Computers and Electronics in Agriculture 150 (2018) 411–417

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Nitrogen fertilization affects Fourier Transform Infrared spectra (FTIR) in *Physalis* L. species

Romeu da Silva Leite[a,*], Salvador Hernandéz-Navarro[b], Marilza Neves do Nascimento[a], Norlan Miguel Ruiz Potosme[c], Paula Carrión-Prieto[b], Elma dos Santos Souza[a]

[a] Biological Sciences Department, DCBIO, State University of Feira de Santana, Avenida Transnordestina, 44036-900 Feira de Santana, Brazil
[b] Agriculture and Forestry Engineering Department, ETSIIAA, Universidad de Valladolid, Avenida de Madrid, 44, 34004 Palencia, Spain
[c] Superior Polytechnic School, European University Miguel de Cervantes, C/ Padre Julio Chevalier 2, 47012 Valladolid, Spain

ARTICLE INFO

Keywords:
Solanaceae
Physalis angulata
Physalis peruviana
FTIR for spectral analysis
Mineral nutrition

ABSTRACT

Assessing the influence of fertilization on medicinal plants in conjunction with spectral analysis may indicate alterations in the chemical profile of the species in response to nitrogen fertilization. The objective consisted in characterizing by fractions of plants of *Physalis peruviana* and *Physalis angulata*, known by cape gooseberry and camapú, respectively, in different nitrogen doses, by means of analysis of Attenuated Total Reflectance in the Infrared with Fourier Transform (ATR-FTIR). The experiment was carried out in individual pots with completely randomized substrate design with 5 repetitions, using four doses of N (0, 200, 400 and 600 $Kg\,ha^{-1}$). The fractions of leaves, stems and roots of both species were characterized by ATR-FTIR spectroscopy. The specific compounds related to the functional groups present in the fractions of the analyzed species, such as cellulose, pectin and phenolic compounds, are induced as a function of nitrogen fertilization, altering the common absorption peaks. The study offers a precise means to identify functional groups present in the species of the genus and with possible pharmacological use.

1. Introduction

The genus *Physalis* (Solanaceae) has more than 100 species that are characterized by the presence of a calyx, enveloping and protecting the fruit against herbivores and weathering (Silva et al., 2013). Among the species, *Physalis peruviana* L., native to the Andes region, has been incorporated into small fruit crops, with high productive potential for subtropical regions (Moura et al., 2016; Trevisani, et al., 2016). The specie *Physalis angulata* L. is native to Brazil and is known for its medicinal use and potential for commercialization (Lorenzi and Matos, 2008).

Due to the great potential of the genus, research is conducted with the species mainly for the identification and evaluation of substances that have medicinal potential (Chang et al., 2016; Sisley et al., 2017), but few are related to their cultivation and management. In this line of research, the works carried out by Rodrigues et al. (2014) and Moura et al. (2016) stand out for *P. peruviana*. For *P. angulata*, the studies developed by Cruz et al. (2015) and Leite et al. (2017). However, more studies are needed for the establishment of commercial crops of these species, especially related to mineral nutrition, either for the production of fruits or phytopharmaceuticals.

In natural or cultivated environments, plants are subject to nutritional stress, due to the lack or excess of nutrients, as in the Brazilian semi-arid, one of the regions of occurrence of *P. angulata* and which, according to Freitas et al. (2011), has soils with low nitrogen levels. Among the macronutrients, nitrogen is one of the most required for the growth of plants and, in addition, its availability influences the concentrations of secondary compounds (Ibrahim et al., 2011). Plants of the genus *Physalis* present phenolic compounds (mainly physalins), flavonoids and antioxidant activities, these are substances that play important roles in the protection and prevention of different diseases (Olivares-Tenorio et al., 2016; Carniel et al., 2016).

Reconciling studies of mineral nutrition in medicinal plants, such as those of the genus *Physalis*, with infrared analysis may indicate the variability of the chemical profile in response to the fertilization used. In this sense, infrared spectroscopy with Fourier Transform (FTIR) offers a fast and non-destructive way to obtain a biochemical fingerprint of the samples, where the main functional groups and connections can be identified, providing structural information about the chemical compounds present (Palacio et al., 2014).

There are no literary studies available related to the analysis of infrared spectra on the influence of mineral nutrition in the fractions of

* Corresponding author at: State University of Feira de Santana, Biological Sciences Department, Avenida Transnordestina, 44036-900 Feira de Santana, Brazil.
E-mail address: leiteromeu@hotmail.com (R. da Silva Leite).

https://doi.org/10.1016/j.compag.2018.05.021
Received 14 February 2018; Received in revised form 16 April 2018; Accepted 18 May 2018
0168-1699/

Fig. 1. *Physalis angulata*, also known as camapú (left); *Physalis peruviana*, also known as cape gooseberry (right).

leaves, stems and roots of the genus *Physalis*. In view of the above, the present work has the objective of characterizing different fractions by means of ATR-FTIR of plants of *P. angulata* and *P. peruviana* under different nitrogen doses.

2. Material and methods

2.1. Obtaining plant material

The study was realized at the Higher Technical School of Agricultural Engineering, University of Valladolid, Palencia Campus, Spain, during the period from February to June 2017. *Physalis angulata* and *Physalis peruviana* plants were grown in a greenhouse under natural photoperiod, with opening the zenith window when the temperature exceeded 22 °C (Fig. 1). The pots were maintained at field capacity throughout the experimental trial.

The plants were produced from seeds obtained from matrices of *P. angulata* and *P. peruviana* cultivated in the Horto Florestal Experimental Unity, belonging to the State University of Feira de Santana, Brazil. The seeds were sown in a polypropylene seedbed with commercial substrate and kept on heated benches. 30 days after the emergence of the seedlings, when they reached two pairs of true leaves, the transplant was performed for individual pots with 65% commercial substrate, 30% soil and 5% washed sand. The chemical characteristics of the substrate were, in $g\,m^{-3}$: NO_3-N = 84; NH_4-N = 60; K_2O = 288; SO_3 = 18.5; MgO = 27.75; P_2O_5 = 164.88; Fe = 8.58; Mn = 3.17; CaO = 2.50; Mo = 2.43; Cu = 1.94; Zn = 0.98; B = 0.46; and pH 6.0.

The design used was completely random, with two species – *Physalis angulata* and *Physalis peruviana*, 4 treatments (0, 200, 400 and 600 $kg\,ha^{-1}$ of N) and 5 repetitions. The doses were defined according to the recommendation of 400 $kg\,ha^{-1}$ for the tomato crop in Spain according to the Ministry of Agriculture and Fisheries, Food and Environment (Mompó and García, 2010), using calcium ammonium nitrate to supply the needs of N.

2.2. Sample preparation and FTIR measurements

The culture was completed 60 days after the transplant and three plants were used per treatment for the analyzes, defined at random. The samples were separated into different fractions (leaves, stems and roots), brought to the oven at 60 °C until reaching a constant weight, following the analogous procedure described by Cruz et al. (2015) and then weighed on an analytical balance. To obtain a 1 mm powder, the samples were crushed in an ultracentrifugal mill and homogenized (Sanchez-Sastre, 2016).

The prepared samples were analyzed and characterized by infrared attenuated total reflectance spectroscopy with Fourier transform (ATR-FTIR) using ThermoNicolet iS50 spectrophotometer (ThermoFissher Scientific, Walthanm, MA, USA). The spectra were recorded in the medium infrared range (4000–400 cm^{-1}) at a spectral resolution of 4 cm^{-1}, with 32 scans per sample (Carrión-Prieto et al., 2017).

2.3. Statistics

The vibratory data were analyzed with the software SIGMAPLOT 11.0 (Systat Software Inc., Chicago, USA), focusing on the region of the fingerprint (1900–800 cm^{-1}). The comparison was made in relation to the FTIR spectral peaks and analysis of the corresponding functional groups. The data were correlated with the presence of spectral peaks characteristic of the species analyzed in different levels of fertilization. The dry mass data have been subjected to the analysis of variance and regression, adjusting the equations of the evaluated characteristics, as dependent variables of the nitrogen concentrations (Leite et al., 2017).

3. Results and discussion

3.1. Spectroscopic analysis

The different infrared spectra are presented in Fig. 2, where the absorption peaks of the different functional groups are observed for the species analyzed in the control treatment (0 $Kg\,ha^{-1}$ of N). The highest absorption peaks in leaves, stems and roots, occurred at wavelengths between 3500 and 3000 cm^{-1}, corresponding to the absorption due to the stretching of the OH bands (Jones, 2012), at 2920 cm^{-1} and 2850 cm^{-1}, attributed to the presence of polysaccharides, lipids and carbohydrates (CH stretch) (Cao et al., 2017), and in the range of 1900–800 cm^{-1}, which is the fingerprint region, in the which occurs most of the variations of infrared absorption (Carrión-Prieto et al., 2017).

The common peaks observed in the spectra of both species are the fingerprints and the exclusive peaks represent the presence of specific compounds that can be induced due to environmental stress and seasonal changes (Kumar et al., 2016), as well as under the amount of nutrients supplied. Variations in absorbance were observed in the fingerprint range for the different amounts of N and between the fractions of *P. angulata* and *P. peruviana*, showing the influence of nitrogen fertilization on the functional groups present (Fig. 3).

The peaks in the region of the phenolic rings (Carpita et al., 2001) were observed in the different fractions of the species analyzed. In the leaves of *P. angulata* the deficiency of N promoted a greater absorbance for this structural group (Fig. 3a). According to Godoy et al. (1997), plants adapted to poor nutrient environments, such as *P. angulata*, have low levels of nitrogen and high content of phenolic substances in the leaves, which is an important characteristic for commercial crops for phytopharmaceutical production. Increases in phenols under nitrogen deficient conditions were also reported by Ibrahim et al. (2011), being a behavior different from that observed for the species *P. peruviana*, where an increase in the content of the phenolic compounds is suggested with the supply of N (Fig. 3b).

The low absorbance values at the wavelengths of 1339 and