Agronomic performance of *Stylosanthes guianensis* cv. Pucallpa in the American tropical rain forest ecosystem

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Abstract

The purpose of this study is to define the range of adaptation of *Stylosanthes guianensis* CIAT 184, released in 1985 as cv. Pucallpa by IVITA (Instituto Veterinario de Investigaciones Tropicales y de Altura) and INIPA (Instituto Nacional de Investigación y Promoción Agropecuaria) in Perú. Data from 32 RIEPT (International Network for Tropical Pastures Evaluation) type B trials conducted in the American humid tropics between Mexico and Bolivia were used for this study. The study shows that cv. Pucallpa is tolerant to anthracnose under a wide range of soil, climate and locations; the cultivar is better adapted to low altitudes (<850 m.a.s.l.), on soils that are acid (pH <5.0), which have low levels of organic matter (<3.4%), are moderately sandy (18-56% sand), and which have rainfall accumulated in 12 weeks > 800 mm. At higher altitudes (>1000 m.a.s.l.), the cultivar appears to respond to higher levels of organic matter.

Resumen

El objetivo de este estudio es definir el rango de adaptación de la leguminosa Stylosanthes guianensis *CIAT 184, liberada en 1985 como cv. Pucallpa por el IVITA (Instituto Veterinario de Investigaciones Tropicales y de Altura) y el INIPA (Instituto Nacional de Investigación y Promoción Agropecuaria), en Perú. Los datos de 32 pruebas regionales agronómicas de la RIEPT (Red Internacional de Evaluación de Pasturas Tropicales), conducidas en el Tropico húmedo de America entre Méjico y Bolivia, fueron utilizados como fuente de información. El estudio demuestra que el cv. Pucallpa es tolerante a la antracnosis en un muy amplio rango de condiciones de suelo, clima y altura; que se adapta mejor a bajas altitudes (<*850 m.s.n.m.), a suelos *ácidos (pH <*5.0), con baja materia org*á*nica *(<3.4%), moderadamente arenosos (18-56% de arena) y con precipitación acumulada en 12 semanas >800mm. En sitios de mayor altura (>1000 m.s.n.m.), el cultivar responde positivamente a incrementos en el nivel de materia orgánica.*

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Introduction

Stylosanthes guianensis var. *vulgaris* originates from South America. Several commercial cultivars which were released in Australia, viz. Schofield, Cook, Endeavour, and Graham, when reintroduced into tropical America in the 1950s, were very heavily attacked by the fungus anthracnose (*Colletotrichum gloesporiodes*) because of the greater biotic pressure from this disease in tropical South America.

As a result of the initial multilocational trials of the RIEPT (International Tropical Pastures Evaluation Network), *Stylosanthes guianensis* CIAT 184 was selected as a promising line for the humid tropics in South America. Although this material is susceptible to anthracnose under savanna conditions, it is not in the humid tropics. Lenné and Ordóñez (1988) found that antagonistic bacteria on leaf surfaces, common in the humid tropical environments, hindered the spread of anthracnose. In addition, Lenné and Toledo (1985) found that due to the small change in temperature between day and night, a characteristic of the humid tropics, the infection caused by anthracnose in CIAT 184 remained latent and non-systemic.

Between 1979 and 1984 *Stylosanthes guianensis* CIAT 184 was evaluated in plot trials in many locations and under grazing in Peru. As a result, IVITA (Instituto Veterinario de Investigaciones Tropicales y de Altura) and INIPA (Instituto Nacional de Investigación y Promoción Agropecuaria del Perú) released this line as cultivar Pucallpa in January 1985. Later grazing trials conducted in producers' fields demonstrated the ease in establishing this cultivar and its value for animal production in both weight gain and milk production (CIAT 1988; 1989).

The purpose of this study is to define the range of adaptation of cv. Pucallpa in the humid tropical ecosystem of America.

Methodology

Source of Information

Data from 32 RIEPT type B regional trials were used for this study, whose methodology for management and evaluation was described by Toledo and Schultze-Kraft (1982). RIEPT type B regional trials correspond to multilocational agronomic evaluation experiments for distinct legume ecotypes, among which *Stylosanthes guianensis* CIAT 184 was included. The 32 regional trials were conducted at different sites in the humid tropics ecosystem located between Mexico and Bolivia. They represent a major RIEPT research activity between 1980 and 1988. Figure 1 illustrates the geographical location of the 32 trials and Table 1 shows the range of environmental conditions covered by the sites selected for this study. The sites varied widely in altitude, precipitation in periods of maximum and minimum rainfall, and minimum daily temperature at the experimental sites. Likewise, the sites vary widely in soil fertility.

Analysis of information

The following agronomic indicators were used to quantify the agronomic performance of *Stylosanthes guianensis* cv. Pucallpa:

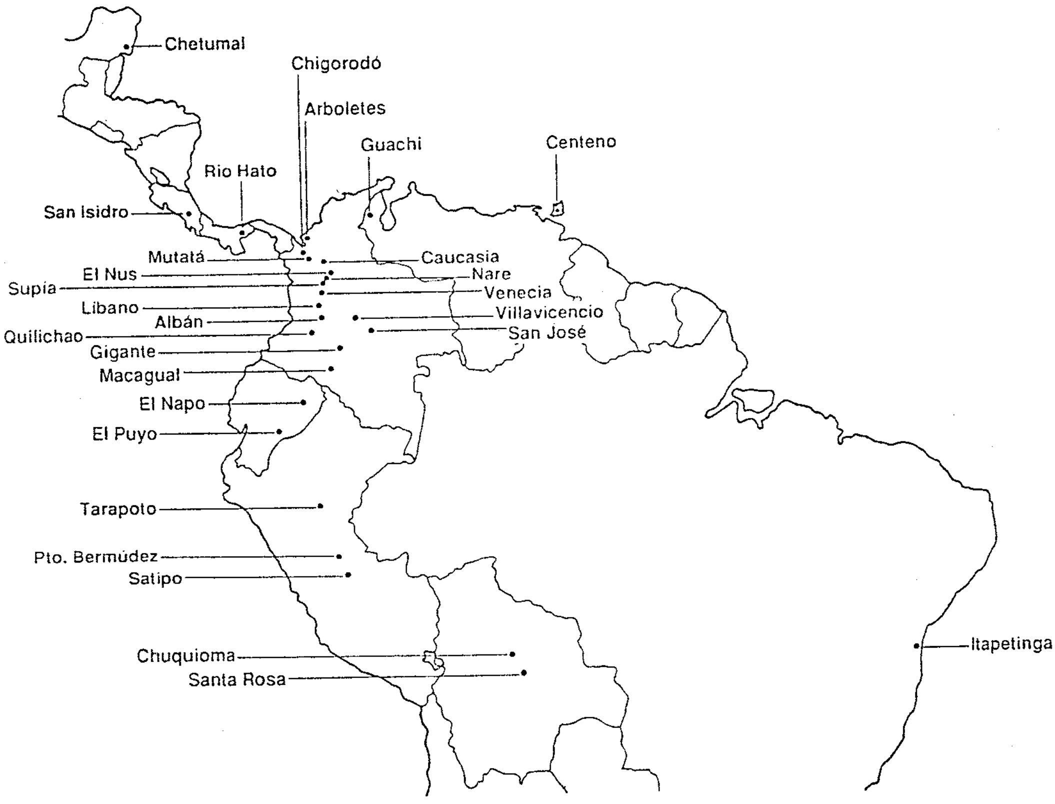

Figure 1. Sites of evaluation of *S. guianensis* CIAT 184 (now cv. Pucallpa).

Table 1. Range of environmental conditions at the 32 regional trial sites

Parameter	Minimum	Maximum
Climate and location		
altitude (m.a.s.l.)	4	1600
rainfall accumulated in 12 weeks (mm)		
maximum	310	1843
minimum	52	1535
minimum temperature at site (°C)		
period of maximum rainfall	15.0	25.0
period of minimum rainfall	14.3	25.3
Soil		
sand (%)	1.5	73.0
pH (H_2O, 1:25)	3.7	7.3
organic matter (%)	0.8	12.5
P-Bray 2 (ppm)	0.0	14.2

a) *Rapidity in establishment*
- percentage of soil cover at 12 weeks from planting,
- plant height at 12 weeks from planting.

b) *Agronomic productivity*:
- dry-matter production (kg/ha) in maximum rainfall period at 12 weeks after a uniform cutting;
- dry-matter production (kg/ha) in minimum rainfall period at 12 weeks after a uniform cutting;
- maximum anthracnose reaction; that is, the maximum ranking for damage to the plants, observed between the two seasonal periods. Ranking was expressed on a 0-4 scale, where 0 = absence of damage and 4 = more than 40% of plants affected (according to Toledo and Schultze-Kraft 1982.)

The analysis of information covered three stages: a) The identification of environmental parameters that would affect establishment and production; b) The identification of groups of similar sites, in terms of the environmental parameters detected in the first stage; and c) The description of agronomic performance of cv. Pucallpa in each group.

The purpose of the first stage of the analysis was to identify among the environmental parameters described in Table 1, those that would affect establishment and production of the cultivar. To do this, stepwise regressions were carried-out, with the agronomic indicator as the dependent variable in each regression, and environmental parameters (of soil, climate, and location) as independent variables. In order to avoid the inclusion of correlated environmental parameters within the set of independent variables in the regressions, a reduced set of non-correlated ones was selected. Those environmental parameters whose estimates in the regression model became significant, with maximum admissible probability of F of 0.20, were considered important sources of variability on the agronomic performance of cv. Pucallpa, whether in its establishment phase or in its biomass production phase.

The purpose of the second stage of the analysis was to identify groups of sites of similar environmental conditions for the cultivar. Environmental parameters detected in the first stage of the analysis as significantly affecting establishment and/or production of the cultivar, were used as classification criteria. The cluster analysis technique used was hierarchical cluster analysis with Ward's Minimum Variance as the clustering method (Everitt 1980).

Once the groups of sites with similar environmental conditions for the cultivar were identified, the agronomic performance of cv. Pucallpa in each group and its reaction to anthracnose was described.

Results

Table 2 shows descriptive statistics for the agronomic performance of cv. Pucallpa over the 32 experimental sites considered. As can be observed, this material shows wide variation in its rapidity of establishment, with percentages of soil area covered at 12 weeks after planting varying between 8 and 100 percent, and plant heights between 7 and 66 cm. The cultivar also shows a wide range in biomass production: from 795 to 10,540 kg/ha in the period of maximum rainfall and from 560 to 16,937 kg/ha in the period of minimum rainfall. Throughout the range of environments tested, the cultivar showed itself to be very resistant to anthracnose: its average overall ranking for damage was 1.6 on a scale of 0 to 4; and, as can be observed in Table 3, at 81% of the sites where anthracnose damage was evaluated, only mild damage (<20% affected) to plants was detected.

Given that some of the environmental parameters were significantly correlated among themselves (with $p < 0.05$, Table 4), a reduced set of non-significantly correlated ones was chosen to be used as independent variables in the regressions. As altitude of the site is negatively correlated with rainfall accumulated in 12 weeks

Table 2. General agronomic performance of cv. Pucallpa

Agronomic indicator	Mean	s.d.	CV	Range
Cover at 12 weeks (%)	63.7	31.6	50	8-100
Plant height at 12 weeks (cm)	39.5	17.1	43	7- 66
Yield under maximum rainfall (kg/ha/12 weeks)	4376.0	2347.0	54	795-10,540
Yield under minimum rainfall (kg/ha/12 weeks)	4070.0	3843.0	94	560-16,937
Reaction to anthracnose (0-4 scale)	1.6	1.1	74	0-4

Table 3. Distribution of the 32 sites based upon the reaction of cv. Pucallpa to anthracnose

Score (Scale 0-4)	Sites		
	No.	%	Cumulative %
0 = No damage	6	19	19
1 = 5% plants affected	9	28	47
2 = 5-20% affected	11	34	81
3 = 20-40% affected	5	16	97
4 = >40% affected	1	3	100
	32	100	100

and with minimum site temperature under both periods of maximum and minimum rainfall conditions, and as rainfall accumulated in 12 weeks and minimum site temperature are also highly correlated among themselves, then, altitude of the site was selected as an indicator of the climate and location of the experimental site. Therefore, five non-significantly correlated environmental parameters were chosen to be used as independent variables in the stepwise regressions. They are: altitude of the site (m.a.s.l.), organic matter content, pH, sand content, and P availability (ppm).

The regression analysis (Table 5) identified "location altitude" as the environmental parameter that most affects rapidity of establishment for cv. Pucallpa. The regression parameters (b, F, and probability (F)) indicate that establishment is better at low altitudes.

On the other hand, yield production of cv. Pucallpa in both seasonal periods is also shown to be influenced by location altitude, and additionally by percentage of sand in the soil, and the pH of the soil. The regression parameters indicate that yield production is better at lower altitudes, at higher levels of sand content, and at lower levels of pH. In the maximum rainfall period, in addition, the percentage of soil organic matter plays an important role.

The cluster analysis for classifying similar environments in terms of altitude a.s.l., % sand, pH and % organic matter, i.e. those environmental conditions previously identified as

Table 4. Pearson correlation coefficients between environmental variables

Environmental variable	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Correlation coefficient (probability of significance)				
1) Site altitude (m.a.s.l.)	−0.67 (0.001)	−0.93 (0.0001)	−0.84 (0.0001)	0.07 (0.60)	−0.18 (0.33)	0.37 (0.09)	0.06 (0.75)
2) Rainfall accumulated in 12 weeks, (period of maximum rainfall) (mm)		0.48 (0.04)	0.42 (0.05)	0.04 (0.87)	0.08 (0.75)	−0.35 (0.18)	0.13 (0.60)
3) Minimum site temperature period of maximum rainfall (°C)			0.93 (0.001)	−0.31 (0.22)	0.31 (0.23)	−0.37 (0.08)	0.17 (0.53)
4) Minimum site temperature, period of minimum rainfall (°C)				−0.43 (0.08)	0.31 (0.23)	−0.45 (0.09)	0.08 (0.75)
5) Sand (%)					−0.21 (0.28)	−0.14 (0.50)	−0.39 (0.06)
6) pH						−0.15 (0.45)	−0.09 (0.65)
7) Organic matter (%)							0.13 (0.55)
8) P (ppm)							

Table 5. Environmental parameters shown to affect establishment and production of cv. Pucallpa

Agronomic indicator	Environmental parameters that affect indicator	b	F	Prob.(F)[1]
Percentage soil cover	Location altitude	−0.012	1.2	0.20
Plant height (cm)	Location altitude	−0.010	2.4	0.14
Yield — maximum rainfall	Location altitude	−1.74	9.5	0.01
	% organic matter	328.00	9.5	0.01
	pH	−1216.00	6.9	0.03
	% sand	16.40	1.0	0.20
Yield — minimum rainfall	Location altitude	−3.00	4.4	0.06
	% sand	85.30	3.4	0.09
	pH	−1824.00	1.7	0.20

[1] Maximum admissible Prob.(F) = .20

influencing the establishment and yield production of cv. Pucallpa, allowed the identification of five large groups of environments (Table 6). This grouping explains 79% of the total variability observed among the sites included in the analysis. The first three groups correspond to low altitudes (<850 m.a.s.l.), with low levels of organic matter (<3.4%) and a higher level of precipitation in the maximum rainfall period (>800 mm accumulated during the 12 weeks of evaluation), but they are very distinct in terms of percentage of sand in the soil (group 1 is the lowest (10%) and group 3 the highest (56%)), and acidity (group 1 shows the highest pH level (6.6) while groups 2 and 3 show low pH levels (4.4 and 4.7 respectively)). Groups 4 and 5 correspond to high altitudes (above 1000 m.a.s.l.) with less precipitation in the maximum rainfall period (<600 mm) and average percentages of sand of around 35%. They are distinguished from each other by their level of organic matter: group 4 identifies highland sites with very low levels of organic matter (3.3%), while group 5 identifies highland sites with high relative levels of organic matter (9.5%).

Table 6 shows the agronomic indicators of cv. Pucallpa in these five environmental groups. It can be observed that the best overall performance of the cultivar occurs in groups 2 and 3. It can then be said that its best general adaptation occurs at low altitudes (<850 m.a.s.l.), in acid soils (pH <5.0) with low levels of organic matter (<3.4%) that are moderately sandy (between 18% and 56% sand). At higher altitudes, above 1000 m.a.s.l., having moderately sandy soils (35% sand, on the average), this material reacts very favorably to increases in the level of organic matter. This can be observed when comparing the higher level of biomass production in group 5 than in group 4. On the other hand, lowland clayey sites (with very low sand content, an average of 10%) do not seem to be favorable for general adaptation of cv. Pucallpa, as can be observed from the statistics on its performance in group 1.

Even for the wide variability of environmental conditions in which cultivar Pucallpa was evaluated, it is very tolerant to anthracnose. Data in table 7 shows that the cultivar reaction to anthracnose is not dependent on the environmental conditions. At low altitudes (<850 m.a.s.l.) it showed less than 20% of plants of the experimental plot affected by the fungus at 84% of the sites. At higher altitudes (≥1000 m.a.s.l.) the percentage of sites with mild anthracnose damage was also high.

Conclusion

This study permits the following conclusions:

(i) Cv. Pucallpa is tolerant to anthracnose under a wide range of soil conditions, climate, and locations. At 80% of the sites where it was evaluated, there was only mild damage to anthracnose. At the remaining sites, there was only one, where damage was severe (> 40% of plants affected).

(ii) *Stylosanthes guianensis* cv. Pucallpa (CIAT 184) is better adapted to low altitudes (<850 m.a.s.l.), on soils that are acid (pH<5.0), which have low levels of organic matter (<3.4%), are moderately sandy (18-56% sand) and which have rainfall > 800mm.

Table 6. Classification of environments (cluster analysis, R^2 = 79%, 5 groups)

Group[1]	Characterization		Agronomic indicators			
			Cover	Height	Yield at 12 weeks	
					Max. rain period	Min. rain period
			(%)	(cm)	(kg/ha)	
1 (N=3)	Low altitudes (<850 m.a.s.l.) Low organic matter (OM) (3<3.4%) Higher precipitation (>800 mm)	Low sand (10%) High pH (6.6)	85	38	2919	1027
2 (N=5)		Medium sand (18%) Acid soils (pH = 4.4)	54	36	5051	3027
3 (N=11)		High sand (56%) Acid soils (pH = 4.7)	75	52	3996	4583
4 (N=3)	High altitudes (≥1000 m.a.s.l.) % sand = 35, low precipitation (<600 mm)	Low % OM (3.3) Acid soils (pH = 5.0)	49	26	1789	2255
5 (N=3)		High % OM (9.5) more acid soils (pH = 4.4)	53	28	4831	2819

[1] Classification criteria: location altitude, % OM, % sand, and pH. Although *precipitation* was not used as a classification criteria as it was not identified as significant in the first stage of the analysis, we have included it as a descriptive parameter for the groups characterization, for a better understanding.

(iii) At higher altitudes, above 1000 m.a.s.l., the cultivar appears to respond to higher levels of organic matter.

In general, cv. Pucallpa shows excellent adaptation to tropical rain forest conditions in the American continent.

Table 7. Reaction to anthracnose according to environmental groups (high altitude groups (1,2,3) vs. low altitude groups (4,5))

Level of anthracnose damage at site	Altitude (m.a.s.l.)		Total
	≥1000	≤850	
	number of sites and percentage		
<20% plants affected (mild damage)	4 (67%)	17 (84%)	20 80%
≥20% plants affected (moderate and severe damage)	2 (33%)	3 (16%)	5 20%
Total number of sites in Cluster Analysis groups	6	19	25

References

CIAT (1989) *Pastos Tropicales, Informe Anual 1989.* Documentos de Trabajo No. 59. (CIAT: Cali, Colombia).

CIAT (1990) *Pastos Tropicales, Informe Anual 1989.* Documento de Trabajo No. 69. (CIAT: Cali, Colombia).

EVERITT, B.S. (1980) *Cluster Analysis.* 2nd Edn. (Heineman: London).

LENNE, J.M. (1982) Evaluación de enfermedades en pastos tropicales en el área de actuación. En: Toledo, J.M. (ed) *Manual para la Evaluación Agronómica.* Red Internacional de Evaluación de Pastos Tropicales. pp. 45-55. (CIAT: Cali, Colombia)

LENNE, J.M., PIZARRO, E.A. and TOLEDO, J.M. (1985) Importance of diseases as constraints to pasture legume adaptation in the Tropical American lowlands. *Proceedings of the XV International Grassland Congress. Kyoto, Japan, August 1985.* pp. 810-812.

LENNE, J.M., and ORDOÑEZ, J.H. (1988) The importance of the diseases in pasture establishment and potential control strategies. *Reunión del Comité Asesor de la Red Internacional de Evaluación de Pastos Tropicales (RIEPT), Méjico, 1988* (in press).

TOLEDO, J.M. and SCHULTZE-KRAFT, R. (1982) Metodologia para la evaluación agronómica de pastos tropicales. *En:* Toledo, J.M. (ed) *Manual para la evaluación agronómica. Red Internacional de Evaluación de Pastos Tropicales.* pp. 91-110. (CIAT: Cali, Colombia).

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