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Original Paper

Therapeutic role of alcoholic extract of *Ephedra alata* against lead acetate-induced hepatotoxicity in male albino rats

Athraa AbdulJabbar Hasan[1*], **Loay H. Ali**[1]

[1]Department of Biology, College of Education for Pure Sciences, University of Anbar, Ramadi, Anbar 31001, Iraq

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Corresponding author
Athraa AbdulJabbar Hasan
ath221005@uoanbar.edu.iq

ABSTRACT

This experiment aimed to assess the effect of *Ephedra alata* on toxic changes induced by lead acetate in rats. Forty male albino rats (185-215 g) were randomly assigned to five equal groups: the first received distilled water (control); the second received lead acetate alone (120 mg/kg); the third received alcoholic extract of *E. alata* alone (30 mg/kg); the fourth was pretreated with *E. alata* and then given lead acetate; and the fifth received lead acetate followed by *E. alata*. In the lead-acetate group, biochemical tests showed significant increases in aspartate transaminase (AST), alanine aminotransferase (ALT), malondialdehyde (MDA), interleukin-1β (IL-1β), and transforming growth factor-β (TGF-β), together with a decrease in total antioxidant capacity (TAC), compared with the control group. Results for the *E. alata*-only group were comparable to controls. In both the pretreatment and post-treatment groups, levels of AST, ALT, MDA, IL-1β, and TGF-β decreased, whereas TAC increased, relative to the lead-acetate group. Histopathological examination revealed marked hepatic changes in rats exposed to lead acetate alone compared with controls, while the remaining groups did not show severe alterations. These findings indicate a therapeutic role of *E. alata* extract against lead-acetate-induced hepatotoxicity.

Keywords: *Alanda, Heavy metal, Hepatotoxicity, Liver toxicity, TAC*

1 INTRODUCTION

Herbal remedies have been used for millennia, especially in emerging nations, not only for cultural and economic reasons but also because many contemporary pharmaceuticals have limitations and botanical agents often carry milder side effects [1]. Plant-derived natural compounds provide extensive opportunities for discovering novel therapeutics [2].

Ephedra alata (Arabic: "Alanda") is a perennial species in the family Ephedraceae, order Gnetales [3]. The plant is pale green, robustly branched, and dioecious, typically reaching 50-100 cm in height. It is indigenous to multiple regions, including Iran, Palestine, Saudi Arabia, Algeria, Morocco, Egypt, Tunisia, Libya, Lebanon, Jordan, and Iraq [4]. In traditional herbal practice, the decanted stem of *E. alata* is used to treat diverse ailments, including kidney disorders, bronchial asthma, circulatory and digestive problems, as well as fungal and bacterial infections [5,6].

Multiple in vitro and in vivo studies of *E. alata* extracts indicate that its phytochemicals are linked to diverse biological activities, including antibacterial, anti-inflammatory, antioxidant, anti-obesity, anti-diabetic, antiviral, and anticancer effects. As noted by [7], the 70% ethanol extract of *E. alata* exhibits antimicrobial activity and anticancer effects in a breast cancer cell line. The methanolic fraction likewise shows anti-obesity and antioxidant properties [6]. These benefits are attributed to a high content of bioactive constituents, including phenolic acids, tannins, flavonoids, cardiac glycosides, alkaloids, reducing sugars, and saponins [8].

Heavy metals, particularly lead, pose serious health risks to living organisms [9]. Lead and other heavy metals are widely present at low levels across natural

environments, yet lead has no physiological role in the human body [10]. Exposure can cause long-term disease, including hepatic, neurologic, and renal disorders [11]. Most toxicity cases arise from contact with dangerously high concentrations of lead (Pb) in industrial settings and waste sites [12]. Because they are not effectively eliminated by normal physiological mechanisms, heavy metals, especially cadmium, mercury, lead, and chromium, accumulate in organisms and enter the food chain [13]. Among these, lead is one of the most hazardous and is a major public health concern [14].

Lead is a toxic heavy metal that accumulates in the liver, testes, kidneys, bones, and brain [15]. After hepatic uptake, a portion of absorbed lead is bound and ultimately excreted in urine via the kidneys. Progressive accumulation disrupts multiple organ functions, particularly in the liver, a primary site of Pb toxicity [16]. This study was designed to evaluate the hepatoprotective and antioxidant effects of the aerial organs of *Ephedra alata* in rats intoxicated with lead acetate.

2 MATERIALS AND METHODS

2.1 Animals

Forty adult male albino rats (185-215 g) were used. Animals were purchased from the Animal Research Center, Tikrit University (Iraq), and housed in the animal facility of the College of Pure Science Education, University of Anbar. Rats were acclimated for 10 days under standard conditions (12-h light-dark cycle; 25-28 °C) with free access to pelleted chow and tap water. During acclimatization, animals were housed in polycarbonate cages with appropriate bedding and environmental enrichment. All procedures conformed to the International Guidelines for the Ethical Care of Laboratory Animals and the Hygiene Standards of the Redesigned Laboratory Biological Clinic; approval was granted under Document No. 243 (dated 12/26/2024).

2.2 Lead acetate

Lead acetate (analytical grade) was purchased from Sigma-Aldrich (St. Louis, MO, USA). A dose of 60 mg/kg was used, following [17].

2.3 Plant materials

Aerial parts (twigs and leaves) of *Ephedra alata* were collected from the Western Desert, Anbar Governorate, Iraq. The plant was taxonomically identified and authenticated by Prof. Dr. Muhammad Othman Musa, Desert Studies Center, University of Anbar.

2.4 Preparation of the *Ephedra alata* extract

Aerial parts were air-dried for 15 days at ambient temperature, protected from light and humidity, then pulverized to a fine powder. The ethanolic extract was prepared by macerating 50 g of powder in 150 mL of 70% ethanol with magnetic stirring for 72 h at room temperature, protected from light. The macerate was filtered through Whatman filter paper, the residue was re-macerated once under the same conditions, and the two filtrates were combined. Solvent was removed at 50 °C using a rotary evaporator (Laborota 400). The dried extract was stored refrigerated until use [17].

2.5 Experimental design

Animals were randomly assigned to five groups for treatment. Group I (control) received distilled water at 5 mL/kg. Group II received lead acetate at 120 mg/kg diluted in distilled water. Group III received the alcoholic extract of *Ephedra alata* orally at 30 mg/kg (1 mL per rat). Group IV was given lead acetate for six weeks and then *E. alata* extract for six weeks at the same concentration. Group V received *E. alata* extract first and, two hours later, received lead acetate at the same concentration described above.

2.6 Blood sampling

Under general anesthesia, blood was collected by cardiac puncture, allowed to clot at room temperature, and centrifuged at 3,000 rpm for 10 minutes to obtain serum. The separated serum was transferred into labeled plain (additive-free, white) tubes for subsequent biochemical analyses. Immediately after blood collection, animals were humanely euthanized using an institutionally approved method. All procedures conformed to the International Guidelines for the Ethical Care of Laboratory Animals and the Hygiene Standards.

2.7 Biochemical analysis

Serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were assayed as indicators of hepatic injury [18]. Oxidative-stress markers of malondialdehyde (MDA) activity and total antioxidant capacity (TAC) concentration were determined according to the referenced methodologies [19] and [20], respectively.

2.8 Immunological analysis

The concentration of IL-1β in rat plasma was measured by enzyme-linked immunosorbent assay (ELISA) using the rat ELISA kit (ABclonal Biotechnology, Cat. No. RK00020), following the manufacturer's protocol. Microplates were treated with antibodies specific for IL-1β as directed. Plasma TGF-β was quantified with the rat TGF-beta1 ELISA kit (BT LAB, China), according to the manufacturer's datasheet.

2.9 Histological Study

Fresh liver samples from each rat were rapidly excised and fixed in 10% neutral buffered formalin, then dehydrated through graded ethanol (70%, 80%, 90%, and 100%). Tissues were embedded in paraffin wax, sectioned at 5-7 µm on a rotary microtome, and stained with standard hematoxylin and eosin (H-E). Histological slides were examined by light microscopy, and representative photomicrographs were captured accordingly [21].

2.10 Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 17. Differences among groups were assessed by one-way analysis of variance (ANOVA) followed by Duncan's test. Results are presented as mean $\pm$ SEM, and differences were considered statistically significant at $p \leq 0.05$.

3 RESULTS

Figures 1-A and 1-B display the enzyme data obtained in this study. There was a significant increase in serum aspartate transaminase (AST) and alanine aminotransferase (ALT) in Group II (oral lead acetate) compared with the healthy control group. The figures also show that oral administration of *Ephedra alata* extract, whether given before or after lead acetate, produced a significant reduction in both enzymes in Groups IV and V relative to Group II. By contrast, enzyme values in Group III (extract of *E. alata* alone) were comparable to those of the control group.

There was a significant rise in malondialdehyde (MDA) with a concomitant fall in total antioxidant capacity (TAC) in Group II, which received lead acetate at 60 mg/kg. In contrast, Group III (alcoholic extract of *Ephedra alata* alone) showed MDA and TAC values within the normal range. Compared with Group II, Groups IV and V, administered *E. alata* either before or after lead acetate, exhibited the opposite pattern, with a significant decrease in MDA and a significant increase in TAC. These findings are illustrated in Figures 2-A and 2-B.

Results in Figures 3-A and 3-B show a significant increase in interleukin-1β (IL-1β) and transforming growth factor-β (TGF-β) in the group that received oral lead acetate compared with the control group. By contrast, values for these markers in Group III (alcoholic extract of *Ephedra alata* alone) were nearly identical to controls. In Groups IV and V, oral administration of *E. alata*, either before or after lead acetate, was associated with decreased IL-1β and TGF-β relative to the lead-acetate group.

Histological examination of the control group showed the normal architecture of liver tissue: a regularly structured central vein (CV), hepatocytes (HC) arranged radially around the CV, blood sinusoids (S), and Kupffer cells (KC), as shown in Figure 4-1. Histological findings in the *E. alata*-only group were comparable to the control liver architecture Figure 4-2. In contrast, the group dosed with lead acetate alone exhibited severe pathological alterations, including thickening of the central vein wall (TW), disruption of the normal radial plates of hepatocytes around the central vein, marked leukocytic inflammatory infiltration (LI), vascular congestion (CON), cellular degeneration, and areas of necrosis (N), with amyloid deposition (AM) also observed, Figure 5 (1-4).

In the preventive group, histological examination showed a near-normal architecture, with only mild changes, simple congestion and dilation of blood sinusoids, and minimal hemorrhage (HE), as shown in Figures 6-1 and 6-2. In the treatment group (Figures 6-3 and 6-4), liver morphology appeared most similar to the control, with overall restoration of tissue structure and only residual, minor alterations characterized by slight cellular degeneration.

4 DISCUSSION

The aim of the current investigation was to examine the effect of co-administration of *E. alata* on lead acetate-induced toxicities in Wistar albino rats. Although lead affects multiple organ systems, this study specifically focused on liver enzyme activities. Lead is a toxic metal pollutant worldwide; occupational and environmental exposure can include lead in drinking water [11], leached from plumbing and fixtures that contain lead. Absorbed lead is stored in soft tissues, predominantly the liver. As the first organ to receive nutrients directly via the

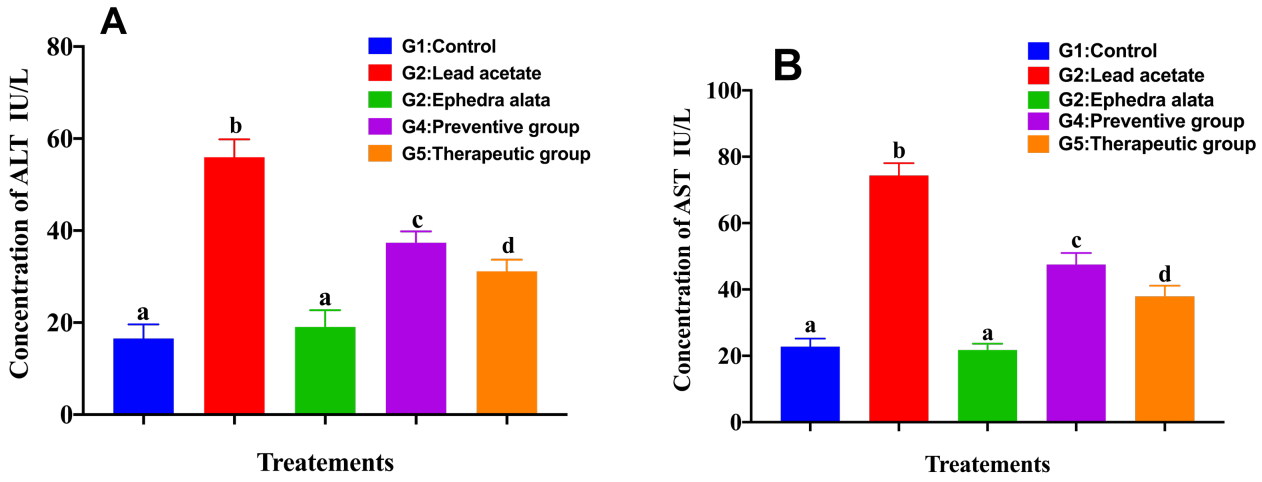

Fig. 1 Effect of *Ephedra alata* extract on serum ALT (A) and AST (B) activities in male albino rats treated with lead acetate. G1: control, G2: lead acetate, G3: *Ephedra alata*, G4: Preventive group, G5: Therapeutic group. Each group contained n = 8 rats. Different lowercase letters denote a significant difference between groups, whereas identical letters indicate no significant difference

portal vein, the liver is a primary site of exposure and toxicity [22].

The administration of lead acetate to rats produced a marked rise in serum AST and ALT compared with the control group. Lead exhibits hepatotoxic properties that impair hepatocytes, leading to elevated circulating AST and ALT; its harmful effects stimulate the release of these enzymes into the bloodstream. Increased plasma/serum AST and ALT have been linked to greater fluidity of liver microsomal membranes, free-radical generation, and compromised hepatocellular integrity following lead-acetate exposure [23, 24]. The elevation in ALT and AST activities may also reflect lead-acetate toxicity-induced increases in basal cellular metabolic rate, heightened irritability, and adverse alterations in liver function [25]. In addition, higher serum ALT and AST primarily result from leakage of these enzymes from damaged hepatocytes [26]. In our study, oral administration of the crude extract of *E. alata* at 30 mg/kg daily for 90 days significantly reduced plasma AST and ALT activity compared with the lead-acetate group, suggesting that the extract helped protect the liver from lead-induced injury [27]. The *E. alata* extract, which is rich in bioactive compounds such as phenols and flavonoids, may exert protective effects by stabilizing the biofilm structure, scavenging free radicals, and mitigating lipid peroxidation processes that contribute to toxin-mediated hepatic damage [28, 29].

In a similar vein, the present study showed that lead-acetate exposure in rats increased lipid peroxidation (elevated MDA) and reduced total antioxidant capacity (TAC) compared with the control group. Enzymes within the antioxidant defense system are critical for maintaining the balance between pro-oxidants and antioxidants; however, high lead levels induce oxidative damage by increasing free-radical generation while weakening cellular defenses, lowering TAC and GSH, inhibiting sulfhydryl-dependent and other antioxidant enzymes, and amplifying lipid peroxidation (MDA) [10, 30]. Our findings further demonstrated that treatment with *E. alata* lowered MDA and increased TAC. Thus, *E. alata* improved lipid-peroxidation status, highlighting potent chemopreventive and antioxidant properties against lead-acetate-induced hepatotoxicity in rats [27]. As previously concluded, *E. alata* exhibits antioxidant activity attributable to biomolecules known to scavenge reactive oxygen species (ROS) [28].

Lead acetate exposure caused an increase in inflammatory markers, including IL-1β and TGF-β, compared with the control group. Lead activates circulating monocytes and tissue macrophages, thereby promoting the synthesis and release of pro-inflammatory cytokines such as TNF-α, IL-1β, and TGF-β [31]. Lead-induced toxicity is also associated with inflammatory-cell infiltration of the interstitium, driving inflammation-mediated apoptosis via the extrinsic pathway [30]. In contrast, treatment

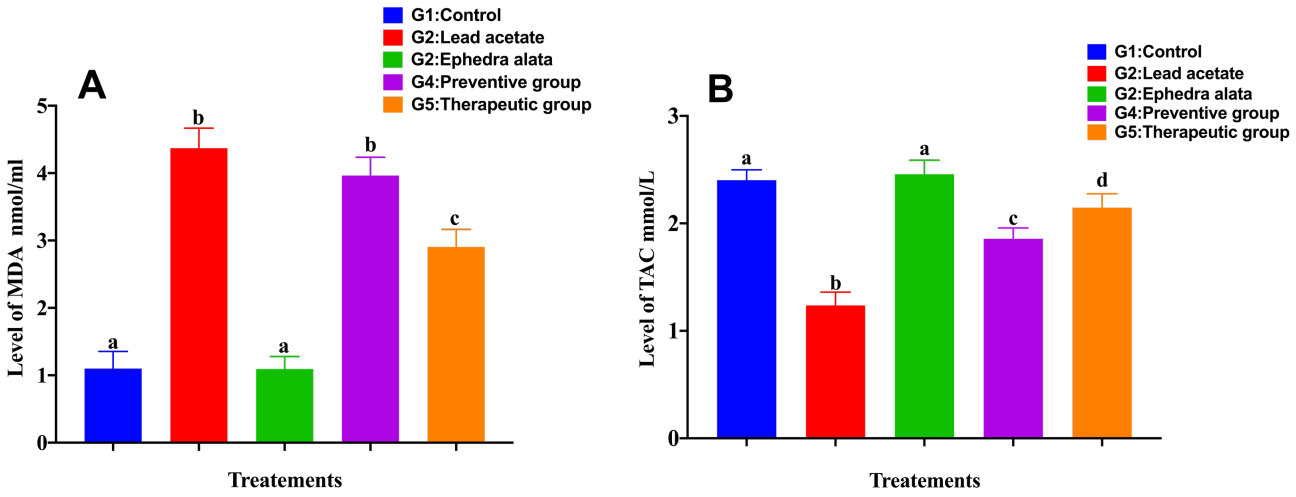

Fig. 2 Effect of *Ephedra alata* extract on MDA (A) and TAC (B) levels in male albino rats treated with lead acetate. Each group contained n = 8 rats. Different lowercase letters denote a significant difference between groups, whereas identical letters indicate no significant difference

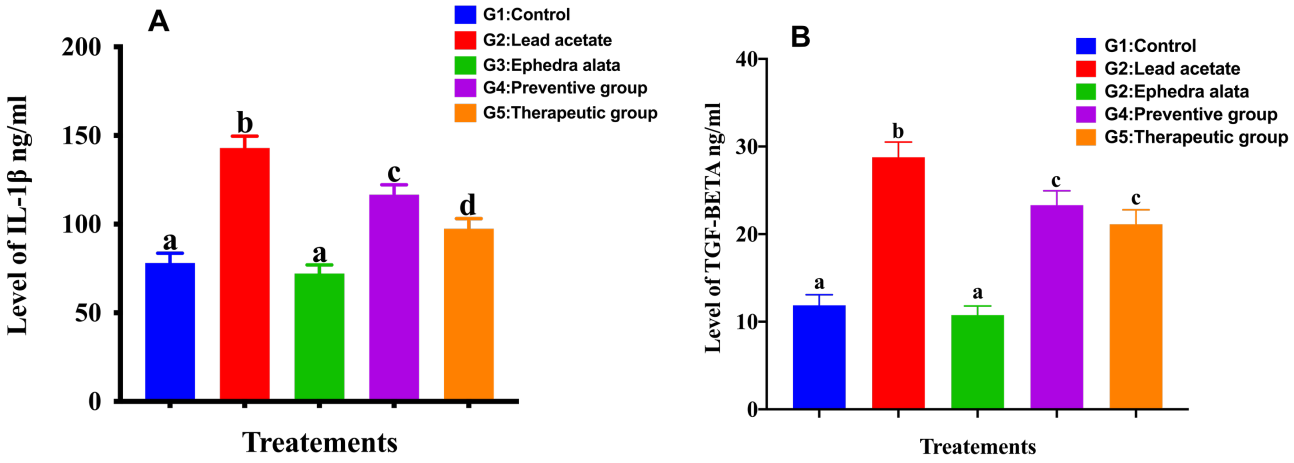

Fig. 3 Effect of *Ephedra alata* extract on IL-1β (A) and TGF-β (B) levels in male albino rats treated with lead acetate. Each group contained n = 8 rats. Different lowercase letters denote a significant difference between groups, whereas identical letters indicate no significant difference

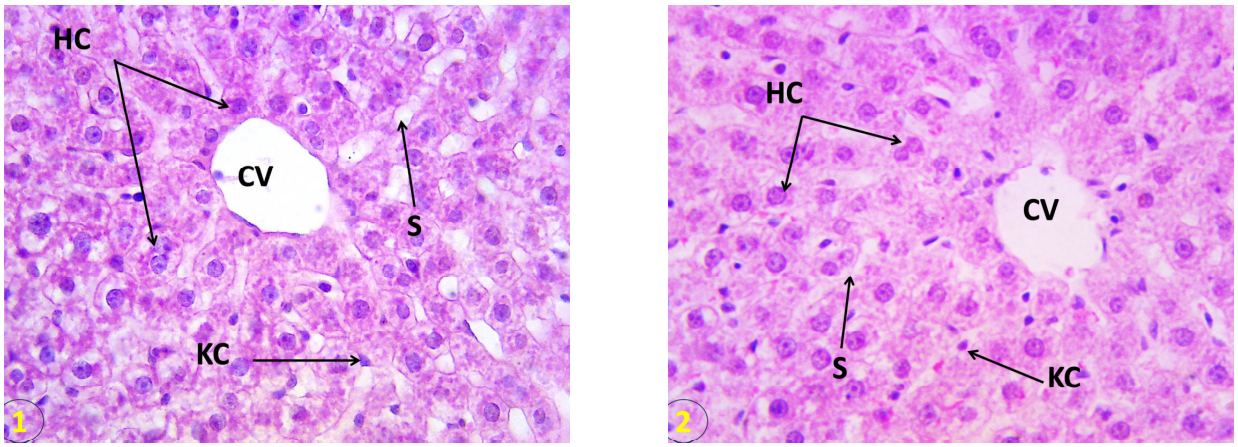

Fig. 4 (1): Cross-section of control rat liver showing the central vein (CV) with radial plates of hepatocytes (HC), blood sinusoids (S), and Kupffer cells (KC). H and E, 400×. (2): Cross-section of *Ephedra alata*-only group showing a normal CV with surrounding HC plates, S, and KC, similar to control. H and E, 400×

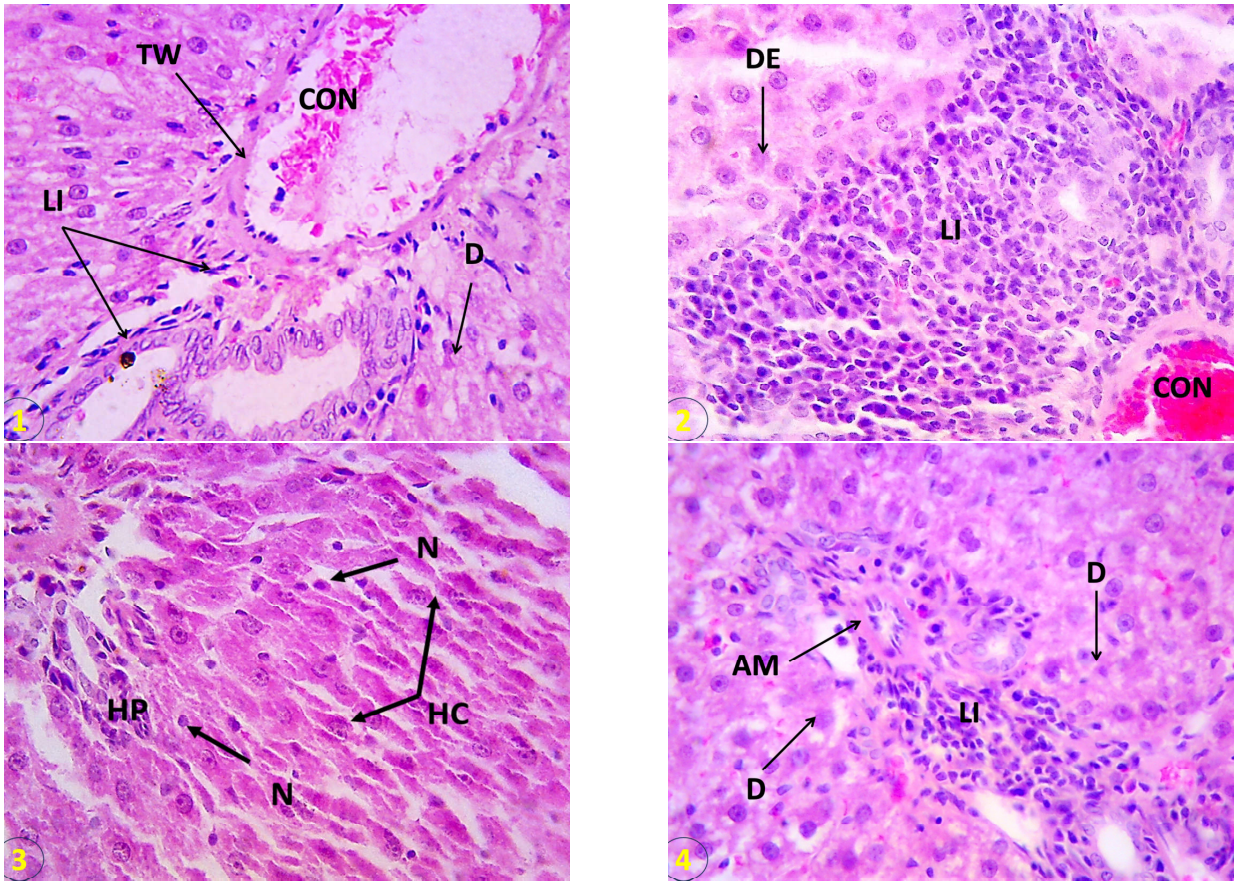

Fig. 5 (1): Lead-acetate group: increased thickness of the central vein wall (TW), cellular degeneration (D), inflammatory infiltration (LI), and congestion (CON). H and E, 400×. (2): Lead-acetate group: severe LI with marked CON in the CV and widespread cellular degeneration (D). H and E, 400×. (3): Lead-acetate group: irregular arrangement of HC around the CV, cellular necrosis (N) with hyperplasia (HP), and degeneration (D). H and E, 400×. (4): Lead-acetate group: LI with cellular degeneration (D) and amyloid deposition (AM). H and E, 400×

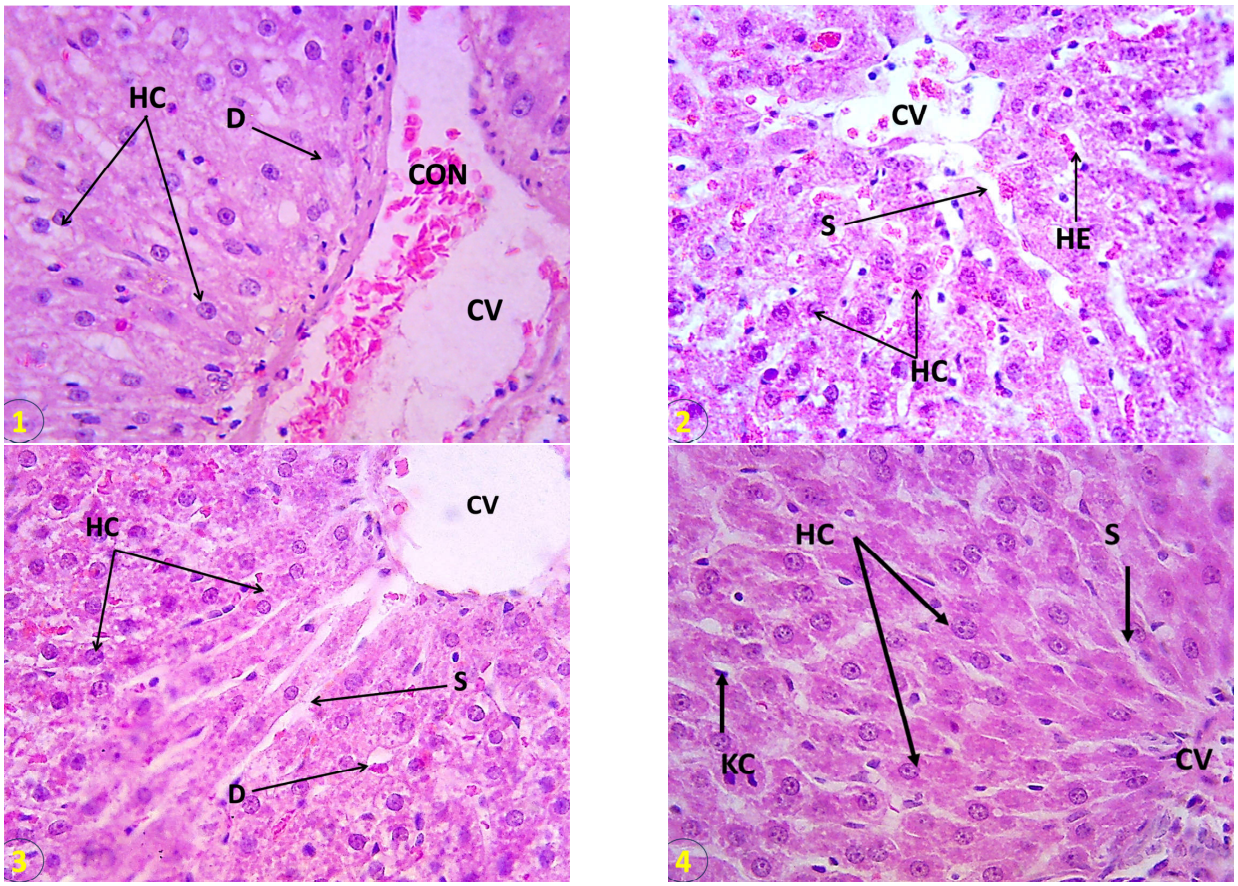

Fig. 6 (1) Preventive regimen (*E. alata* → lead acetate): near-normal hepatic architecture with HC arranged around the CV, mild cellular degeneration (D), and vascular congestion (CON). H and E, 400×. (2) Preventive regimen (*E. alata* → lead acetate): near-normal CV-centered architecture with mild hemorrhage (HE) and dilated blood sinusoids (S). H and E, 400×. (3): Treatment regimen (lead acetate → *E. alata*): hepatic architecture approximating control with HC around the CV, mild residual cellular degeneration, and intact S. H and E, 400×. (4): Treatment regimen (lead acetate → *E. alata*): normal arrangement of HC around the CV with evident S and KC. H and E, 400×

with *E. alata*, at either lower or higher doses, produced a marked reduction in serum IL-1β and TGF-β, consistent with prior reports. *E. alata* has been noted to suppress IL-1β and TNF-$alpha$ synthesis through inhibition of the NF-kB pathway [3].

The pathological alterations observed after lead acetate exposure are attributable to lead's toxic effects, which drive excess free-radical generation. This, in turn, increases lipid peroxidation of membranes and cellular components and reduces total antioxidant capacity (TAC) [32]. Lead acetate exposure was also associated with hepatic necrosis. Numerous studies have examined the impact of lead acetate on liver structure and function [33]. For example, intraperitoneal lead acetate at 15 mg/kg for seven consecutive days markedly elevated serum liver enzymes in rats and produced histological liver injury with hepatocyte necrosis. Mechanistically, lead interacts with hepatic enzymes and proteins in the interstitium, disrupting the antioxidant defense system and promoting reactive oxygen species (ROS) generation [34]. The protective effects of *E. alata* extract against lead acetate-induced liver injury likely relate to its antioxidant properties. Consistent with prior work and our findings, *E. alata* appears to mitigate hepatocyte damage and dysfunction by lowering inflammatory cytokines, scavenging free radicals and ROS, and enhancing antioxidant capacity in tissue and serum [29,35]. These antioxidant activities are attributed to constituents with diverse functional groups, including ephedrine and multiple phenolic compounds such as trans-cinnamic

acid, catechin, syringin, epicatechin, symplocoside, and kaempferol-3-O-rhamnoside [28].

5 CONCLUSION

This study indicates that the *Ephedra alata* extract exerted a therapeutic effect against lead-acetate-induced hepatotoxicity in male albino rats, as evidenced by improved biochemical markers (AST, ALT, MDA, TAC, IL-1β, TGF-β) and supportive histopathology. These findings support a hepatoprotective role for *E. alata* under the conditions tested.

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DECLARATIONS

Conflict of interest

The authors declare that they have no competing interests.

Consent to publish

Not applicable.

Ethical approval

All experimental procedures involving animals were reviewed and approved by the Redesigned Laboratory Biological Clinic (Ethics Committee), Document No. 243 dated 12/26/2024. All work conformed to the International Guidelines for the Ethical Care of Laboratory Animals and the Hygiene Standards of the Redesigned Laboratory Biological Clinic. To minimize pain and distress, animals were anesthetized prior to any procedure; terminal blood sampling was performed first, followed immediately by humane euthanasia using an institutionally approved method.

REFERENCES

[1] Gunjan M, Naing TW, Saini RS, Ahmad A, Naidu JR, Kumar I. Marketing trends & future prospects of herbal medicine in the treatment of various disease. World Journal of Pharmaceutical Research. 2015;4(9):132-55

[2] Alamgir ANM. In: Medicinal, Non-medicinal, Biopesticides, Color- and Dye-Yielding Plants; Secondary Metabolites and Drug Principles; Significance of Medicinal Plants; Use of Medicinal Plants in the Systems of Traditional and Complementary and Alternative Medicines (CAMs). Springer International Publishing; 2017. p. 61–104. 10.1007/978-3-319-63862-1_3

[3] Soumaya B, Yosra E, Rim BM, Sarra D, Sawsen S, Sarra B, et al. Preliminary phytochemical analysis, antioxidant, anti-inflammatory and anticancer activities of two Tunisian Ephedra species: Ephedra alata and Ephedra fragilis. South African Journal of Botany. 2020;135:421–428. 10.1016/j.sajb.2020.09.033

[4] Jaradat N, Hussen F, Al Ali A. Preliminary phytochemical screening, quantitative estimation of total flavonoids, total phenols and antioxidant activity of Ephedra alata Decne. Journal of Materials and Environmental Science. 2015;6(6):1771-8

[5] Al-Rimawi F, Abu-Lafi S, Abbadi J, Alamarneh AAA, Sawahreh RA, Odeh I. Analysis Of Phenolic And Flavonoids Of Wild Ephedra Alata Plant Extracts By Lc/Pda And Lc/Ms And Their Antioxidant Activity. African Journal of Traditional, Complementary and Alternative Medicines. 2017;14(2):130–141. 10.21010/ajtcam.v14i2.14

[6] Khattabi L, Boudiar T, Bouhenna MM, Chettoum A, Chebrouk F, Chader H, et al. RP-HPLC-ESI-QTOF-MS Qualitative Profiling, Antioxidant, Anti-Enzymatic, Anti-Inflammatory, and Non-Cytotoxic Properties of Ephedra alata Monjauzeana. Foods. 2022;11(2):145. 10.3390/foods11020145

[7] Tiss M, Souiy Z, Achour L, Hamden K. Ephedra alata extracts exerts anti-obesity, anti-hyperglycemia, anti-antipyretic and analgesic effects. Nutrition & Food Science. 2022;52(1):119–128. 10.1108/nfs-03-2021-0086

[8] Dbeibia A, Emhemmed F, Bahia W, Amri Z, Mahdhi A, Znati M, et al. Phenolic Profile with Biological Activities Assessment of Ethanolic and Aqueous Extracts from Ephedra alata. Chemistry Africa. 2024;7(5):2495–2506. 10.1007/s42250-024-00940-3

[9] Zaynab M, Al-Yahyai R, Ameen A, Sharif Y, Ali L, Fatima M, et al. Health and environmental effects of heavy metals. Journal of King Saud University-Science. 2022;34(1):101653. 10.1016/j.jksus.2021.101653

[10] Balali-Mood M, Naseri K, Tahergorabi Z, Khazdair MR, Sadeghi M. Toxic mechanisms of five heavy metals: mercury, lead, chromium, cadmium, and arsenic. Frontiers in pharmacology. 2021;12:643972. 10.3389/fphar.2021.643972

[11] Raj K, Das AP. Lead pollution: Impact on environment and human health and approach for a sustainable solution. Environmental Chemistry and Ecotoxicology. 2023;5:79-85. 10.1016/j.enceco.2023.02.001

[12] Rahman MS, Ahmed Z, Seefat SM, Alam R, Islam ARMT, Choudhury TR, et al. Assessment of heavy metal contamination in sediment at the newly established tannery industrial Estate in Bangladesh: A case study. Environmental Chemistry and Ecotoxicology. 2022;4:1–12. 10.1016/j.enceco.2021.10.001

[13] Singh A, Sharma A, K Verma R, L Chopade R, P Pandit P, Nagar V, et al. In: Heavy Metal Contamination of Water and Their Toxic Effect on Living Organisms. IntechOpen; 2022. 10.5772/intechopen.105075

[14] Uddin MM, Zakeel MCM, Zavahir JS, Marikar FMMT, Jahan I. Heavy Metal Accumulation in Rice and Aquatic Plants Used as Human Food: A General Review. Toxics. 2021;9(12):360. 10.3390/toxics9120360

[15] Vajargah MF, Azar H. Investigating the effects of accumulation of lead and cadmium metals in fish and its impact on human health. Journal of Aquaculture & Marine Biology. 2023;12(2):209–213. 10.15406/jamb.2023.12.00376

[16] Aslam M, Aslam A, Sheraz M, Ali B, Ulhassan Z, Najeeb U, et al. Lead toxicity in cereals: mechanistic insight into toxicity, mode of action, and management. Frontiers in plant science. 2021;11:587785. 10.3389/fpls.2020.587785

[17] Kittana N, Abu-Rass H, Sabra R, Manasra L, Hanany H, Jaradat N, et al. Topical aqueous extract of Ephedra alata can improve wound healing in an animal model. Chinese Journal of Traumatology. 2017;20(2):108–113. 10.1016/j.cjtee.2016.10.004

[18] Reitman S, Frankel S. In vitro determination of transaminase activity in serum. Am J Clin Pathol. 1957;28(1):56-63

[19] Ohkawa H, Ohishi N, Yagi K. Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. Analytical Biochemistry. 1979;95(2):351–358. 10.1016/0003-2697(79)90738-3

[20] Apak R, Güçlü K, Özyürek M, Çelik SE. Mechanism of antioxidant capacity assays and the CUPRAC (cupric ion reducing antioxidant capacity) assay. Microchimica Acta. 2007;160(4):413–419. 10.1007/s00604-007-0777-0

[21] Suvarna KS BJ Layton C. Bancroft's theory and practice of histological techniques. Elsevier; 2019. 10.1016/c2015-0-00143-5

[22] Collin MS, Venkatraman SK, Vijayakumar N, Kanimozhi V, Arbaaz SM, Stacey RGS, et al. Bioaccumulation of lead (Pb) and its effects on human: A review. Journal of Hazardous Materials Advances. 2022;7:100094. 10.1016/j.hazadv.2022.100094

[23] AL-Megrin WA, Alkhuriji AF, Yousef AOS, Metwally DM, Habotta OA, Kassab RB, et al. Antagonistic Efficacy of Luteolin against Lead Acetate Exposure-Associated with Hepatotoxicity is Mediated via Antioxidant, Anti-Inflammatory, and Anti-Apoptotic Activities. Antioxidants. 2019;9(1):10. 10.3390/antiox9010010

[24] Abdelhamid FM, Mahgoub HA, Ateya AI. Ameliorative effect of curcumin against lead acetate–induced hemato-biochemical alterations, hepatotoxicity, and testicular oxidative damage in rats. Environmental Science and Pollution Research. 2020;27(10):10950-65. 10.1007/s11356-020-07718-3

[25] Yuniarti WM, Krismaharani N, Ciptaningsih P, Celia K, Veterianantа KD, Ma'ruf A, et al. The protective effect of Ocimum sanctum leaf extract against lead acetate-induced nephrotoxicity and hepatotoxicity in mice (Mus musculus). Veterinary World. 2021;14(1):250. 10.14202/vetworld.2021.250-258

[26] Srinivasan S, Murali R, Vinothkumar V, Raajasubramanian D, Narendra K, Ashokkumar N, et al. In: Therapeutic Potential of Honey Against Hepatotoxicity and Renal Toxicity: Insight into Its Mechanisms of Action. Springer Nature Singapore; 2024. p. 389–410. 10.1007/978-981-97-3565-5_17

[27] Sioud F, Ben Toumia I, Lahmer A, Khlifi R, Dhaouefi Z, Maatouk M, et al. Methanolic extract of Ephedra alata ameliorates cisplatin-induced nephrotoxicity and hepatotoxicity through reducing oxidative stress and genotoxicity. Environmental Science and Pollution Research. 2020;27(11):12792–12801. 10.1007/s11356-020-07904-3

[28] Hussein S, Abdalla mousa mohamed M, Eltawaty S, Soliman A. Phenolic Compounds From Ephedra Alata veill Growing in Libya and The Ameliorative Effect Towards CCl4-Induced Hepatotoxicity in Rats. Egyptian Journal of Chemistry. 2024;67(3):235-43. 10.21608/ejchem.2023.217103.8126

[29] Chouikh A. Phytochemical Profile, Antioxidant, Analgesic And Hypolipidaemic Effects Of Ephedra Alata Decne. Female Cones Extract. FARMACIA. 2020;68(6):1011–1020. 10.31925/farmacia.2020.6.7

[30] Abd allah ESH, Badary DM. Folic acid protects against lead acetate-induced hepatotoxicity by decreasing NF-kB, IL-1β production and lipid peroxidation mediataed cell injury. Pathophysiology. 2017;24(1):39–44. 10.1016/j.pathophys.2017.02.002

[31] Harshitha P, Bose K, Dsouza HS. Influence of lead-induced toxicity on the inflammatory cytokines. Toxicology. 2024;503:153771. 10.1016/j.tox.2024.153771

[32] Ozkaya A, Sahin Z, Dag U, Ozkaraca M. Effects of Naringenin on Oxidative Stress and Histopathological Changes in the Liver of Lead Acetate Administered Rats. Journal of Biochemical and Molecular Toxicology. 2016;30(5):243–248. 10.1002/jbt.21785

[33] Haouas Z ZIHHMIMM Sallem A. Hepatotoxic Effects of Lead Acetate in Rats: Histopathological and Cytotoxic Studies. Journal of Cytology & Histology. 2014;5(5). 10.4172/2157-7099.1000256

[34] Ahmed AH, Salman SS, Khaleel ZI. Histological Study On The Effect Of Different Concentrations Of Lead Acetate In The Liver, Heart And Bone Marrow In Mice (Mus Musculus). Biochemical & Cellular Archives. 2019;19(2). 10.35124/bca.2019.19.2.3751

[35] Khattabi L, Chettoum A, Hemida H, Boussebaa W, Atanassova M, Messaoudi M. Pirimicarb induction of behavioral disorders and of neurological and reproductive toxicities in male rats: Euphoric and preventive effects of Ephedra alata Monjauzeana. Pharmaceuticals. 2023;16(3):402. 10.3390/ph16030402

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