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Evaluation of radioprotective properties of *Trianthema portulacastrum* L. stem extract *in vivo*

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The common Giant Pigweed or Black Pigweed *Trianthema portulacastrum* L.is a well-known hepatoprotactant against chemical-induced toxicity. In this study, we evaluated the radioprotective activity of *T. portulacastrum* stem extract in Swiss albino mice through survival assay and confirmed by histopathology of the liver and jejunum. We observed that at higher concentrations (200 mg/kg body wt.) of extract, the survival of mice was 20% higher. The mechanism of protection was evaluated by endogenous colony-forming assay, bone marrow cell count, membrane integrity, and antioxidant enzymes of the liver. Histopathology of the liver and jejunum revealed that irradiated animals to have suffered loss of normal architecture of the liver in the form of hepatic sinusoid dilation and neutrophil infiltration, and distorted structure of villi in the jejunum of mice was observed. Pre-treatment of mice with extracts of *Trianthema portulacastrum* (50, 100 and 200 mg/kg body wt.) attenuated the effects of radiation in a dose-dependent manner. Further, the increased spleen colony numbers and augmented number of bone marrow cells in extract pre-treated mice, in comparison with untreated irradiated mice suggest the protective activity of *T. portulacastrum*. The treated group of mice also showed increased activities of antioxidant enzymes measured in tissue homogenates of the liver as compared to the untreated irradiated controls. Our present study demonstrated dose-dependent radioprotective property of *T. portulacastrum* against membrane damage.

Keywords: Antioxidants, Black Pigweed, Giant Pigweed, Hepatoprotective, Jejunum, Liver, Radioprotective activity

Nearly 30-50% of all cancer patients require radiotherapy either alone or in conjunction with chemotherapy and surgery[1]. Nowadays, linear accelerator (LINAC) is widely used to treat cancer patients. LINAC can produce customizable high-energy X-rays (ionizing radiation) and electrons used to kill malignant cells[2]. Radiation kills cancer cells and damages the adjacent normal cells and tissues, which are responsible for inflammation and organ dysfunction[3]. It also damages several organs such as lymphoid organs, bone marrow, kidneys, lungs, ovaries, and testes, and hinders cell growth[4].

Irradiation (IR) directly destroys protein, lipids, and DNA and indirectly damages cells through the generation of reactive oxygen and nitrogen species (RONS)[5]. RONS generation reduces the antioxidant levels, depletes stem cells, and leads toward apoptosis[6]. Liver function is affected significantly which consequently develops fibrosis, necrosis and vascular damage[1]. Cells exhibit some intrinsic adaptive responses to protect organs against radiation through the induction of cellular antioxidant enzymes. But these cellular antioxidants are not sufficient to protect the cells and organs against high doses[7]. Supplementation with antioxidants reduces the harmful effects of radiation[8].

Epidemiological studies have supported that antioxidant from natural sources showed better protection possibly due to less toxicity compared to chemical/synthetic antioxidants against IR-induced damage[9]. Several plant-based antioxidants such as *Vitis vinifera* L. reduce radiation-induced oxidative stress and apoptosis[10], *Zingiber officinale* protects the mice from radiation-induced gastrointestinal and bone marrow syndromes and reduces morbidity and mortality[11]. Therefore, antioxidants have gained importance in radiotherapy (RT) due to their radical scavenging and medicinal properties[12].

Trianthema porulacastrum L., commonly called Giant Pigweed or Black Pigweed, has been used since

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ancient period to treat quite a plethora of diseases by African and Indian societies[13]. The anticancer property of *T. portulacastrum* has been reported in hepatocytes[14]. The hepatoprotective activities of *T. portulacastrum* against chemical-induced toxicity by CCl_4, paracetamol and thioacetamide have been reported already[13]. In this study, we have investigated the radio-protective activity of *Trianthema portulacastrum* through *in vivo* animal model after whole body irradiation, and further studied the damages in liver, spleen, bone marrow and jejunum.

Material and Methods

Materials

Chemicals were procured from different companies such as Roswell Park Memorial Institute medium (RPMI)-1640 and fetal bovine serum (FBS) from HiMedia; 5,5′-dithiobisnitro benzoic acid (DTNB), Nicotinamide adenine dinucleotide reduced (NADH), Nicotinamide adenine dinucleotide phosphate reduced (NADPH), 5 methylphenaziniummethosulfate (PMS), reduced glutathione (GSH), oxidized glutathione (GSSG), 2,4-dinitrophenyl-hydrazine (DNPH), 1-chloro-2,4-dinitrobenzene (CDNB), 5,5-dithiobisnitro benzoic acid (DTNB), naphthylethylenediaminedihydrochloride (NEDD), NADH, nitrobluetetrazolium (NBT) from SRL Chemical Co.; Folin–Ciocalteu's phenol reagent, sodium pyrophosphate and gallic acid from Merck India Ltd. and all other chemicals of analytical reagent grade were procured from SRL India Ltd and Merck India Ltd.

Extract preparation

Stem extract was prepared as described elsewhere[15]. In brief, dry powder of stem (100 g) was extracted with 500 ml petroleum ether for 24 h with constant shaking and then filtered. The same procedure was repeated once again (total two times). Ethyl acetate, acetone, and ethanol solvents were used sequentially followed by petroleum ether. Solvents were evaporated and dried using a lyophilizer.

Plant extract preparation

Previous studies have shown that the stem extract of the plant *T. portulacastrum* was the most effective. Hence, the extract was dissolved in 1 × PBS to different concentrations for oral administration with doses of 50, 100 and 200 mg/kg body wt.

Animals

Male Swiss albino mice, 8-10 weeks old and weighing 20-25 g, were obtained from the approved vendor of the Institute (Chakraborty Enterprise), and maintained under standard conditions of temperature (25°C ± 2°C) and humidity. Animals were provided with food and water *ad libitum*. Five animals were housed in each sterile polypropylene cage. The experiment was designed following the guidelines of the Institutional Animal Ethics Committee (IAEC) of the University of Kalyani (dated 27/03/2019).

Survival of irradiated mice after treatment

In the survival assay, mice were irradiated with a higher dose of irradiation to generate irreversible symptoms of central nervous system (CNS) syndrome that is responsible for mortality[16]. Generally, in pre-clinical studies, this assay is used to identify the radioprotective drugs. To identify, the radioprotective activity of *T. portulacastrum*, a survival study was performed as follows.

Treatment protocol for survival assay

Mice were divided into the following six groups of five mice in each group. Gr. I, Control group treated with phosphate-buffered saline; Gr. II, Extract control group treated with plant extract @200 mg/kg body wt.; Gr. III, Experimental control group given ionizing radiation (IR) @8 Gy; and Gr. IV-VI, Experimental groups treated with plant extract @50, 100 and 200 mg/kg body wt. for five days followed by 8 Gy of IR.

Oral administration of *T. portulacastrum* extract on mice was carried out for 5 consecutive days. Twenty-four hours after the last extract treatment, the mice were exposed to radiation at a dose of 8 Gy for survival assay. The irradiation of the mice was carried off in SAD (distance from the source of the radiation to the axis of the beam or isocenter) using 6 MV X-Ray from Elekta synergy Linear Accelerator (LINAC) with a dose rate of 400 MU/min at the Chittaranjan National Cancer Institute, Kolkata. During the survival study, changes in body weight and behaviour were observed in all the above mentioned groups for the next 45 days[17].

Radioprotection mechanism study *in vivo*

The mechanism of radioprotection in mice was evaluated after irradiation with a sublethal dose to determine the pathophysiological conditions, whereas in survival assay lethal dose of irradiation is used[18]. This study revealed the self-renewing capacity of mice and how the desired drug can boost protective activity.

Treatment protocol for mechanism study

Mice were divided into six groups of five mice as above. However, the dose of IR was selected 6.5 Gy.

Changes in body weight and behaviour were noted in all the above-mentioned groups for the next 14 days.

Isolation of tissues

As radiation-induced liver disease (RILD) is generally observed from 2-12 weeks after RT[19]; blood was collected from the retro-orbital plexus of mice after 13 days from irradiation and were sacrificed in anaesthetic condition. Liver, small intestine, spleen, and femur bones were collected. A small part of the liver and small intestine were fixed in a 10% formalin solution.

Estimation of aminotransferase activities

Serums separated from blood were used to estimate the activities of alanine aminotransferases (EC 2.6.1.2) and aspartate aminotransferases (EC 2.6.1.1) using a diagnostic kit from Coral Clinical Systems, India.

Estimation of antioxidant status from liver tissue homogenate

Liver tissue was homogenized in 1X PBS solution and evaluated the content of antioxidant non-enzymes such as reduced glutathione (GSH)[20], nitric oxide (NO)[15] and malondialdehyde (MDA)[15]; and activities of antioxidant enzymes such as catalase[15], superoxide dismutase (SOD)[15], glutathione s-transferase (GST)[15], glutathione reductase (GR)[15] and glutathione peroxidase (GPx)[20].

Bone marrow cellularity assay

The muscles and tissue residue surrounding the femur were removed using sterile forceps and scissors. Both the ends of the femurs were cut with scissors and the bone marrow was flushed out with 10 ml RPMI-1640 media. Cells were then passed through 70 µm nylon cell strainers to remove debris before centrifugation at 950 g for 5 min. The cell pellet was re-suspended in RPMI-1640 media and all the hematopoietic stem cells were counted using a hemocytometer after staining with trypan blue[21].

Spleen colony forming assay

After the sacrifice, the spleen was collected and preserved in a 10% formalin-PBS solution. Then, the colonies formed in the spleens due to radiation stimuli were counted manually[17].

Histopathology of liver and jejunum

A part of the liver and the middle part of the small intestine (jejunum) were collected. The content within jejunum was washed with RPMI 1640 media. The tissues were fixed in 10% formalin solution (in PBS), processed routinely, and embedded in paraffin. 4 µm thick sections were cut and stained with hematoxylin and eosin (H&E) to evaluate the morphological changes under microscope[20].

Statistical analysis

All the results were expressed as mean ± standard error. Significant differences were assessed using the one-way analysis of variance (ANOVA), followed by the Tukey test for individual differences using the Statistical Package for Social Science (SPSS) software, version 23. A value of $P < 0.05$ was considered statistical significance. For the survival analysis, a dead mouse was counted as censored 1 whereas a live mouse was defined as censored 0. Kaplan–Meier's estimation of lifetime analysis was performed using Graph Pad Prism 5 software (GraphPad Software, Inc.).

Results

The radioprotective efficacy of *Trianthema portulacastrum* was observed in Swiss albino mice using the survival study. The mice were exposed to 8 Gy of whole-body irradiation. Mice without extract treatment and irradiation (experimental control mice) lost their life within 36 days of post-irradiation. Five days pre-treatment with *T. portulacastrum* stem extract increased the number of survival days of irradiated mice dose-dependently. All the doses of extract increased their life span as compared to irradiated control and 20% protection was observed at 200 mg/kg body wt. (Fig. 1A). During the survival studies, the weight of mice of each group was also monitored and it has been observed that mice pre-treated with extract followed by irradiation were able to retain their body weight to some extent as compared with the experimental control group. The reversal of body weight was proportional to the concentration of extract treatment (Fig. 1B).

ALT level elevated by 2.3 folds and AST level elevated by 2.6 folds with respect to the control group in irradiated mice (Table 1). However, treatment with the highest dose of plant extract reduced the ALT and AST levels to 1.3 and 1.6 folds, respectively against the Experimental control group (Table 1).

Reduced glutathione (GSH) content decreased by 31.8%, MDA level increased by 1.9 fold and NO content increased by 2.1 fold in the liver of irradiated mice compared to the control group (Table 1). *Trianthema portulacastrum* stem extract pre-treatment reversed these alteration dose dependently (Table 1). IR caused decrease in activities of GPx and

GST; while increase in activities of GR, SOD and catalase in liver homogenate compared to the control group (Table 1). Pre-treatment with *T. portulacastrum* extract showed a dose-dependent reversal in activities in these enzymes in mice liver homogenate compared to the experimental IR group (Table 1) and maximum reversal was observed in mice pre-treated with plant extract at a dose of 200 mg/ kg body wt. (Table 1).

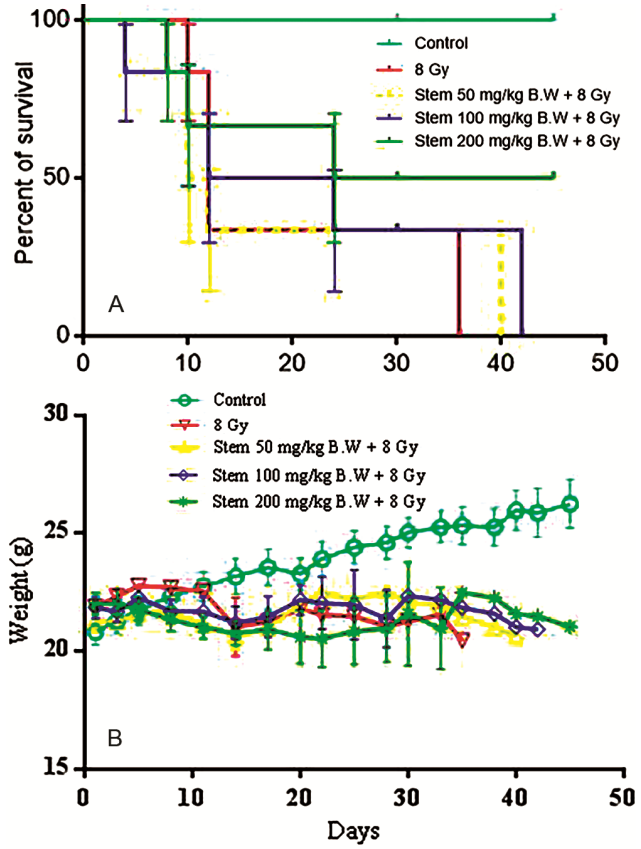

Fig. 1 — Effect of *Trianthema portulacastrum* stem extract against radiation through the survival assay. (A) Survival study; and (B) Respective weight chart of each group.

The self-renewing capacity of bone marrow cellularity in mice within a maximum tolerable dose of radiation (6.5 Gy) was assessed (Fig. 2). The cell numbers were reduced to around 41.1% as compared to the control group after 14 days of irradiation and in pre-treatment with *T. portulacastrum* extract groups showed dose-dependent attenuation in cell count (Fig. 2A). Post irradiation, the mice were monitored every alternate day to observe their body weight. Pre-treatment with *T*, *portulacastrum* extract showed partial recovery in weight gain in mice after irradiation (Fig. 2B).

The *in vivo* radioprotective mechanisms of *T. portulacastrum* were also monitored using spleen colony forming unit (CFU) capability in non-irradiated and irradiated mice (Fig. 3A). Nearly, 7 fold increase in CFU count was observed in irradiated mice in comparison with control and the TP extract treatment showed a dose-dependent protective effect on spleen colony formation, which was approximately 2.4 fold at higher concentrations with respect to the radiation group (Fig. 3B). The consequence of irradiation was also reflected in the spleen index (ratio of spleen weight to body weight of mice). Irradiated mice showed a significant reduction in spleen index i.e., up to 1.4 fold, whereas the mice pre-treated with TP extract were able to retain their spleen index ratio to some extent dose-dependently (Fig. 3C).

Table 1 — Effect of *Trianthema portulacastrum* stem extract on various liver parameters (*in vivo*)

Parameters	Control	Plant extract control group (200 mg/ kg bw)	Experimental control group (6.5 Gy)	Plant extract followed by irradiation (6.5 Gy) (50 mg/kg bw)	(100 mg/kg bw)	(200 mg/kg bw)
ALT (IU/L)	24.6±1.6	24.2±1.7	58±3*	53.6±1.9	47.2±1.8$	42.2±4.1$
AST (IU/L)	22.2±2.1	22±2	56.8±2.7*	46.2±2.5$	39.8±1.91$	34.4±1.9$
GSH content (nmol/mg protein)	11.39±0.78	12.10±0.39	7.81±0.65*	8.33±0.55	9.31±0.59	10.28±0.46$
MDA (µmol/mg protein)	0.82±0.06	0.8±0.05	1.61±0.06*	1.47±0.05	1.33±0.07$	1.2±0.1$
NO content (µmol/mg protein)	12.3±1.2	11.8±1.1	26.0±1.82*	23.4±1.2	20.2±1.1$	17.2±1.4$
GPx activity (U^a/mg protein)	27.2±2.0	25.8±1.4	12.6±1.4*	13.8±1.3	18.4±1.44$	23±2$
SOD activity (U^b/mg protein)	24.2±1.2	23.8±1.4	37.2±1.6*	34.4±1.7	31.0±2.0	29.0±1.0$
Catalase activity (U^c/mg protein)	15.2±1.4	14.8±1.8	25.4±1.6*	22.4±1.2	19.4±1.4	18.6±1.3$
GR activity (U^d/mg protein)	17.6±1.6	17.2±1.4	26.4±1.6*	23.8±1.2	22.6±1.4	19.0±1.0$
GST activity (U^e/mg protein)	7.18±0.3	7±0.5	5.52±0.26*	6.01±0.23	6.4±0.2	6.75±0.15$

[ALT, Alanine transaminase; AST, Aspartate transaminase; GPx, Glutathione peroxidise; GR, Glutathione reductase; GSH, Reduced glutathione; GST; Glutathione s-transferase; MDA, Malondialdehyde; NO, Nitric oxide; SOD, Superoxide dismutase; and bw, Body weight. Values are Mean ± standard error. p values: *<0.05 significant against control; $< 0.05 significant against 6.5 Gy of irradiation. [a]µM NADPH breakdown/min/mg protein, [b]One Unit of SOD enzyme is defined as the enzyme concentration required to inhibit the OD at 560 nm of chromogen produced by 50%/min under assay condition; [c]mM H_2O_2 decomposed/min/mg protein; [d]nM NADPH breakdown/min/mg protein; [e]mM CDNB conjugate formed/min/mg protein]

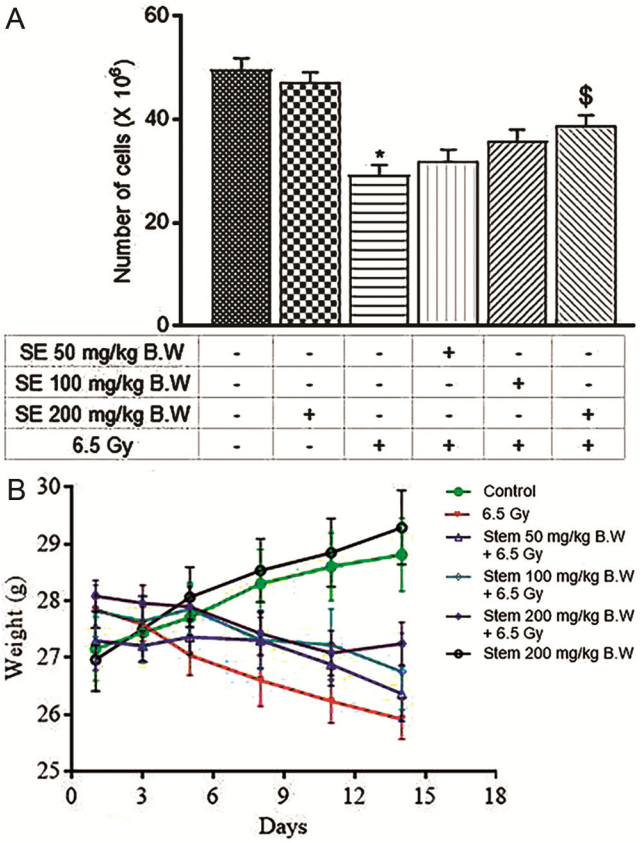

Fig. 2 — Effect of *Trianthema portulacastrum* stem extract on hematopoietic system against IR. (A) Bone marrow cell count; and (B) Corresponding weight chart during the 13 days' time period. [Values are Mean ± standard error of 5 samples. P values: *<0.05 significant against control, $<0.05 significant against 6.5 Gy of irradiation]

Histopathological studies of the liver of irradiated mice showed an increased number of sinusoids and neutrophil infiltration in comparison to the control group (Fig. 4). These changes attenuated in TP extract-treated irradiated mice and this effect was dose-dependent.

On the other hand, the histopathology of jejunum revealed that the radiation distorted the structural integrity and degenerate villi (Fig. 5). Pre-treatment with TP extract dose-dependently attenuated the villi from the impact of radiation-induced intestinal damage.

Discussion

Ionizing radiation generates reactive oxygen and nitrogen species (RONS) and alters the antioxidant status resulting in cellular damage[5]. Studies have established that *T. portulacastrum* extract exhibits free radical scavenging properties[15]. Whole body radiation induces gastro-intestinal (GI), hematopoietic, and cerebrovascular injury depending on the radiation dose, which is often lethal[17]. However, no reliable treatment is available against IR-induced GI injury except symptomatic treatment, and only transplantation of bone marrow can avert the hematopoietic syndrome[17]. It is relevant to look for effective radioprotectors to prevent radiation-induced damage. The different plant extracts and phytochemicals have been extensively studied as safe and effective radioprotectors by observing the changes in the intensity of damage or reversal of damage in the intestine, bone marrow, and in different body tissues[17,22].

Survival study is considered a gold standard to find radioprotectors[23]. Therefore, the radioprotective activity of *T. portulacastrum* was evaluated through *in vivo* model system. The survival study was carried out for 45 days, which showed that the extract increased survival in a dose-dependent manner, and at 200 mg/kg body wt. of extract survival was 20% higher as compared to irradiated control. The respective weight chart demonstrated the recovery in body weight that suggested the protective action of *T. portulacastrum*. In one study, *Centella asiatica* extracts at a dose of 200 mg/kg body wt. protects the mice from radiation[24]. Although, *Centella asiatica* extract was able to extend survival of mice only up to 2-days post-irradiation, where mice were irradiated with 10 Gy of gamma rays (only irradiated mice achieve 100% mortality on the 10th day; whereas extract pre-treated mice followed by irradiation achieved 100% mortality on 12th day). *C asiatica* extract also protected the cell membrane and DNA damage as measured by comet assay[16]. On the other hand, *T. portulacastrum* stem extract at dose of 50 mg/kg body wt. increased the survival up to 4 days as compared to only irradiated mice (8 Gy) and 20% of mice survived up to 45 days at the highest dose (200 mg/kg body wt.).

IR not only wreaks deleterious effect on living cells but also damage vital organ such as liver through the ROS production[24]. Kupffer cells, hepatic stellate cells, and sinusoidal endothelial cells (hepatic non-parenchymal cells) are highly radiosensitive compared to hepatocytes of the liver. These cells release several constituents responsible for fibrosis, structural distortion, and impaired liver function[25,26]. A significant increase in activities of liver enzymes (ALT and AST) in irradiated mice reflected the

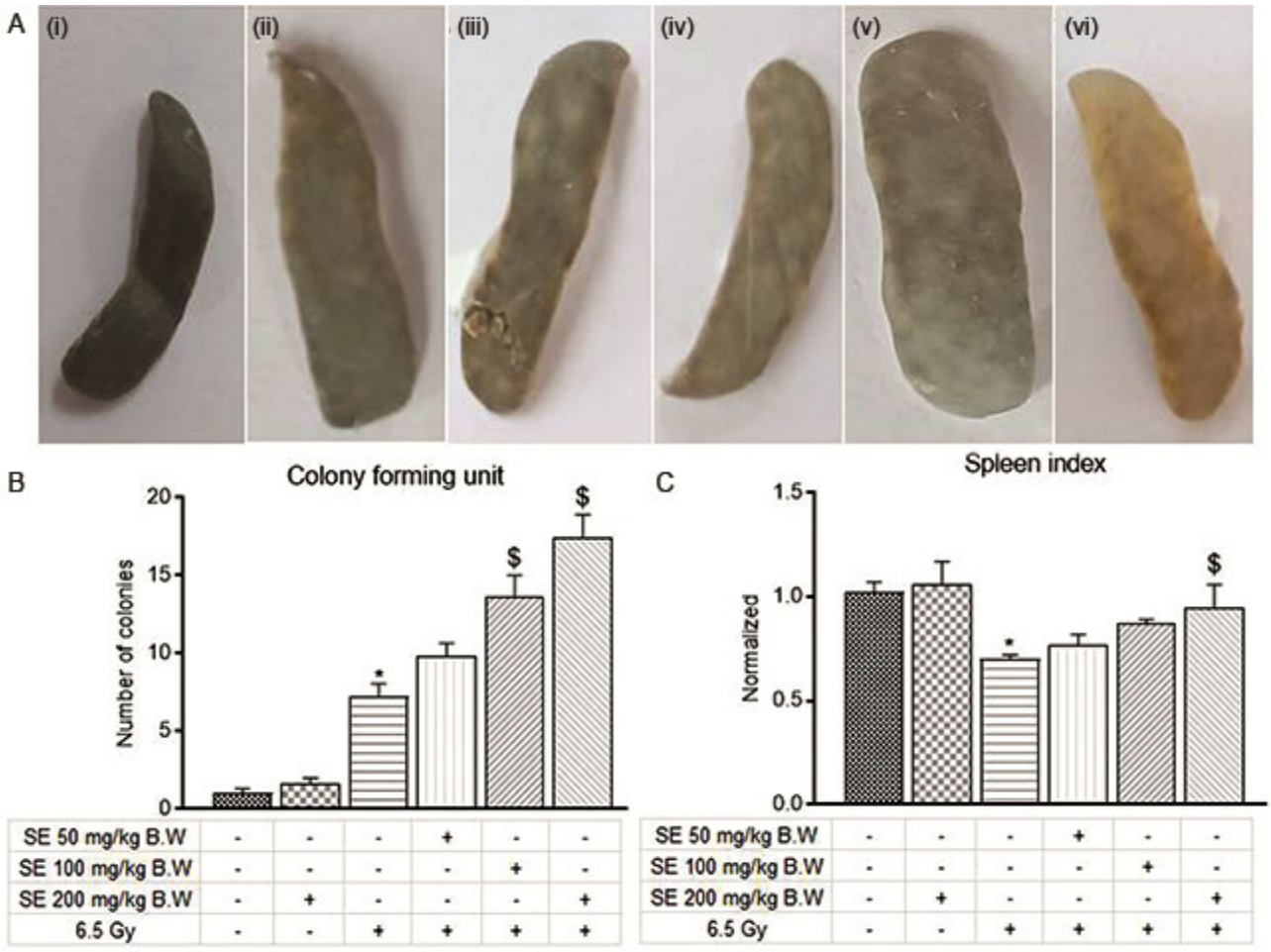

Fig. 3 — Effect of *Trianthema portulacastrum* stem extract on endogenous spleen colony forming assay. (A) Representative images of spleen colonies [(i) control, (ii) stem 200 mg/kg body wt., (iii) 6.5 Gy, (iv) 6.5 Gy + stem 50 mg/kg body wt., (v) 6.5 Gy + stem 100 mg/kg body wt., and (vi) 6.5 Gy + stem 200 mg/kg body wt.]; (B) Graphical representation of number of spleen colony; and (C) Spleen index. [Values are Mean ± standard error of 5 samples. P values: *<0.05 significant against control, $^{\$}$<0.05 significant against 6.5 Gy of irradiation]

hepatic injury and cellular leakage of the hepatocyte membrane[27]. Similarly, our present study also showed the liver protective activity of *T. portulacastrum* along with its radioprotective properties.

IR-induced ROS is primarily countered by cellular antioxidants such as GSH, GPx, and SOD. A significant reduction in GSH content in irradiated mice in this study is possibly due to increased exploitation of ROS[26,28]. Generation of MDA occurs due to oxidative stress through various pathological conditions including radiation[29]. Radiation-induced nitrosative stress is a common phenomenon, where NO generation is mediated through the increased expression of inducible nitric oxide synthase (iNOS)[5]. *T. portulacastrum* stem extract protected the liver from IR-induced damage dose-dependently by increasing GSH concentration and decreasing MDA and NO formation.

GPx play the first line of defence by upholding the redox balance[31]. GST accelerates the detoxification process after binding with GSH against several exogenous and endogenous toxic compounds such as drugs, toxins, carcinogens, and ROS[32]. GSTπ protein is found in liver and lung abundantly. Experimentally it has been shown that ablation of GSTπ is associated with fibrosis in mice[33]. Radiation-induced decrease in GPx and GST in our study was ameliorated due to pre-treatment with *T. portulacastrum* extracts.

SOD deactivates superoxide ions ($O_2^{\bullet}$) in cells by converting the ions to H_2O_2, which further catalyzes to O_2 and H_2O by catalase enzyme[34,35]. Studies reported that cellular SOD activity fortifies the

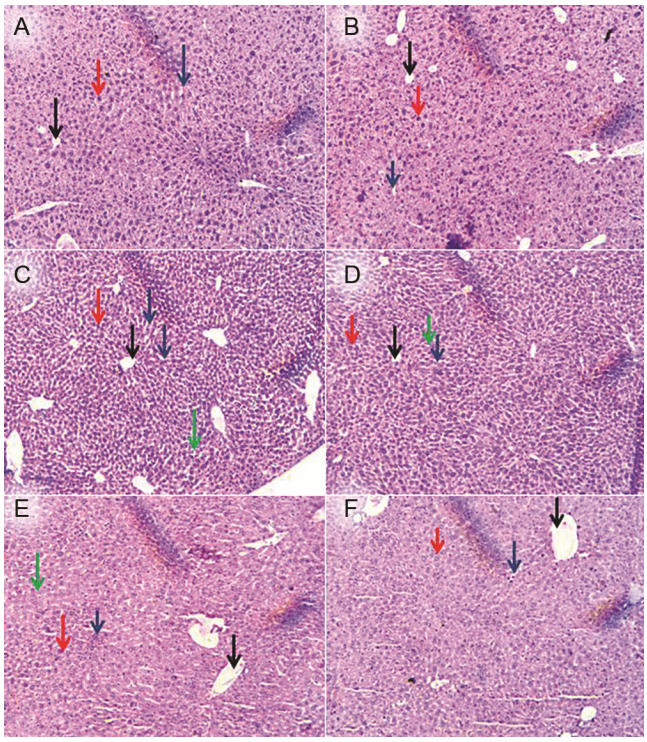

Fig. 4 — Effect of *Trianthema portulacastrum* stem extract on liver architecture and morphology observed through the histopathology. (A) Control; (B) stem 200 mg/kg body wt.; (C) 6.5 Gy; (D) 6.5 Gy + stem 50 mg/kg body wt.; (E) 6.5 Gy + stem 100 mg/kg body wt.; and (F) 6.5 Gy + stem 200 mg/kg body wt. [Black arrow shows the vein, red arrow shows the hepatocytes, blue arrow shows the synoside and green arrow shows Infiltration]

radioprotective activity[29]. Few studies also reported that radiation exposure increased the cellular antioxidant level, known as radiation-induced adaptive responses[7]. IR-induced oxidative stress up-regulates the defensive antioxidant enzymes such as SOD, catalase, and several others[5]. These are the endogenous defense mechanism of cells or tissues involved to minimize the genotoxic effects by upregulating the antioxidant enzymes such as catalase, SOD, GR and other enzymes[36]. GR also regulates the GSH content through oxidation-reduction reaction and regulates the redox balance of cells[37]. Our study also exhibited the radiation-induced adaptive responses for SOD, catalase and GR activity in the liver, which were upregulated due to irradiation, and pre-treatment with extracts balanced enzyme activities. It has been reported that a consistent increase in adaptive response is responsible for chromosomal and DNA damage[38]. Amelioration of these changes by *T. portulacastrum* extract implies its importance as radioprotective agent.

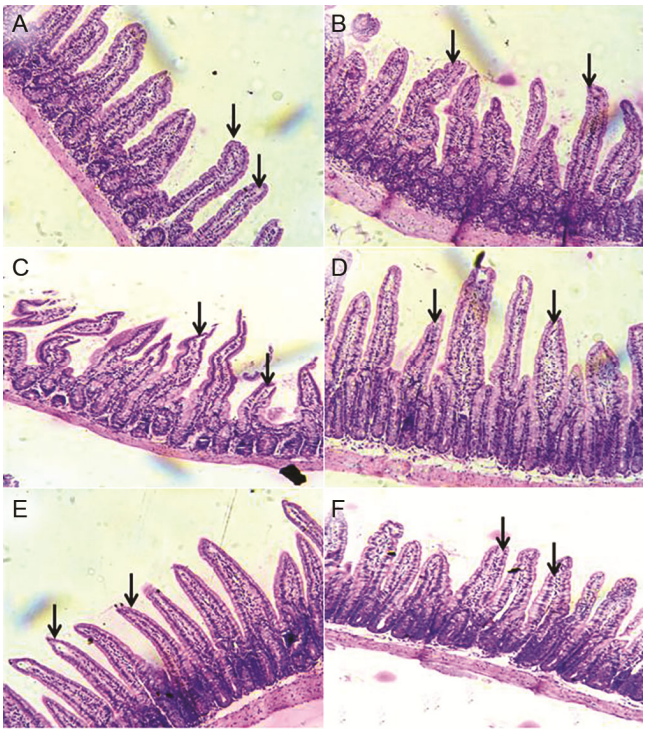

Fig. 5 — Effect of *Trianthema portulacastrum* stem extract on Jejunum architecture was observed through the histopathology. (A) Control; (B) stem 200 mg/kg body wt.; (C) 6.5 Gy; (D) 6.5 Gy + stem 50 mg/kg body wt.; (E) 6.5 Gy + stem 100 mg/kg body wt.; and (F) 6.5 Gy + stem 200 mg/kg body wt. [Black arrow shows the villi]

Radiation-induced damage includes the impairment of bone marrow, which is enormously vulnerable to radiation. Radiation-induced bone marrow damage is the primary side effect of radiotherapy (RT) that reduces the triumph of RT against cancer[39]. IR destroys both mature blood cells and hematopoietic progenitor/stem cells of bone marrow. Loss of mature blood cells is a key factor in radiation morbidity and mortality and is believed to occur due to prolonged myelo-suppression due to loss of hematopoietic progenitor cells (HPCs) and primitive hematopoietic stem cells (HSCs)[17]. Irradiated mice showed a lower number of cells in the bone marrow. The treatment with *T. portulacastrum* extracts dose-dependently affects bone marrow cellularity.

Irradiation increased the chance of bone marrow failure, which is responsible for abnormal blood cells that lead patients toward immunosuppressed conditions[40]. IR damage hematopoietic and lymphoid systems via a multifaceted cascade, which is known as hematopoietic syndrome responsible for septicemia and death[41]. Therefore, the rejuvenation of hematopoietic cells and triggering of the immune

system (e.g., by developing the spleen colony number) are effective therapeutic strategies against radiation[41]. *T. portulacastrum* extracts protected bone marrow cells as observed by cell count, probably due to its antioxidant and anti-inflammatory properties[42]. In this study, we observed that the treatment with *T. portulacastrum* stem extract dose-dependently increased the number of spleen colony-forming units.

IR-induced hematopoietic and GI syndrome is due to the loss of hematopoietic stem cells (HSC) and the death of intestinal stem cells (ISCs), intestinal sub-epithelial myofibroblasts (ISEMF), stromal endothelial cells and distorted villi length respectively[43-45]. Radiation-induced intestinal damage is responsible for reduced survival rate, probably due to multiple organ failure[46,47]. Radiation decreased the functionality of the intestinal barrier and distorted the size of villi as well as increased the fusion and blunting of villi that ultimately hamper its absorption and defensive role[48]. The radiation-induced intestinal damage, especially in the jejunum and liver as observed in this study was mitigated by the pre-treatment with *T. portulacastru*m stem extract.

Conclusion

Our study confirms the hepatoprotective and radioprotective activity of Giant Pigweed *Trianthema portulacastrum* through the antioxidant mechanism *in vivo*. The radioprotective action of the stem extract helped to maintain the hematopoietic cells in the bone marrow and spleen.

Conflict of interest

Authors declare no competing interests.

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