Urban inflorescence litter of Jacaranda mimosifolia and Piscidia piscipula improves soil with nutrimental elements and provides a specific elemental stoichiometric fingerprint

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Abstract

There are many natural resources generated in cities that are not being used. Inflorescences litter produced by trees in cities can have great potential for use and little is known about the nutritional contributions and chemical composition they could have as soil improvers. The objective of this study was to evaluate the nutritional properties and chemical composition of inflorescence litter of two tree species commonly used in urban landscaping, Jacaranda (Jacaranda mimosifolia) and Jabin (Piscidia piscipula), and mixtures of inflorescence litter material with Andosol type soil. Soil was mixed with inflorescence litter material in different proportions and after an incubation period of 69 days. Changes in nutrient concentrations and chemical composition of substrates were recorded using infrared spectroscopy. It was found that the physical state of the matter and its transformation dynamics differ according to the litter material of the inflorescence and the proportion of mixtures; each species reacts differently to the availability, immobilization or sequestration of elements such as C, N, P, K, Na, Ca, Mn, Mg, Zn and Cu. Microbial capacity intrinsically contained in substrates could partly explain these results, changing the structural and chemical composition, and the physical state of the matter in substrates. The use of inflorescence litter to fertilize or improve soil can be an innovative but still unexplored technique, and a viable line of research to take advantage of a sustainable natural resource that is generally wasted in urban areas.

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Abstract

There are many natural resources generated in cities that are not being used. Inflorescences litter produced by trees in cities can have great potential for use and little is known about the nutritional contributions and chemical composition they could have as soil improvers. The objective of this study was to evaluate the nutritional properties and chemical composition of inflorescence litter of two tree species commonly used in urban landscaping, Jacaranda (*Jacaranda mimosifolia)* and Jabin (*Piscidia piscipula*), and mixtures of inflorescence litter material with Andosol type soil. Soil was mixed with inflorescence litter material in different proportions and after an incubation period of 69 days. Changes in nutrient concentrations and chemical composition of substrates were recorded using infrared spectroscopy. It was found that the physical state of the matter and its transformation dynamics differ according to the litter material of the inflorescence and the proportion of mixtures; each species reacts differently to the availability, immobilization or sequestration of elements such as C, N, P, K, Na, Ca, Mn, Mg, Zn and Cu. Microbial capacity intrinsically contained in substrates could partly explain these results, changing the structural and chemical composition, and the physical state of the matter in substrates. The use of inflorescence litter to fertilize or improve soil can be an innovative but still unexplored technique, and a viable line of research to take advantage of a sustainable natural resource that is generally wasted in urban areas.

Keywords: Urban green areas; Sustainable cities; inflorescence litter; organic waste.

Introduction

Relationships between solid waste management, health and the economy of communities are recognized worldwide (Hamer, 2003; Sha'Ato et al., 2007; Campos-Alba et al., 2021). Urban plant residues are a potentially unused raw material. Managing plant residues as waste results in air pollution and soil degradation, among other environmental problems (Sivacoumar et al., 2001, Wang, 2016). Excessive use of inorganic fertilizers has generated problems of water and soil contamination; therefore, recycling wasted plant biomass in cities and using it as compost can be an important route to develop urban sustainable agriculture and floriculture (Wang et al., 2016a; Schröder et al., 2021).

A large volume of inflorescence litter that falls on the ground or urban pavement and sidewalks is discarded in some tropical cities when it could be used efficiently. Many plant residues are not being used due probably to the lack of information about their nutrient concentrations and structural chemical composition. As far as we know, there is little information related to use of floral tissues as the main organic residue in the constitution of organic substrates to fertilize and / or improve soils (but see, Wang et al., 2021). It has been reported that flowers and inflorescences can be a good resource that can decompose and form litter capable of modifying soil biogeochemistry and improving nutrient availability by improving soil microbial dynamics in alpine environments (Wang et al., 2021). Inflorescence litters are characterized by a distinct physical texture, and their chemical lignin-cellulose indexes significantly differ from those of other litters (Wang et al., 2016b). Floral tissue is expected to differ in chemical composition from other plant tissue such as leaves (Jia et al., 2016) or wood due to plant differential resource allocation to sexual structures with specific roles such as attracting pollinators.

Our objective was to evaluate nutrients and structural chemical composition of plant species inflorescence litter (*Jacaranda mimosifolia* and *Piscidia piscipula*) and its effect in soil mixes. We expected that residual inflorescence litter of *J. mimosifolia* and *P. piscipula* may increase soil nutrient availability and improve soil microbial dynamics.

Methods

Study area

The study site was in the metropolitan area of the nearby cities of Xalapa and Coatepec, Veracruz, Mexico, between 19° 29 'and 19° 36' North latitude, 96° 48 'and 96° 58' West longitude, 700-1 600 m altitude, with a mean annual temperature of 18° C and mean annual rainfall of 1200 - 1700 mm (Hernández-Vargas et al., 2019 and references therein). The most common soil type in the studied area is Andosol (Hernández-Vargas et al., 2019) and the type of vegetation is tropical mountain cloud forest (Hamilton et al., 1995). Around the Xalapa and Coatepec metropolitan areas there are different agriculture patches (coffee and sugar cane), and urban agriculture and floriculture activities are common.

Study species

There is a wide distribution of *J. mimosifolia* and *P. piscipula* in urban areas of the Xalapa region. Flowering of *J. mimosifolia* blooms between April whereas *P. pscipula* blooms between January and May (Roman-Miranda et al., 2018).

Jacaranda mimosifolia D. Don (Bignoniaceae) commonly called "Jacaranda", is not a Mexican native species and reaches a size of up to 5-15 m tall and up to 20-25 m in suitable environments. This species is considered a native species from Central and South America and has been widely introduced in several countries as an ornamental tree due to its striking blue-violet inflorescences (Xie et al., 2021). Inflorescences of *J. mimosifolia* develop in open and terminal panicles, with a reduced calyx, widely campanulate with a purplish-blue corolla (Fig 1 A). In Xalapa, several *J. mimosifolia* organisms have been planted as ornamentals.

Piscidia piscipula (L) Sarg. (Fabaceae), commonly called "Jabín", is a Mexican native species and reaches a size of up to 20 m high. Synonyms for this species are *P. communis* (S.F. Blake) and*Ichthyomethia communis* S.F. Blake (Jamaican dogwood). Jabin is native from humid and sub-humid tropical regions of America and has economic importance in the Mayan area (Rico-Gray et al., 1991). It is distributed from Southern Florida to the Antilles and South Mexico, Central America, and the Northern part of South America (Sarg, 1891). In Mexico, it is found naturally in Tamaulipas, Veracruz, Tabasco, Campeche, Yucatán, Quintana Roo, Chiapas, Oaxaca, Guerrero, Michoacán, and Jalisco. In Coatepec, several *P. piscipula* trees have been planted as ornamentals (Fig. 1 B).

We calculated the volume of available inflorescence litter material based on the approximate daily amount of material collected, and the area under the tree canopy from which it was obtained. Approximate volume of potentially available inflorescence litter produced per individual of *J. mimosifolia* (i.e., dry material accumulated under the tree canopy) was estimated at 58.15 g / m^2 / day. For the entire flowering season (ca. 93 days) at this same production rate, it was calculated that, in one square meter, an individual of this species produces around 5,408.0 g / m^2 of dried inflorescences as a residue for potential use. For *P. piscipula* the production was estimated at 4,012.3 g / m2 of dry inflorescence biomass per individual produced throughout the flowering season (ca. 98 days; 40.9 g /m^2 / day). The*J. mimosifolia* individuals used for this study (n = 8) had a mean height (± standard error) of 14.2 (± 0.7) m, trunk perimeter of 2.49 (± 0.09) m and coverage of 24.4 (± 1.2) m^2. The individuals of *P. piscipula* used for this study (n = 2) showed an average height (± standard error) of 18.8 (± 3.2) m, trunk perimeter of 2.5 (± 0.13) m and a coverage of 30 (± 1) m^2 (Table 1).

Obtaining inflorescence litters

Inflorescence litter on pavement or sidewalks was collected during March and April 2016 (Table 1). Inflorescences were obtained by hand and placed in paper bags. Subsequently, they were manually cleaned of

garbage and other organic tissues. Inflorescences were dried at 65 ° C for three days, the resulting material was pulverized with a mill and sieved with a mesh of 2 mm opening (Fig. 1 A-C). A fine inflorescence powder was obtained. Inflorescence material was subsequently used for mixtures with soil for experiments and chemical and nutrient composition analyses.

Obtaining soil samples

Soil was collected in November 2016 in the surroundings of the state university library (USBI) in Xalapa in an Andosol soil site. The sample was obtained from the surface and up to 15 cm depth of mineral soil (without soil litter), in an area of 20 x 20 cm. The soil sample was dried in an oven at 65^{o}C for three days and sieved before mixing with inflorescence litter for all treatments. Only dry material was used in the mixtures.

Mixture experiment

Inflorescence litter was mixed with soil in different inflorescence litter-soil proportions (100% inflorescence litter- 0% soil, 20% inflorescence litter-80% soil and 50% inflorescence litter- 50% soil). Thus, each mixing ratio constituted an experimental unit of 10 g each. We obtained groups of 15 repetitions per experimental unit for each species (2 inforescense species x 3 litter soil proportions x 15 repetitions, N = 90). Afterwards, we subjected the mixtures to an incubation process consisting of incubating all experimental units for a period of 69 days at 35 ° C in a drying oven. To keep nutrient mineralization processes activated in resulting substrates, the same volume of water was added to each sample every third day during the experiment. Subsequently, its chemical and structural composition was evaluated (see following sections).

Nutrient analysis of inflorescence litters, soil, and mixtures before and after the incubation experiment

We made determinations before and after the incubation process in five randomly selected samples of each treatment to study its effect on substrate nutrients and several elements were determined: C, N, P, K, Mg, Ca, Na, Mn, Zn. Total K, Mg, Ca, Na, Mn, Zn were determined by an elemental spectrophotometer. For these elements, a value was obtained for each repetition individually. For total C, N and P the determination was made from composite samples for each treatment. Total C and N were determined by complete combustion on a Leco Truspec analyzer (Michigan, USA). Total P was determined by digestion with nitric and perchloric acid and with vanadate-molybdate reagent determined by a visible light spectrum photometer, Spectronic 21.D model (Milton-Roy, USA).

Characterization by infrared spectroscopy (FTIR-ATR) of inflorescence litter, soil, and mixtures

All substrates were analyzed by FTIR-ATR spectroscopy to know inflorescences, soil, and substrate mixtures structural chemical composition before and after the experiment (t_0 and t_1). For this purpose, a Frontier model spectrophotometer (Perkin Elmer) equipped with an external module for Attenuated Total Reflectance (ATR) was used with the following operating specifications: 32 scans per sample; spectral resolution of 4 cm^{-1}; wavenumber range from 4000 to 400 cm^{-1}. Spectrum and Spekwin 32 software were used for instrumental control and data processing respectively. Samples were placed fully covering ATR diamond lens area and a similar pressure was used for each measurement (80 % as it is recommended by manufacturer). Spectra magnitudes were normalized to bands with the highest intensity (between 1000-900 cm^{-1} region) to perform quantitative comparisons using the absorbance intensities of each band. There were five spectra replicas for each sample. Observed bands were assigned to specific compounds based on reports from previous studies (see Table 2). Initial state of mixtures to FTIR-ATR analysis was not of our interest.

Data analysis

We used two-way ANOVA models for comparison between substrates before and after the incubation experiment regarding K, Ca, Mg, Mn, Zn and Na values. Sources of variation in the model were mixtures (100% inflorescence litter- 0% soil, 20% inflorescence litter -80% soil and 50% inflorescence litter- 50% soil), incubation time (t_0 and t_1) and their statistical interaction. Analyses were carried out separately for each

species and soil-only samples. When assumptions of normality and homoscedasticity were not met, logarithmic data transformations were performed (Montgomery, 1991). When some of the terms in the model were significant with an alpha equal to or less than 0.05, the means between mixtures and incubation time groups were compared with Tukey contrast tests with Bonferroni correction (Rice, 1989). For total C, N and P concentration values, only the values per substrate before and after incubation are shown. Analyses were performed with statistical R software (R Core Team, 2020).

A principal component analysis (PCA) was used for comparison between inflorescence litter, soil, and substrate mixtures structural chemical composition by absorbance intensity of spectra bands values obtained for each substrate (Table 2). The ACPs were developed using the XLSTAT software (Addinsoft, Paris, France).

Results

Nutrient analysis of inflorescence litter, soil, and mixtures before and after the incubation experiment

3.1.1 *Jacaranda mimosifolia* samples

The *J. mimosifolia* substrates before and after incubation experiment differed according to the mixture treatments for K ($F_{2,22} = 73.3$, $P < 0.0001$); Na ($F_{2,22} = 46.5$, $P < 0.0001$); Ca ($F_{2,22} = 14.7$, $P < 0.0001$); and Cu ($F_{2,22} = 6.9$, $P = 0.005$). In the 100%*J. mimosifolia* inflorescence litter -0% soil mixture treatment, K, Na, Ca, and Cu elements increased after incubation (Fig. 1 A-D). In the 20% *J. mimosifolia* inflorescence litter - 80% soil mixture treatment, K, Na and Ca concentrations did not differ after incubation. In the 50% *J. mimosifolia* inflorescence litter - 50% soil mixture treatment, K, Na and Ca concentrations decreased after incubation, and Cu values increased. For Mn concentration, the higher values were observed in mixtures that included the highest soil proportion ($F_{2,22} = 135.5$, $P<0.0001$; Fig. 2 E) and decreased after incubation ($F_{1,22} = 12.3$, $P = 0.002$; Fig. 2 F). Mixtures with a higher proportion of *J. mimosifolia* showed the highest concentration for Zn ($F_{2,22} = 10.4$, $P = 0.0007$; Fig. 2 G) and increased after incubation ($F_{1,22} = 42.4$, $P <0.0001$; Fig. 2 H). Mg showed an increase in its concentration after incubation for all mixture treatment ($F_{1,22} = 14.1$, $P = 0.001$; Fig. 3 I).

In composite samples, the highest concentration of C was found in mixtures that included a higher *J. mimosifolia* inflorescence litter compared to mixture treatments with higher soil concentration (Fig. 3 A). Carbon in *J. mimosifolia* inflorescence litter considerably decreased with incubation for all mixtures except for the 100% *J. mimosifolia* inflorescence litter -0% soil mixture treatment. Nitrogen increased after incubation in the 100% *J. mimosifolia* inflorescence litter -0% soil mixture treatment, but not so for the other mixtures (Fig. 3 B). Phosphorus increased for all the samples in this species but with a higher concentration in 100%*J. mimosifolia* inflorescence litter -0% soil mixture treatment (Fig. 3 C). The C: N and C: P ratios decreased in all samples after incubation (Fig. 3 C and D). While for the N: P ratio, the 100%*J. mimosifolia* inflorescence litter -0% soil mixture treatment was the one that presented the lowest concentrations compared to the mixtures with the highest soil concentration before incubation (Fig. 3 E). After incubation, the N: P ratio value decreased almost by half in the 20% *J. mimosifolia* inflorescence litter - 80% soil mixture treatment (Fig. 3 E) compared to the 50% *J. mimosifolia*inflorescence litter - 50 % soil mixture treatment.

3.1.2 *Piscidia piscipula* samples

The *J. piscipula* substrates before and after incubation experiment differed according to the mixture treatments for for K ($F_{2,22} = 55.8$, $P <0.0001$); Na ($F_{2,22} = 104.3$, $P <0.0001$); Ca ($F_{2,22} = 13.8$, $P <0.0001$); Mn ($F_{2,22} = 32.3$, $P = 0.005$) and Zn ($F_{2,22} = 22.5$, $P <0.0001$). In the 100% *P. piscipula* inflorescence litter -0% soil mixture treatment K, Na, Ca and Zn increased after incubation (Fig. 4 A-E). In the 20% *P. piscipula* inflorescence litter - 80% soil mixture treatment, the concentration of K, Na and Ca decreased significantly after incubation, while Mn and Zn increased. Mn and Zn presented the higher concentration in mixtures that included the highest soil proportion. For the 50% *P. piscipula* inflorescence litter - 50% soil mixture treatment, K, Na and Mg concentrations increased after incubation, while Ca decreased, and Zn remained constant. The higher Mg concentration values were found in mixtures that included the highest*P.*

piscipula inflorescence litter proportion ($F_{2,22}$ = 11.5, P = 0.0004; Fig. 4 F), and showed a significant increase after incubation ($F_{1,22}$ = 97.9, P <0.0001; Fig. 4 G). Cu showed a decrease in its concentration after incubation regardless of mixtures ($F_{1,22}$ = 10.7, P = 0.0006; Fig. 4 H). Concentration of elements such as K, Na, Mg and Cu in *P. piscipula*inflorescence litter samples were higher compared to those observed in*J. mimosifolia* inflorescence litter samples, but lower for Zn, and similar for Ca and Mn (Fig. 2 AI and Fig. 4 AH).

The highest concentration of C and N were observed in samples that included the highest *P. piscipula* inflorescence litter proportion (Fig. 5 A and B), but the concentrations decreased after incubation. In 100% *P. piscipula* inflorescence litter - 0% soil mixture treatment, P concentration increased more than twice after incubation (Fig. 5 C). C: N and C: P ratios in *P. piscipula* inflorescence litter samples were lower than those of *J. mimosifolia* and decreased even more with incubation (Fig. 3 D and E). N: P ratio decreased after incubation in all *P. piscipula* inflorescence litter mixture treatments (Fig. 5 E).

3.1.3 Soil samples

Soil samples presented lower concentrations than inflorescence litter samples for all elements analyzed except for Mg, Mn, and Zn (Fig. 6 A-F). We observed increases after incubation in soil samples for K ($F_{1,8}$ = 33.3, P = 0.0004) and Zn ($F_{1,8}$ = 6.2, P = 0.04), reductions for Ca ($F_{1,8}$ = 6.7, P = 0.03) and Mn ($F_{1,8}$ = 25.0, P = 0.001). In Na ($F_{1,8}$ = 2.2, P = 0.2), Mg ($F_{1,8}$ = 0.04, P = 0.85) and Cu ($F_{1,8}$ = 0.68, P = 0.43) no changes were observed with incubation. Soil composite samples presented lower C, N and P values than inflorescence litter samples and mixture treatments, as well as C: N and C: P ratios, but similar values in N: P ratio (Fig. 7 AF). Values of soil C, C: N, C: P and N: P decreased with incubation, while soil P and N values increased, but N to a lesser extent than P (Fig. 7 B and C).

Structural chemical composition characterization by FTIR-ATR of inflorescence litter, soil, and mixtures

Structural chemical compositions clearly differ between inflorescence litter samples and soil (Fig. 8 A). Out of the 16 main spectral signals (bands) obtained, peaks labeled as 1, 2, 15 and 16 were soil samples representative (Fig. 8A). Signals with peaks 1 [3695 cm^1] and 2 [3626 cm^{-1}] are found in the region between 3700 and 3620 cm^{-1}, associated with OH bonds of phenolic compounds and clay minerals (Table 2). The signal with peak 15 [909 cm^{-1}], between the region 1200 and 900 cm^{-1}, is associated with polysaccharides, carbohydrates and with clays in soil (Table 2). Peak 15 also appeared in the inflorescence litters, with *P. piscipula*being the one with the highest intensity and with the greatest prominence compared to the rest of peaks observed for all substrates (Fig. 8 A). Peak 16 [890 cm^{-1}] is associated with minerals (Table 2).

Signals with peaks 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 were only observed in inflorescence litter spectra of both *J. mimosifolia*and *P. piscipula* , their chemical composition was similar, but showed differences in absorbance intensities. *P. piscipula*presented signals with greater intensity for peaks 3 and 6 through 12 (Fig. 8 A). Peak 3 [3300 cm^{-1}] is presented as a broadly distributed unimodal signal related to the presence of cellulose (Table 2). Intensities in peaks 4 [2927 cm^{-1}] and 5 [2855 cm^{-1}] where peak 4 is prominent, are found in the region of lipid and alkene presence respectively (Table 2). Peak 6 [1730 cm^{-1}] is associated with unconjugated ketones and free aldehydes (Table 2). Peak 7 [1630 cm^{-1}] is associated with double C-O, C-N and single bonds of N compounds, while N-H is associated with primary and secondary amides (proteins) (Table 2). Peak 8 [1608 cm^{-1}] is associated with aromatic rings and lignin (Table 2). Peak 9 [1516 cm^{-1}] is also associated with aromatic compounds but also with lignin [1510 cm^{-1}] (Table 2). Peaks 10 [1414 cm^{-1}], 11 [1378 cm^{-1}] and 12 [1240 cm^{-1}] are associated with CH_2, C-O-H, C-N and PO_2 bonds associated in turn with carbohydrates and nitrogenous compounds such as proteins and nucleic acids (Table 2). Peaks 13 [1157 cm^{-1}] and 14 [1118 cm^{-1}] are associated with carbohydrates and polysaccharides (Table 2). Both for inflorescence litter and soil, signals less than 900 cm^1 were associated with a mineral region, where the intensities for inflorescence litter are notably higher compared to soil signals.

Soil mixtures and inflorescence litter for both species *J. mimosifolia* (Fig. 8 A) and *P. piscipula* (Fig. 8 B) acquire similar signals compared to soil, although intensities were higher for points associated with

inflorescence litter material. Mixtures with 50% inflorescence litter material and 50% soil are the mixtures that contrast more with soil.

Structural chemical composition was different between soil and inflorescence substrates, with few points of convergence within analysis. However, based on the ACP (Fig. 9), intensities of functional groups for each species differ between inflorescence substrates despite presenting superpositions of spectra inflorescence litter species.*Jacaranda mimosifolia* inflorescence litter spectrum (JC) presents a lower intensity associated with 6 bands: 3300, 1630, 1608, 1516, 1414 and 1378 cm^{-1} at initial time, in contrast to *J. mimosifolia* inflorescence litter after the incubation processes (JC1), and with both substrates of *P. piscipula* inflorescence litter before and after incubation (JB, JB1); the latter have the highest intensity of these 6 bands. This information is represented by main component one (F1), with 44.53% of the variation. Main component two (F2, 32.01%) shows a decrease in intensity of 5 bands for *P. piscipula* samples after the incubation process (JB1): 2927, 2855, 1730, 1240 and 1157 cm^{-1}. The remarkable heterogeneity of*P. piscipula* composition among samples (high dispersion in Fig. 9) diminishes after the incubation process, becoming noticeably more homogeneous (clustering); a pattern not so clear for *J. mimosifolia* samples. A third main component F3 (14.42%, not presented), showed that most of *J. mimosifolia* samples after incubation increased their absorbance intensity in the 890 cm^1 band, associated with mineral content.

Discussion

Biogeochemical processes drive matter transformation in natural and transformed ecosystems. These processes generate a specific nutrients ratio, a stoichiometric fingerprint, resulting from mass balance between organisms and their environment, and useful for predicting ecosystem functioning (Reiners, 1986; Sterner and Elser, 2002). Our results suggest that different nutrient mixtures and substrates show specific differences for each nutrient, resulting in a specific chemical fingerprint for each inflorescence litter. We observed that some nutrients increase, other decrease while others remain stable depending on the litter species and the soil-mix proportions. Nutrient increase after incubation could be due to mineralization and / or solubilization processes, whereas nutrient decrease could be due to nutrient immobilization in microbial biomass and/or geochemical adsorption processes. Our results can be explained by differential inflorescence litter degradation processes, in addition to the existence of differential microbial activity in the substrates (see, Wang et al., 2016b; Wang et al., 2021), and by characteristics of the type of soil used in the mixtures evaluated.

Microbial activity is important during organic matter decomposition and degradation (McGill and Cole, 1981; Bargett, 2005; Paul, 2014), by means of processes such as mineralization (transformation of organic materials towards inorganic elements; Paul, 2014; Binkley and Fisher, 2019) or solubilization (transformation of complex inorganic compounds to simpler and available forms; Binkley and Fisher, 2019). Both mineralization and solubilization increase availability of essential nutrients in soil solution (Binkley and Fisher, 2019). In *J. mimosifolia* , Zn, Mg and P were the nutrients that increased after incubation probably by degradation, mineralization or solubilization processes, as observed for the 100% floral litter treatment. In *P. piscipula,* the concentrations recorded for 100 % floral litter treatment were higher than for *J. mimosifolia* . The mixture 20% inflorescence - 80% soil mixture treatment for *P. piscipula* is interesting since it seems to improve the microbial immobilization dynamic. This treatment included the highest soil proportion, and the P, Ca and Zn decreased after incubation. This result may be explained by the existence of a higher soil microbial biomass limited by these nutrients in soil, such that, when mixed with inflorescence litter material, the microbial biomass immobilized it (see Fisher and Binkley, 2019). Nevertheless, geochemical processes could also be occurring. Andosols are distinguished by a high phosphorus (P) adsorption capacity. A fertilization study with P in Andosol soil showed that after an incubation period of 49 days, the 32P recovered in non-recalcitrant fractions showed that the incorporated P remained available and exchangeable, which contributed to soil fertilization (Bayuelo -Jimenez et al., 2019). Changes in C:N, C:P ratios suggest that in the 20% inflorescence - 80% soil mixture treatment, P decreased for both species. This result can be explained by the strong P sorption attributed to Andosol-type soils (Hernandez- Vargas et al., 2019). According to Stewart (1987), an adequate supply of other nutrients can increase the adsorption of P in the soil. The dynamics of soil P and C:P ratios are very complex and further analyses must be carried out to

understand its behavior in inflorescence material and samples of different soil types. Studies on the relative importance between microbial immobilization and adsorption processes in Andosol soils with artificial fertilization would be important to understand the mechanisms of nutrient enrichment in these soils. Our results suggest that nutrient assimilation and immobilization by microbial activity or adsorption mechanisms are faster in soil when the litter of *P. piscipula* is added, compared to that of *J. mimosifolia* , probably due to different levels of lability and content of recalcitrance substrates for each inflorescence litter.

The FTIR-ATR analysis (Fig. 8 AC and Fig. 9 AB) showed differences between inflorescence litters. The *P. piscipula* inflorescence litter appears to be richer in labile compounds such as cellulose (associated with the 3300 cm^{-1} signal, peak 3; Table 2; Fig. 8A), proteins and nucleic acids (as indicated by 1240 cm^{1}, peak 12, and 1630 cm^{-1}, peak 7 bands). Also, *P. piscipula* showed more recalcitrant compounds compared to *J. mimosifolia* such as lignin, aromatic compounds, carbonyl groups and C-OH bonds, as evidenced by the intensity of 1608 cm^{-1} (peak 8), 1516 cm^{-1}, 1510 cm^{-1} (peak 9), 1414 cm^{-1} (peak 10) and 1240 cm^{-1} (peak 12) bands associated with hemicellulose and lignin (Artz et al., 2008; Musule et al. , 2016). Chemical composition was different between soil and inflorescences, with few points of convergence within the analysis (Fig. 9 A-B). Aqueous extracts of *J. mimosifolia* floral material have been reported to contain 1,6-dimethyldecahydronaphthalene, oleic acid and citronellyl propionate as the main volatile components (Sharma et al. , 2016). However, we could not find similar chemical analyses of floral material for *P. piscipula* . For both inflorescence materials, the wide signal at 3300 cm^{-1} corresponds to tension vibration of H-O, coming from cellulosic material (Artz et al., 2008; Musule et al. , 2016). Peaks at 2927 and 2855 cm^{-1} can be attributed to symmetric and asymmetric stretching of aliphatic C-H type bonds (Musule et al. , 2016). The signal at 1730 cm^{-1}, higher in *J. mimosifolia*material which is rich in oleic acid, as well as the peak at 1630 cm^{1}, are characteristic of C = O stress vibrations (Sharma et al. 2019). The band at 1608 cm^{-1} can be attributed to the bending mode of O-H bond from water adsorbed by the samples. Peaks between 1516 and 1240 cm^{-1} correspond to deformation vibrations of CH_2 and tension C-OH (Musule et al., 2016; Bekiaris et al., 2020), while the signal at 1157 cm^{-1} can be attributed to symmetric vibrations of the C-O-C bond (Musule et al., 2016). The signal at 1118 cm^{-1} corresponds to C-O vibration of polysaccharides or polysaccharide (Aslan-Sungur et al., 2013), and that at 1414 cm^{-1} to the C-OH bond tension vibration (Jia, 2016). However, it is interesting to note that after the incubation process peak intensities decreased considerably in mixtures treatments, while the band at 1516 cm^{-1} of peak 9 (Table 2) is still appreciable. This is consistent with studies such as that of Madari et al., (2006), in which the relative persistence of different compounds is compared when they are found in soils because their degradation process is slower. On the other hand, the faster degradation of less recalcitrant compounds indicates the occurrence of microorganisms (Madari et al., 2006). Further studies are necessary to prove this premise of relative recalcitrance material, and the existence of microorganisms associated with these substrates, and in combination with soil mixtures. Each inflorescence litter type provides a specific stoichiometric fingerprint that can be distinguished even in the different proportions of soil used.

According to Wang (2021), inflorescence litter is a soil improvement due to an increase in microbial capacity to cycle soil nutrients. Microbial dynamics seem to trigger processes such as immobilization, mineralization or solubilization according to the type of inflorescence litter. The *P. piscipula* inflorescence litter presents the highest N and K values before the incubation period, and it could be used as green manure (unprocessed in incubations), which would facilitate its use. Our results suggest that inflorescence litters can constitute a good source of usable biomass in organic fertilization as a green or processed manure. These results could contribute to search for new alternatives for soil nutrient enrichment with the purpose of reducing the use of inorganic fertilizers, as well as the environmental consequences that they cause. It is important to address in greater detail quantification of inflorescence litter volume that can be produced by ornamental trees in urban environments. In addition, it is recommended to carry out phyto-toxicological analysis of species such as*J. mimosifolia* inflorescence litter material (see, Olowoyo et al. 2010), to know if it can be used as organic fertilizer in soils destined for food production. *P. piscipula* inflorescence litter can probably be used for food production since there are reports of its use in traditional dishes from the Mayan region.

5. Conclusions

Our results suggest that each inflorescence litter type provides a specific elemental stoichiometric fingerprint, probably due to differential inflorescence litter degradation processes and differential microbial activity combined with the characteristics of the type of soil to which it is added. Our results suggest that nutrient assimilation and immobilization by microbial activity and/ or soil adsorption mechanisms are faster when the litter of *P. piscipula* is added, compared to that of *J. mimosifolia* , probably due to different levels of lability and content of recalcitrance substrates for each inflorescence litter. The *P. piscipula* inflorescence litter appears to be richer in labile compounds such as cellulose, proteins and nucleic acids, and the *J. mimosifolia* material is rich in oleic acid. However, further studies are necessary to prove this premise of relative recalcitrance material, and the existence of microorganisms associated with in these substrates, and in combination with soil mixtures. This study proposes to continue with research evaluating inflorescence litters in urban areas as raw material for soil enriching and / or improving at local scales.

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Conflict of interest

The authors declare no conflicts of interest.

Author contributions

DS and YP designed the study. DS and IP collected the data. DS, YP and RM conducted the data analysis. DS, YP, RM, ZD and IP collaborated on data interpretation. DS and YP wrote the initial manuscript. All authors substantially contribute to revisions.

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Tabla 1. Geographical location of individuals in the study and their morphometric characteristics (height, trunk perimeter and crown coverage).

Individual	**Individual**	**Species**	**Municipality**	**North**	**West**	**Height (m)**	**Trunk peri**
1	*P. piscipula*	*P. piscipula*	Coatepec, Ver.	19°26' 55.2"	96°57' 14.1"	22	2.66
2	*P. piscipula*	*P. piscipula*	Coatepec, Ver.	19°26' 55.5"	96° 57' 14.2'	15.6	2.4
3	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°31'21.1"	96º55'39.3"	16.7	2.75
4	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°31'20.5"	96°55'39.3"	16	2.6
5	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°32' 22.4"	96° 55' 50.8'	12	2.2
7	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°32'22.5"	96°55'51.7"	15	2.5

8	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°33'42.1"	96°55'49"	13	2.45
9	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°33'43.4"	96°55'49.2"	11	2.1
10	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°33'35.6"	96°55'54.3"	14	2.55
11	*J. mimosifolia*	*J. mimosifolia*	Xalapa, Ver.	19°33'38.3"	96°55'54.6"	15.7	2.8

Tabla 2. Association between molecules and bands used for spectrogram interpretation derived from the ATR-FTIR analysis. References: (1) Aitkenhead and Robertson, 2016, (2) Artz et al., 2008 (3), Aslan-Sungur et al., 2013, (4) Teong et al., 2016, (5) Madari et al., 2006, (6) Musule et al., 2016, (7) Nandiayato et al., 2010, (8) Bekiaris et al., 2020, (9) Fels et al., 2014. * Carbohydrates CO [1200-900]; ** Amide III (Protein) and Nucleic Acids [1230-1238]; *** Aromatic compounds [1600-1650]; **** Lipids [2950-2800]; ***** Phenols [3640-3530]

Band number	**Wavenumber (cm^{-1})**	**Assignment**
1	3695	Clay minerals
2	3626	Clay minerals, Phenols O – H*****
3	3300	O-H Vibration, Cellulose O-H, N-H
4	2927	Aliphatic C-H Vibration, Lipids C-H****
5	2855	Alkenes
6	1730	Vibration of C = O in unconjugated ketones and free aldehydes, hemicellulose
7	1630	Vibration of aromatic C = C ***, Nitrogenous compounds, Proteins (Amide I,
8	1608	Vibration of aromatic rings C = C ***, Lignin
9	1516, 1510	Vibration of aromatic C = C ***, Lignin
10	1414	CH_2, C-OH vibration
11	1378	Vibration of C-H
12	1240	Vibration of C-O, C-O Carbohydrates *, Amide III (Protein) and C-N Nucleic
13	1157	Asymmetric C – O – C vibration, C-O * carbohydrates, cellulose, and hemicellu
14	1118	C-O vibration of polysaccharides or polysaccharides as substances, C-O Carboh
15	909	Minerals, Carbohydrates C-O *
16	890	Minerals

Table 3 . ANOVA table for different nutrients (response variables) depending on the treatment (inflorescences litter, soil, and mixtures), before and after incubation in 69 days t_0 and t_1.

Response variable	**Source of variation**	**df**	**SS**	**MS**	F	P
K	Treatment (T)	3	13332.9	4444.4	25.9885	> 0.0001
	Incubation time (IT)	1	8.1	8.1	0.0476	0.8281
	T * IT	3	672.9	224.3	1.3115	0.2793
Na	Treatment (T)	3	11694.5	3898.2	20.0334	> 0.0001
	Incubation time (IT)	1	4.3	4.3	0.0222	0.8821
	T * IT	3	955.8	955.8	1.6374	0.1906
Ca	Treatment (T)	3	19420.8	6473.6	113.29	> 0.0001
	Incubation time (IT)	1	454.5	454.5	7.95	0.006556
	T * IT	3	699.2	233.1	4.07	0.010708
Mg	Treatment (T)	3	1251	417	2.3346	0.08326
	Incubation time (IT)	1	10240.8	10240.8	57.3358	> 0.0001
	T * IT	3	1961.8	653.9	3.6612	0.01738
Mn	Treatment (T)	3	17575	5858.3	106.692	> 0.0001
	Incubation time (IT)	1	1412.4	1412.4	25.724	> 0.0001
	T * IT	3	1779.9	593.3	10.805	> 0.0001
Zn	Treatment (T)	3	218.9	73	0.2425	0.08.66

Incubation time (IT)	1	5242.5	5242.5	17.4226	> 0.0001
T * IT	3	1037.1	345.7	1.1489	0.3371054

Figure captions

Fig. 1. Inflorescences litter of (A) *Jacaranda mimosifolia* (STRI;*http://biogeodb.stri.si.edu/bioinformatics/dfm/metas/view/*
(B) *Piscidia piscipula* (CICY;*https://www.cicy.mx/sitios/flora%20digital/ficha_virtual.php?especie=1653*)
And (C) grinding process of dried inflorescence litters material.

Fig. 2 Mean values and standard error of nutrients in *J. mimosifolia* inflorescence litter with significant differences ($p < 0.05$) associated to the interaction between incubation time and mixture proportions (A-D), for mixture regardless of incubation time (E, G), and for incubation time regardless of mixture (F, H, I) according to ANOVA models (see Table 3).

Fig. 3 Values of nutritional concentration of (A) carbon, (B) nitrogen, (C) phosphorus and their proportions (D-F) of composite samples of *J. mimosifolia* inflorescence litter and for mixtures before and after incubation.

Fig. 4 Mean values and standard error of nutrients for *P. piscipula* inflorescence litter with significant differences associated to the interaction between incubation time and mixture proportions (AE), for mixture regardless of incubation time (F), and for incubation time regardless of mixture (G, H) according to ANOVA models (see Table 3).

Fig. 5 Values of nutritional concentration of (A) carbon, (B) nitrogen, (C) phosphorus and their proportions (D-F) of composite samples of *P. piscipula* inflorescence litter and for mixtures before and after incubation.

Fig. 6 Mean values and standard error to soil nutrients (Andosol type) with significant differences associated with incubation time (A-G) according to ANOVA models (see Table 3).

Fig. 7 Nutrient concentration values of (A) carbon, (B) nitrogen, (C) phosphorus and their proportions (D-F) of composite soil samples (Andosol) for the mixtures before and after incubation.

Fig. 8 Comparison by treatment of spectra resulting from the analysis by FTIR-ATR spectroscopy for (A) *J. mimosifolia*inflorescence litter, *P. piscipula* inflorescence litter, and soil, (B) *J. mimosifolia* inflorescence litter and mixtures with soil, (C) *P. piscipula* inflorescence litter and mixtures with soil.

Fig. 9 Multiple component analysis plot for inflorescences before and after incubation time. Where JC = *J. mimosifolia* (t0), JC1 = *J. mimosifolia* (t1), JBC = *P. piscipula* (t0), JB1 =*P. piscipula* (t1).