Nativa, Sinop, v. 12, n. 2, p. 390-396, 2024.
Pesquisas Agrárias e Ambientais
DOI: https://doi.org/10.31413/nativa.v12i2.16596
ISSN: 2318-7670

Phytochemistry and biological activities of floral ethanolic extract from *Pontederia cordata* L. (Pontederiaceae)

Sávio Ferreira da SILVA [1], Antonio Carlos Pereira de Menezes FILHO *[2], Porshia SHARMA [3], Carlos Frederico de Souza CASTRO [2], Matheus Vinícius Abadia VENTURA [1,2], Aurélio Ferreira MELO [1], Tiago Carnevalle ROMÃO [2], Aparecida Sofia TAQUES [4], Geraldo Pereira de Souza NETO [2,5], Frederico Antônio Loureiro SOARES [2], Marconi Batista TEIXEIRA [2]

[1] UniBRAS University Center, Rio Verde, Goiás, Brazil.
[2] Federal Institute of Education, Science and Technology Goiano, Rio Verde, Goiás, Brazil.
[3] University of Hohenheim, Stuttgart, Germany.
[4] Federal Institute of Education, Science and Technology of Mato Grosso, Cuiabá, Mato Grosso, Brazil.
[5] Rio Verde University, Rio Verde, Goiás, Brazil.
*E-mail: astronomoamadorgoias@gmail.com

Submitted on: 11/05/2023; Accepted on: 05/31/2024; Published on: 06/07/2024.

ABSTRACT: *Pontederia cordata*, an annual aquatic species with bioremediation properties, was the subject of our study. We collected *P. cordata* inflorescences and produced an ethanolic extract. Our qualitative evaluation of the phytochemistry revealed several significant phytochemical groups. A UV-*Vis* spectrophotometer scan was conducted to identify the high-concentration absorption of the main phytochemical groups. The DPPH free radical reduction assay determined the antioxidant activity, the total phenolic content by colorimetry, and the cytotoxic action at different concentrations on the lethality in *Artemia salina*. Antifungal activity was evaluated against phytopathogens *Sclerotinia sclerotiorum*, *Colletotrichum gloeosporioides*, *C. acutatum*, and *Rhizopus stolonifer*. The photoprotective effect was determined by UV spectrophotometry. Our findings revealed the presence of several phytochemical groups, especially flavonoids, with potential antioxidant activity in reducing DPPH by 89%, total phenolics at 487 mg GAE g^{-1}, and lethality at 345.4 µg mL^{-1}. We also observed antifungal activity against R. stolonifer with 44% mycelial inhibition and UVA and UVB photoprotective effects. The floral extract of *Pontederia cordata* demonstrated a positive impact on the biological activities tested, thereby instilling confidence in the validity of our research and encouraging further biological studies with this plant species.
Keywords: *Pontederia cordata*; antioxidant activity; alkaloids; photoprotective activity; *Sclerotinia sclerotiorum*.

Fitoquímica e atividades biológicas do extrato etanólico floral de *Pontederia cordata* L. (Pontederiaceae)

RESUMO: *Pontederia cordata* é uma espécie aquática que produz flores anualmente e é utilizada como espécie vegetal biorremediadora. Foram coletadas inflorescências de *P. cordata* e produzido o extrato etanólico. A fitoquímica para diversos grupos fitoquímicos foi avaliada qualitativamente. Uma varredura espectrofotômetro UV-*Vis* foi realizada para determinar a absorção em alta concentração dos principais grupos fitoquímicos. O ensaio de redução de radicais livres DPPH determinou a atividade antioxidante, o conteúdo fenólico total por colorimetria e a ação citotóxica em diferentes concentrações sobre a letalidade em *Artemia salina*. A atividade antifúngica foi avaliada contra os fitopatógenos *Sclerotinia sclerotiorum*, *Colletotrichum gloeosporioides*, *C. acutatum* e *Rhizopus stolonifer*. O efeito fotoprotetor foi determinado por espectrofotometria UV. Vários grupos fitoquímicos foram observados, especialmente flavonóides, potencial atividade antioxidante na redução do DPPH 89%, fenólicos totais 487 mg EAG g^{-1} e letalidade = 345,4 µg mL^{-1}. A atividade antifúngica, especialmente para *R. stolonifer*, apresenta 44% de inibição micelial e efeitos fotoprotetores UVA e UVB. O extrato floral de *Pontederia cordata* demonstrou impacto positivo nas atividades biológicas testadas, incentivando novos estudos biológicos com esta espécie vegetal.
Palavras-chave: *Pontederia cordata*; atividade antioxidante; alcalóides; atividade fotoprotetora; *Sclerotinia sclerotiorum*.

1. INTRODUCTION

Pontederia cordata L. (Figure 1) belongs to the Pontederiaceae family and is an emergent, aquatic, entomophilous, tristylous breeding system and perennial plant species from Southern Canada to Northern Argentina (PRICE, BARRETT, 1982; HARDER, BARRETT, 1992; ASHRAFUZZAMAN et al., 2023). During the flowering period, the inflorescences produce between 10-40 tubular flowers daily, lasting around 6-8 h. This important wetland species has potential applications in river and lake

landscaping.

This aquatic macrophyte species has robust rhizome, developed roots, large biomass, and high ornamental value, being considered a candidate for revegetation and reestablishment of wetlands where, in addition to these characteristics, it presents studies that demonstrate aptitude in the removal of total Nitrogen (N) and Phosphorus (P) in water bodies in eutrophication between 80 and 77% (ZHANG; TIAN, 2018). In addition, *P. cordata* is a tolerant species in water contaminated with heavy metals Cd^{2+} and Pb^{2+} and has a high absorption capacity of these metals being used in bioremediation in contaminated water (QIAN et al., 2019; XIN et al., 2020). According to Reimer; Duthie (1993), *P. cordata* also immobilizes Zinc (Zn) and Chromium (Cr) in its roots.

Although this aquatic plant presents data on the maintenance, balance, and recovery of water bodies contaminated with heavy metals and eutrophication, its biological activities are still unknown in favor of human and animal knowledge about the phytochemical constitution, in particular, the floral organ and its possible characteristics capable of acting on pathogenic and phytopathogenic microorganisms, on the reduction of free radicals and their harmful effects on biomembranes, and cytotoxic capacity.

This study aimed to evaluate the qualitative phytochemical constitution and biological activities of the floral ethanolic extract of *Pontederia cordata*.

Figure 1. *Pontederia cordata* inflorescence. Source: Authors, 2023.
Figura 1. Inflorescência de *Pontederia cordata*. Fonte: Autores, 2023.

2. MATERIAL AND METHODS

2.1. Reagents and equipment

Acetic acid P.A-ACS (Vetec, Brazil), acetone P.A-ACS (Neon, Brazil), acetylcholinesterase from *Electrophorus electricus* (Sigma-Aldrich, U.S.A), benzene P.A-ACS (Quimex, Brazil), chloroform P.A-ACS (Neon, Brazil), ethanolic alcohol P.A-ACS (Dinâmica, Brazil), ferric chloride P.A-ACS (Synth, Brazil), gallic acid P.A-ACS (Sigma-Aldrich, U.S.A), hydrochloric acid P.A-ACS (Dinâmica, Brazil), isopropyl alcohol P.A-ACS (Dinâmica, Brazil), iron chloride P.A-ACS (Brazil), metalic zinc (Vetec, Brazil), phenolphthalein P.A-ACS (Synth, Brazil), potassium dichromate P.A-ACS (Neon, Brazil), potassium hydroxide P.A-ACS (Neon, Brazil), sodium acid phosphate P.A-ACS (Synth, Brazil), sodium bicarbonate P.A-ACS (Neon, Brazil), sodium chloride P.A-ACS (Baker, U.S.A), sulfuric acid P.A-ACS (Dinâmica, Brazil), 2,2-diphenyl-1-pikryl-hydrazyl (Sigma-Aldrich, U.S.A), 5,5'-dithiobis (2-nitrobenzoic acid) P.A-ACS (Sigma-Aldrich, U.S.A).

Spectrophotometer UV-*Vis* (Bel Photonics, Mod. M-51, Italy),

2.2. Species collection and identification

P. cordata (flowers) were collected in bloom from 5 to 10 July 2023 in Goiás State, Brazil. 350 g of inflorescences were collected in a single dam area. The species was identified using an identification key for the *Pontederia* genus. A Voucher specimen was deposited at the Laboratory of Plant Systematics, Goiano Federal Institute, Rio Verde, Goiás State, Brazil (HRV: 32784).

2.3. Extract production

The ethanolic extract was obtained from 150 g of inflorescences. The static maceration system was used, and the phytocompound extraction period was 48 hours. Then, the extract was reduced in a rotary evaporator under negative pressure and lyophilized. The percentage extract yield was calculated using the following equation:

$$\text{yield (\%)} = (\text{weight of extract/weight of dried plant material}) \times 100$$

2.4. Phytochemical prospection

A solution containing 50 mg of floral extract in 100 mL of ethanol was prepared for phytochemical determination. The extracts were subjected to phytochemical tests for plant special metabolites, alkaloids, carbohydrates, reducing sugars, glycosides, cardiac glycosides, proteins and amino acids, flavonoids, phenolic compounds, tannins, phlobatannins, saponins, phytosterols, cholesterol, terpenoids, triterpenoids, carotenoids, quinones, anthraquinones, anthocyanins, leucoanthocyanins, carboxylic acid, coumarins, emodins, gums and mucilages, resins, fixed oils and fat, and volatile oils (SHAIKH; PATIL, 2020).

2.5. UV-*Vis* spectrophotometric analysis

The floral extract was performed by scanning a UV-*Vis* spectrophotometer between 420 and 750 nm using a single field 1 cm quartz cuvette.

2.5. Free radical scavenging activity

The antioxidant activity was determined using the 1,1-diphenyl-2 picrylhydrazyl (DPPH) radical reduction method (Shimamura et al., 2014) modified. In a 96-well plate, 25 µL of floral extract solution of different concentrations was added, followed by the addition of 75 µL of ethanol) and 50 µL of freshly prepared DPPH solution in ethanol (800 µM) was added, and the assay plate was incubated for 60 min in the dark at room temperature. Ascorbic acid was used as the positive control. The antioxidant activity corresponding to the scavenging of DPPH radicals was measured at 520 nm with a UV-*Vis* spectrophotometer using the formula:

$$\text{DPPH reduction (\%)} = 100 \times (A - B)/A$$

where: A is the control absorbance of DPPH radicals without the sample, and B is the absorbance after reacting with the floral extract sample.

2.6. Total phenolic content (TPC)

According to Dirar et al. (2019), the phenolic content of the floral extract was determined using a spectrophotometric method. To each of the 96 wells, 100 µL of ultra-pure water was added, followed by 50 µL of either sample or standard and 50 µL of *Folin–Ciocalteu's* reagent. After the solutions had been mixed and left for 5 min, 100 µL of (7.5 g L^{-1}) $NaHCO_3$ was added to each well. The solutions were incubated in the dark at 25 °C for 60 min.

The absorbance at 550 nm was measured with a UV-*Vis* spectrophotometer. The test was performed in quadruplicate. Gallic acid (GAE) was standard for calibration curves (R^2 = 0.9996). The TPC of the floral extract was determined using an equation obtained from the standard gallic acid (GA). The calibration curve regarding gallic acid equivalent (mg of GAE g of $extract^{-1}$) was expressed.

2.7. Brine shrimp lethality assay (BSLA)

The assay was carried out according to the method previously described by Meyer et al. (1982) modified. Brine shrimp eggs (*Artemia salina*) were placed in a small tank filled with seawater, with constant stirring at 70 rpm, fully aerated, and under lighting with a 60 W white neon lamp. After 48 h incubation at room temperature and under illumination, the resulting nauplii (larvae) were collected with a *Pasteur* pipette. The sample for testing was prepared by initially dissolving 50 mg of floral extract in 5 mL of dimethyl sulfoxide (DMSO) and further diluted with seawater to produce the required concentrations. Appropriate amounts (500, 50, or 5 µL for 1000, 100, and 10 µg mL^{-1}, respectively) were transferred to test tubes. Ten brine shrimps were transferred to each sample test tube; seawater was added to make 5 mL.

Tests for each concentration were done in quadruplicate. A control experiment containing 500, 50, and 5 µL DMSO in 5 mL of seawater and ten brine shrimps was performed in quadruplicate for each concentration. The test tubes were maintained under illumination (60 W lamp). Survivors were counted after 24 h with the aid of a brush with fine bristles, and the percentage of mortality in each flask and control was determined using the equation:

$$\% \text{ mortality} = (\text{no. of dead nauplii/initial no. of live nauplii}) \times 100$$

Probit analysis by Finney (1971) was used to determine the concentration at which lethality to brine shrimp represents 50% Lethal concentration (LC_{50}) (Peteros; Uy, 2010).

2.8. Antifungal assay

Antifungal activity was evaluated on isolates of *Sclerotinia sclerotiorum*, *Colletotrichum acutatum*, *Colletotrichum gloeosporioides,* and *Rhizopus stolonifer* in different concentrations of floral extract. The agar diffusion methodology was used in this study. Isolates of *S. sclerotiorum* were collected in soybean fields, and *C. gloeosporioides* and *C. acutatum* were collected in fruits (papaya and strawberry fruit). Cultures were maintained using potato, dextrose, and agar (PDA) medium.

The antifungal activity of floral extract on the mycelial growth of fungal isolates was evaluated through different concentrations, starting from pure floral extract 100 and successive dilutions 50; 25 and 12.5 µL mL^{-1} in Tween 80 (0.1% *v/v*). As a negative control, the control (absence of floral extract) and pure Tween 80 were used, and as a positive control, the commercial fungicide Frowncide® 500 SC (Fluazinam) at a concentration of 10 µL mL^{-1}. Different concentrations of floral extract (100 µL mL^{-1}) were added to the PDA culture medium after sterilization and cooling, as well as for treatments with commercial fungicide and DMSO.

After solidification of the medium, in a bacteriological laminar flow chamber, a disc of mycelium for each isolate of *S. sclerotiorum*, *C. gloeosporioides*, *C. acutatum,* and *R. stolonifer* measuring 7 mm in diameter, was deposited in the center of the *Petri* dish measuring 10 cm in diameter. They were then incubated in an oven at 20 °C. The evaluation consisted of daily measurements of the diameter of the colonies, using a digital caliper, starting 24 h after the start of incubation and ending when the fungal colonies from the control treatment completely reached the internal area of the plate. The diameter of the inhibition zone was measured and recorded as an indicator of antifungal activity. The percentage of inhibition of mycelial growth was calculated using the following equation described by Toigo et al. (2022).

$$\text{IMG (\%)} = [(\text{control growth} - \text{treatment growth})/(\text{control growth})]*100$$

2.9. Photoprotection assay

The photoprotection assay was carried out as described by Menezes Filho et al. (2022). A scan was performed at the floral extract between wavelengths 200 to 400 nm in a UV-*Vis* spectrophotometer, using a 1.0 cm quartz cuvette to verify the ultraviolet absorption in the regions (UVA, UVB, and UVC).

2.10. Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA), and the means followed by SD were evaluated by the *Scott-Knott* test at a significance level of 5% using the ASSISTAT software.

3. RESULTS

3.1. Phytochemical prospecting

The phytochemistry results are presented in (Table 1). The floral extract of *P. cordata* demonstrated the positive presence of the main groups of phytomolecules alkaloids, reducing sugars, flavonoids, phenolic compounds, condensed tannins, aliphatic compounds, hemolytic saponins, phytosterols, cholesterol, diterpenes, coumarins, emodins, and volatile oils.

In Figure 2, three peaks are observed in the floral extract of *P. cordata* between 441 nm Abs = 1.6282, 473 nm Abs = 1.2455, and 669 nm = 0.3533.

The DPPH radical reduction capacity was greater than 80%, and it was greater than 90% for the ascorbic acid standard. Both showed a statistical difference according to the test (Table 2). The TPC content was greater than 480 mg GAE g of floral $extract^{-1}$. The floral extract of *P. cordata* resulted in an LC_{50} value of less than 1000 µg mL^{-1} over *A. salina*.

The floral extract of *P. cordata* demonstrated efficacy in fungal inhibition, especially for *R. stolonifer*, with inhibition greater than 40%. Na effect on mycelium inhibition was also observed for *S. sclerotiorum* and *C. gloeosporioides* at a maximum concentration of 100 µL mL^{-1}. For *C. acutatum*, the floral extract did not demonstrate effectiveness, with inhibition of

less than 10%. All results obtained inferior inhibition responses to the standard fungicide Frowncide 500 SC (Table 3).

Table 1. Phytochemical prospecting of the floral extract of *Pontederia cordata*.
Tabela 1. Prospecção fitoquímica do extrato floral de *Pontederia cordata*.

Phytochemical group	Results
Alkaloids	+
Carbohydrates	-
Reducing sugars	+
Non-reducing sugars	-
Glycosides	-
Cardiac glycosides	-
Proteins and Amino acids	-
Flavonoids	+
phenolics	+
Tannins	Green
Aliphatic or carbonyl compounds	Yellow
Phlobatannins	-
Foaming saponins	-
Hemolytic saponins	+
Phytosterols	+
Cholesterol	+
Terpinoides	-
Triterpenoids	-
Diterpenes	+
Lignins	-
Carotenoids	-
Quinones	-
Anthraquinones	-
Anthocyanins	-
Leucoanthocyanins	-
Carboxylic acids	-
Coumarins	+
Emodins	+
Resins	-
Gums and mucilages	-
Fixed oils and fat	-
Volatile oils	+

Note: (+) positive. (-) negative. Green = condensed or catechism tannins. Yellow = aliphatic compounds. Source: Authors, 2023.
Nota: (+) positivo. (-) negativo. Verde = taninos condensados ou catéquicos. Amarelo = Compostos alifáticos. Fonte: Autores, 2023.

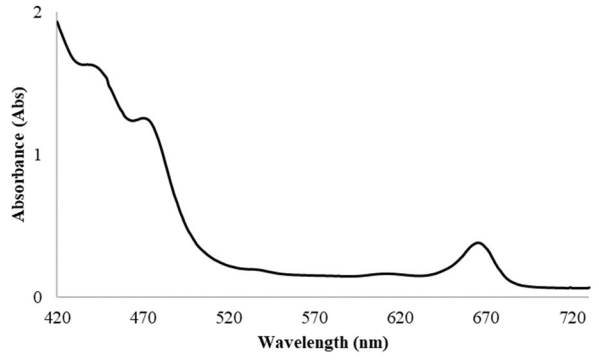

Figure 2. UV-*Vis* spectroscopy of *Pontederia cordata* floral extract. Source: Authors, 2023.
Figura 2. Espectroscopia UV-*Vis* do extrato floral de *Pontederia cordata*. Fonte: Autores, 2023.

Table 2. Antioxidant activity, total phenolic content, and lethality assay on *Pontederia cordata* floral extract.
Tabela 2. Atividade antioxidante, conteúdo de fenólicos totais e ensaio de letalidade sobre o extrato floral de *Pontederia cordata*.

Sample	DPPH (%)	TPC (mg GAE g^{-1})	BSLA LC_{50} (µg mL^{-1})
FE*	89.13b	487.18	345.4
Sd**	98.45a[1]	nd[2***]	>1000[3]

Note: *FE = Floral extract. **Sd = Standard. ***It was not compared to any standard compound other than gallic acid. [1]Ascorbic acid. [2]Not determined. [3]Saline water.
The same letters in the column do not differ significantly, using the Scott-Knott test, which has a 5% significance. Source: Authors, 2023.
Letras iguais na mesma coluna não difere significativamente pelo teste de *Scott-Knott* com 5% de significância. Fonte: Autores, 2023.

Table 3. Antifungal activity of *Pontederia cordata* floral extract on phytopathological fungi.
Tabela 2. Atividade antifúngica do extrato floral de *Pontederia cordata* sobre fungos fitopatológicos.

Fungi	Antifungal activity in (%) Inhibition concentrations µL mL^{-1}				
	Sd*	100	50	25	12.5
1	100a	18b	9c	0d	0d
2	100a	14b	5c	0d	0d
3	100a	6b	0c	0c	0c
4	100a	44b	35c	21d	10e

Note: 1 = *Sclerotinia sclerotiorum*. 2 = *Colletotrichum gloeosporioides*. 3 = *Colletotrichum acutatum*. 4 = *Rhizopus stolonifer*. *Sd = Standard antifungal 10 µL mL^{-1}. Equal letters on the same line do not differ statistically according to the *Scott-Knott* test with a 5% probability. Source: Authors, 2023.
Nota: 1 = *Sclerotinia sclerotiorum*. 2 = *Colletotrichum gloeosporioides*. 3 = *Colletotrichum acutatum*. 4 = *Rhizopus stolonifer*. *Sd = antifúngico padrão 10 µL mL^{-1}. Letras iguais na mesma linha, não difere estatisticamente pelo teste de *Scott-Knott* com 5% de probabilidade. Fonte: Autores, 2023.

The floral extract of *P. cordata* demonstrated two peaks at wavelengths 316 and 332 nm corresponding to the UVB and UVA absorption types.

4. DISCUSSION

This study is a pioneer in the knowledge about the phytochemical constitution of *P. cordata* and some biological activities. The qualitative profile on the phytochemical constitution of the floral extract, *P. cordata*, showed to contain several important phytochemical groups that are involved in several biological activities such as antioxidant, antifungal, antibacterial, cytotoxic, photoprotective, sedative, digestive properties, expectorant, antidiarrheal, diuretic, anti-inflammatory, antiseptic, hemostatic-pharmaceuticals, anticancer, among others (KEBEDE et al., 2021; ALQETHAMI, ALDHEBIANI, 2021).

These phytochemical groups observed in the floral extract have diverse biological activities in the treatment of liver diseases, as well as anti-inflammatory, analgesic, cytotoxic, antifungal, antibacterial, antitumor, anticancer, antiscorbutic, and cardiovascular disorders (BAWAZEER et al., 2021; PRADO et al., 2022).

A simple scan between certain wavelengths on a spectrophotometer makes it possible to verify the absorption of several phytochemical groups, as observed in our study for flavonoids between 420-470 nm. Menezes-Filho et al. (2020) observed a pattern similar to ours for the floral extract of *Styrax ferruginous,* with peaks between 436 and 663 nm corresponding to the flavonoid group. Furthermore, the peak close to 670 nm may be related to the red electromagnetic

spectrum associated with the absorption of chlorophylls (a/b) that absorb between 600-700 nm. Similar results were obtained by Marques et al. (2012), who used this same quick and effective technique to verify the absorption peaks of flavonoids in *Bauhinia forficata* leaf extract, where they obtained peaks between 250-300 nm, 300-350 nm, and between 400-450 nm.

Flavonoids, which are part of this phytochemical group, also have high potential as antioxidant agents (SAFE et al., 2021). The high antioxidant activity of *P. cordata* floral extract may be involved with this phytochemical group and total polyphenols since flavonoids and phenolic compounds have strong antioxidant activity against free radicals such as singlet oxygen and DPPH.

Serrano-Díaz et al. (2012) verified antioxidant activity in *Crocus sativus* flower petals for LOO•, OH•, and $ABTS^+$ radicals due to phenolic compounds, anthocyanins, and flavonoids. Pandino et al. (2011) also obtained surprising results with the floral extract of *Cynara cardunculus* genotypes, where the authors add that such antioxidant activity on the free radical ferric reducing-antioxidant power (FRAP) is due to the concentration of phenolic acids and flavonoid groups in the extract floral values that varied between 4.1-20.0 after 4 min and between 5.2-31.0 after 60 min mmol Fe^{2+} kg^{-1} of DM. Furthermore, these free radical-reducing properties may suggest the application of floral extracts as functional and active ingredients with consequent added value.

Cytotoxic activity is easily obtained by evaluating extracts and compounds isolated from plants on the crustacean *A. salina*. In our study, it was observed that the floral extract of *P. cordata* presents moderate toxicity. Lima et al. (2009) add that several phytochemical groups extracted from plant metabolism have toxic characteristics, such as flavonoids, tannins, and saponins, which corroborates our findings in preliminary phytochemistry (Table 1). There are still few studies in the literature with floral extracts, although the number of studies has been growing annually testing their cytotoxic capacity. Barcelos et al. (2017) verified a cytotoxic effect on *A. salina* by evaluating the floral extract of *Tabebuia serratifolia* with activity at a concentration equal to 679 μg mL^{-1}.

Furthermore, the *A. salina* lethality assay has been used in primary screening to investigate plant extracts with cytotoxic capacity because it is low cost and provides satisfactory results. Results lower than > 1000 μg mL^{-1} indicate that the extract or isolated compound may present cytotoxic properties in *in vitro* testing. According to Peteros and Mylene (2010), this essay presents applications in the study of pesticide residues, mycotoxins, pollutants, anesthetics, dinoflagellate toxins, morphine and its compounds, the carcinogenicity of phorbol esters and toxic pollutants in freshwater and seawater.

Plant extracts are widely evaluated for inhibiting the growth of various pathological and phytopathological bacteria and fungi with encouraging results (MANN et al., 2011; MENEZES FILHO et al., 2022). In our study, encouraging results were obtained for the floral extract of *P. cordata* on *R. stolonifer* that causes contamination and agricultural losses in rice cultivation worldwide. *S. sclerotiorum* and *C. gloeosporioides* also demonstrate that they are sensitive to higher concentrations of floral extract. *C. acutatum* showed resistance at the highest concentration of 100 μL mL^{-1}.

Possibly higher concentrations may demonstrate inhibition activity against this strain, which leads to the possibility of future work. The same was observed in studies by Naim et al. (2022), where they also found an inhibition effect on *R. stolonifer* and *Penicillium digitatum* evaluating the extract of *C. sativus* petals with the lowest concentration of 10% and for *Botritys cinerea* with 5% concentration where there was inhibition of mycelial and spore germination of 100%. Ali et al. (2020) also verified the potential suitability for the floral extract of *Tagetes erecta* on the phytopathogenic fungus *Fusarium verticillioides* with inhibition between 44-65%.

Our *P. cordata* floral extract demonstrated potential capacity for use in natural sunscreen, as it presented two peaks that absorb UV energy UVA and UVB in the UV-*Vis* spectrophotometry scan. UV spectrophotometry has proven to be a viable and rapid option for determining the scanning spectrum in plant extracts between 200-400 nm, where highly energetic UVA, UVB, and UVC sources and their concentration predominate in this wide range. Both chemical and natural sunscreens have maximum absorption in different regions, and it is necessary to determine in which range or ranges their photoprotective capacity predominates. Violante et al. (2009) discuss the integration of wavelengths between 290-320 nm for the UVB energy source and between 320-400 nm for the UVA energy source.

Therefore, plant extracts that exhibit absorption between these wavelengths have phytochemical compounds in their composition, similar to synthetic sunscreens (RANCAN et al., 2002). Corroborating Table 1, several authors link the presence of flavonoids to their photoprotective capacity, and their absorption spectrum presents peaks between 240-280 nm and 300-550 nm. Still, in the study by Violante et al. (2009), researchers verified photoprotective capacity in different plant extracts for *Macrosiphonia velame* UVB, *Lafoensia pacari*, and *Oxalis hirsutissima* with UVA absorption type.

5. CONCLUSIONS

The floral extract of *Pontederia cordata* in this pioneering research that evaluated numerous biological activities demonstrated in the results its suitability with an antioxidant effect on DPPH, cytotoxic on *Artemia salina*, antifungal on phytopathogenic fungi that cause large agricultural losses every year and as a photoprotector on highly energetic sources UVA and UVB, in addition to a high concentration of flavonoids, which present numerous biological activities. This species has complete respect and encourages researchers for new biological studies.

6. REFERENCES

ALI, A. J.; JUBAIR, A. F.; MOHAMMADALI, M. T. Antifungal activity of *Tagetes erecta* extract and *Trichoderma harzianum* on the pathogenic fungus *Fusarium verticillioides*. **Plant Archives**, v. 20, n. 1, p. 185-188, 2020.

ALQETHAMI, A.; ALDHEBIANI, A. Y. Medicinal plants used in Jeddah, Saudi Arabia: phytochemical screening. **Saudi Journal of Biological Sciences**, v. 28, p. 805-812, 2021. https://doi.org/10.1016/j.sjbs.2020.11.013

ASHRAFUZZAMAN, M.; JONE, M. J. H.; ASHRAF, S. B. Aquatic plants of Bangladesh agricultural University botanical Garden: species diversity and potential uses. **Indian Journal of Ecology**, v. 50, n. 3, p. 555-565, 2023. https://doi.org/10.55362/IJE/2023/3935

BARCELOS, I. B.; BULIAN, A. L.; CALAZANS, R. S. P.; DEGEN, A. N.; ALVES, L. O.; SOBRAL, F. O. S.;

SALVI, J. O. Análise fitoquímica e das atividades citotóxica, antioxidante, e antibacteriana das flores de *Tabebuia serratifolia* (Vahl) Nicholson. **Revista Fitos**, v. 11, n. 1, p. 9-23, 2017. 10.5935/2446-4775.20170002

BAWAZEER, S.; RAUF, A.; SHAH, S. U. A.; SHAWKY, A. M.; AL-AWTHAN, Y. S.; BAHATTAB, O. S.; UDDIN, G.; SABIR, J.; EL-ESAWI, M. A. Green synthesis of silver nanoparticles using *Tropaeolum majus*: Phytochemical screening and antibacterial studies. **Green Processing and Synthesis**, v. 10, p. 85-94, 2021. https://doi.org/10.1515/gps-2021-0003

DIRAR, A. I.; ALSAADI, D. H. M.; WADA, M.; MOHAMED, M. A.; WATANABE, T.; DEVKOTA, H, P. Effects of extraction on total phenolic and flavonoid contents and biological activities of extracts from Sudanese medicinal plants. **South African Journal of Botany**, v. 120, p. 261-267, 2019. https://doi.org/10.1016/j.sajb.2018.07.003

HARDER, L. D.; BARRETT, C. H. The energy cost of bee pollination for *Pontederia cordata* (Pontederiaceae). **Functional Ecology**, v. 6, p. 226-233, 1992. https://doi.org/10.2307/2389759

KEBEDE, T.; GADISA, E.; TUFA, A. Antimicrobial activities evaluation and phytochemical screening of some selected medicinal plants: a possible alternative in the treatment of multidrug-resistant microbes. **PLos ONE**, v. 16, n. 3, e0249253, 2021. https://doi.org/10.1371/journal.pone.0249253

LIMA, J. M.; SILVA, C. A.; ROSA, M. B.; SANTOS, J. B.; OLIVEIRA, T. G.; SILVA, M. B. Prospecção fitoquímica de *Sonchus oleraceus* e sua Toxicidade sobre o microcrustáceo *Artemia salina*. **Planta Daninha**, v. 27, n. 1, p. 7-11, 2009. https://doi.org/10.1590/S0100-83582009000100002

MANN, A.; SALAWU, F. B.; ABDULRAUF, I. Antimicrobial activity of *Bombax buonopozense* P. Beauv. (Bombacaceae) edible floral extracts. **European Journal of Scientific Research**, v. 48, n. 4, p. 627-630, 2011.

MARQUES, G. S.; MONTEIRO, R. P. M.; LEÃO, W. F.; LYRA, M. A. M.; PEIXOTO, M. S.; ROLIM-NETO, P. J.; XAVIER, H. S.; SOARES, L. A. L. Avaliação de procedimentos para quantificação espectrofotométrica de flavonoides totais em folhas de *Bauhinia forficata* Link. **Química Nova**, v. 35, n. 3, p. 517-522, 2012. https://doi.org/10.1590/S0100-40422012000300014

MENEZES FILHO, A. C. P.; VENTURA, M. V. A.; CASTRO, C. F. S.; FAVARETO, R.; BELISÁRIO, C. M.; TEIXEIRA, M. B.; SOARES, F. A. L. Phytochemical and physicochemical evaluation, and photoprotection, antioxidant, antifungal, and antibacterial activities of the floral extract of *Schubertia grandiflora* Mart. & Zucc. (Apocynaceae). **Brazilian Journal of Science**, v. 1, n. 1, p. 8-22, 2022. https://doi.org/10.14295/bjs.v1i1.4

MENEZES FILHO, A. C. P.; VENTURA, M. V. A.; CASTRO, C. F. S.; TAQUES, A. S.; ALVES, I. Phytochemistry and biological activities of the floral hydroethanolic extract of *Ipomoea carnea* Jacq. (Convolvulaceae). **Brazilian Journal of Science**, v. 1, n. 2, p. 1-7, 2022. https://doi.org/10.14295/bjs.v1i2.9

MENEZES-FILHO, A. C. P.; SANTOS, M. S.; SOUSA, W. C.; CASTRO, C. F. S. Avaliações físico-químicas, fitoquímicas e bioativas do extrato hidroetanólico floral de *Styrax ferrugineus* Nedd & Mart. (Laranjinha-do-cerrado). **Brazilian Journal of Natural Sciences**, v. 3, n. 3, p. 380-398, 2020. https://doi.org/10.31415/bjns.v3i2.108

NAIM, N.; FAUCONNIER, M-L.; ENNAHLI, N.; TAHIRI, A.; BAALA, M.; MADANI, I.; ENNAHLI, S.; LAHLALI, R. Chemical composition profiling and antifungal activity of saffron petal extract. **Molecules**, v. 27, n. 24, 2022. https://doi.org/10.3390/molecules27248742

PADINO, G.; LOMBARDO, S.; MAUROMICALE, G.; WILLIAMSON, G. Phenolic acids and flavonoids in leaf and floral stem of cultivated and wild *Cynara cardunculus* L. genotypes. **Food Chemistry**, v. 126, p. 417-422, 2011. https://doi.org/10.1016/j.foodchem.2010.11.001

PETEROS, N. P.; UY, M. M. Antioxidant, and cytotoxic activities and phytochemical screening of four Philippine medicinal plants. **Journal of Medicinal Plants Research**, v. 4, n. 5, p. 407-414, 2010.

PRADO, J. M. A.; MENEZES FILHO, A. C. P.; VENTURA, M. V. A.; CASTRO, C. F. S.; TEIXEIRA, M. B.; SOARES, F. A. L. Prospecção fitoquímica e atividade antifúngica de extratos florais de *Tabebuia roseoalba* (Ridl.) Sandwith e *Jacaranda cuspidifolia* Mart. **Nativa**, v. 10, n. 4, p. 554-558, 2022. https://doi.org/10.31413/nativa.v10i4.14447

PRICE, S. D.; BARRETT, S. C. H. Tristyly in *Pontederia cordata* (Pontederiaceae). **Canadian Journal of Botany**, v. 60, n. 6, P. 897-905, 1982. https://doi.org/10.1139/b82-115

QUIAN, Y-P.; LI, X-T.; TIAN, R-N. Effects of aqueous extracts from the rhizome of *Pontederia cordata* on the growth and interspecific competition of two algal species. **Ecotoxicology and Environmental Safety**, v. 168, p. 401-407, 2021. https://doi.org/10.1016/j.ecoenv.2018.10.086

SAFE, S.; JAYARAMAN, A.; CHAPKIN, R. S.; HOWARD, M.; MOHANKUMAR, K.; SHRESTHA, R. Flavonoids: structure-function and mechanisms of action and opportunities for drug development. **Toxicological Research**, v. 37, p. 147-162, 2021. https://doi.org/10.1007/s43188-020-00080-z

SERRANO-DÍAZ, J.; SÁNCHEZ, A. M.; MAGGI, L.; MARTÍNEZ-TOMÉ, M.; GARCÍA-DIZ, L.; MURCIA, A.; ALONSO, G. Increasing the applications of *Crocus sativus* flowers as natural antioxidants. **Journal of Food Science**, v. 77, n. 11, p. C1162-C1168, 2012. https://doi.org/10.1111/j.1750-3841.2012.02926.x

SHAIKH, J. R.; PATIL, M. K. Qualitative tests for preliminary phytochemical screening: an overview. **International Journal of Chemical Studies**, v. 8, n. 2, p. 603-608, 2020. https://doi.org/10.22271/chemi.2020.v8.i2i.8834

SHIMAMURA, T.; SUMIKURA, Y.; YAMAZAKI, T.; TADA, A.; KASHIWAGI, T.; ISHIKAWA, H.; MATSUI, T.; SUGIMOTO, N.; AKIYAMA, H.; UKEDA, H. Applicability of the DPPH assay for evaluating the antioxidant capacity of food additives - inter-laboratory evaluation study. **Analytical Sciences**, v. 30, p. 717-721, 2014. https://doi.org/10.2116/analsci.30.717

TOIGO, S. E. M.; FERNANDES, C. C.; MIRANDA, M. L. D. Promising antifungal activity of two varieties of *Capsicum chinense* against *Sclerotinia sclerotiorum*, *Rhizopus stolonifer* and *Colletotrichum gloeosporioides*. **Food Science and Technology**, v. 42, e52722, 2022.

https://doi.org/10.1590/fst.52722

VIOLANTE, I. M. P.; SOUZA, I. M.; VENTURINI, C. L.; RAMALHO, A. F. S.; SANTOS, R. A. N.; FERRARI, M. Avaliação *in vitro* da atividade fotoprotetora de extratos vegetais do cerrado de Mato Grosso. **Revista Brasileira de Farmacognosia**, v. 19, n. 2a, p. 452-457, 2009.

XIN, J.; MA, S.; LI, Y.; ZHAO, C.; TIAN, R. Pontederia cordata, an ornamental aquatic macrophyte with great potential in phytoremediation of heavy-metal-contaminated wetlands. **Ecotoxicology and Environmental Safety**, v. 203, e111024, 2020. https://doi.org/10.1016/j.ecoenv.2020.111024

Acknowledgments: To the Goiano Federal Institute and the Southwest Goiano University Center; to the Technological Chemistry, Water and Effluents, Agricultural Microbiology, Organomineral Fertilizers and Phytochemistry and Phytochemistry Laboratories; Fundação de Amparo à Pesquisa do Estado de Goiás – FAPEG, CNPq – Conselho Nacional de Dsenvolvimento Científico e Tecnológico, FINEP – Fianciadora de Estudos e Projetos, CAPES – Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

Authors contribution: S. F. S. – conceptualization is the contribution responsible for the ideas, formulation, and evolution of the objectives to be achieved in the research or article. A. C. P. M. F. – methodology is the contribution related to the development of scientific methodology applied in research and the creation of models. P. S. – investigation or data collection the conduct of the research and investigation process (carrying out experiments, collecting data and evidence, and writing (original draft). C. F. S. C. – acquisition of financing is the contribution that refers to activities related to the acquisition of financial support for the research in question. M. V. A. V. – statistical analysis collaboration in the applications of data analysis techniques and methods. A. F. M. – validation is the collaboration to verify the quality and potential for replication/reproduction of research results. T. C. R. — acquisition of financing is the contribution that refers to activities related to the acquisition of financial support for the research in question. A. S. T. – writing (original draft), This is the collaboration of writing the original draft of the article, in addition to preparing the presentation of the work. G. P. S. N. – acquisition of financing is the contribution that refers to activities related to the acquisition of financial support for the research in question. F. A. L. S. – acquisition of financing this is the contribution that refers to activities related to the acquisition of financial support for the research in question. M. B. T. – acquisition of financing, This is the contribution that refers to the activities associated to the acquisition of financial support for the research in question.

Financing: *Not applicable.*

Review by institutional committee: Not applicable.

Ethics Committee: Not applicable.

Data availability: Study data can be obtained by e-mail from the corresponding author or the second author upon request.

Conflicts of Interest: The authors declare no conflict of interest.