

Research Article

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Management of Radiation Injuries by *Panax ginseng* Extract

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Chemical radiation protection is an important strategy to protect living beings against the deleterious effects of radiation. In the present study, the radioprotective effect of hydro-alcoholic extract of *Panax ginseng* extract (PGR-HAE) was studied on radiation-induced deleterious alterations in Swiss albino mice. Oral administration of such extract (25 mg/kg b wt/day/animal) for 5 consecutive days, half an h. before whole-body exposure to 6 Gy gamma radiation, enhanced the 30 days survival and also inhibited the radiogenic sickness, weight loss and life shortening. PGR-HAE ameliorated radiation induced depletion in blood constituents at different necropsy intervals between 12 h to 30 d, and significantly increased the number of femoral spleen colony forming units that survived after irradiation. Furthermore, it checked depletion of glutathione and antioxidant enzymes (superoxide dismutase, catalase, and glutathione S-transferase) as well as elevation of lipid peroxidation (LPO) level in blood and liver. The significant reduction in the yield of LPO demonstrates that PGR-HAE protects the membranes against radiation-induced oxidative damage. These findings conclude that such plant extract provides significant radioprotection, and it may be potentially valuable in the prevention of injuries caused during planned and unplanned radiation exposure.

Keywords: *Panax ginseng*, Radiation protection, Hematological constituents, Antioxidants, Swiss albino mice

INTRODUCTION

In the era of expanding nuclear energy program all over the world, the role of radiation biology has acquired greater relevance and significance in addressing the health issues. In the present time, nuclear terrorism and weapons related effects are raising much alarm and concern to public health. Obviously, radiation biology research has great potential in diagnosis, therapy and establishing standards for assessment risks from radiation exposure. To combat such syndrome, a need was felt to protect human beings against these ill effects. Radiation protection concepts and philosophy have been evolving over the past few decades. The inadvertent exposure of living beings from various sources of radiation causes

ionization of molecules, setting off potentially damaging reactions *via* free radical production. Free radicals are believed to play a role in more than sixty different health conditions, including the ageing process, cancer, radiation damage, atherosclerosis etc. [1,2]. Fortunately, there are many plant derived natural antioxidants that interfere with free radicals before they can damage the body. Antioxidants work in several ways by reducing the energy of the free radicals, stop the free radical from forming in the first place or interrupt an oxidizing chain reaction to minimize the damage of free radicals.

The development of radioprotective agents has been the subject of intense research in view of their potential

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for use within a radiation environment; however, no ideal, safe synthetic radioprotectors are available till date, so the search for alternative sources, including plants, has been on going for several decades [3,4]. The damaging effects of ionizing radiation lead to cell death and are associated with an increased risk for numerous genetically determined diseases [5]. With respect to radiation damage to humans, it is important to protect humans from adverse effects induced by ionizing radiation. The use of radioprotectors represents an obvious strategy to improve the therapeutic index in radiotherapy. Although synthetic radioprotectors such as the aminothiols have yielded the highest protective factors, typically they are more toxic [6] than naturally occurring protectors [7]. In general, the uses of the best radioprotective agents have also been reported to result in the highest behavioral toxicity [8,9]. Hence, the search for alternative sources, including bioactive principles of plant origin, has been an ongoing task worldwide. In recent years, it has become well known that antioxidant phytochemicals are present in plants, fruits, and vegetables [7,10,11]. Indeed, herbal medicine/phytomedicine is generally considered a well-established form of complementary medicine. It is estimated that within the population in the United States, use of complementary medicine has increased tremendously [12,13]. In an attempt to find potent natural antioxidants, some herbal medicines have recently gained recognition as biological response modifiers [14,15]. In particular, the use of herbs for their potential as possible modifiers of the radiation response is receiving considerable attention [16,17].

Plants such as *Ocimum sanctum*, *Moringa oleifera*, *Mentha arvensis*, and *Syzygium cumini* have been reported to protect mice against radiation-induced sickness and mortality [18-21]. Similarly, other plants such as *Spirulina platensis*, *Allium sativum*, *Withania somnifera*, *Chlorella vulgaris*, *Phyllanthus niruri*, *Panax ginseng*, and *Ginkgo biloba* have also been reported to protect mice against radiation-induced tissue damage [7]. *P. ginseng*, a well-known medicinal herb in traditional Asian medicine grows in China and Korea, has a variety of beneficial biological actions that include anti-carcinogenic, anti-diabetic and anti-inflammatory as well as cardiovascular protection and neuroprotection [22-24]. The present communication deals with the radiomodulatory effects of this plant extract in Swiss albino mice by taking some hematological and biochemical end points.

MATERIALS AND METHODS

Animals care & handling

Animals care and handling were performed according to the guidelines set by the World Health Organization, Geneva (Switzerland) and the Indian National Science Academy, New Delhi (India). Male Swiss albino mice (*Mus musculus*), 6-8 weeks old & weighing 20-24 gm from an inbred colony, were used for the present study. These animals were maintained under the controlled conditions of temperature and light (light:dark, 10 h:14 h). They were provided standard mice feed (Ashirwad Industries, Chandigarh, India) and water *ad libitum*. Tetracycline powder in drinking water once a fortnight was given as preventive measures against infections. The Departmental Animal Ethical Committee has approved the present study.

Irradiation

Cobalt teletherapy unit (ATC-C 9) at the Cancer Treatment Centre, Department of Radiotherapy SMS Medical College & Hospital, Jaipur was used for the irradiation. Unanaesthetised animals were restrained in the well-ventilated Perspex box and exposed to gamma radiation at the distance of 77.5 cm from the source to deliver the dose-rate of 1.32 Gy/min.

Plant material & extract preparation

The red ginseng root was obtained from Korea Ginseng Cooperation (Seoul, Korea) in powder form. The hydro- alcoholic extract of the root of such plant has been prepared by refluxing with the double distilled water (DDW) and alcohol (3:1) for 36 (12x3) h at 40°C. The liquid extract was cooled and concentrated by evaporating its liquid contents in vacuo and freeze dried. The prepared extract of *P. ginseng* was stored at low temperature until its further use. Such extract was redissolved in DDW prior to the oral administration in mice.

Experimental design

Determination of optimum dose of *P. ginseng* extract against irradiation

The dose selection of the *P. ginseng* extract (PGR-HAE) was carried out on the basis of drug tolerance study. For this purpose, the various doses of PGR-HAE (10, 15, 20, 25, 40, and 50 mg/kg b wt/day) were tested for their effects on the tolerance to 8.0 Gy gamma radiation in Swiss albino mice and the survival-rate of these animals was observed. Thus, the most optimum and tolerable dose of PGR-HAE was selected, and used for the further detailed experimentation

Endogenous spleen colony assay

The endogenous spleen colony assay (CFU-S) was done with the slight modification in the method of Till and McCulloch [25]. For this, animals were irradiated to 6 and 10 Gy gamma radiation with or without PGR-HAE. These were necropsied on 10th day after single total body irradiation and their spleen was removed, weighed, fixed in Bouin's fluid and grossly visible nodules on the surface of the spleen were counted.

Modification of radiation response

A total of 70 animals used for this experiment were assorted into 4 groups. Ten animals were used in group-I ($n=5$) and II ($n=5$), and 60 were utilized in group-III ($n=30$) and IV ($n=30$). Five animals were necropsied at each interval in group III and IV. Animals of group-I were administered with DDW, volume equal to PGR-HAE by oral gavage, to serve as normal (vehicle treated control). Mice of group-II were administered orally PGR-HAE, once daily with the dose of 25 mg/kg b wt/animal/day for 5 consecutive days and this group served as a drug treated control. In group-III, double distilled water, volume equal to PGR-HAE, was administered for 5 consecutive days (as in group-I), and 1 hr. after the last administration of DDW, animals were exposed to 6 Gy gamma rays. Group-IV was treated with PGR-HAE, orally for 5 consecutive days (as in group-II), and were exposed to 6 Gy gamma radiation 1 h. after the last administration of PGR-HAE on day 5th. All these animals were observed daily for any sign of sickness, morbidity, behavioral toxicity, mortality and abnormality, if any. Five animals from each group were necropsied on 12 h, day 1, 3, 7, 15, and 30 post-treatment intervals to evaluate hematological and biochemical alterations.

Hematological study

For this study, blood was collected from the orbital sinus of necropsied animals from each group in a vial containing 0.5 M EDTA. Total number of erythrocytes, leucocytes, neutrophils, lymphocytes, hemoglobin content and hematocrit values were determined by adopting standard procedures.

Biochemical study

Lipid peroxidation

The lipid peroxidation level in liver and serum was measured by the assay of thiobarbituric acid reactive substances using the method of Ohkawa *et al.* [26] in which the absorbance was read at 532 nm with a UV-VIS-108 Systronics spectrophotometer.

Glutathione

The glutathione level in the liver was determined by the method of Moron *et al.* [27] Briefly, liver homogenate was added to 20% trichloro acetic acid, centrifuged, and the supernatant was collected. The supernatant was mixed with 0.3 M Na_2HPO_4 and 5-5, dithiobis-2-nitrobenzoic acid (DTNB) reagent, and allowed to stand for 10 min. at the room temperature. The absorbance was read against blank at 412 nm using a UV-VIS Systronics spectrophotometer.

The glutathione (GSH) content in the blood was measured spectrophotometrically using DTNB as a coloring reagent according to the method of Beutler *et al.* [28]. Briefly, 0.2 mL of blood was mixed in 1.8 mL of double distilled water and added to the precipitating solution, centrifuged and supernatant was collected. This supernatant was mixed with 0.3 M disodium hydrogen sulphate and DTNB reagent, and was allowed to stand for 2 min. at the room temperature. The absorbance was read at 412 nm during a UV-VIS Systronics spectrophotometer.

Superoxide dismutase

Superoxide dismutase (SOD) activity was assayed in the blood and liver by using the technique of Marklund and Marklund [29] which involves inhibition of pyrogallol auto oxidation at pH 8.0

Catalase

Catalase (CAT) activity was assayed in the blood and liver by the method of Aebi [30]. It was estimated at 240 nm by monitoring the disappearance of H_2O_2 .

Glutathione S-transferase

The activity of Glutathione S-transferase (GST) in the supernatant of the blood and liver was determined spectrophotometrically at 37°C according to the procedure of Habig *et al.* [31]. The reaction mixture (3 mL) contained 1.7 mL of 100 mM phosphate buffer (pH 6.5), 0.1 mL of 30 mM GSH and 0.1 mL of 30 mM CDNB. After preincubating the reaction mixture at 37°C for 2 min, the reaction was started by the addition of 0.1 ml diluted supernatant and the absorbance was followed for 3 min at 340 nm. Reaction mixture without the enzyme was used as the blank. The specific activity of GST was expressed as m mole GSH-CDNB conjugate formed per min per mg of protein using an extinction coefficient of $9.6 \text{ mM}^{-1} \text{ cm}^{-1}$.

Statistical analysis

The results obtained from all the groups at various

necropsy intervals were expressed as mean±standard error. To find out whether mean of sample drawn from various groups deviates, Student's t-test was used by the method of Bourke *et al.* [32]. The significance of the results was computed at different levels as $p<0.05$, $p<0.01$, and $p<0.001$.

RESULTS

Radiation sickness & mortality

No adverse effects in terms of sickness, body weight, urination, defecation pattern and mortality were observed in animals treated with DDW or PGR-HAE alone (group-I, II). Some animals of group-III and IV exhibited signs of sickness after radiation exposure. These symptoms included anorexia, dizziness, diarrhea, slow gait, body weight loss, and ruffled fur. However, the magnitude of such symptoms was found to be lesser and a gradual recovery towards normal health was noted in PGR-HAE treated experimental animals (group-IV)

than the irradiated control (group-III).

Selection of optimum dose of PGR-HAE against radiation

The optimum dose of PGR-HAE against lethal gamma radiation (i.e., 8 Gy) in Swiss albino mice was selected on the basis of survival experiment, where number of deaths and surviving animals were recorded up to 30 days of irradiation. Mice treated with PGR-HAE at doses of 10, 15, 20, 25, 40, and 50 mg/kg b wt/d for 5 consecutive days prior to irradiation exhibited 28, 43, 60, 89, 50, and 45 percent survival, respectively (Fig. 1). The dose 25 mg/kg b wt was found to be the optimum based on the above data, and the further study was carried out using this dose of PGR-HAE.

Endogenous spleen colony assay

Oral administration of PGR-HAE to Swiss albino mice for 5 consecutive days before exposure to sub-lethal (6 Gy) and lethal dose (10 Gy) of gamma radiation

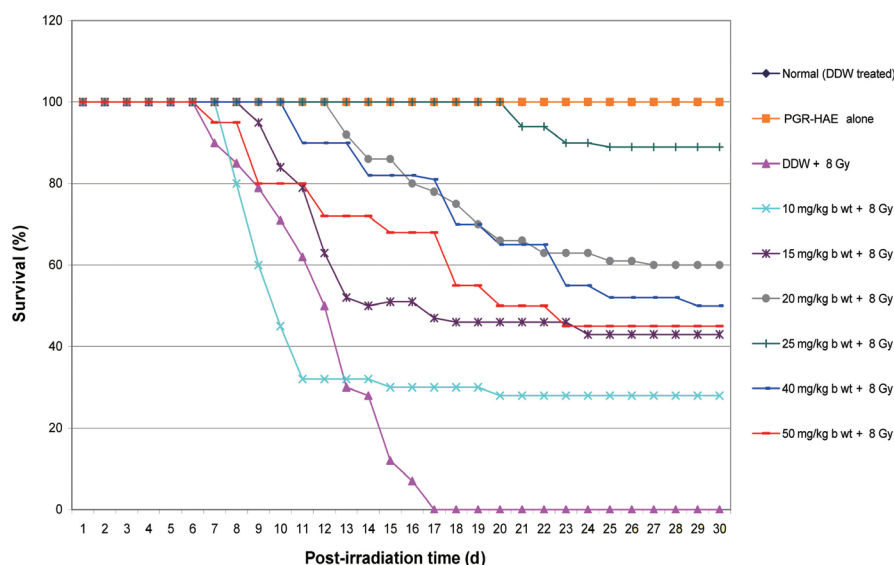


Fig. 1. 30 Days survival of mice after exposure to 8 Gy gamma radiation in the presence (experimental) or absence (irradiated control) of *Panax ginseng* extract (PGR-HAE). DDW, double distilled water.

Table 1. Spleen colony forming units on day 10 in mice after exposure to gamma rays with (experimental) or without (irradiated control) *Panax ginseng* extract

| Radiation dose (Gy) | Groups | Spleen weight (mg) | No. of macroscopic colonies |
|---------------------|--------------------|--------------------|-----------------------------|
| 6 | Irradiated control | 20.02±0.23*** | 1.80±0.34*** |
| | Experimental | 34.04±0.13*** | 12.80±0.4*** |
| 10 | Irradiated control | No survival | No survival |
| | Experimental | 30.8±0.35*** | 24.45±0.66*** |

Normal spleen weight=38.80±0.76 mg.

Significant level: normal vs. irradiated control; irradiated control vs. experimental.

*** $p\leq0.001$.

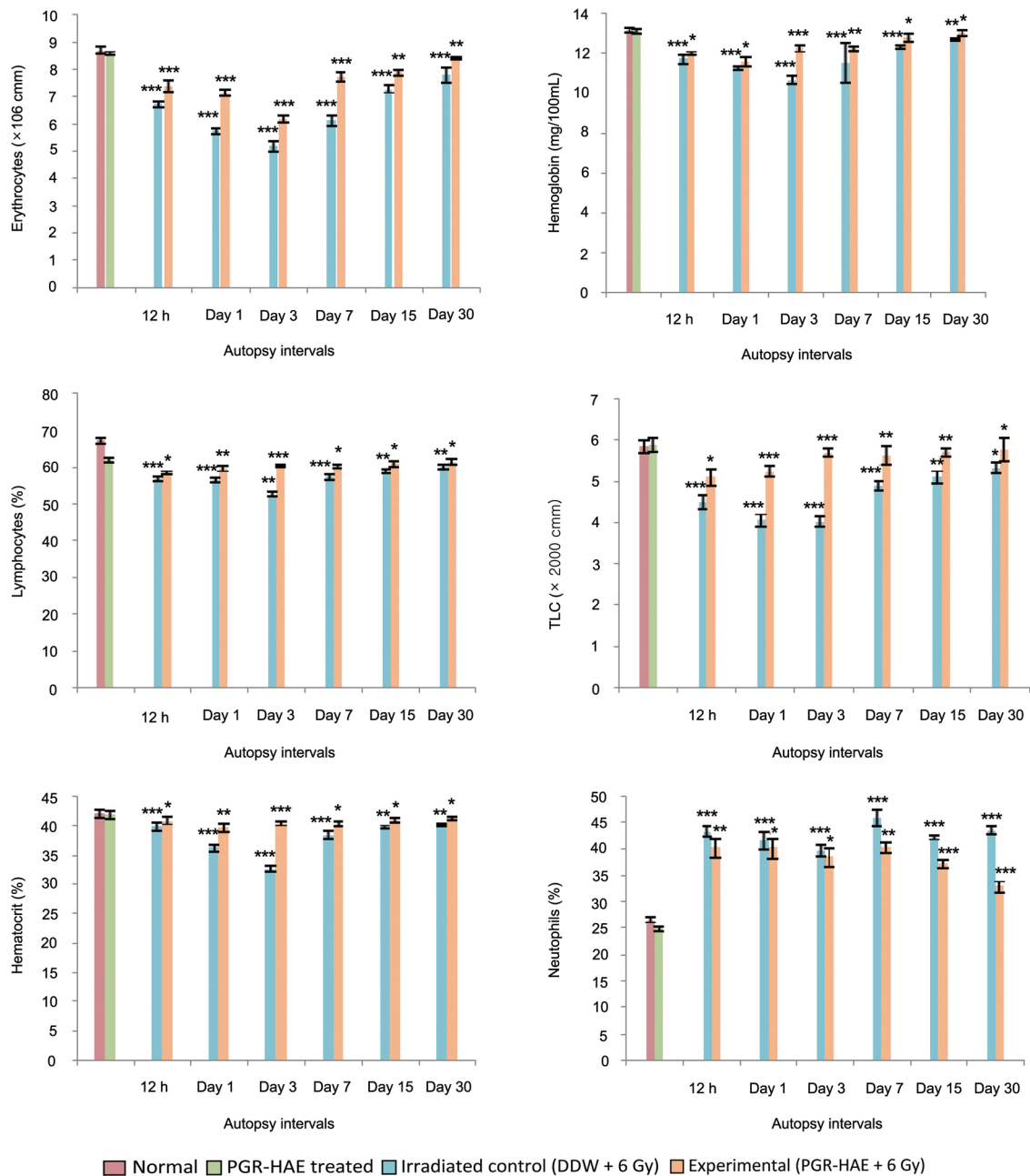


Fig. 2. Variations in different hematological constituents in peripheral blood of mice after exposure to 6 Gy gamma radiation with (experimental) or without (irradiated control) *Panax ginseng* extract (PGR-HAE). Significant level: normal vs. irradiated control; irradiated control vs. experimental. DDW, double distilled water. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

was found to be effective in increasing the frequency of radiation-induced CFU-S at day 10 post-irradiation. There was a significant increase in the number of spleen colonies in PGR-HAE pretreated irradiated group as compared to irradiated control. Furthermore, a considerable loss in spleen weight following irradiation was noticed at day 10, but a significant increase in such weight was evident in PGR-HAE pretreated irradiated animals

(Table 1). However, no animal could survive till day 10 in irradiated control group after exposure to 10 Gy gamma radiation.

Hematological study

Animals treated with PGR-HAE alone (group-II) did not show any significant change in various hematological constituents (erythrocytes, leucocytes, neutrophils,

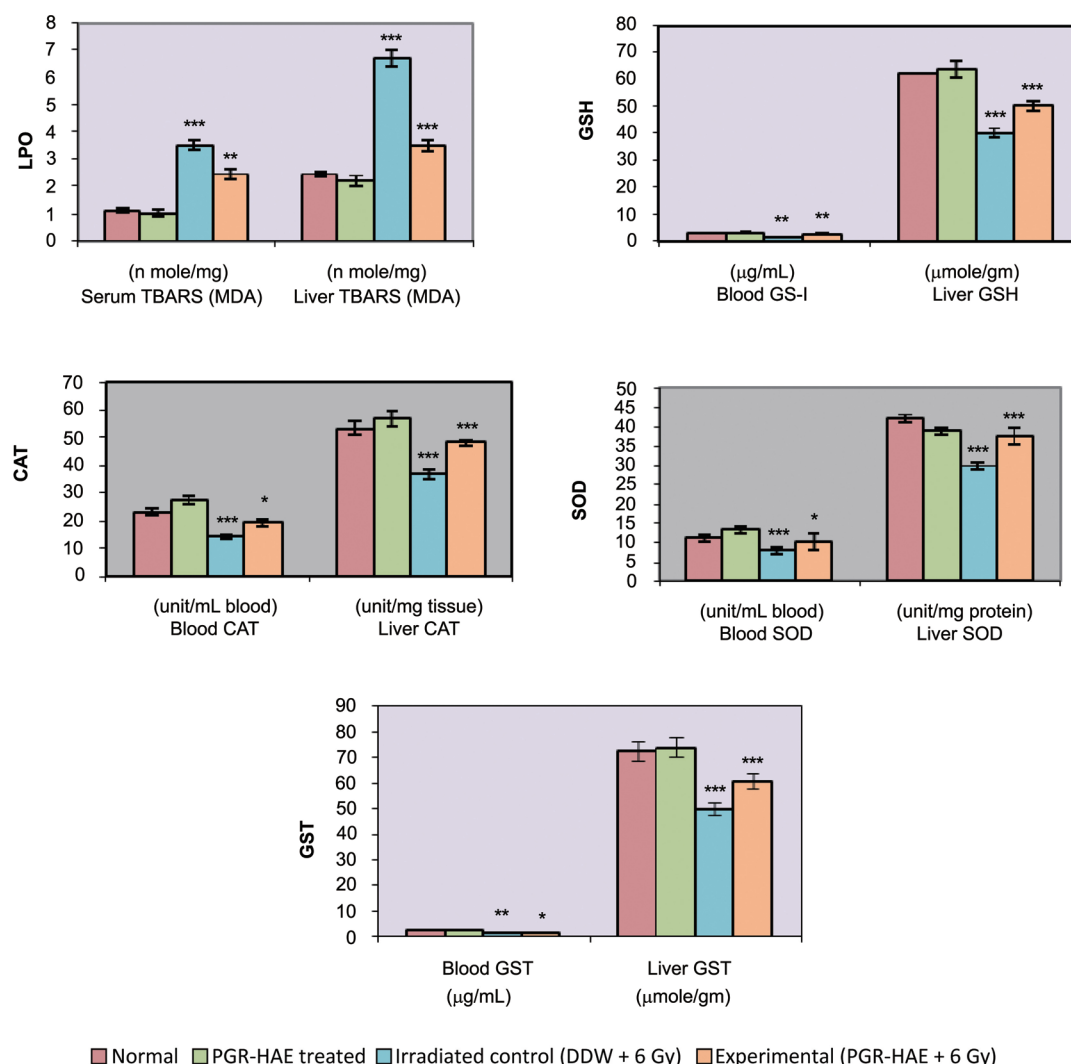


Fig. 3. Variations in different biochemical parameters in blood and liver of mice after exposure to 6 Gy gamma radiation with (experimental) or without (irradiated control) *Panax ginseng* extract (PGR-HAE). LPO, lipid peroxidation; TBARS, thiobarbituric acid reactive substances; MDA, melanoaldehyde; GSH, glutathione; CAT, catalase; SOD, superoxide dismutase; GST, glutathione S-transferase. Significant level: normal vs. irradiated control; irradiated control vs. experimental. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

lymphocytes, hemoglobin, and hematocrit values) in comparison to vehicle treated normal (group-I). Erythrocytes count decreased after irradiation and their minimum number was observed on day 3rd autopsy interval. Such blood cells showed a significant decrease ($p < 0.001$) as compared to group-I throughout the experiment. In the animals of group-IV, a significant ($p < 0.001$, $p < 0.01$) increase in the number of erythrocytes with respect to irradiated control was noticed during the entire period of study and the same restored almost a normal value by the last autopsy interval i.e. day 30 (Fig. 2). Hemoglobin concentration in irradiated mice (group-III) showed the maximum decrease on day 3 but it had a gradual increase thereafter without returning to normal. Animals

irradiated with pretreatment of PGR-HAE (group-IV) exhibited a higher hemoglobin concentration than the group-III, and value was found to be near normal by the end of experiment (Fig. 2).

Hematocrit percentage was measured significantly ($p < 0.001$) lower in irradiated control (group-III) as compared to normal (group-I) throughout the experiment. However, in experimental animals (group-IV), hematocrit values were significantly higher than the irradiated control with a recovery from the 15th day and reached to near normal by the 30th day post-treatment (Fig. 2). Leucocytes exhibited a gradual fall by reaching to minimum on day 3 post-irradiation and later a progressive increase till the last autopsy interval, but a normal value

could not be attained. However, significantly higher counts of such cells were recorded in PGR-HAE-treated irradiated mice (group-IV) and almost the normal counts were regained by day 30th post-treatment. Administration of PGR-HAE before irradiation rendered recovery in the counts of lymphocytes and neutrophils in comparison to irradiated alone group, and their values close to normal were registered in experimental group on day 30 of irradiation (Fig. 2).

Biochemical study

Lipid peroxidation

No significant difference in blood as well as liver lipid peroxidation (LPO) levels was observed in PGR-HAE alone treated animals (group-II) as compared to normal (group-I). A significant increase ($p < 0.001$) in blood and hepatic lipid peroxidation levels from the normal was noted in the irradiated control mice (group-III). However, such levels were found to be significantly declined in PGR-HAE pretreated irradiated animals (group-IV) (Fig. 3).

Glutathione

No significant alteration in GSH contents of liver and blood were observed between normal and PGR-HAE treated animals. However, a statistically significant decrease in GSH was noted in the irradiated control animals (group-II) as compared to vehicle treated normal (group-I). PGR-HAE pretreated irradiated animals (group-IV), exhibited a significant elevation in GSH (blood and liver) as compared to those irradiated without-PGR-HAE (group-III), however, the values remained below the normal (Fig. 3).

Superoxide dismutase

There was no significant difference in SOD contents of liver and blood between group-I and II mice. PGR-HAE-treated animals (groups-IV) exhibited a significant increase ($p < 0.001$) in hepatic and blood SOD activities as compared to irradiated control (group-III) (Fig. 3).

Catalase

No difference was noted in the level of CAT in PGR-HAE alone (group-II) and DDW treated (group-I) animals. CAT activity increased significantly ($p < 0.001$) in liver in the PGR-HAE-administered animals (group-IV) in contrast to irradiated control (group-III) (Fig. 3).

Glutathione S-transferase

GST was found to be significantly decreased in the

irradiated control mice as compared to animals who received DDW or PGR-HAE. Contrary, a significant increase ($p < 0.001$) in GST level in liver and blood was measured in the animals treated with PGR-HAE (group-IV) (Fig. 3).

DISCUSSION

Herbal extracts/products have been gaining prime importance in radioprotective drug discovery due to lesser side effects, cultural acceptability and better compatibility with body systems as reviewed extensively by many authors [4,33]. The damage to DNA and membrane lipids are the critical factors in radiation-induced cellular lesions and reproductive cell death. The herb (*P. ginseng*) tested in the present experiment has the ameliorative capacity of radiation-induced hematological and oxidative damage. Treatment of mice with PGR-HAE before irradiation to 6 Gy gamma rays reduced and delayed the symptoms of radiation sickness and mortality; whereas, irradiated control animals exhibited radiation sickness within 3-5 d of exposure. The symptoms including reduction in food and water intake, irritability, weight loss, lethargic nature, diarrhea and ruffling of hairs. Similar symptoms have been observed in mice after gamma irradiation by others also [20,34,35]. PGR-HAE pretreatment enhanced the survival in mice, and also the protection against hematopoietic death, probably by shielding hematopoietic stem cells which are responsible for the regeneration and recovery of the system. It possibly stimulated cellular regeneration and thus causes an early recovery. Similarly, some plant extracts and herbal formulations such as *Liv. 52*, *Podophyllum hexandrum*, *Ocimum sanctum*, *Mentha piperita*, *Aegle marmelos*, *Embllica officinalis* have also been found to have radioprotective effects in mammals [36-41]. The results in present investigation suggest that the hematopoietic stem cells can be protected against radiation damage which was evident in increased number of radiation induced CFU-S and spleen weight in PGR-HAE pre-treated irradiated animals, and there by a subsequent increase in hematological constituents of peripheral blood was observed.

The hematopoietic system is known to be one of the most radiosensitive systems, and its damage may play lead to the development of hematopoietic syndrome and results into death. Survival after irradiation actually results from the recovery of several target systems such as the bone marrow, gastro-intestinal tract, skin and hematopoietic system [42]. Death from the so-called hemato-

poietic syndrome results from the infections due to the impairment of the immune system [43]. Various mechanisms, such as the prevention of the damage through the inhibition of free radical generation or its intensified scavenging, enhancement of DNA and membrane repair, replacement of dead hematopoietic and other cells and the stimulation of immune cells activities, are considered to be important for radioprotection [44]. The results obtained from the Sham-treated/irradiated animals indicate that neither normal animals (group-I) nor PGR-HAE alone treated animals (group-II) exhibited any significant hematological changes in the peripheral blood of mice. These observations are in close agreement with the others [41,45,46], who also could not find any hematological alterations in Sham-irradiated or radioprotector alone treated mice. In the present investigation, a significant fall in hematological constituents was observed in the peripheral blood of whole-body irradiated mice (group-III). The decrease in hematological constituents may be attributed to damage caused by gamma radiation in peripheral blood and bone marrow of mice. The decrease in all these blood constituents is responsible for anemia. Maximum decline in such blood components was observed on the 3rd day following irradiation, which is an agreement with the findings of the others [35,46,47]. The reduction in erythrocytes, hemoglobin and hematocrit in the irradiated group was attributed to many factors like the impairment of cell division, obliteration of blood forming organs, alimentary tract injury, depletion of factors needed for erythroblast differentiation and reticulocytes release from the bone marrow and the cellular loss from the circulation by hemorrhage or leakage through capillary walls and/ or the direct destruction of mature circulating cells [48,49]. PGR-HAE pretreatment before irradiation checked significantly the radiation induced decline in erythrocytes, hemoglobin and hematocrit. The extract of the *P. ginseng* used in the present study, provided significant protection to erythropoietic cells in the bone marrow, which is subsequently responsible to increase the number of erythrocytes, hemoglobin and hematocrit in the peripheral blood. The bone marrow cells have been reported to be protected against radiation-induced damage by various other plant extracts also [50-52]. The initial rapid fall in the leucocytes counts in the present study may be mainly due to a fast decline of lymphocytes in the peripheral blood that are the most radiosensitive as revealed by their significant decrease in blood after radiation exposure. Leucocytes show an early response to irradiation with a maximum decline in their counts on day 3 of irradiation. It is due to radiation

induced direct destruction of such cells in the peripheral blood. Similar results have been reported by others also after irradiating mice with different doses of gamma rays [53-55]. It was observed that the neutrophilic granulocytes altered inversely as compared to lymphocytes. These cells exhibited an early elevation from the normal number while the lymphocytes declined soon after exposure, thus showing an opposite behavior. This can be explained by an abortive rise phenomenon as described earlier by [56]. Lipid peroxidation is an important event related to cell death, and has been reported to cause severe impairment of membrane functions through increased membrane permeability and membrane protein oxidation, DNA damage, cyto-toxicity and eventually cell death [57-60]. It has been indicated that the hydroxyl radical is the most active species involved in radiation induced LPO [61,62]. The increase of LPO byproduct (i.e., malondialdehyde) following radiation exposure as revealed in the present study is a clear indication of the increased oxidative stress. It is well known that there is an increase in free radicals following radiation exposure, which ultimately elevates LPO process and simultaneously increases malondialdehyde production. In the present study, it has been observed that although PGR-HAE treatment did not alter the LPO level in unirradiated animals but it significantly lowered the radiation-induced LPO in terms of malondialdehyde production. Inhibition of LPO in the bio-membranes, as evident by its lower level in experimental group, can be attributed due to various antioxidants present in PGR-HAE.

Maintenance of the cellular GSH, a free radical scavenger, is critical for keeping a check on cellular homeostasis. The GSH/GST detoxification system is an important part of cellular defense against a large array of injurious agents. GSH offers protection against oxygen derived free radicals and cellular lethality following exposure to ionizing radiation [63]. Under normal conditions, the inherent defense system including glutathione and antioxidant enzymes protect against the oxidative damage [63,64]. A significant decline in GSH was noticed in irradiated control group as compared to normal. A sharp decrease in GSH of mouse liver was reported earlier after whole-body gamma irradiation [65]. This could be due to its enhanced utilization as an attempt to detoxify the free radicals generated by radiation. The oral administration of PGR-HAE did not influence the endogenous GSH content but it significantly inhibited the radiation-induced GSH depletion. These results suggest that endogenous non protein sulphhydryl content (GSH) is maintained by PGR-HAE if is given before ir-

radiation. The anti-oxidative and free radical scavenging effects of ginseng and some of its selected ingredients have been extensively investigated and well documented [66].

A significant decline was found in antioxidant enzymes (CAT, GST, and SOD) in irradiated group as compared to the normal. This study was supported by the others who have also noted depletion in these enzymes after irradiation [67,68]. Pretreatment with PGR-HAE significantly elevated such endogenous antioxidant enzymes after radiation exposure in mice. Free radical generated oxidative stress has been implicated in the pathogenesis of a wide variety of clinical disorders, resulting usually from deficient natural antioxidant defense. Potential antioxidant therapy, therefore, includes either natural free radical scavenging antioxidant enzymes or agents which are capable of augmenting the activity of such enzymes. The mechanism of the radioprotective action of *P. ginseng* plant extract in this animal model may be due to its free radical scavenging activity and its ability to protect cellular molecules from oxidative damage. Furthermore, it inhibited LPO and modulated GSH levels in blood as well as liver. The activity of this plant extract may also be attributed to stimulating or protecting hematopoiesis in bone marrow which in turn may be responsible for a subsequent rise of hematological constituents in the peripheral blood as compared to irradiated control. Since significant protection was obtained at a non-toxic low dose, therefore, such plant extract may have an advantage over the other known radioprotectors. Further, investigations are in progress to study the exact mechanism of action and clinical applicability of *P. ginseng* in chemical radioprotection.

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