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Environmental function and control of heno motita (*Tillandsia recurvata*) in the atmospheric basin of Tula de Allende Hidalgo

Función ambiental y control de heno motita (*Tillandsia recurvata)* en la cuenca atmosférica de Tula de Allende Hidalgo

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Abstract

The purpose of this article is to make a proposal for the control of heno motita (*Tillandsia recurvata*), based on the analysis of its environmental function within the atmospheric basin of Tula, to contribute to the solution of a state forest problem. Its approach is quantitative experimental since it seeks to explain how the application of 5% acetic acid and 80g / l sodium bicarbonate affects the emergence of new shoots and the Hay Motita plant directly, as well as to identify the function that said plant fulfills. within the microenvironment. The findings show that heno motita is a plant that seeks a support to capture nutrients from the air, however, shading causes the host plant to decrease its efficiency in capturing energy, likewise there is mechanical damage due to its weight and a chemical one since it secretes an allelopathic substance that damages the new shoots. On the other hand, Tillandsia recurvata "sequesters" particles of different materials such as heavy metals in its trichomes, thus contributing to the sanitation of the atmosphere. Finally, the steps to follow to develop a specific management program are proposed.

Environmental sanitation, environmental pollution, heavy metals

Resumen

El presente artículo tiene como propósito realizar una propuesta de control del heno motita (*Tillandsia recurvata*), con base en el análisis de su función ambiental dentro de la cuenca atmosférica de Tula, para contribuir en la solución de un problema forestal estatal. Su enfoque es cuantitativo experimental dado que se busca explicar cómo afecta la aplicación de ácido acético al 5% y Bicarbonato de sodio 80g/l, al surgimiento de nuevos brotes y a la planta de Heno Motita directamente, así como identificar la función que cumple dicha planta dentro del microambiente. Los hallazgos muestran que el heno motita es una planta que busca un soporte para captar los nutrientes del aire, sin embargo, al hacer sombra genera que la planta huésped disminuya su eficiencia en la captación de energía, así mismo existe un daño mecánico por su peso y uno químico ya que, segrega una sustancia alelopática que daña a los nuevos brotes. Por otro lado, Tillandsia recurvata "secuestra" en sus tricomas partículas de diferentes materiales como por ejemplo metales pesados contribuyendo de esta manera al saneamiento de la atmósfera. Finalmente, se proponen los pasos a seguir para elaborar un programa de manejo específico.

Saneamiento ambiental, Contaminación ambiental, Metales pesados

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Introduction

According to data from Semarnat (2020), the state of Hidalgo has an area of 20.8 thousand km^2 (the 1.1% of the national territory) and in 2015 there were 2.86 million inhabitants (2.4% of the national population) and it has three main atmospheric basins, in which 1.5 million inhabitants are concentrated.

The Tula atmospheric basin (see figure 1), made up of 12 municipalities, has 58 local and federal companies, is home to a refinery, two electricity generation plants (one conventional thermoelectric and one combined cycle with natural gas), six cement plants, four lime scale, industries of the metal-mechanic and chemical industry, among others.

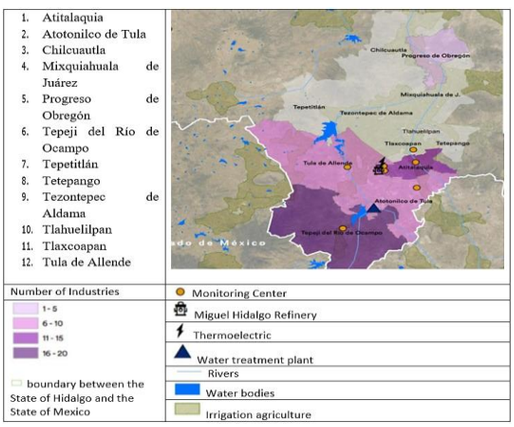

Figure 1 Atmospheric basin of Tula
Source: SEMARNAT, 2020

The Tula Atmospheric Basin (CAT) is the largest generator of pollutants in Hidalgo (see table 1), since it contributes 97% of the sulfur dioxide (SO2), 45% of the PM2.5 particles and 43% of the nitrogen oxides (NOx) emitted in the state.

Fountain	P.M10	P.M 2.5	SWtwo	CO	NOx	VOC	NH_3
Fixed	12,062	8,498	148,339	9,838	31,605	4,039	258
Area	24,859	9,807	248	67,341	11,305	34,379	18,887
Road mobiles	2,546	2,335	762	95,887	30,770	10,820	152
No mobiles roads	195	189	80	1,025	1,976	194	two
Total	**39,662**	**20,829**	**149,429**	**174,091**	**75,656**	**49,432**	**19,297**

Table 1 Emission of pollutants into the atmosphere of the Tula de Allende basin, Hgo (2016)
Source: Inventory of emissions of criteria pollutants, Semarnath, INEM (to be published)

In turn, a higher incidence of parasitic plants and epiphytic plants is observed in disturbed areas and has caused concern among the general population, especially in the Tula-Tepeji and Mezquital Valley Regions (National Forestry Commission, State Management of Hidalgo, 2017).

The Secretariat of the Environment and Natural Resources in Hidalgo (Semarnath), reports the impact on the Mezquital Valley, in the municipalities of Actopan, Alfajayucan, El Arenal, Atitalaquia, Atotonilco de Tula, Chapantongo, Francisco I. Madero, Huichapan, Ixmiquilpan, Mixquiahuala, Nopala, Progreso, San Agustín Tlaxiaca. As well as in Santiago de Anaya, San Salvador, Tasquillo, Tecozautla, Tepejí del Río, Tepetitlán, Tetepango, Tezontepec de Aldama, Tlahuelilpan, Tlaxcoapan and Tula de Allende. (Wheel S., 2017 and Sánchez, J. 2017).

According to the National Forestry Commission, State Management of Hidalgo, (2017), parasitic plants and epiphytes represent one of the greatest management and control challenges in the state of Hidalgo. Focusing its greatest incidence on the Sierra Gorda, Sierra Alta, La Altiplanicie Pulquera and the TulaTepeji Zone and the Mezquital Valley. The owners and possessors of forest land have requested to give attention, especially to heno motita (Tillandsia recurvata) since its abundant presence and infestation has caused the inhabitants of urban areas to show greater interest and concern in its management and control, all Once it is possible to observe its presence in urban parks, and in areas of common use and small owners with properties abandoned by actions of agriculture and livestock,

This problem has also been observed in the Tula-Tepeji industrial zone, affecting 1,200 hectares according to the National Forestry Commission (Conafor, 2018). Among the trees most affected within the study area we find mesquite and huizaches that represent 45% of the total. This affectation brings as a consequence: decrease of the vegetal cover, decrease in the capture of CO_2. Likewise, the Huizache (Acacia farnesiana), is of great importance in its flowering season for the bees that collect pollen as well, it has a high nutritional value due to its crude protein content (23%) and is a plant resource of wide Bioavailability that has not been fully exploited, which could be a low-cost option to feed livestock in critical times.

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According to Edison A. Diáz-Álvarez (2018), heno motita (Tillandsia recurvata) is ideal for studying the traces of air pollution because it absorbs pollutants in a different way through the air and rain. Hay absorbs nitrogen oxides directly from the air and facilitates its monitoring through its tissues, and they are effective since they show the same pattern detected by electronic monitors used to evaluate air quality.

Due to the problems presented, it is the purpose of this study to analyze the environmental function of heno motita and find, where appropriate, a way to control its population, through a proposal in order to mitigate the affectation of trees in the atmospheric basin of Tula in the Hidalgo state, Mexico.

Theoretical framework

Background

Motita hay (Tillandsia recurvata) is one of the best known epiphytic species in Mexico, even by the urban population, since it is very easy to find it commonly attached to power lines, poles and trees (huizaches and mesquite). It is a common plant in humid places, both in temperate and tropical regions. Although it may not seem like it, these plants are not parasites, but through millions of years of evolution they learned to grow on other plants to achieve sunlight. That is, these plants obtain their food from the wind and the sun, in addition the wind encourages the movement of dust which is retained in the hairs of your body and in this way they capture minerals and nutrients,

Unlike parasitic plants, these are called epiphytes (epi = on top and phytos = plant); with the characteristic that its roots do not develop within the host plant and therefore do not feed on it, although if they proliferate too much, they can limit the sprouting of the trees and contribute to their weakening and can be damaged by fungi or true parasitic plants.

Epiphytes are plants that grow on other plants, without having direct contact with the vascular bundles of their hosts (Lüttge U. 1989 and Benzing DH, 1998), therefore, as they do not have roots in the soil, epiphytes have an extraordinary dependence on the atmosphere for the acquisition of the nutrients and water they need, which makes them sensitive to air humidity (Benzing DH 1990) and therefore according to Lugo and Scatena (1992) and (Helliker, Griffiths. 2007), are useful for measuring the response to changes in climate.

Thus, epiphytic bromeliads are one of the most threatened groups, since the root system only adheres them to the host, and the nutrients and water necessary for their growth are absorbed by the leaves.

One of the main evolutionary responses of plants growing in epiphytic habitats is crassulaceae acid metabolism (CAM), which is present in many species of epiphytic bromeliads. This is a photosynthetic pathway that allows plants to use water efficiently. (Andrade, Cervera, Graham, 2009, De la Barrera, Reyes-García, Ricalde, Vargas-Soto and Cervera 2007, Benzing, 2000 and Martin, 1994).

Type of photosynthesis of Tillandsia recurvata. Approximately 89% of the plants that inhabit the planet carry out C_3-type photosynthesis, 10% are CAM and the remaining 1% are C_4; additionally, a few species are known to be C_3-C_4 intermediates.

Unlike C_3 and C_4 plants, CAM plants assimilate atmospheric CO_2 into four-carbon acids, predominantly at night and subsequently prefix it during the following day via the Calvin cycle. The stomata of CAM plants remain open at night and closed for most of the day, thus resulting in minimal water loss and reduced photorespiration (Herppich and Peckmann, 2000).

Therefore, CAM plants exhibit rates of water use efficiency five to ten times higher than C4 plants, resulting in considerable competitive advantage in environments where water is the limiting factor, such as deserts or environments. epiphytes (Cushman, 2001). Furthermore, CAM plants are further distinguished from C_3 or C_4 plants by a considerable number of unique characteristics (Cushman and Bohnert, 1997).

First, CAM plants accumulate organic acids in the vacuole during the night phase, predominantly in the form of malic acid, and undergo a reciprocal accumulation of reserve carbohydrates such as soluble starch, glucans or hexoses during the day phase. Second, to accommodate these large diurnal changes in four-carbon acids and carbohydrates, CAM plants display large amounts of PEPC for nocturnal CO fixation.two and have active decarboxylase enzyme systems to provide diurnal CO refixationtwo through the Calvin cycle. Third, PEPC is activated at night by phosphorylation and inactivated during the day by phosphorylation, a pattern opposite to that found in C_3 or C_4 plants. In addition to these unique biochemical characteristics, CAM plants have evolved in a number of morphological and anatomical aspects (see table 2).

Kind	Separation of fixation inicial from CO_2 and cycle by Calvin	Open stomata	Better adapted to
C_3	There is no separation	Day	Environments fresh and damp
C_4	Between the mesophyll and day cells of the vascular bun (in space)		Environments warm and sunny
CAM	Between day and night	Night	Very hot and dry environments

Table 2 Comparison of Types of Photosynthesis: C_3, C_4 and CAM
Source: Adapted from (Guralnick, Lonnie, Cline, Smith and Rowan 2008)

In CAM photosynthesis, gas exchange takes place at night, (See table 1), when the demand for evaporation to the atmosphere is low, which reduces the loss of water through transpiration.

Plants that have CAM photosynthesis do not owe their production to the use of water, only to the temporary nocturnal fixation of CO_2, since the enzyme phosphoenol pyruvate carboxylase (PEPc), responsible for the primary uptake of COtwo, has a higher affinity for this gas than the enzyme ribulose bisphosphate carboxylase / oxygenase (RUBISCO), the CO-binding agenttwo, in the Calvin cycle[1]; so the plants with CAM can fix higher amount of CO_2 in relation to the amount of water lost during gas exchange.

A combination of stress due to low water availability and high solar radiation can cause photo inhibition. For this reason, epiphytic bromeliads have evolved in their structures and physiological mechanisms (formation of tanks for water uptake, foliar succulence, foliar trichomes specialized in the absorption of water and nutrients, as well as CAM photosynthesis), which have allowed them to adapt successfully to the environment with low amounts of water, high light densities and instability of the branches of the phorophytes (trees on which they grow) in the face of strong winds.

Description of *Tillandsia recurvata*

Next, a general diagram and description of the main structures of heno motita are presented (see figure 2).

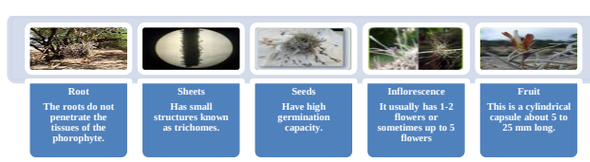

Figure 2 Structures of *T. recurvata*
Source: Own elaboration based on Padilla and Gardner, 1977

Root

It is used mainly for anchoring and supporting the plant. The roots do not penetrate the tissues of the phorophyte (host), only the development of a suber not greater than 400 µm thick is observed, with dead cells, radially dilated and with crystalline inclusions, thin walls and wide lumen, alternating with cells radially tablets with thick walls that contain substances that are observed in a dark tone which are also found above the suber (Páez *et al*., 2005).

[1] The reactions of the Calvin cycle belong to the so-called independent phase of light, which is responsible for fixing CO_2.

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Sheets

According to Kamila (2005), this species has small structures known as trichomes, which replace the roots in the function of absorbing nutrients and water. Distinct orderly, 3-17 cm long, densely pruinous-scaly with ashen or iron-like scales; sheaths elliptical-ovate, thin, multinveined with a wide hyaline enervated margin, with the extreme base glabrous, and in the rest densely scaly and with a ciliated margin of elongated scales, imbricated and completely hiding the caule; blades typically recurved, sometimes only patent or still erect, linear, plump, 0.5-2 mm in diameter, a little soft with a weak point (Matuda, 1957).

Inflorescence

It usually has 1-2 flowers or sometimes up to 5 flowers, dense; floral bracts like scape bracts, but smaller, equal to or longer than sepals, but often distinctly shorter, varionervative, densely scaly. Flowers erect, sub-sesile. Sepals lanceolate, usually acute, 4-9 mm long, slender, with 3 or more prominent nerves, up to 13 cm long, about 0.5 mm in diameter; scape bracts, somewhat scaly species in a growing proportion of specimens.

Petals narrow, pale-violet or white. Stamens deeply exceeding the pistil. Slender cylindrical capsule, abruptly short-beaked, up to 3 cm (Matuda, 1957).

Fruit

This is a cylindrical capsule about 5 to 25 mm long, with two or more carpels, with a variable number of cavities and lines of dehiscence, abruptly ending in a short beak. Inside it houses several seeds of a viscous consistency (Villarreal, 1994).

Seeds

The seeds contained in capsules, open with maturity and have high germination capacity, are disseminated by the wind and some birds after the dehiscence or natural opening of the capsules; In addition, the seeds have trichomes, a characteristic that gives them a greater possibility of adherence to the bark of the host trees and shrubs (Crow, 2000).

Vegetative and reproductive phenology Reproduction

They reproduce in two ways. The first and most common is by pollination and seed production. They do not self-fertilize and the pollen has to come from another plant of the same species. The other way is the reproduction of seedlings called “suckers”. New plants emerge from the mother plant, often on the stem. This usually happens after flowering. A plant can have several suckers that can be removed and developed alone separately or left together with the mother plant, to form a colony (Páez *et al*., 2005).

Biological cycle

According to Arellano *et al*., (2007) begins with the fertilization of the ovules by pollen and the consequent formation of numerous seeds in the chamose fruits called capsules. The numerous seeds are dispersed by the wind or by animals germinate in trees, rocks or soil that meet the conditions for their development, such as light, humidity and temperature. A small percentage of the total released seeds germinate and give rise to seedlings. After several days of development, the species blooms, bears fruit and dies, thus closing its life cycle. Its reproduction by shoots are suckers that are born next to the mother plant, (this method is used to keep the species perpetuated in cultivation places proper when the plant finally blooms and will soon dry up (Ceja, 2008).

Effect of *Tillandsia recurvata* towards the phorophyte

According to Neumann (2004) affirms that *T. recurvata* secretes an allelopathic substance called hydroperoxycycloartan through its rhizoids, said substance according to this author causes the death of buds and the absition of the foliage.

In turn, (Barbosa *et al*., 2004), point out that *T. recurvata* absorbs heavy metals that are found in the air as a product of environmental pollution, and could exert a toxic effect on the host tree.

According to (Páez *et al*., 2005), the roots do not penetrate the tissues, the presence of hay causes the plant to develop a suber response no greater than 400 µm thick, with dead cells, radially dilated and with crystalline inclusions, alternating with cells with thick walls that contain substances that are observed in a dark tone which are also found above the suber[2].

Thus, *T. recurvata* also damages its host through the accumulated weight that they generate on the branches and shading (Ruiz and Coronado, 2012). According to Crow (2000), it blooms in summer and reproduces both sexually and asexually. The seeds are spread by wind, birds, insects, and other organisms; germinates easily.

With the force of the wind, the *Tillandsia* shoots are detached and when they settle on another branch or any other structure, they form a new individual. These plants do not tolerate direct contact with the sun, preferring an indirect but abundant light. Given their anatomical structure with rosette and waxy branches, they retain a lot of humidity so they resist long periods of drought and strong frosts.

All these advantages such as: CAM photosynthesis, development of trichomes for water uptake, uptake of nutrients from the air, allelopathic phenomenon, asexual and sexual reproduction and the ease of dissemination of both seeds and suckers makes *T. recurvata* have advantages competitive with respect to the host plant, which although it cannot be considered a parasite because it does not absorb nutrients from the host, if there is a relationship in which the hay benefits and the tree is harmed, so we can consider the Hay motita as an epiparasite, for being on the tree and damaging it.

Objective

Carry out a proposal for the control of heno motita (*Tillandsia recurvata*), based on the analysis of its environmental function within the Tula-Tepeji industrial corridor, to be implemented in the surrounding communities and thus contribute to the solution of a state forest problem.

Based on the objective, the following working hypotheses are established:

Hypothesis

The application of 5% acetic acid and 80g / l sodium bicarbonate on the heno motita controls its spread by 100%.

Methodology

The focus of the study is quantitative with experimental design since the study manipulates the variables, measures and controls in comparison groups to explain the recovery of infected plants that receive treatment, as well as the role that the heno motita fulfills within the microenvironment.

According to Labrada *et al*. (2021), the participation of university students in attending to environmental problems in their municipalities allows: the construction of knowledge, integration of personal experiences and contributes to the development of their own modes of professional performance.

In the development of the field and experimental work, a group of 30 Environmental Engineering students to the Universidad Tecnológica de Tula-Tepeji.

Variables

Dependent: treatment.

Independent: tree involvement.

Show

At the state level, the affectation of plants by heno motita is approximately 1,200 hectares in the state of Hidalgo, the study area corresponds to the Tula Atmospheric Basin, which is made up of 12 municipalities. In order to carry out a punctual monitoring and control of the plants, only 3 municipalities, Tula, Tepeji del Rio and Atitalaquia, were considered at the discretion of the researchers since these localities are the most important industrial corridors in the state and therefore where they are located. generates a higher level of environmental pollution. The inclusion criteria were.

[2] Variety of protective or epidermal tissue, formed by dead cells, which externally covers plants over a year old, especially trees.

- Location.
- Number of specimens affected.
- Degree of infestation.
- Plant height and size.

Being distributed as follows (see tabla 3)

Parameter / Type Mezquites	Tree	Huizaches	Capulin	Jacaranda	Others
Grade of Infestation (%), average	90	70	3	1	1
Height (meters)	2-10	1-4	3-10	4-8	2-8
Size (Diameter from shadow on meters)	8	3	4	4-6	2-6

Table 3 Trees affected by heno motitay, within the study areas in Tula de Allende, Tepeji del Río and Atitalaquia Hidalgo
Source: Own elaboration

Huizache trees were selected mainly for their ease of handling since they are shorter in stature and have second place in degree of infestation and number of affected individuals (45%); likewise for its environmental importance in the region.

To determine the degree of infestation, the procedure of Hawksworth, (1980) is followed.

- Divide the tree crown into 3 parts, each third is evaluated separately and the ratings that will be given are 0.1 and 2, where: 0 is not visible, 1 light infection (half of the branches infected), and 2 severe infection (more than half of the branches infected).
- Finally, the qualifications of each third are added, to know their level of infestation and also take the necessary measures.

The selected trees were labeled to identify the type of treatment

Control sample

A control sample of Heno motita was collected in the community of Villa del Carbón, state of Mexico, as a reference, since it is an area far from the industry and with an important population of trees.

Types of Treatment and grouping

The selected trees were classified in two groups: Group 1 was applied treatment with acetic acid 5% Group 2 with sodium bicarbonate 80g / l.

In each group, the degree of infestation was identified, making 4 subgroups: 70%, 50%, 20% and controls.

From each subgroup, 3 types of treatment were applied:

3 (in triplicate), trees received chemical treatment,

3 (in triplicate) first received manual removal of the heno motita and chemical treatment, only in the sprouts and the last ones did not receive chemical treatment (see summary table 4).

The trees received different treatments, following the NOM-011-RECNAT-1996 standard.

Group 1. Treatment with acetic acid 5% Group 2. Treatment with sodium bicarbonate 80g / l			
70% of infestation	50% of infestation	20% of infestation	Witness No treatment
3 trees (in triplicate) 5% acetic acid was applied directly on the heno motita			
3 trees (in triplicate) the hay heno motitas removed manually and chemical control was applied only on the sprouts			
3 trees (in triplicate) the hay heno motita removed manually and no chemical control was applied.			

Table 4 Chemical treatment to control Hay speck (*Tylandsia recurvata*)
Source: Own elaboration

For the identification of contaminants in the infected plants, the following steps were carried out:

Observation under the light microscope

The collected hay was observed under the light microscope with a magnification of 10X.

Hay treated with both vinegar and bicarbonate was observed to identify changes on exposure to treatment.

Determination of heavy metals

- A sample was taken from the collected hay in a simple random manner.
- The hay sample was dried in an oven at 40 °C for 72 hr.
- Once dry, digestion with nitric acid was carried out for 4 hr.
- The determination of heavy metals was carried out under NMX-AA-051-SCFI-2016.

Results

To respond to the objective, the comparison results to explain the recovery of infected plants that receive treatment, the following was obtained:

Treatment

Manual Removal of heno motita

Once the heno motita is removed and the sprouts are treated with either 5% acetic acid or 80g / l sodium bicarbonate, the tree improves by 80%, but the speed at which the heno motita sprouts and is regenerates is a fast process since they appear on the second day after the hay has been removed. Therefore, the tree returns to the degree of initial infestation in a few weeks. Due to this situation, it is not feasible to withdraw manually without any treatment.

To remove Hay from a tree with more than 70% infestation; The option is to cut down the affected parts and apply manual removal on the less affected branches, adding the chemical treatment of the sprouts with either 5% vinegar or 80g / l bicarbonate.

To completely remove Hay speck from a tree with 70% or less infestation; the option is: manual removal of 100% of the hay rosettes and treatment of the sprouts by applying vinegar or bicarbonate directly on the sprout, for at least 10 days.

In figure 3 we can see that when applying vinegar with an acidic pH (pH = 3.0) or sodium bicarbonate (pH = 8.0), the trichomes, being very thin structures, are destroyed and the plant loses its ability to capture the trichomes. water and nutrients; since it is the trichomes that retain particles of different sizes PM 2.5, PM 5.0, PM 10, etc., and composition.

These particles that get trapped in the trichomes are some of them; dissolved and used as nutrients and others are simply retained.

Figure 3 Destruction of trichomes from the application of 5% acetic acid
Source: Own source

Macroscopically, the plant deteriorated by the application of the chemicals can be seen on the left side and the damage caused to the trichomes can be seen on the right side.

In addition, during the collection of the sample it was observed that heno motita is an ecological niche for insects, arachnids, reptiles, rodents and birds; of different sizes since when carrying out the removal they came out of the hay rosettes, likewise they retain a diversity of particles from the environment, as additional data, bird nests were found built with heno motita where cobwebs and growth of various fungi appear, which presents another micro ecosystem (see figure 4).

Figure 4 "Rosettes" of heno motita that function environmentally as: ecological niche of arachnids, insects, reptiles, birds and rodents
Source: Own elaboration

Identification of contaminants

In the digest of heno motitacollected in the Tula atmospheric basin, the presence of Pb, Fe, Cr, Cu and Cd was detected. In table 5 we can see the results obtained in duplicate, having an average of 0.06m / l of Pb, 4.62 mg / l of Fe, 0.031mg / l of Cr and 0.0515 mg / l of Cu; all of them metals, possibly products of the different emissions from fixed and mobile sources in the basin.

Villa del Carbón			Study zone		
Sample number	Heavy Metal	Reading mg/L	Sample number	Heavy metal	Reading mg/L
1	Pb	0.085	1	Pb	0.04
2	Pb	0.1	2	Pb	0.08
Sample blank	Pb	0.0	3	Pb	0.00
1	Fe	12.37	1	Fe	4.04
2	Fe	13.2	2	Fe	5.2
Sample Blank	Fe	0.0	3	Fe	0.0
1	Cr	0.043	1	Cr	0.029
2	Cr	0.046	2	Cr	0.033
Sample blank	Cr	0.000	3	Cr	0.000
1	Cu	0.091	1	Cu	0.047
2	Cu	0.078	2	Cu	0.056
Sample blank	Cu	0.0	3	Cu	0.0
1	Cd	0	1	Cd	0
2	Cd	0	2	Cd	0
Sample blank	Cd	0	3	Cd	0

Table 5 Heavy metal concentration in collected heno motita
Source: Self made

Likewise, in the digests of heno motita collected in Villa del Carbón, a lower concentration of these metals was detected: 0.095mg / l of Pb, 12.78mg / l of Fe, 0.044mg / l of Cr and 0.084mg / l of Cu and Cd was not detected.

The samples from Villa del Carbón are used comparatively since the settlement of fixed and mobile sources is less than that found in Tula, however; heno motita contaminated with heavy metals was also detected. The foregoing suggests carrying out another study to identify sources of pollution that could be carried by the winds, for which it would be necessary to study the dynamics of the Tula air basin and the direction of the winds.

Proposal for use for Hay speck

Due to the microscopic observation of the leaves, we can see that the trichomes are "trapping" particles of different composition, including heavy metals; It is proposed to use heno motita as a filter material. That is, it can be fixed to inert materials in the construction of fences outdoors as "green filtering walls" (see figure 5) and indoors for the same purpose and even as a decorative plant (see figure 6).

Figure 5 Use of Hay speck as a biofiltering material in green walls
Source: Own Elaboration

Figure 6 Use of heno motita in interior decoration and purification
Source: Own Elaboration

Because it has embedded in its trichomes particles of different composition that depend on the pollutants of the environment in which it is found; being able to find pollen, minerals, parasite eggs, heavy metals, etc. Not recommended as: soil improver, animal feed or for composting. In Figure 7 we observe a proposal for the elaboration of a management program for heno motita (*Tillandsia recurvata*) for the air basin of Tula de Allende, Hidalgo, Mexico. Consists in:

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- Carry out a diagnosis that includes a sensing of the area to be controlled. Know the quantity and type of trees, as well as their degree of infestation and review of the applicable legal framework.

- With the above information, choose the type of control to apply: preventive, removal with equipment such as pressurized air or water, or manual removal; as well as chemical regrowth treatment. Budgeting: materials, protective equipment, transportation, personnel, consumables, etc.

- Identify follow-up actions and their corresponding budget; evaluate the experience and its results. Disseminate the experience and results, provide feedback and train.

- Analyze the contaminants "trapped" by the heno motita to determine the proper final disposal and / or the use that will be applied to the collected.

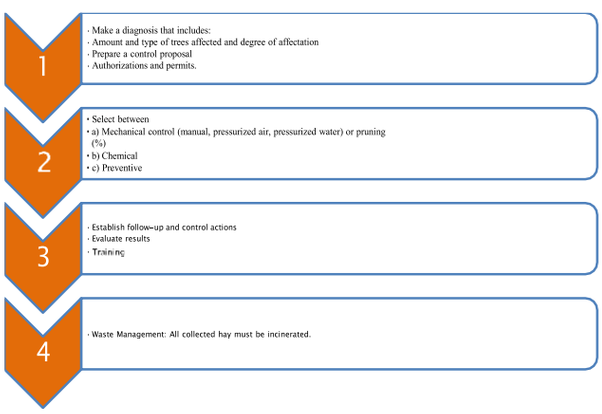

Figure 7 Proposal for the next step to formulate and implement a control and monitoring program for heno motita
Source: Own elaboration

Conclusions

Speck hay is a plant that seeks support from which it can capture nutrients from the air, since it does not absorb nutrients from the plant it uses, it has developed the ability to hold better and better and ensure its survival. Unfortunately, by shading its host, its efficiency in capturing light energy decreases, suffering a deterioration that adds to the allelopathic effect, even causing the total loss of the affected tree.

It is observed that the proximity to contaminants facilitates the spread of heno motita; It is possible to indicate that the levels of contamination favor the proliferation of heno motita, since the hay completely depends on absorbing all its nutrients from the air (C, H, O, N, S and P), mainly CO_2.

Similarly, the control sample of hay collected in Villa del Carbón, state of Mexico, presented almost the same amounts of heavy metals in relation to what was observed in the study region. The treatment of 5% acetic acid and 80mg / l sodium bicarbonate if it manages to damage the integrity of the trichome structure and therefore affect the survival of the heno motita. On the other hand, the separation of important amounts of heavy metals from the atmosphere (Pb, Cr, Cu and Fe) was observed, thus contributing to improve air quality.

In addition, the study made it possible to study the environmental function of Hay motita, since it is possible to carry out tests to place the collected hay on alternate supports, even inert ones, and provide the hay with a space at a height equal to that of the infested trees so that it complies with the environmental functions detected which are:

- Ecological niche.

- Capture of particles of different composition, including heavy metals.

- Contribution of material for nests of birds and rodents.

- Particle collector of different sizes and materials.

- Biomonitor.

- Efficient CO_2 collector.

- CAM photosynthesis.

It is recommended to remove the Hay speck, and to apply the treatment of the sprouts either with acetic acid or with sodium bicarbonate to avoid reinfestation.

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Environmental education plays a fundamental role in the construction of a society more aware of the complexity, relationships and interdependencies of each of the organisms that inhabit the planet (Manzanares, 2021). The participation of students in experimental and field work contributed to the articulation of the knowledge acquired in the classrooms and managed to involve them in addressing environmental problems.

Another line of study remains open, where the direction of the wind and the pollutants that can be carried from industrial areas to green areas are analyzed.

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