1.27	1.97	1.03	0.93	1.7a	1.6a
Zn	mg.kg^{-1}	Olsen modified	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	nd	nd
Cu	mg.kg^{-1}	Olsen modified	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	nd	nd
B	mg.kg^{-1}	Monobasic calcium phosphate	0.27	0.21	0.08	0.09	0.19	0.2	0.07	0.05	0.15a	0.13a

EC: electric conductivity; SOM: soil organic matter; P: available phosphorus; S: available sulfur; Al+H: exchangeable acidity; Al: exchangeable aluminum; Ca: exchangeable calcium; Mg: exchangeable magnesium; K: exchangeable potassium; Na: exchangeable sodium; ECC: exchangeable cation capacity; Fe: available iron; Mn: available manganese; Zn: exchangeable zinc; Cu: available copper; B: available boron; Statistic Analysis: Tukey test with significance level at 5%; Different letters denote statistical significance.

Discussion

For PH variable in *C. argentea*, heights were found at 60 days of 10.7cm, these results are comparable in variability to the report by Enríquez, Hernández & Pérez (2003), who reported 101cm. Nevertheless, Lobo, Higuera, Pabón & Sandoval, (1996), obtained for the same evaluation days 57cm in average. This difference can be attributed to the amount of nutrients present in the soil. On the other hand, Enríquez, Hernández & Pérez (2003), report a high content of P, Mg and low percentage of soil organic matter (SOM) and a high content of SOM (7.4%), high in Al (76%) and low in P (6ppm Bray II) compared to the present research, where the same contents ranged from 0.11-0.28% (Table 2).

Enríquez, Hernández & Pérez (2003), in plant density of 10000 plants.ha-1, showed significant differences ($p < 0.05$), compared to plant densities of 20000 plants.ha^{-1} where the stem diameter (SD) variable was lower. In fact, in a later work carried out by Babu, Rana, Yadav & Singh (2014), obtained plant heights of 38.05cm and 87.75cm in average at 30 and 60 days, respectively, with an alkaline pH (7.5), which differs from those obtained in the current research of 30.0 ± 6.09 and 53.3 ± 7.12 on average at 28 and 56 days (correspondingly), with a pH between 5.8 and 6.89.

In this sense, factors such as SOM and the availability of soil nutrients can directly influence. These results are comparable in variability to the report by Enríquez, Hernández & Pérez (2003), and Lobo, Higuera, Pabón & Sandoval, (1996), where the plant growth of *C. argentea* was 89.4% and 81.2% lower, respectively. Its difference with other species lies in the plant growth of each evaluated species. With respect to the time at which was assessed, did not show the desired adaptability for location conditions. On the other hand, *C. ensiformis*, presented great ability of acclimatization, a rapid plant growth excels at par with pigeon pea development. Therefore, data reported by Lobo, Higuera, Pabón & Sandoval (1996), for *C. argentea*, show protein percentages ranging from 14.98% to 17.92% in different cut age groups (60 and 90 days), which differ from those obtained in the present study. In addition, they obtained percentages of NDF from 52.6% to 61.4% (60 and 90 days), which are not different from those found in the current research (58.53%). On the part of *C. cajan*, the percentage of NDF presented by Martínez (2002), of 48.8% is close to that found in this work (52.82%). In fact, a difference in protein percentage was obtained since Martínez (2002), found 19.41% compared to 9.66%.

On the other hand, *C. ensiformis* with a percentage of protein of 9.58% is unequal with respect to the data reported of 17-24% by Cáceres, González & Delgado (1995). For both cases, the differences are large, this could possibly be due to biological nitrogen fixation, which depends on the amount of the bacteria of the genus Rhizobium present in the medium, which, accordingly to Loredo, López & Espinosa (2004), is influenced by the availability of nutrients, together with a low content of soil organic matter (SOM), which for the evaluated soils was up to 0.28% (Table 5).

In this sense, the use of plant species that adapt to these poor conditions has also been reported by multiple authors as follows: Hu, Liu, Yin & Song (2016); Raphael, Calonego, Milori & Rosolem (2016); Stumpf, Pauletto & Pinto (2016), respectively. This implies the need to carry out long-term evaluations of soil degradation processes under this type of exploitation in order to contribute to soil conservation as the basis for all agricultural production.

Conclusions

The PH variable in the evaluated species is different since each presents a different plant growth dynamics due to genetic and environmental factors. For all species, the SD variable, presents differences after the transplant to the field, due to specific factors of species and the conditions present in the study area. The evaluated species present directly proportional increases for PH, FDL and SD variables.

Conversely, *C. cajan* showed constant plant growth rates over time, which shows its ability to adapt to degraded soils. The slow and difficult plant growth of *C. argentea* for PH, FDL and SD variables shows that are species not suitable for evaluated soils with low SOM contents for the time of the experiment.

For *C. ensiformis*, homogeneous increasing was found in the plant growth evaluated variables. The species *C. ensiformis* and pigeon pea, were well adapted to mixtures of materials strata remaining due to mining operations in the study area, is believed to be an outcome of low organic matter content, low cation exchange capacity and low minor element contents. While the species *C. argentea*, did not perform adaptability to the evaluated conditions in the stipulated time for measurements in this research.

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