



Phytochemical profiling of ethanolic fractions from the stem and root of *Tradescantia pallida* (Rose) D.R.Hunt by HPLC-DAD and evaluation of their nephroprotective effects against cisplatin-induced nephrotoxicity in Wistar rats

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Abstract

Cisplatin is a potent chemotherapeutic drug that is clinically utilised but is limited by dose-dependent nephrotoxicity linked to oxidative stress, inflammation and apoptosis. *Tradescantia pallida* (Rose) D.R. Hunt is a medicinal plant with high polyphenolic content, but its nephroprotective activity against renal toxicity induced by cisplatin has not been extensively studied. The aim of the study was to establish the bioactive compounds of the separate ethanolic fractions of stem and root of *T. pallida* by high-performance liquid chromatography with diode-array detection (HPLC-DAD) and to assess the nephroprotective activity of the fractions in a rat model of cisplatin-induced nephrotoxicity. In the phytochemical identification, the retention time and the UV spectra of the identified compounds were compared to those of the authenticated reference standards, catechin, esculetin, p-coumaric acid, ferulic acid, morin, cyanidin and luteolin. Cisplatin was used to induce nephrotoxicity and the animals were given single dose of the stem or root ethanolic fractions apart, with the reference drug being silymarin. To study the nephroprotective activities of both parts of the plants against the renal injury caused by cisplatin, the renal function biomarkers and histopathological changes were evaluated. In the root fraction, five major compounds were identified: catechin, esculetin, p-coumaric acid, ferulic acid and morin. In the stem fraction, seven major compounds were identified: five of which were also detected in the root fraction, in addition to luteolin and cyanidin. Good linear relationships ($R^2 > 0.999$) were obtained for the calibration curves. Serum creatinine and blood urea levels were reduced significantly after treatment with *T. pallida* fractions and renal histopathological damage was remarkably ameliorated. The results suggest that the nephroprotective effect of *T. pallida* might be linked to its polyphenolic compounds, which in combination have an overall antioxidant, anti-inflammatory and anti-apoptotic impact on cisplatin-induced oxidative stress, inflammation and apoptosis. In general, the ethanolic fractions of the stem and root showed good nephroprotective activity with the decrease in elevated renal function markers and decrease in histopathological damage after cisplatin treatment.

Keywords: cisplatin; HPLC-DAD; nephrotoxicity; *Tradescantia pallida*

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1. Introduction

In the clinic, cisplatin (cis-platin) is one of the most potent and widely used cytotoxic chemotherapeutic drugs for the treatment of several solid tumors, such as those from the head and neck, bladder, testicular and ovarian organs (1). It is highly effective in therapy, but has important and marked side effects, especially nephrotoxicity, which is dose dependent (1, 2). Cisplatin is used to treat many types of malignancy and about one-third of all cancer patients receiving this therapy will develop acute kidney injury (AKI) or renal dysfunction in days of administration (2). The mechanism of cisplatin nephrotoxicity is extremely complex and multifactorial and involves

preferential renal proximal tubular epithelial cell accumulation of the drug mediated by organic cation transporters (2, 3). After entering these cells, the cisplatin activates a cascade of intracellular events, such as increased generation of reactive oxygen species (ROS), extensive lipid peroxidation, reduction in endogenous antioxidant defense systems and activation of pro-inflammatory cytokines and intrinsic apoptotic signaling pathways (3, 4).

The clinical approaches used for prevention or treatment of cisplatin-induced nephrotoxicity to date are based mainly on treatment with forced diuretics and aggressive intravenous hydration. But these therapies are not fully effective and fail to

specifically target the molecular damage to the tubular structures in the kidneys (5). Thus, it is becoming increasingly important to discover natural bioactive compounds derived from plants that can reduce the toxicity of chemotherapy without affecting its anti-cancer activity (5, 6).

The potential of their strong free-radical-scavenging activity, high reducing capacity and modulating effects on cellular inflammatory pathways has led to a significant interest in their use as secondary metabolites in plants (6, 7).

Purple heart or purple queen (Fig. 1) is a perennial evergreen herb of the family Commelinaceae (8), known as *Tradescantia pallida* (Rose) D.R. Hunt. Despite being a widely used ornamental plant, recent pharmacological investigations have shown that *T. pallida* display various biological activities, such as high antioxidant, anti-inflammatory, antimicrobial and cytoprotective properties (8, 9). The pharmacological properties displayed are a result of the high phytochemical content of this plant which contains anthocyanins, phenolic acids and different flavonoid glycosides (9, 10).

Nevertheless, the antioxidant properties of its different anatomical parts have not been well documented, especially those of the root and stem and its complete phytochemical profile and utility for the protection against specific chemically induced organ toxicities (e.g., cisplatin-induced nephrotoxicity) have yet to be fully delineated.

Hence, the present work aimed for systematic profiling and quantification of the major polyphenolic and flavonoid constituents of the ethanolic extracts of stem and root of *T. pallida* by high-performance liquid chromatography (HPLC) coupled with diode-array detection (DAD). Furthermore, nephroprotective activity of these fractions against cisplatin-induced acute renal injury in a rodent model was evaluated to decipher their renal protective effects on renal cellular architecture and possible contribution of their identified phytochemical constituents.

2. Materials and Methods

Chemicals and reagents

All reagents were analytical grade. Cisplatin, silymarin and distilled water were purchased from local pharmacies in Baghdad, Iraq. Authenticated reference standards of polyphenols and flavonoids (including catechin, esculetin, p-coumaric acid, ferulic acid, morin, cyanidin and luteolin) were purchased from ChemFaces (China).

Plant material

Plant authentication

Plants of *T. pallida* were collected from Al-Qanat nurseries, Baghdad, Iraq. The plant was authenticated by Assist. Prof. Dr. Sukaina Abbas Alawi (College of Science, University of Baghdad). The accepted botanical name, *Tradescantia pallida* (Rose) D.R.Hunt, was verified using Plants of the World Online (Kew Science).

Preparation of plant material and sequential solvent extraction

Fresh plants of *T. pallida* were gathered and washed with distilled water. The plant materials were divided into stems and roots and air-dried for 3 weeks under shade at room temperature. The dried materials were then finely ground in an electric grinder. The stem and root were then each extracted by sequential maceration with solvents of increasing polarity (hexane, chloroform, ethyl acetate and ethanol) as described previously (11, 12) to yield 250 g of stem powder and 250 g of root powder. All solvents extracts were filtered through Whatman No. 1 filter paper prior to further processing.

The extraction yields of the different fractions obtained from the stem were 0.63 g (0.25 %), 2.31 g (0.92 %), 0.77 g (0.31 %) and 50 g (20 %) for hexane, chloroform, ethyl acetate and ethanolic fraction respectively. For the root, the corresponding yields were 0.75 g (0.30 %), 1.10 g (0.44 %), 0.75 g (0.30 %) and 11 g (4.4 %), respectively. The ethanolic fractions were selected for further study as they yielded the highest quantity from the fractions obtained and yielded adequate amount of fractions for the next step of the animal study. After sequential extraction, the ethanolic filtrates from stem and root were concentrated under reduced pressure in rotary evaporator at 45 °C. The concentrated ethanolic fractions were kept at room temperature for further processing.

High-performance liquid chromatography with diode-array detection identification of polyphenolic constituents in stem and root

The bioactive polyphenolic and flavonoid constituents of ethanolic extracts from the stem and root of *T. pallida* were analysed by phytochemical characterisation and quantitative profiling by using a HPLC-DAD; Sykam, Germany. The separation was performed on a Poroshell EC-C18 column (250 × 4.6 mm, 5 µm particle size) at a controlled column temperature of 30 °C.

The mobile phase was a binary solvent system made up of Solvent A, 0.1 % (v/v) glacial acetic acid in Milli-Q water and Solvent B, HPLC-grade acetonitrile containing 0.1 % (v/v) glacial acetic acid. Optimised linear gradient elution program at constant flow rate of 1.0 mL/min was used. The gradient was programmed as follows: 5–20 % B from 0 to 5 min, 20–45 % B from 5 to 15 min, 45–70 % B from 15 to 25 min and 70–90 % B from 25 to 35 min.



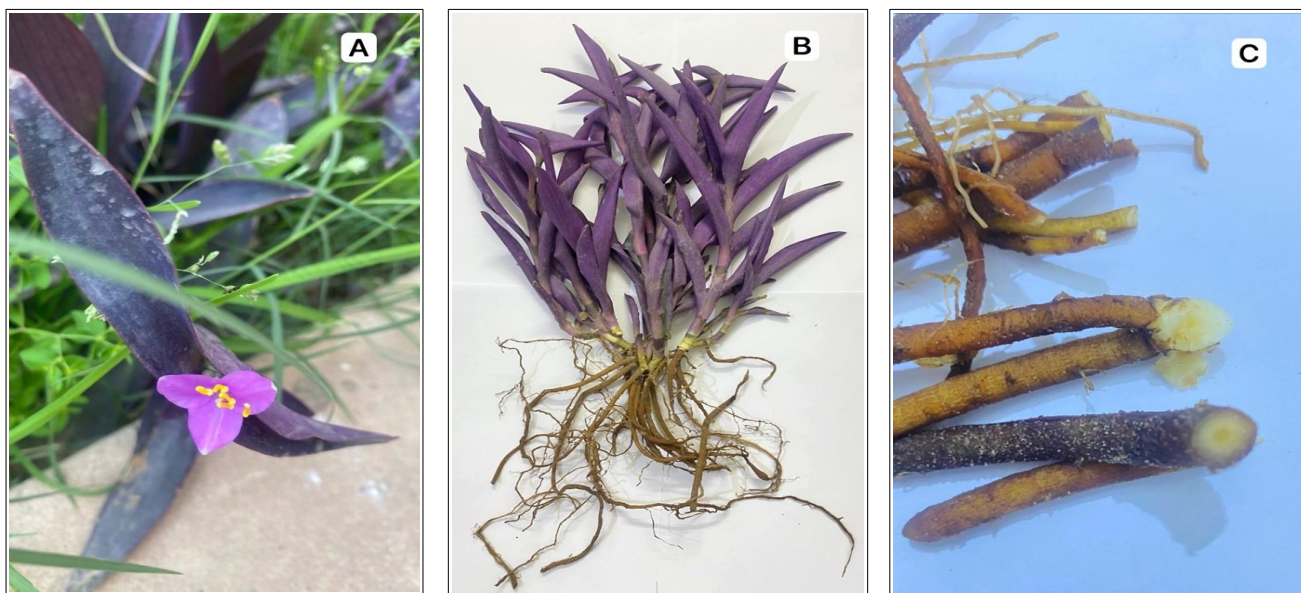


Fig. 1. Morphological features of *Tradescantia pallida*: (A) flowering aerial part of the plant; (B) whole plant showing the purple leaves, stems and root system; (C) freshly cut root segments showing the external surface and cut ends.

The mobile phase was held at 90 % B until 40 min as a column washing step which was decreased from 90 % to 5 % B between 40 and 45 min to re-equilibrate the column to its initial conditions. The total chromatographic run-time was 45 min. A small injection volume of 20 μ L was used to prevent overloading the column and peak distortion.

The DAD was used for monitoring the eluent in a wide range of ultraviolet–visible (UV–Vis) wavelengths, 200–600 nm. Selected wavelengths were used for quantitative monitoring as per the absorption wavelength (λ_{max}) of the desired compound classes such as catechins (280 nm), coumarins (320 nm), flavonoids (360 nm) and anthocyanins (520 nm). Before sample analysis, external calibration curves were built with authenticated reference standards (catechin, esculetin, p-coumaric acid, ferulic acid, morin, cyanidin and luteolin).

The compounds identified in the fractions of *T. pallida* were compared to the retention time (min) and characteristic UV-Vis spectrum of the reference standards. Prior to injection into the HPLC system (13), all samples and the mobile phase were filtered through 0.22 μ m membrane filters and degassed by sonication. The concentrations of each identified phytochemicals were calculated from their respective external calibration curves by correlating the peak area with the standard calibration equation and were expressed as ppm (μ g/mL).

Experimental animals and ethical approval

Experimental animals were adult female Wistar rats (8–10 weeks old) weighing (200–250 g) obtained from the animal house of the Biotechnology Research Center, University of Baghdad, Iraq and maintained

under standard laboratory conditions (The rats were housed at 20–24 °C under a 12 hr light /12 hr dark cycle with a relative humidity of 30–60 % and free access to food and water (*ad libitum*) throughout the experimental period.

Determination of nephroprotective activity *in vivo*

Experimental design and induction of cisplatin-induced nephrotoxicity

In 35 female rats, which were randomly assigned to the 7 groups ($n = 5$ rats in each group), the nephrotoxicity of cisplatin was confirmed. The first group (Normal control) was given distilled water orally for 10 days in a row. Stem and root fractions were given orally to the 2nd and 3rd groups respectively at the dose of 100 mg/kg body weight for 10 days. To assess the nephroprotective effect, the 4th group (stem fraction + cisplatin) and the 5th group (root fraction + cisplatin) were orally gavaged with the corresponding ethanolic fractions for 5 consecutive days prior to the administration of a single i.p. dose of cisplatin (7 mg/kg) on day 7. The 6th group (silymarin + cisplatin) received silymarin (100 mg/kg/day, orally) for 5 consecutive days before the injection of cisplatin on day 7, while the 7th group (distilled water + cisplatin) received distilled water for 5 consecutive days before the injection of cisplatin on day 7. Four days after cisplatin treatment (day 11), all animals were humanely euthanised. The blood samples were collected for biochemical and histopathological analyses (14).

Assessment of renal function biomarkers

Urea and creatinine levels of the serum were determined spectrophotometrically with commercial diagnostic kits using an automated analyser (MinDray BS-230), as per the manufacturer's instructions.

Statistical analysis

All statistical calculations were done in GraphPad Prism (Version 10; GraphPad Software, Inc., La Jolla, CA, USA). Welch's one-way ANOVA followed by Tukey's multiple comparisons test was used to compare the experimental groups. Data are presented as mean $\pm$ standard deviation (SD). A statistical significance of 0.05 or less was considered significant.

Histopathological assessment

The formalin-fixed rat kidney tissue samples were paraffin-embedded, cut into 4–5 μ m thick sections and stained with hematoxylin and eosin (H&E). The stained areas were studied using a light microscope (15).

3. Results

High-performance liquid chromatography with diode-array detection identification of major phytochemicals in stem and root ethanolic fractions

The primary active phytochemical and polyphenolic compounds found in the ethanolic fraction of *T. pallida* (stem and root) were precisely qualitatively profiled and verified using HPLC-DAD (Fig. 2 A and B). A series of standard solutions containing the targeted reference substances were injected under optimised conditions to provide their definitive retention times (min) (Fig. 2 C) and their characteristic peak profiles. The chromatograms of the plant fractions were compared with the corresponding reference-standard chromatograms.

Each standard reference compound was individually calibrated by plotting of the peak responses (Y) against the established concentration gradients (X, μ g/mL) to validate the reliability, resolution and reproducibility of the chromatographic system before the sample analysis. Linear regression equations ($Y = mX + C$) and the correlation coefficient (R^2) were calculated. The calibration curves exhibited a very good linearity ($R^2 > 0.999$). These regression equations were then used to identify and quantify the compounds in the stem and root ethanolic fractions (Fig. 3). This analytical technique verified the linearity of the detector response and verified the validity of the quantitative determination of the detected compounds.

Bioactive compounds present in the stem and root ethanolic extracts of *T. pallida* were successfully confirmed by comparing and matching the retention time (min) of the peaks of the plant extracts with the reference standards that were injected. The sharp

resolution and alignment of peaks of the examined plant showed the successful identification of the main active components in the ethanolic fraction of the roots and stems of the plant studied, which provided a good analytical basis for the biological activity of the studied plant (Fig. 2, Table 1 and 2).

Serum biochemical analyses

This study demonstrated that cisplatin significantly induced nephrotoxicity, as evidenced by marked increases in serum urea and creatinine levels ($p < 0.001$) compared with the control group. Pre-treatment with the stem and root ethanolic fractions significantly reduced the elevated serum urea and creatinine levels ($p < 0.001$), with the quantitative results expressed as mean $\pm$ SD and presented in (Table 3). The nephroprotective effects of the stem and root ethanolic fractions were also compared with those of silymarin as the reference drug. Administration of the stem and root ethanolic fractions alone, without cisplatin, did not produce significant changes in serum urea or creatinine levels compared with the control group ($p > 0.05$), suggesting that neither fraction caused an apparent adverse effect on renal function at the tested dose of 100 mg/kg body weight.

Effect of stem and root ethanolic fractions of *Tradescantia pallida* on renal function biomarkers

The serum profile indicates proper kidney function (Fig. 4, Table 3). Serum creatinine and urea, determine the glomerular filtration rate and were considered as functional nephrotoxicity indices. Cisplatin-induced nephrotoxicity was apparent from the elevated ($p < 0.001$) levels of serum creatinine (1.21 ± 0.10 mg/dL) and urea (104.62 ± 6.39 mg/dL) compared to control group (0.31 ± 0.02 mg/dL and 45.10 ± 2.01 mg/dL respectively). Pre-treatment with the reference drug silymarin partially ameliorated the toxic effect of cisplatin by significantly reducing the elevated serum creatinine and urea levels ($p < 0.001$), to (0.70 ± 0.07 mg/dL and 69.22 ± 4.23 mg/dL), respectively. However, a significant restoration ($p < 0.001$) of the serum urea and creatinine levels was observed in rats pre-treated separately with the stem and root ethanolic fractions of *T. pallida* compared with the cisplatin-treated group. The stem ethanolic fraction reduced serum creatinine levels to (0.49 ± 0.03 mg/dL) and urea to (56.8 ± 1.7 mg/dL), whereas the root ethanolic fraction reduced serum creatinine and urea level to (0.50 ± 0.03 mg/dL and 58.52 ± 1.72 mg/dL), respectively. Both fractions demonstrated strong nephroprotective effects compared to silymarin-treated group, with serum urea and creatinine levels approaching those of the control group.



Fig. 2. Overlaid high-performance liquid chromatography (HPLC) chromatograms of root and stem ethanolic fractions. Vertical lines identify retention times of the supplied reference standards. Panel B compares only matched peaks using the reported relative integration areas.

HPLC calibration curves of reference standards

Linear regression plots; equations and correlation factors are reproduced from the supplied calibration-curve images.

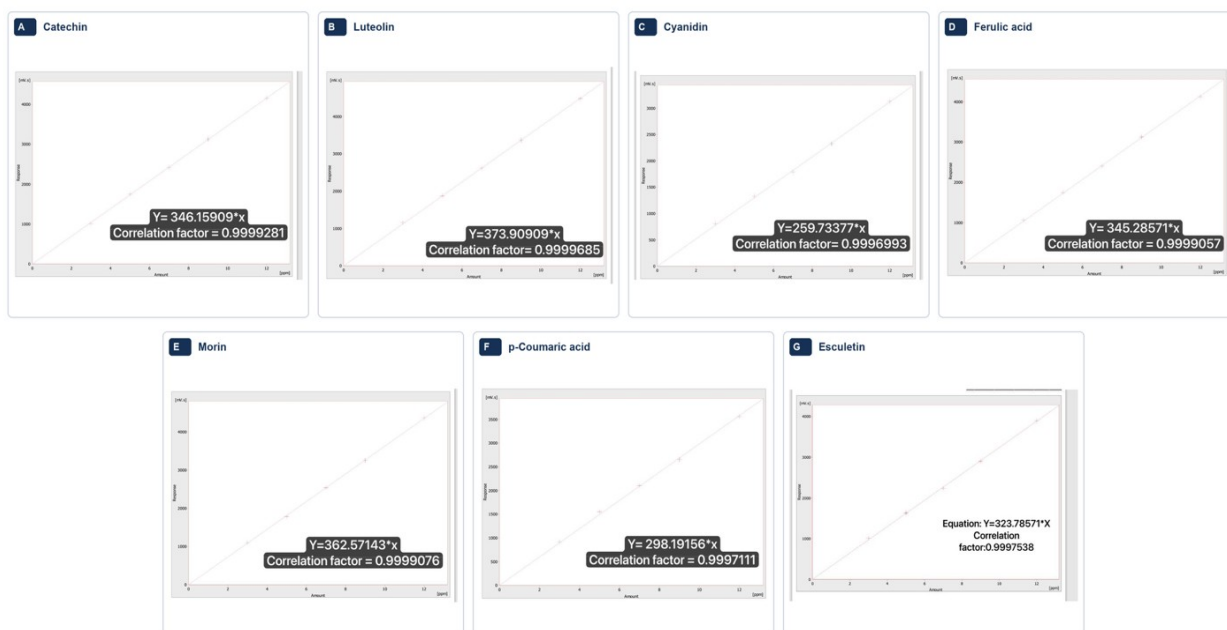


Fig. 3. Calibration curves of the reference standards: (A) catechin; (B) luteolin; (C) cyanidin; (D) ferulic acid; (E) morin; (F) p-coumaric acid; (G) esculetin.

Table 1. High-performance liquid chromatography with diode-array detection (HPLC-DAD) profile of major polyphenolic compounds identified in the root ethanolic fraction of *Tradescantia pallida*

Sl. No.	Compound Name	Retention time (min)	Area (mAU.s)	Height (mAU)	Area (%)	Height (%)	W 05 (min)	Con. ppm (µg/mL)
1	Catechin	8.80	18954.08	805.65	20	20	0.13	54.75
2	Esculetin	17.40	12654.74	588.98	16	16	0.08	3.91
3	p-coumaric acid	19.48	16554.02	674.14	18	18	0.10	55.51
4	Ferulic acid	24.68	4123.32	187.45	8	8	0.03	11.94
5	Morin	28.14	8574.99	389.65	12	12	0.07	23.65

Table 2. High-performance liquid chromatography with diode-array detection (HPLC-DAD) profile of major polyphenolic compounds identified in the stem ethanolic fraction of *Tradescantia pallida*

Sl. No.	Compound name	Retention time (min)	Area (mAU.s)	Height (mAU)	Area (%)	Height (%)	W 05 (min)	Con. ppm(µg/mL)
1	Catechin	8.71	15952.65	599.85	12	12	0.05	46.09
2	Cyanidin	12.17	27440.56	841.12	19	19	0.13	105.65
3	Esculetin	17.41	6521.23	374.57	7	7	0.03	2.02
4	p-coumaric acid	19.49	13212.05	433.41	11	11	0.06	44.31
5	Ferulic acid	24.71	1542.99	104.45	3	3	0.01	4.47
6	Morin	28.19	11421.11	441.12	9	9	0.05	31.50
7	Luteolin	39.58	10332.65	432.66	7	7	0.05	27.63

Table 3. Descriptive and one-way analysis of variance (ANOVA) of serum creatinine and blood urea levels in the experimental groups

	F	df1	df2	p
Serum creatinine	92.8	6	12.2	< .001
Blood urea	110.9	6	12.2	< .001

	Groups	N	Mean	SD	SE
Serum creatinine	Control	5	0.304	0.0230	0.01030
	Cisplatin	5	1.208	0.1055	0.04716
	Silymarin + Cisplatin	5	0.696	0.0702	0.03140
	Root fraction	5	0.300	0.0158	0.00707
	Stem fraction	5	0.314	0.0207	0.00927
	Root fraction + Cisplatin	5	0.500	0.0339	0.01517
	Stem fraction + Cisplatin	5	0.490	0.0339	0.01517
Blood Urea	Control	5	45.100	2.1036	0.94074
	Cisplatin	5	104.620	6.3990	2.86171
	Silymarin + Cisplatin	5	69.220	4.2340	1.89352
	Root fraction	5	44.860	0.9397	0.42024
	Stem fraction	5	45.900	1.1292	0.50498
	Root fraction + Cisplatin	5	58.520	1.7196	0.76903
	Stem fraction + Cisplatin	5	56.820	1.7196	0.76903

Protective effects on cisplatin-induced histopathological kidney damage

In the present study, no mortality was observed in the cisplatin-treated rats or in the other experimental groups at the end of the experiment. Histological examination revealed that the kidneys obtained from cisplatin-treated rats (7th group) had serious tubular damage, characterised by tubular dilation, necrosis, vacuolisation and hyaline cast formation (Fig. 5). The glomeruli also showed compensatory enlargement and capillary congestion, appearing larger than those observed in the control group. In contrast, pre-treatment with silymarin (6th group) markedly attenuated the cisplatin-induced tubular damage, with reduced tubular necrosis and no apparent hyaline cast formation, while the glomerular structure was relatively preserved. Similarly, pre-treatment with the stem and root ethanolic fractions of *T. pallida* (4th and 5th groups, respectively) resulted in relatively well-

preserved renal architecture. The glomeruli look uniform and well-anchored, the tubules are tightly arranged with distinct epithelial walls and open, clear lumens and there is a complete absence of the hyaline cast formation compared with the cisplatin-treated group.

4. Discussion

Phytochemical profiling via high-performance liquid chromatography with diode-array detection

The identification of these classes of chemical compounds has been reported previously, where it was observed that the species *T. pallida*, *Tradescantia zebrina* Regel and *Tradescantia spathacea* Sw. are rich in phenolic compounds, flavonoids and anthocyanins that could protect plant tissues against oxidative damage.

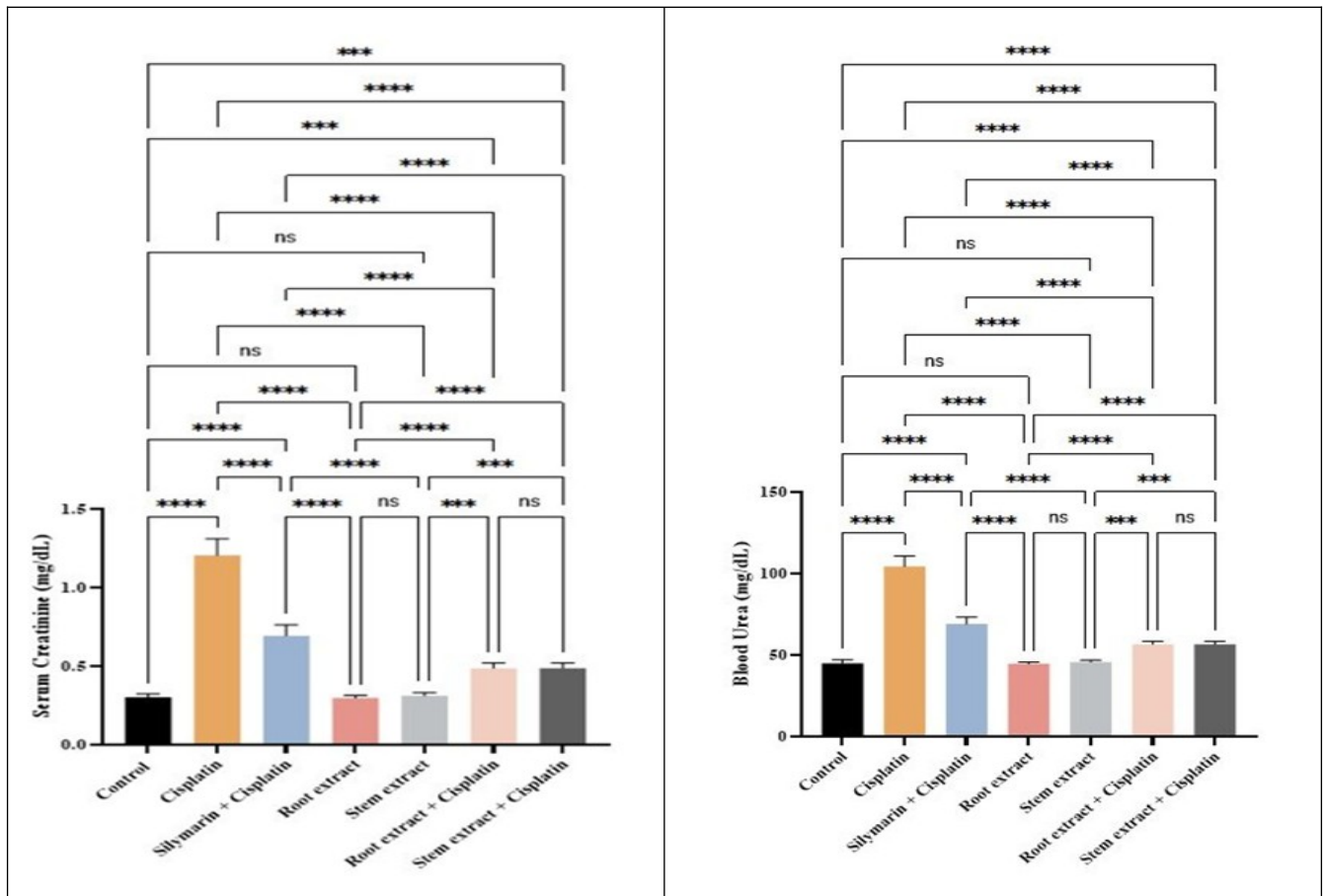


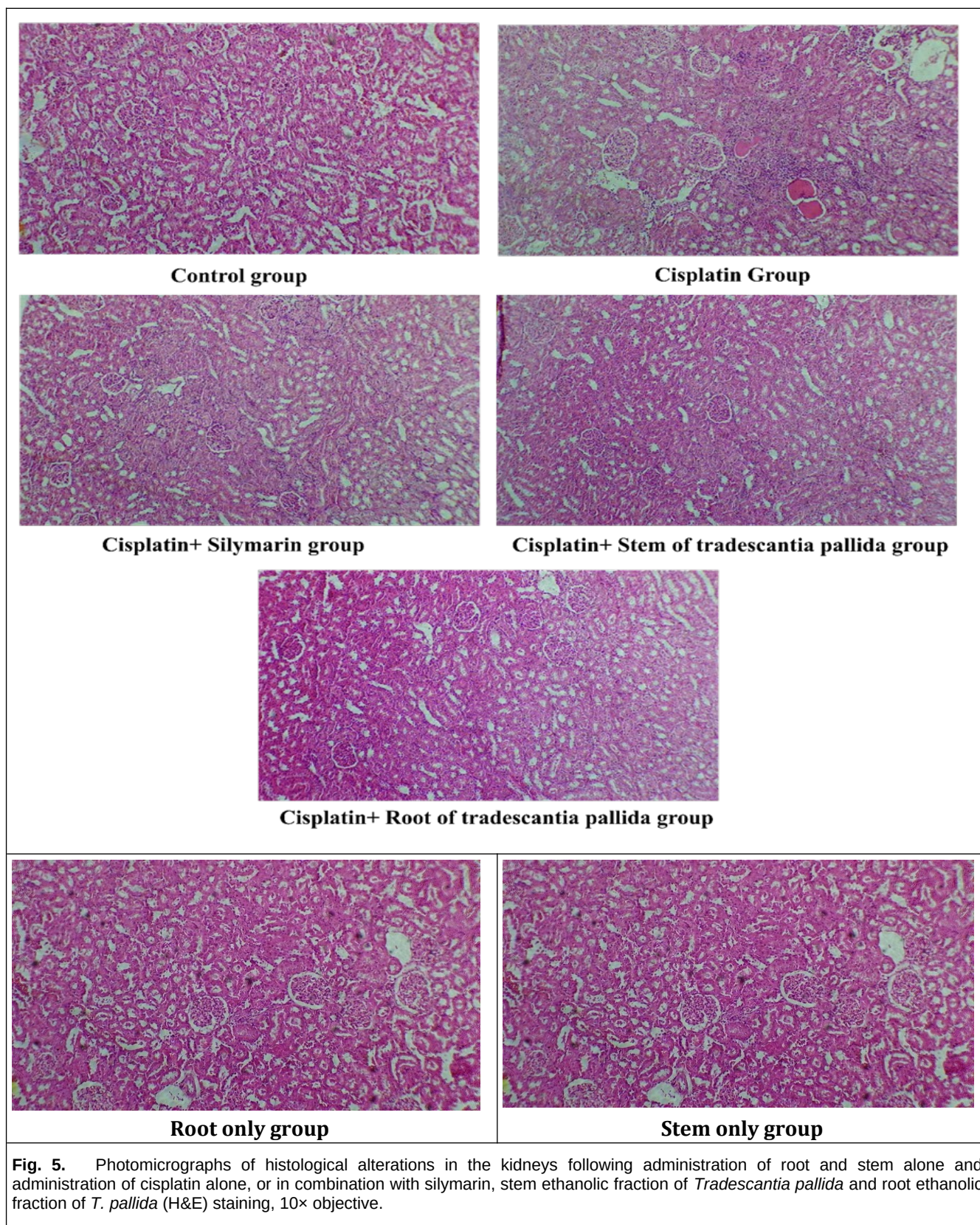
Fig. 4. Effects of *Tradescantia pallida* stem and root ethanolic fractions in cisplatin-treated rats. (A) Serum creatinine levels. (B) Blood urea levels. Data are presented as mean $\pm$ SD (n = 5). Statistical significance was determined using Welch's one-way ANOVA followed by Tukey's multiple-comparisons test.

In addition, the presence of key phenolic acids and flavonoids in the present study corroborates with previous findings which found a rich polyphenolic profile and biological activities in *T. pallida*, *T. zebrina* and *T. spathacea* (16). The antioxidant activity of these secondary metabolites has been shown to have antioxidant properties including free-radical-scavenging and reducing effects (17). Thus, the phytochemical profile obtained by the developed HPLC method could be a source of chemical explanation for the biological activity found in the investigated fractions.

Nephroprotective potential against cisplatin-induced injury

Silymarin is a natural compound with well-known antioxidant and anti-inflammatory effects and has been studied for its potential to protect against renal damage induced by the anti-cancer drug cisplatin. These antioxidant-protective properties could be related to its ability to decrease oxidative stress, lipid peroxidation and inflammation in cisplatin-induced kidneys and to increase the endogenous antioxidant defences (17–19).

The antioxidant and anti-inflammatory activity of the phenolic, flavonoids and anthocyanin constituents of the stem and root ethanolic fractions of *T. pallida* that has been reported previously may be responsible for the observed protective effects in the present study. Phytochemical analysis by HPLC revealed several compounds, including esculetin, luteolin and cyanidin, which may account for the renal protective effects against cisplatin-induced changes. Esculetin has been reported to dampen down oxidative and inflammatory responses and luteolin has been shown to be a modulator of inflammatory signaling and oxidative damage (16, 20). Likewise, cyanidin and other anthocyanins might also play a role in antioxidant defence by scavenging of ROS and increase of endogenous antioxidant capacity (16, 20). These observations are important because oxidative stress and inflammation are known to play a role in the development of cisplatin-induced nephrotoxicity (21, 22). The potential role of esculetin in the protective effect observed in the present study has been further demonstrated by recent experimental studies in which it was shown to have the ability to attenuate renal injury through a reduction in oxidative stress and inflammatory responses (23, 24).



The biological activity of the fractions might thus be because of several phytoconstituents, not a single compound. Various constituents may play roles in various facets of cisplatin-induced renal injury such as the restraint of oxidative injury and the modulation of inflammatory response or lipid peroxidation. The combined biological actions that can be expected

from the simultaneous presence of these compounds in the fractions may then occur. The individual compounds and combinations of compounds were not individually tested in the present study, however and a synergy interaction could not be determined. Observed nephroprotective response should be

rather attributed to a possible combination or complementary effect of several phytoconstituents.

The biochemical and histopathological results corroborate the protective activity of the fractions of *T. pallida* as observed in the present study. However, the results obtained should be taken with the limitations of the parameters studied. The evaluation of antioxidants, oxidative stress and inflammatory pathways was not directly measured, while the assessment of the selected biochemical and histopathological markers was done. As such, the suggested mechanisms are potential mechanisms of the observed renal protection and not established. Furthermore, it is important to remember that comparisons made between the relative efficacy of the fractions in comparison with silymarin should be taken with caution unless a direct statistical comparison of the respective treatments is available.

The other disadvantage of the present study is the assessment of the effect of only one dose (100 mg/kg) for each ethanolic fraction. As a result, a dose–response relationship could not be identified and the amount of drug necessary for optimal efficacy is therefore unknown. Further studies are needed to evaluate multiple dose levels and to assess further indicators of renal injury, oxidative stress, antioxidant enzyme activity, inflammatory mediators and lipid peroxidation. The investigations would generate more convincing evidence on the dose dependent, effective and underlying mechanisms of the nephroprotective effects of the stem and root ethanolic fractions of *T. pallida*. Whilst the present findings are encouraging, the present results are preliminary in Wistar rats and need further experimental and ultimately clinical investigations to confirm these findings.

5. Conclusion

The results of the present study suggest that the ethanolic extracts of root and stem of *Tradescantia pallida* protected against renal injuries induced by cisplatin in rats, as reflected by the reduction in the elevation of blood urea and creatinine levels and the improvement in the histopathological changes caused by cisplatin in rats. They were found to contain esculetin, luteolin and cyanidin and other phenolic and flavonoid constituents as determined by high-performance liquid chromatography (HPLC), which could account for the protective effects observed, due to their reported biological activity. The antioxidant and anti-inflammatory mechanisms, however, were not investigated directly in the present study and, hence, cannot be confirmed. The observed nephroprotective effects suggest the possible source of bioactive phytoconstituents with renal protective properties in the stem and root ethanolic fractions of *T. pallida*. Additional research is needed to fully understand efficacy and mechanisms

for dose–response evaluation, isolation of individual components and direct assessment of oxidative stress, antioxidant and inflammatory pathways.

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Authors' contributions

SMK conceived and designed the study, performed all laboratory experiments, collected and analysed the data, interpreted the results and prepared the original manuscript. DAA supervised the research, provided scientific guidance throughout the study, critically reviewed and revised the manuscript. Both authors read and approved the final version of the manuscript for publication.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

The experimental protocol was approved by the Research Ethics Committee of the University of Baghdad-College of Pharmacy (Approval No. RECAUCP 1792025048R, Date: 17 September 2025).

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT and Gemini for language editing and grammar correction. After using this tool, the author reviewed and edited the content as needed and take full responsibility for the content of the publication.

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