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Article

Ecogeographical Characterization of *Passiflora cincinnata* Mast. and *Passiflora setacea* DC. Native to the Central-Southern Mesoregion of Bahia

Messulan Rodrigues Meira [1], Thalana Souza Santos Silva [2], Carolina Gusmão Souza [3] Carlos Bernard Moreno Cerqueira-Silva [4]

[1] Doutora. Universidade Estadual do Sudoeste da Bahia. ORCID: 0000-0003-2447-342X. E-mail: messulan.meira@gmail.com

[2] Doutoranda. Universidade Estadual do Sudoeste da Bahia. ORCID: 0000-0001-5747-6489. E-mail: thalana-souza@hotmail.com

[3] Doutora. Universidade Estadual do Sudoeste da Bahia. ORCID: 0000-0002-4920-3269. E-mail: carolinagusmao@uesb.edu.br

[4] Doutor. Universidade Estadual do Sudoeste da Bahia. ORCID: 0000-0002-1883-4543. E-mail: csilva@uesb.edu.br

RESUMO

Passiflora cincinnata e *Passiflora setacea* são duas espécies nativas do semiárido nordestino com ampla distribuição na mesorregião centro-sul baiano. Essas espécies são reconhecidas pela produção de bioflavonoides, porém, apesar da relevância econômica, pouco se conhece quanto aos aspectos ecogeográficos, morfológicos e ecofisiológicos. Portanto, objetivou-se caracterizar os atributos físico-químico e granulométricos do solo bem como as condições edafoclimáticas em 12 locais de ocorrência natural de *P. cincinnata* e *P. setacea* na mesorregião centro-sul baiano. Os resultados identificaram os ambientes pertencentes à ecotonos dos biomas Cerrado, Caatinga e Mata Atlântica. Nestas fitofisionomias, os solos variam entre cambissolo, latossolo e planossolo e apresentam textura arenosa com pH ácido. Também apresentam características ecogeográficas variadas com altitudes entre 481 e 929 metros, precipitação entre 478 e 1.644 milímetros e temperatura média variando entre 15 e 31 graus. Os locais com temperaturas médias de até 28°C, altitude entre 670 e 860 m, pH 4,3-5,11, saturação por base <50 e H+Al entre 2-5, favorece as duas espécies. Temperaturas de até 31°C, pH entre 5 e 6, saturação por base > 50 e H+Al≤1,5, favorece *P. cincinnata*. Ambientes com temperaturas de até 27°C, altitudes superiores a 900 m, pH médio de 4,5, saturação por base média de 30 e H+Al média de 3, favorece *P. setacea*.
Palavras-chave: adaptação ambiental; ecogeografia; recursos genéticos; maracujá do mato; maracujá do sono.

ABSTRACT

Passiflora cincinnata and *Passiflora setacea* are two native species from the northeastern semiarid region, with wide distribution in the central-southern mesoregion of the Bahia state. These species are recognized for the production of bioflavonoids. However, although they have economic relevance, little is known about ecogeographic, morphological and ecophysiological aspects. Therefore, the goal was to characterize the physiochemical and granulometric attributes of the soil as well as the edaphoclimatic conditions in 12 locations of naturally occurring *Passiflora cincinnata* and *Passiflora setacea* in the central-southern mesoregion of Bahia. The results showed environments belonging to the ecotones of the Cerrado, Caatinga and Mata Atlântica biomes. In these phytophysiognomies, the soils varied between cambisol, oxisol and planosol and presented a sandy texture and acidic pH. They also have varied ecogeographic characteristics with altitudes between 481 and 929 meters, precipitation between 478 and 1.644 millimeters and average temperature ranging between 15 and 31 degrees. Sites with average temperatures of up to 28 degrees, altitude between 670 and 860 meters, pH between 4.3 and 5.11, base saturation smaller than 50 and H+Al between 2-5 favor both species. Temperatures up to 31 degrees, pH between 5 and 6, base saturation bigger than 50 and H+Al smaller equal 1.5 favor *P. cincinnata*. Environments with temperatures of up to 27 degrees, altitudes above 900 meters, average pH of 4.5, average base saturation of 30 and average H+Al of 3, favors *P. setacea*.
Keywords: **e**nvironmental adaptation; ecogeography; genetic resources; wild passion fruit; sleep passion fruit.

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Introduction

The genus Passiflora is the most important of the Passifloraceae family. In Brazil, the diversity is concentrated in the Center- North region of the country, with approximately 120 species (Leal et al. 2020). Of this number, 83 are endemic to Brazil, in which 44 species occur in the state of Bahia (Bernacci et al. 2020). Among the economically viable species are the wild passion fruit (*Passiflora cincinnata* Mast.

Passiflora cincinnata, is native to the northeaster semi-arid region and, has purplish Flowers with opaque straw green fruits (Monte & Santos 2021). The fruits have an acidic flavor with a fruity aroma (D'Abadia et al. 2020). *Passiflora setacea* D.C. is predominant in the Caatinga and Cerrado biomes. Both species are rich in bioflavonoids which have high pharmacological activity with antioxidant, anti-hepatotoxic, anti-ulcerogenic, anti- inflammatory, sedative, neroprotective, anxiolytic, antidepressant and hypoglycemic value (De Carvalho et al. 2018, Duarte et al. 2020, Leal et al. 2020).

The two species have a wide distribution in the northeast regions and are resistant to prolonged drought and phytopathogen attack (Carmo et al. 2017). However, there is still a lack of information about ecophysiological aspects. This shortage is due to the habitat loss caused by human activities, which has compromised native populations. However, the remaining plants are in process of adapting to the current ecosystem scenario (Leal et al. 2020).

To avoid plant genetic erosion, many species have been kept in *ex situ* collections in a cultivated way. However, the best way to conserve these resources is to keep them in their original environment. But for this, ecogeographically characterizing and knowing the influence of anthropic issues on native populations of economic interest is necessary (Zhivotovsky et al. 2015). Since it is not possible to conserve all plants *ex situ*, because the maintenance of the germoplasm bank requires resources and skilled labor, which encumbers the cost (Zonneveld et al. 2018). In view of the above, the objective of this research was to characterize the physicochemical and granulometric attributes of the soil, as well as the soil and climate conditions in 12 naturally occuring places of *Passiflora cincinnata* Mast. and *Passiflora setacea* DC. in the central-south region of Bahia.

Material and Methods

The study was conducted from January 2019 to July 2020 *Passiflora setaceae* were collected from May to August and *Passiflora cinccinnata* from November to January. The research was registered in the National System for Management of Genetic Heritage and Associated Traditional Knowledge – SisGen, under the registration numbers A2A69DB and AD81869.The environments were previously located by consulting the information contained in the INCT data base – Virtual Herbarium of Flora and Fungi and by the information system of scientific collections Species Link ® and by walking in the region. The locations of occurrence were identified by GPS (Global Positioning System) Oregon 550 Garmin® by which the latitude, longitude and altitude data were determined.

The location and soil map was prepared using data provided by the IBGE (2020) and Brazilian Agricultural Research Company (EMBRAPA, 2020). These data were reprojected to the geographic coordinate system, Datum SIRGAS 2000 (Geocentric Reference System for the Americas), code EPSG 4674. To classify the environments the biome, the type of vegetation, the average annual of precipitation and temperature were identified, using thematic maps made available by the IBGE.

To each place flowering botanical material was collected for the manufacture of exsiccates. The exsiccates were identified by Biologist Avaldo de Oliveira Soares Filho, curator of the Herbarium of the State University of the Southwest of Bahia, Vitória da Conquista, BA-HUESB-VC. The soil Chemical analysis, samples were

taken in each place of occurrence at 0-20cm of depth using a Dutch auge. Five auger samples were taken per site in order to form each composite sample. Chemical analysis was performed at the Campo® Paracatú –

MG Soil Analysis Laboratory. Analytical determination was obtained according to extraction and determination margins proposed by Brazilian Agricultural Research Corporation. Soils were classified according to the Brazilian Soil Classification System (Santos et al. 2018).

Chemical and granulometric analysis data of the occurrence sites of the species were submitted to principal component analysis (PCA). Variables were first submitted to Pearson correlation analysis (r) (p-value≤0.5) in order to verify whether they had the minimum correlation to justify their use in the data matrix. The retention of PCA axes to be interpreted was obtained by reducing the data set in linear combinations, which generated scores around 90% of the total variation. This enabled the identification of the most relevant chemical properties in the discrimination of the different sites of occurrence. From the correlation matrix generated, it was then possible to generate groups based on their measurements. These analysis was performed using the statistical software Ntsys-pc 2.1 (Rohlf 2000).

Result and Discussion

The 12 collection environments are located in the central-south baiano mesoregion, belonging to four micro-regions of Guanambi (Caculé-CAC, Caetité-CAE, Ibiassucê-IBI and Urandi-URA), Brumado (Malhada de Pedras-MP), Vitória da Conquista (Vitória da Conquista-VCA, Anagé-ANA, Serra dos Pombos-SEP, Cândido Sales-CS and Divisa Alegre-DA) and Itapetinga (Encruzilhada-ENC and Assentamento Primavera-AP) (Figure 1).

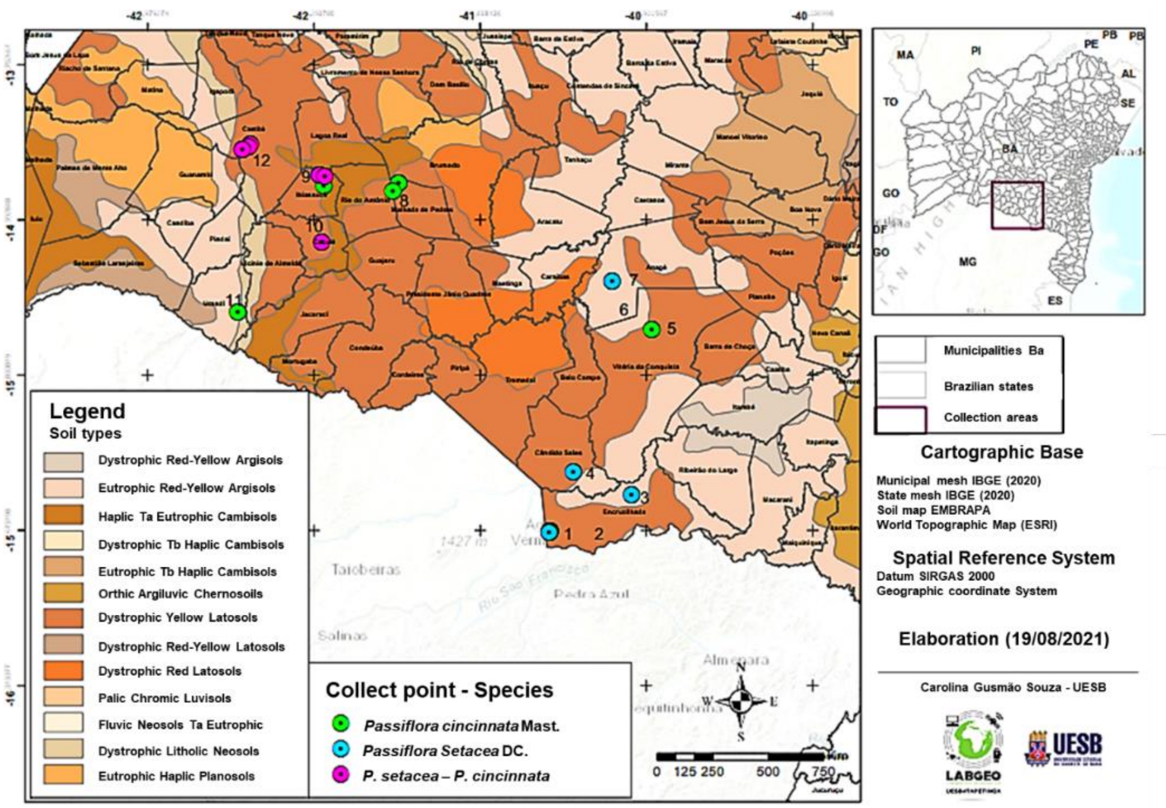

Figure 1. Location and soil classification of 12 sites of occurence of the species *Passiflora cincinnata* Mast. and *Passiflora setacea* DC. in the central-south region of Bahia. Source: Souza

The soils varied between cambisol, latosol and planosol (Table 1). Most sites (CS, MP, IBI, CAE, DA, CAC and AP) presented eutrophic cambisol. Dystrophic characteristics were observed in ENC, and CS showed intermediate characteristics between two types. VCT showed characteristics of dystrophic yellow latosol, ANA and SEP of eutrophic red yellow latosol. URA presented soil with eutrophic Planosol characteristics. All these environments are inserted in the drought polygon. These micro-regions in São Francisco and Verde Grande river basins (CAE, URA), Rio Pardo river (CS, ENC, AP, VCT, DA, SEP) and Rio de Contas river (ANA, MP, CAC, IBI). Being VCT bathed by the Rio Pardo river and Rio de Contas river.

Table 1: Location and climatic conditions of 12 occurrence sites of the species *Passiflora cincinnta* and *Passiflora setacea* in the central- south region of Bahia. Source: Meira

Code*	Coordinates		Soil class	Alt. (m)	Prec. (mm)	Temp. (°C)	Nº* / Record HUESBVC			
							P. setacea		P. cincinnata	
DA	15°40’47.2”	41°19’18.5”	Bsh-CXbe	920	1.644	1 7 - 27	30	9166	00	X
ENC	15°31’38.8”	040°59’02.6”	Bsh-CXbd	814	649	1 7 - 26	14	9165	30	9562
AP	15°37’15.3”	040°49’59.4”	Bsh-CXve	823	649	1 7 - 26	00	X	30	9561
CS	15°40’82.5”	41°19’35.5”	Bsh-CXbdbe	929	599	1 7 - 27	30	9164	00	X
VCT	14°50’37.6”	040°53’59.7”	Bsh-LAd	865	711	1 7 - 26	30	9163	30	9564
ANA	14°36’32.7”	041°07’48.2”	Bsh-LVAe	537	478	1 9 – 30	00	X	30	9162
SEP	14°38’50.7”	041°03’49.2”	Bsh-LVAe	745	595	1 8 - 28	30	9563	00	X
MP	14°14’.55.9’	42°35’.24.9’	Bsh-CXbe	639	781	15 - 31	00	X	30	9172
IBI	15°15’.06.0’	40°15’.10.5’	Bsh-CXbe	481	717	1 8 - 28	00	X	20	9560
CAC	14°29’.00.7	42°15’.66.3’	Bsh-CXbe	676	672	1 8 - 28	30	9168	30	9169
URA	14°06’.24.1’	42°35’.24.9’	Bsh-SXe	807	505	1 9 - 30	00	X	04	9170
CAE	14°06’.24.1’	42°35’.24.9’	Bsh-CXbe	732	982	1 7 - 27	22	9167	30	9171

* DA= Divisa Alegre; ENC= Encruzilhada; AP= Assentamento Primavera; CS= Cândido Sales; VCT= Vitória da Conquista; ANA= Anajé; SEP= Serra dos Pombos; MP= Malhada de Pedra; IBI= Ibiassucê; CAC= Caculé; URA= Urandi; CAE= Caetité; N°= Number of individuals collected by location; HUESBVC= Herbarium of the State University of Southwest Bahia; Alt.= Altitude, Prec. Annual precipitation, Temp. Annual minimum and maximum average temperature, CXbe=Haplic Tb Eutrophic Cambisol, CXve= Haplic Ta Eutrophic Cambisol, CXbd= Haplic Tb Dystrophic Cambisol, SXe=Eutrophic Haplic Planosols, Bsh= Hot Semiarid (Santos et al., 2018; IBGE, 2021).

The passion fruit occurrence environments varied from low altitudes. Going from 481m in IBI to higher altitudes 929 m in CS. The temperature gradient ranged from 15°C to 31°C. The higher temperatures occur in ANA and the lowest temperatures in ENC and AP. The higher precipitation occurs in DA with 1.644 mm.ano-^{1}, while the lowest in ANA with 478 mm.ano-^{1} (Table 1). Among the various factors that can influence the temperature, for the ANA site, the high temperatures can be explained by the low rainfall. On the other hand, the DA region, is the only place borderline the Northern mesoregion of Minas Gerais and central-south Bahia, although this is typical of the semiarid region. The vegetation of this environments is from the Atlantic Forest, but due to anthropic activities, the plants have developed xeromorphism plasticity typical of the Cerrado (Muylaert et al. 2018). Similar characteristics were observed in VCT and SEP that due to the change in the hydrological cycle the Atlantic Forest has converted to a vine forest with remnants of Cerrado. Therefore, the current vegetation is secondary forest with ecotone between the Caatinga, Cerrado and Atlantic Forest biomes (Muylaert et al. 2018).

The main reason for the change in plant configuration in recent decades was deforestation to make room for irrigated agriculture (Cunha et al. 2019). CS, ENC and AP also predominates Atlantic Forest vegetation, but over time there was a reduction in precipitation, which led to the adaptation of vegetation to the dry environment (Cunha, et al. 2019, Muylaert et al. 2018). These three environments, as well as ANA and CAC that have ecotone vegetation between the Atlantic Forest and Caatinga, which have in common the presence of shallow and stony soils with mining history (Cunha et al. 2019). URA and CAE have phytophysiognomy of

Caatinga and Cerrado. Despite IBI having a predominance of Caatinga, has tree-shrub species typical of Cerrado.

All these regions have in common deforestation to promote the local economy, that is based on agriculture and family subsistence agriculture. The environments, in addition to agriculture and family farming, also have in common as an economic activity deforestation for power generation ceramist and mining for clay extraction (Almeida 2020, Cunha et al. 2019).

As for the occurrence and population density it was possible to observe variation for the two species (Table 1). There were not records of *Passiflora cincinnata* in DA and CS. Already in IBI and URA, low population density was observed with twenty and four individuals. The small number of individuals in these two environments is a result of the strong anthropism in the region, in which the IBI population occurs on the roadside with stems branching along fences and near the dumping ground. The URA region is occupied by cattle, where this practice of land use and occupation is traditional in the Cerrado and Caatinga domains, mainly in the dry season (Braga et al. 2016). However, during the collection expedition, dry branches of the plant with dried fruits on the fround along rural roads were observed. Therefore there was no aerial part to collect. This observation emphassizes that the species blooms in the rainy season and ends the reproductive cycle in the dry season. (Alvares et al. 2013).

Passiflora setacea did not present registration in four locations (IBI, URA, MP and ANA). Small populations were recorded in AP with fourteen individuals and CAE with twenty-two individuals. AP is a landless settlement located in the municipality of Encruzilhada. Nonetheless, in the same environment there is occurrence of *Manihot* sp. inferring that the population of the species comes from an *ex situ* collection of a private initiative. In the municipality, higher population density was observed on the roadside, urban perimeter with many fruits and flowers. This was identified as ENC.

In CAE, the reason for the low density can be explained by the fact that the passion fruit occurs between the *Manihot* sp. lines in land with wire fence. The other rural areas of the municipality are surrounded by eucalyptus plantations with many local workers involved in the monoculture planting and cutting process. It is known that the Virtual Herbarium of Flora and Fungi has recorded the occurrence of the species in this region according to a collection carried out in 2001 by Correa under an exsiccate record CEPEC 109613. However, if the species were to occur in the region, it would be easily recognized because *P. setacea* blooms in the dry season, the date on which the collection was carried out.

However in improved accessions of the species *P. setacea* there is a phenological difference. Like the BRS Pérola do Cerrado cultivar, which varies in the reproductive cycle. In the state of Goiás, for example, the flowering of this species under cultivation occurs between January and June and fruiting between August and December (De Oliveira Teixeira et al. 2019). In the municipality of Seropédica in Rio de Janeiro, the highest number of flowers was recorded in November and December (Rangel Junior et al. 2018).

As a means of locating populations in the field, in addition to consulting the Virtual Herbarium and Specieslink®, it was also observed that the *Varronia curassavica* Jacq., a specimen of the Boraginaceae family, is a bioindicator of environments of occurrence of *Passiflora setacea* D.C., because in all environments the presence of both species was recorded.

Genetic diversity studies carried out by Pereira et al. (2015) with accessions of *P. setacea* collected in twelve different environments, but in the same mesoregion, low representation was also observed with few individuals per location, which shows the commitment of natural populations by human activities. The authors also emphasize the need for it to be conserved both *ex situ* and *in situ*, since the VCT population was the only one that showed allele exclusivity, which infers a probable founder effect in a highly anthropized environment.

As for the classification of the soils, these presented sandy loam characteristics. In four accessions: CAC, CAE, IBI, MP with 19% clay. In five accessions presented sandy clay loam: ANA, VCT, ENC, URA, AP with 34% clay and three accessions presented clay: SEP, DA and CS with 50% clay. According to the classification of soils in the state of Bahia, the soils of the region are considered haplic cambisol due to the irregular and mountainous topography and without a superficial horizon of humic acid. The loam texture typical of intermediate soil, where the granulometry maintains an average proportion of at least 30% clay, 25% silt and 45% sand (Santos et al. 2018). What differentiates the soil is the activity of the clay. Which varies between dystrophic, with low activity and eutrophic with high activity and also more fertile. Within this classification, only CAC and CAE have clay of high activity (Ta) and fertility. The others have clay of low activity and fertilily (Tb) (Figure 1).

The low activity of clay is directly attributed to the hidrogenic potential of soil colloids

(Santos et al. 2018). Where the pH in water in the twelve places of occurrence of passion fruit showed characteristic of acidic soils, but with variation in acidity, ranging from very high as in CS and AP (pH=<4.5); high acidity in SEP, DA and ENC (pH between 4.36 to 4.54); medium acidity in MP, IBI, VCT and CAC (pH H2O between 5.05 to 5.41) and even weak acidity as observed in ANA and URA (pH= 6.03 and 6.25) (Table 2).

Aluminum saturation was better represented in CAE and DA (m%=36). The ANA, MP, VCT, IBI and URA places did not show aluminum saturation (m%=0). The soils in the region are poor in organic matter, which was low. The highest organic matter content was obtained at AP place with 3.78.

Soil physicochemical attributes are best represented by principal component analysis (PCA) and discriminant analysis. This analysis summarizes the physicochemical variables in the first two principal components (PC). These were retained for interpretation, with accumulated eigenvalues of 89.98% of the variance of all variables. The first component explained 61.46% of the variability for all samples. The attributes evaluated with the highest factor loading in the first component were pH in calcium, magnesium, CEC in pH 7 and base saturation with scores ranging between 0.94 and 0.98. The second component explained 28.51% of the variability. The attributes that contributed to the explanation of this component were clay and potential acidity (H+Al) with negative scores of -0.939 and -0.728 and organic carbon (OC) with a positive score of 0.865 (Table 3).

In the analysis of the main component (MC-1) it is possible to observe the proximity of these places as a function of acidity. Where the pH in calcium of the SEP, DA and ENC environments varied the pH in Ca between 3.91 and 4.11 and the exchangeable acidity (Al^{3+}) presented an approximate average of 0.58 (Figure 2).

The CAE and IBI collection sites were close (quadrant 2) because they had an average acidity between 4.01-6.0 (pH Ca = 4.21 and 4.66 pH H_2O = 5.18) and very low exchangeable acidity lower than the others (Al^{3+}<0.03 and 0.1). These two environments also presented the lowest potassium values among the places with k=26.34 and 44.61. The other places located in quadrant one and four had a high content of this element with K>120, in which presented a high factor loading with r = 0.742 (Table 3). Therefore, the allocation of potassium in the graph near the centroid infers a strong relationship with all collection sites (Table 2 & Figure 2).

Table 2. Soil Chemical attributes of twelve places of occurrence of the species Pas*siflora cincinnata* and *Passiflora setacea* in the central-south region of Bahia. Source: Meira

Code*	Soil Chemical atributes*												
	P	H	Pmeh	K	Ca	Mg^{2+}	Al^{3+}	H+Al	CEC	m	V	OM	OC
	H_2O	Ca	mg dm³		cmoc dm³					%		dag Kg^{-1}	
DA	4.51	4.11	0.30	115.86	0.45	0.35	0.61	3.14	4.24	36	26	0.98	0.6
ENC	4.36	4.05	2.89	122.04	0.14	0.39	0.55	5.69	7.78	21	27	3.40	2.0
AP	4.35	4.02	2.05	152.50	1.02	0.80	0.73	6.02	8.23	0	27	3.78	2.2
CS	4.22	3.81	1.25	182.94	1.21	0.44	0.25	3.30	5.42	11	39	1.35	0.8
VCT	5.11	4.55	5.51	171.97	1.99	0.62	0.01	3.96	7.01	0	44	2.98	1.7
ANA	6.03	5.72	55.9	218.98	1.86	0.68	0.10	0.83	3.93	0	79	0.80	0.5
SEP	4.54	3.91	1.89	171.70	1.46	0.67	0.58	5.03	7.60	18	34	2.07	1.2
MP	5.05	4.39	12.49	171.38	0.46	0.51	0.10	1.24	2.65	0	53	0.43	0.6
IBI	5.18	4.66	3.43	44.61	1.36	0.38	0.10	1.73	3.58	0	52	1.04	0.6
CAC	5.41	4.81	15.16	245.32	2.05	0.74	0.10	2.81	6.23	25	55	2.14	1.2
URA	6.25	5.95	12.44	332.21	8.87	3.58	0.10	1.57	14.87	0	89	1.97	1.1
CAE	5.18	4.21	1.62	26.34	0.27	0.11	0.03	2.06	2.51	36	18	0.77	0.4

*DA= Divisa Alegre; ENC= Encruzilhada; AP= Assentamento Primavera; CS= Cândido Sales; VCT= Vitória da Conquista; ANA= Anajé; SEP= Serra dos Pombos; MP= Malhada de Pedra; IBI= Ibiassucê; CAC= Caculé; URA= Urandi; CAE= Caetité

*pH H2O= pH in water; pH Ca= pH in calcium; P= phosphor; K=potassium; Ca2+=calcium; Mg2+=magnesium; Al3+=exchangeable acidity; H+ Al= potencial acidity; CEC= catio exchange capacity; m=aluminium saturation; V=base saturation; OM=organic matter; OC=organic carbon

In addition to potassium, other macronutrients were also retained to explain the distribution of species in these two quadrants. All plants located in environments belonging to quadrant one had medium acidity (MP and CAC) and weak acidity (ANA and URA) and phosphorus contents greater than twelve (Table 2). These locations also had the best base saturation. URA, for example, had the highest content of calcium and magnesium (Ca= 8.87 and Mg2+=3.58) and together with ANA place, they had the best base saturation (ANA and URA V≥80) (Table 2). On the other hand, CAC and MP presented a slightly lower V, but they were also considered with satisfactory values of average classification for soil analysis with V = 53 and 55. Nevertheless, ANA also stood out with the highest phosphorus value (P = 55.9). The places MP, URA and CAC showed values close to phosphorus with an average of 13.4 (between 12.4 and 15.16). The other places showed values lower than six (P < 6), with an average of 2.26.

Table 3. Soil chemical and physical attributes with the eigenvalues of the main components of the twelve *Passiflora* sp. collection sites in the central-southern mesoregion of Bahia, Brazil. Source: Meira

Variance components		Soil index	
		MC 1	MC 2
Variability (%)		61.46	28.51
Accumulated variability (%)		61.46	89.98
Variables	Average±SD	Factorial loading	
pH in Ca	4.64±0.68	0.970	0.003
pH in H_2O	5.13±0.65	0.789	-0.625
Remaining phosphorus (P in mg L^{-1})	9.58±15	0.679	0.644
Potassium (K in mg dm^{-3})	163±83	0.742	-0.246
Calcium	1.76±2.33	0.987	-0.194
Magnesium	0.77±0.9	0.985	-0.237
Exchangeable acidity (Al^{3+} in cmolc dm^{-3})	0.27±0.26	-0.674	-0.436
Potential acidity (H+Al in cmolc dm^{-3})	3.12±1.75	-0.798	-0.728
Aluminum saturation (m in %)	13.36±14	-0.503	-0.719
Cation exchange capacity (CEC in pH 7.0)	6.17±3.4	0.946	-0.059
Base saturation (V in %)	45.25±21.7	0.945	-0.531
Organic Matter (OM in dag Kg^{-1})	1.80±61	0.017	-0.278
Carbono Orgânico (OC in dag Kg^{-1})	1.07±0.61	-0.427	0.865
Coarse sand (g Kg^{-1})	57.95±17	0.381	-0.249
Silt (dag Kg^{-1})	7.71±5.66	-0.391	-0.118
Clay (dag Kg^{-1})	40.28±24	-0.230	-0.939

*SP= Standard deviation; MC= Main component;

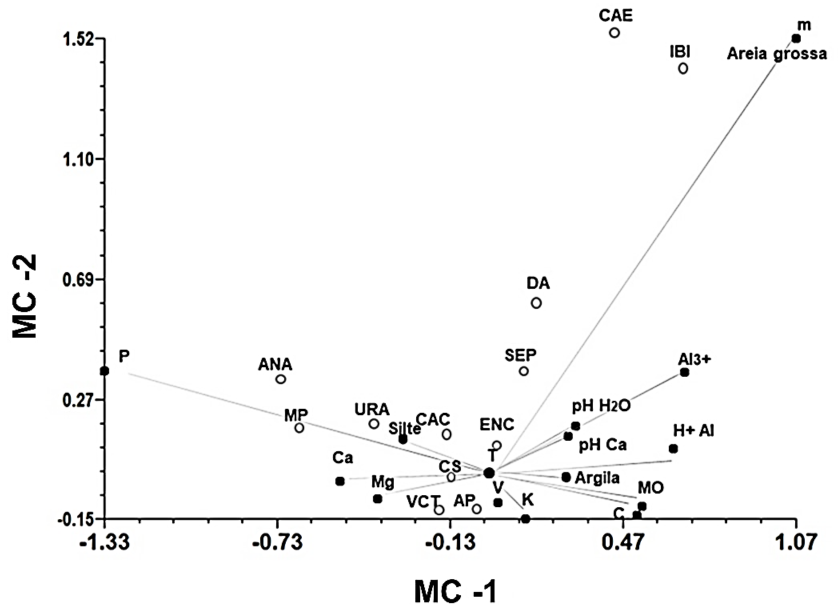

Figure 2. Principal Component Analysis of physical and Chemical soil attributes from twelve naturally occurring sites of *Passiflora setasea* DC. and *Passiflora cincinnata* Mast. in the central-south region of Bahia, Brazil. Source: Meira

Most sites that showed low base saturation (V) were allocated to the second quadrant (SEP, ENC, DA, CAE), the content was V<35. Except for AP which is in quadrant four and also presented low V (V=27) and for IBI which, although allocated in quadrant two, presented median saturation (V=52). For these two places, potential acidity and CEC at pH seven were inversely proportional, being low in IBI with H+Al=1.73; CEC=3.58 and good and medium AP with H+Al=6.02; CEC=8.23) (Table 2). However AP was the only environment explained by MC-2, because this location showed a strong relationship with the parameters organic matter and carbon with 3.78 and 2.02, therefore these variables were allocated close to the axis in MP-2 (Figure 2). The organic matter content was extreme in quadrants one and four. Where the MP site had the lowest content, OM=0.4, quadrant one and AP the highest value to this parameter. Although more distant and in the upper part of the axis, in addition to the attribute H+Al and CEC as mentioned, Al^{3+} also presented the highest value for this location with 0.73. However, the interpretation of soil fertility considers these parameters as having an average value (Santos et al. 2018). This observation justifies these two variables (OM and OC) having been retained to explain the main component MP-2, as well as H+Al also having presented a high factor loading with a negative relationship for the two main components.

Granulometry also corroborates the grouping of environments according to soil classification. This classification corroborates the results of the physico-chemical attributes of the soil for the sites that are classified as eutrophic for having presented base saturation (V) > 50%. The exception was for DA which presented V < 50% and was considered as eutrophic. Generally, dystrophic are poor in cations such as Ca^{2+}, Mg^{2+} and K^+ (MP, DA, CAE, ENC < Ca^{2+}, IBI, CAE < K^+ and CAE and DA < Mg^{2+}). No site had high exchangeable aluminum contents or saturation and so little aluminum saturation > 50% to justify the very poor soil, since all environments had exchangeable acidity (Al^{3+}) < 0.6 and aluminum saturation (m%) < 36. Therefore, soils are not considered acidic to the point of causing toxicity to vegetation (Ronquim 2010, Santos et al. 2018). What is expected for good agricultural productivity of passion fruits V% between 50 and 80% (ANA, MP, IBI, URA, CAC) and pH between 6.0 and 6.5 (ANA and URA) (Ronquim 2010). However, the best fertility indices regarding the values of calcium and magnesium in URA and together ANA the best pH, base saturation and potassium, can be explained by the non-leaching of its elements due these two sites having presented the lowest annual precipitation (478 and 505 $mm.ano^{-1}$) (Table 1).

The results obtained corroborate the literature by reporting that the species *Passiflora cincinnata* Mast. is develops in most of the clay-silica or sílico-clay soils, but it supports any of soil and maintains good productivity (Monte & Santos 2021). *P. setacea* also has a good range, but it seed coat dormancy and the presence of aril. Which makes the species orthodox and withstand long periods of drought, keeping its seeds viable with up to 4.7% humidity (Pádua et al. 2011). The different ecophysiological characteristics of these species make them good providers of ecosystem services for withstanding varied and extreme environmental conditions and for feeding the local fauna in dry periods, which can also be useful in the recovery of degraded areas (Braga et al. 2016, Pereira et al. 2015).

However, the knowledge of the edaphoclimatic and ecogeographic conditions, as well as the multivariate analysis of the physicochemical attributes of the soils of the twelve occurrence sites, emphasize that the two passion fruit species are well-adapted ecotypes. The typical characteristics of the genus represented by these species in the studied environments are altitudes and varied rainfall, shallow, acidic and sandy soils, poor in organic matter, with low aluminum saturation.

Conclusion

Locations with average temperatures of up to 28ºC altitude between 670 and 860 m, pH 4.3-5.11, base saturation <50 and H+Al between 2-5 favor both species *P. cincinnata* and *P. setacea* (CAC, CAE, ENC and VCT). While high temperatures up to 31°C, pH between 5 and 6, base saturation >50 and H+ Al ≤1.5 favor *P. cincinnata* (URA, MP and ANA). Environments with temperatures up to 27°C, altitudes above 900 m, average pH of 4.5, average base saturation of 30 and average H+Al of 3, favors *P. setacea*.

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Reference

Almeida JL 2020. Impactos ambientais provocados pela extração de argila no Município de Ibiassucê-BA. *Revista Científica Multidisciplinar Núcleo do Conhecimento*, 9(3):35-46.

Alvares CASJL, Sentelhas PC, De Moraes Gonçalves JL, Sparovek G. 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift,* 22(6):711–728.

Bernacci LC, Nunes TS, Mezzonato AC, Milward-De-Azevedo MA, Imig DC, Cervi AC (*in memoriam*). 2020. Passiflora. *Flora do Brasil.* 13(1):116. Jardim Botânico do Rio de Janeiro.

Braga MF, Junqueira NTV, Faleiro FG, Bernacci LC. 2016. *Passiflora* spp.: Maracujá-do-cerrado. In *Plantas para o futuro – Região Centro-Oeste. Embrapa Cerrados.* p. 272-279.

Carmo TVB, Martins LSS, Musser RS, Silva MM, Santos JPO 2017. Genetic diversity in accessions of *Passiflora cincinnata* Mast. based on morphoagronomic descriptors and molecular markers. *Revista Caatinga*, 30(1):68-77.

Cunha JS, Oliveira GG, Andrade ML 2019. Estudo socioambiental da bacia do rio pardo: Irrigação, monoculturas e crise hídrica – Relatório de Pesquisa. *Caderno do CEAS: Revista Crítica de Humanidades*, 246(1):227-247.

D'Abadia ACA, Costa AM, Faleiro FG, Rinaldi MM, Oliveira LL, Malaquias JV 2020. Determinação do estádio de maturação e características dos frutos de duas populações de *Passiflora cincinnata* Mast. *Caatinga*, 33(2):349-360.

De Carvalho MVO, De Oliveira L, Costa AM 2018. Effect of training system and climate conditions on phytochemicals of *Passiflora setacea*, a wild *Passiflora* from Brazilian savannah. *Food Chemistry*, 266(1):350–358.

De Oliveira Teixeira TP, Ferreira INM, Borges JPR, Torezan-Silingardi HM, De Melo e Silva Neto C, Fanceschinelli EV 2019. Reprodutive strategy and the effect of floral pillagers on fruit production of the passion flower *Passiflora setacea* cultivated in Brazil. *Brazilian Journal of Botany*, 42(1):63-71.

Duarte IAE, Milenkovic D, Borges TKS, Rosa AJM, Morand C, Oliveira LL, Costa AM 2020. Acute effects of the consumption of *Passiflora setacea* Juice on Metabolic risk factors and gene expression. Profile in humans. *Nutrients*, 12(14):1104-1124.

Leal AEBP, De Oliveira AP, Santos RF, Soares JMD, Lavor EM, Pontes MC, Lima JT, Santos ADC, Tomaz JC, Oliveira GG, Carnevle Neto F, Lopes NP, Rolim LA, Almeida JRGS 2020. Determination, of phenolic compounds, *in vitro* antioxidant activity and characterization of secondary metabolites in different parts of *Passiflora cincinnata* by HPLC-DAD-MS/MS analysis. *Natural Products Research*, 34(7):995-1001.

Monte IA, Santos SCL 2021. O maracujazeiro-do-mato (*Passiflora cincinnata* Mast.) e sua importância econômica: Uma Revisão narrativa. *Research, Society and Development*, 10(7):e18210716464.

Muylaert RL, Vancine MH, Bernardo R, Oshima JEF, Sobral-Souza T, Tonetti VR, Niebuhr BB, Ribeiro MC 2018. Uma nota sobre os limites territoriais da Mata Atlântica. *Oecologia Australis*, 22(3):302-311.

Pádua JG, Schwingel LC, Mundim RC, Salomão NA, Roverijosé SCB 2011. Germinação de Sementes de *Passiflora setácea* e dormência induzida pelo armazenamento. *Revista Brasileira de Sementes*, 33(1):080-085.

Pereira DA, Corrêa RX, Oliveira AC 2015. Molecular genetic diversity and differentiation of populations of 'somnus' passion fruit trees (*Passiflora setacea* DC): Implications for conservation and pre-breeding. *Biochemical Systematics and Ecology*, 59(1):2-21.

Rangel Junior IM, Vasconcellos MAS, Rosa RCC, Cruvinel FF 2018. Floral biology and physicochemical characterization of wild passion fruit *Passiflora setacea* D.C BRS Pérola do Cerrado Cultivated in the state of Rio de Janeiro. *Revista Brasileira de Fruticultura*, 40(6):e-041:1-9.

Ronquim CC 2010. Conceitos de fertilidade do solo e manejo adequado para as regiões tropicais. Vol. VIII, *Boletim de Pesquisa e Desenvolvimento, Campinas: Embrapa Monitoramento por Satélite,* 26pp.

Rohlf FJ 2000. *Numérical taxonomy and multivariate analysis system: version 2.1.* New York: Department of Ecology and Evolution State University of New York, 44pp.

Santos HG, Jacomine PKT, Dos Anjos LHC, Oliveira VA, Lumbreras JF, Coelho MR, Rizzato M, Almeida JA, Araújo Filho JC, Oliveira JB, Cunha TJF 2018. *Sistema Brasileiro de Classificação de Solos 5.ed. Revista e ampliada - Brasília, DF.* Embrapa, 356 pp.

Zhivotovsky LA, Yurchenko AA, Nikitin VD, Safronov SN, Shitova MV, Zolotukhin SF, Makeev SS, Wiss S, Rand OS, Semenchenko AY 2015. Eco-geographic units, population hierarchy, and a two-level conservation strategy with reference to a critically endangered salmonid, Sakhalin taimen *Parahucho perryi*. *Conservation Genetics*, 16(1):431–441.

Zonneveld MV, Thomas E, Castañeda-Álvarex NP, Damme VV, Alcazar C, Loo J, Scheldeman X 2018. Tree genetic resources at risk in South America: A spatial threat assessment to prioritize population for conservation. *Biodiversity and Distribuitions*, 24(6):1-12.