PRECLUSION OF RADIATION-MEDIATED HEMATOLOGICAL AND BIOCHEMICAL VARIATIONS BY ROOT EXTRACT OF *TINOSPORA CORDIFOLIA* (AN INDIAN MEDICINAL PLANT)

by

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The present study deals with the radiomodulatory influence of *Tinospora cordifolia* (Amrita) root extract on the peripheral blood of Swiss albino mice after 5.0 Gy gamma irradiation in the presence (experimental) or absence (control) of *Tinospora cordifolia* (75 mg/kg b.wt/day). The animals from different groups were necropsied and their blood collected on days 1, 3, 7, 15, and 30 postirradiation. A considerable decrease was recorded in the number of erythrocyte and total leucocyte counts, differential leucocytes, hemoglobin content, and hematocrit percentage in the irradiated control group, while a recovery pattern was recorded in experimental animals, however, without the attainment of normal levels up to the end of the experiment. Furthermore, *Tinospora cordifolia* root extract pretreatment significantly ameliorated radiation-induced elevation in cholesterol and lipid peroxidation levels, whereas, a decline in glutathione and total proteins concentration was noted.

Key words: gamma radiation, Tinospora cordifolia, glutathione, hematology, lipid peroxidation, Swiss albino mice

INTRODUCTION

The nuclear era in which human beings live today is both a bane and a boon. Though nuclear energy has offered enormous benefits to mankind, at the same time, it has also created immeasurable evils and challenges that need to be confronted. Ionizing radiation is a million times stronger than anything encountered during our long evolution as a species. After the conversion of radiation to other forms of energy, it has impacted the biological system adversely in a variety of ways through the ionization of water and different biologically essential macromolecules, causing a series of physiological changes stemming from various physical, physiological, and environmental factors.

In the field of radiobiology, the impact of radiation on the hemotopoietic system has been in the focus of interest and on the rise for years. Because of their high proliferating capacity, blood and blood-forming tissues are highly radiosensitive and their damage may lead to the development of the hemopoietic syndrome [1]; hence, peripheral blood constituents may well serve as significant biological indicators. Nevertheless, blood has a remarkable regenerative capacity and will recover within a short period of time [2]. The rapid recovery of the said tissue limits its application as a diagnostic tool to accidental cases of irradiation.

New technologies and research over the past 20 years have provided a greater understanding of the complex nature of radiation injuries at the molecular and cellular level and have, also, paved the way towards the development of radiomodulators and radiorecovery agents that can be efficiently utilized as a protection against the injurious effects of ionizing radiation [3]. In view of this fact, many hundreds of chemical compounds with varied structures and physiological functions have been tested for their radioprotective properties over the past six decades [4, 5]. However, none of them were found to be suitable for clinical application, due to their inherent toxicity at optimum dose concentrations.

The re-invention of the relationship between plants and health is responsible for the launching of a new generation of botanical therapeutics, such as plant-derived pharmaceuticals, multicomponent botanical drugs, functional foods, dietary supplements, and plant-produced recombinant proteins [6]. Due to the presence of natural antioxidants, plant products have diverse pharmacological properties that have been used as a cure for a range of diseases since ancient time. As a consequence, over the past several years, interest in the radioprotective efficiency of plant products has been on the rise [7].

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In this context, *Tinospora cordifolia*, of the *Menispermaceae* family, has been welcomed by researchers as a potential drug of the Ayurveda (Indian system of medicine), where it is believed to have rasayana (rejuvenating), *balya* (tonic), *vayah-sthapana* (antiaging), *aayushyaprada* (lifespan-increasing), *vrishya* (aphrodisiac), and *chakshusya* (eye-disorders-healing) properties [8]. Potential medicinal properties reported by the scientific research on the said plant include antidiabetic, antipyretic, antispasmodic, anti-inflammatory, antiarthritic, antioxidant, antiallergic, antistress, antileprotic, antimalarial, hepatoprotective, immunomodulatory and antineoplastic effects [9-11]. *Tinospora cordifolia* has also been reported to protect against lethal irradiation in mice by decreasing micronuclei and increasing survival in bone marrow cells [12].

We have undertaken the present study with the aim of coming to an understanding of the antioxidant and possible radioprotective potential of the *Tinospora cordifolia* root extract (TCE) on radiation-induced hematological and biochemical alterations in mammals.

MATERIALS AND METHODS

Animal care and handling

Animal care and handling were performed according to the guidelines set by WHO (World Health Organization, Geneva, Switzerland) and INSA (Indian National Science Academy, New Delhi, India). Swiss albino mice, 6-8 weeks old, weighing 22 2 g, from an inbred colony, were used in the study presented. They were maintained under controlled conditions of temperature and light (14 and 10 hours of light and dark, respectively). The animals were provided with standard mice food (procured by Ashirwad Industries, Chandigarh, India) and water ad libitum. Tetracycline water was also given once a fortnight, as a preventive measure against infection. Throughout the experiment, four to six animals were housed in a polypropylene cage containing paddy husk (procured locally) as bedding. Our study was approved by the Institutional Animal Ethical Committee.

Source of irradiation

The animals were irradiated by a ^{60}Co source in the Cobalt Therapy Unit at the Cancer Treatment Center, Department of Radiotherapy, SMS Medical College and Hospital, Jaipur, India. Unanaesthetized mice were restrained in well ventilated boxes and exposed, whole-body, to gamma radiation (5.0 Gy) at a dose-rate of 221 c Gy/min from a source-to-surface distance (SSD) of 80 cm.

Preparation of the plant extract

Tinospora cordifolia was identified by a competent botanist of the Herbarium of Botany Department, University of Rajasthan, Jaipur (RUBL No. 20132). The root of the *Tinospora cordifolia* was collected, cleaned, shade dried, powdered and extracted. The extract was prepared by refluxing with double-distilled water (DDW) for 36 (3 12) hours. The cooled liquid extract was concentrated by evaporating its liquid contents to render it in powder form. An approximate yield of 22% extract was obtained. The extract was re-dissolved in DDW just before oral administration to mice. Henceforth, in this article, the extract of the *Tinospora cordifolia* root will be called TCE.

EXPERIMENTAL DESIGN

Dose selection of TCE

The dose selection of *Tinospora cordifolia* was done in our previous study on the basis of the drug tolerance survival experiment [13].

Modification of radiation response

To evaluate the adverse effects of gamma rays and the possible radioprotective efficacy of the TCE extract, a total of 48 animals were selected from an inbred colony, randomly assorted into four groups of 12 mice each. Animals in group I (Normal/Sham-Irradiated) were administered with double-distilled water (DDW), volume equal to TCE as the vehicle, by oral gavage, once a day for 5 consecutive days, to serve as normal. Mice in group II (Negative Control or TCE-alone treated) were administered with 75 mg/kg b. w.t/day of TCE dissolved in double-distilled water through oral gavage for 5 consecutive days, once a day. In group III (Irradiated Control), the double-distilled water volume equal to TCE was administered for 5 consecutive days (as in Group-I) and then exposed to a 5.0 Gy dose of gamma radiation. This group served as the irradiated positive control. Mice in Group IV (Experimental) were treated with TCE, orally for 5 consecutive days (as in Group-II) and, then, 30 min after the last dose administration on day 5th, such animals were exposed to a 5.0 Gy gamma radiation.

Autopsy schedule

Animals from all the above treated groups (I, II, III, and IV) were regularly observed for 30 days for their weight change, any signs of sickness, morbidity, fur and skin changes, behavioral toxicity, any visible abnormalities, and mortality. A minimum of 6 animals from each group were necropsied at 12 h, 1, 3, 7, 15, and 30 days post treatment, so as to evaluate the hematological and biochemical parameters.

Hematological study

In the study, one hour after irradiation, blood was collected from the cardiac punctures of animals

from each group in a vial containing 0.5 M EDTA. The total number of erythrocytes (RBC), leucocytes (WBC), as well as thematocrit (Hct) and hemoglobin (Hb) percentages, were determined by standard procedures.

Biochemical study

Biochemical alterations were studied in animals of all groups at one hour post exposure to gamma radiation. The level of glutathione (GSH) was determined by blood methods of Beutler *et al*. (1963) [14], respectively. The lipid peroxidation (LPx) level in the serum was measured by an assay of thiobarbituric acid-reactive substances (TBARS), according to the method of Ohkhawa *et al*. (1979) [15].

Statistical analysis

Results for all of the groups at various necropsy intervals were expressed as a Mean Standard Error (S. E.). To find out whether the mean of the sample drawn from the experimental (group IV) deviates significantly from the respective control (group III), Student's t-test was used by employing the method of Bourke *et al*. (1985) [16]. The significance level was set at different levels as $p < 0.05$, $p < 0.01$, and $p < 0.001$.

RESULTS

During the entire study period, no adverse effects in terms of behavioral changes, sickness or mortality were observed in animals of Group I and II, whereas the irradiated controls (Group III) exhibited radiation-induced signs and symptoms, with a 2.38% mortality within the 19th day of irradiation. To the contrary, TCE pretreatment (Group IV) significantly inhibits radiation-induced sickness and increases the survival up to the 30th day.

A significant and continuous depletion in total erythrocyte counts was recorded up to day 3rd (7.12 0.20; $p < 0.001$), followed by a significant increase till the last autopsy interval, where the observed value was found to be 32.57% lesser than the normal. As opposed to this, throughout the experiment, TCE-pretreated irradiated animals exhibited a significant increase in erythrocyte counts over the irradiated control, while the normal level could not be restored. The hemoglobin content significantly dropped up to day 3rd of postirradiation (9.73 0.8; p 0.001) and was found to be 74.45% lesser than the normal. Afterwards, the Hb content started to rise up to day 30th when it was found to amount to 86.45% of the normal (11.30 0.10; p 0.001). TCE-administered animals exhibited a higher

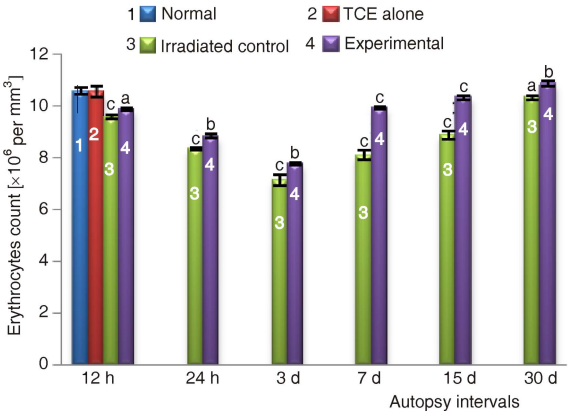

Figure 1. Variations (mean S.E.) in erythrocyte counts in the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental; significance levels: $^a p$ 0.05, $^b p$ 0.01, and $^c p$ 0.001

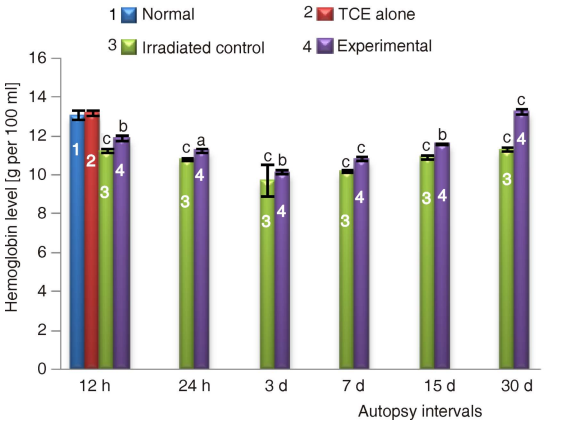

Figure 2. Variations (mean S.E.) in hemoglobin levels in the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental; significance levels: $^a p$ 0.05, $^b p$ 0.01, and $^c p$ 0.001

Hb concentration than Group III, and the values were found to be near normal by the end of the experiment (figs. 1 and 2).

The hematocrit value started diminishing significantly from 12 hours on (38.52 0.2; p 0.001) and attained its minimum on day 3 of postirradiation (36.05 0.23; p 0.001). However, from day 7th onwards, the values increased, while the normal percentage was not regained even by the end of the study, *i. e.* the 30th day (90.75% of normal). TCE-pretreated animals also exhibited a similar pattern of alteration in hematocrit percentage, but the magnitude of variations was fairly lesser and an almost normal level was recovered by the end of the experiment (fig. 3).

In contrast to other hematological parameters, the erythrocyte sedimentation rate (ESR) value was mea-

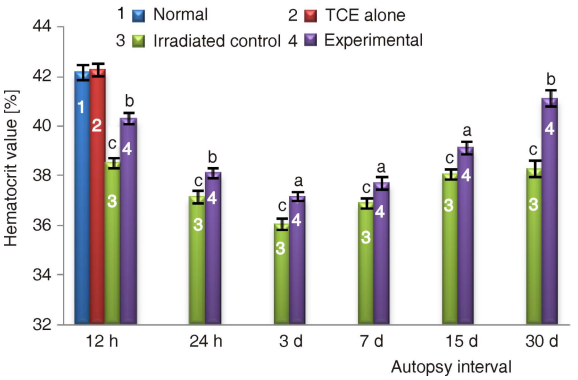

Figure 3. Variations (mean S.E.) in hematocrit value of the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (the irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

sured to be on a significant (p 0.001) rise from the first autopsy interval up to day 7th of postirradiation (6.12 0.05 mm/h). However, in Group III, a significant depression was observed at subsequent intervals, while the normal was not attained. The pattern of alterations was essentially similar in the TCE-pretreated group, but a significantly lower ESR was recorded at all autopsy intervals in comparison to the irradiated controls (fig. 4).

Total leucocyte counts exhibited a significant (p 0.001) declining pattern from the first autopsy interval and were found to reach their minimum on day 3rd of postirradiation, followed by a significant ($p < 0.001$) elevation till the last autopsy day, *i. e.* day 30th. As opposed to this, in the TCE-pretreated group, such cells scored significantly higher than the corresponding irradiated control; however, the normal value could not be recovered up to the end of experimentation (fig. 5).

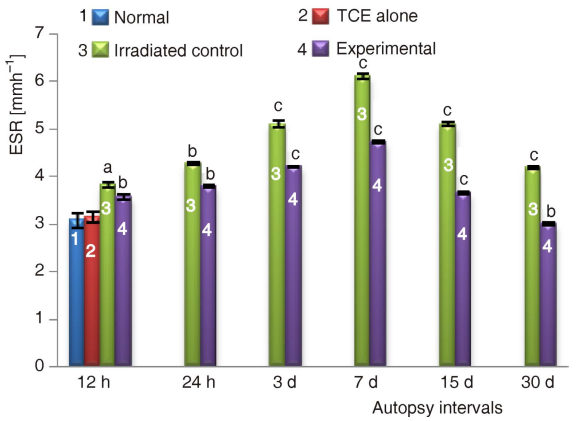

Figure 4. Variations (mean S.E.) in ESR value of the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (the irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

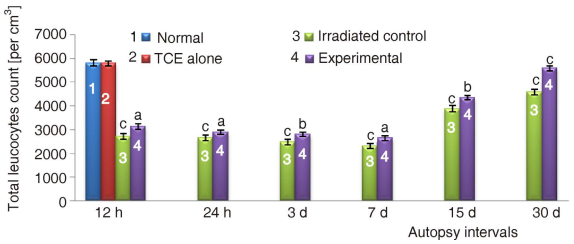

Figure 5. Variations (mean S.E.) in total leucocytes in the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (the irradiated control) TCE. Statistical analysis: normal v/s irradiated control, irradiated control v/s experimental; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

In differential leucocytes, a decreasing pattern was exhibited by lymphocytes, monocytes, and neutrophils up to day 3rd, whereupon the observed values were 53.47%, 39.33 %, and 74.92% lesser than the normal, respectively. Thereafter, reparation in such cellular counts was evident till the end of the study, but the values were still found to be significantly lesser than the standard. In TCE-pretreated animals, this decrease was less pronounced in comparison to irradiated controls, indicating a faster recovery; however, by the end of experimentation, the normal value was not observed (figs. 6-8).

Non-neutrophilic granulocytes (*i. e.* eosinophils and basophils) also significantly (p 0.001) declined from the first autopsy interval (*i. e.* 12 hours) and continued to decline up to day 7 of postirradiation (1.12 0.20, $p < 0.001$). Thereafter, the counts of such cells recovered, but the normal level could not be restored even at the last autopsy interval. Although TCE-pretreated animals also exhibited a similar pattern of variations in these counts, their values were much higher as compared to the respective irradiated control at all autopsy intervals (fig. 9).

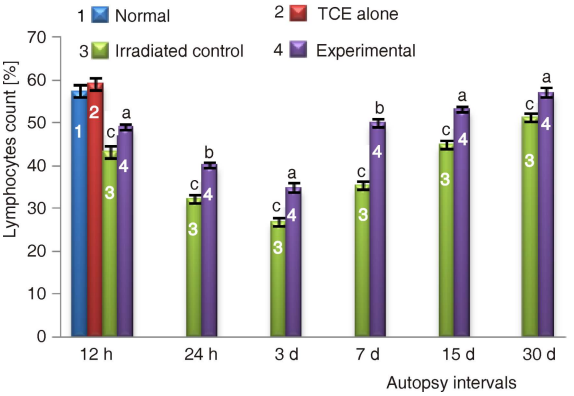

Figure 6. Variations (mean S.E.) in lymphocytes and peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental control; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

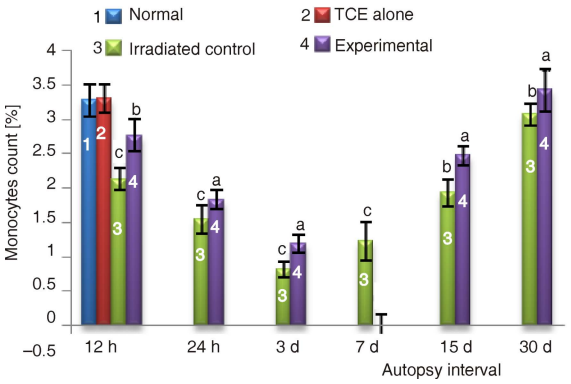

Figure 7. Variations (mean S.E.) in monocytes and peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental control; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

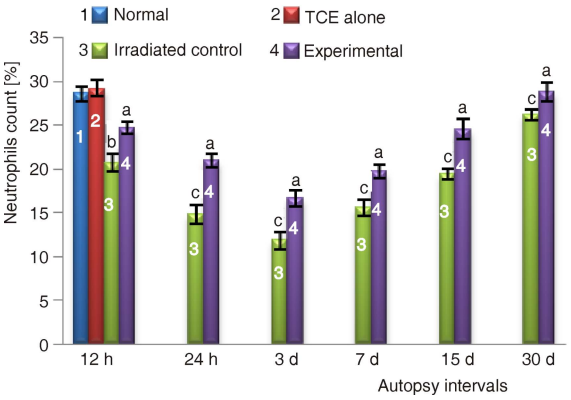

Figure 8. Variations (mean S.E.) in neutrophylls and peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental control; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

A significant rise of lipid peroxidation levels in the blood was observed in irradiated controls (Group III) up to day 7th (173.95%); thereafter, a significant and progressive decrease was recorded on day 15th (142.5%) and 30th (100.58%). On the other hand, TCE pretreatment lowered the LPO value, while exhibiting a similar pattern of alterations at all other autopsy intervals (fig. 10).

The GSH level in blood was found to significantly decrease up to day 7th (28.85 1.13; $p < 0.001$) in the irradiated control, followed by a significant increase up to the last autopsy day, whereas TCE-pretreated animals exhibited a statistically significant elevation in GSH, as compared to the irradiated controls, while the value remained below normal till the last autopsy interval (fig. 11).

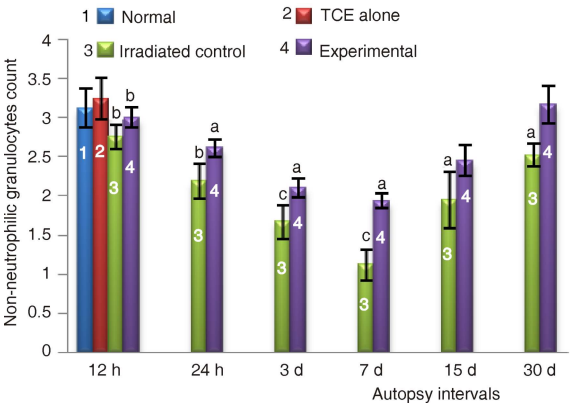

Figure 9. Variations (mean S.E.) in non-neutrophilic granulocytes and peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: Normal v/s irradiated control, irradiated control v/s experimental control; significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

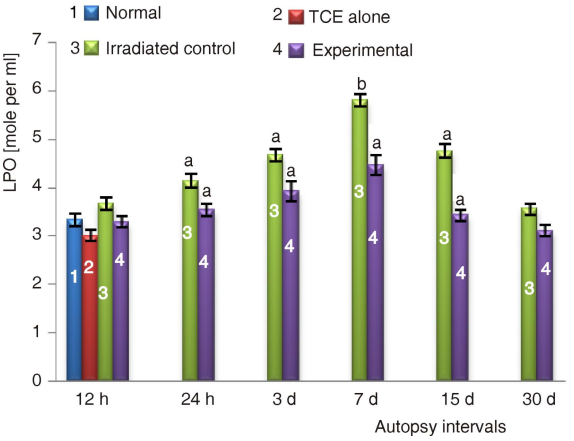

Figure 10. Variations (mean S.E.) in LPO levels and the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: normal v/s irradiated control, irradiated control v/s experimental, significance levels: [a] p 0.05, [b] p 0.01, and [c] p 0.001

DISCUSSION

The damage to blood and blood-forming tissues after radiation exposure may result in the development of the hematopoietic syndrome which can induce various structural and functional dysfunctions. In the experiment presented here, irradiated animals exhibited a 2.38% mortality rate within 19 days of the experiment, to be predominantly attributed to the hematopoietic syndrome and the gastrointestinal syndrome, as suggested earlier [17, 18]. Irradiation inhibits the proliferation of stem cells and, as a consequence, replacements are not available when normal attrition results in the progressive loss of senescent cells. Therefore, any dam-

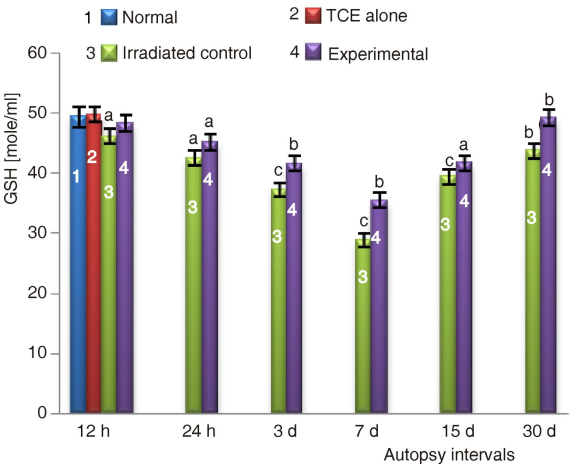

Figure 11. Variations (mean S.E.) in GSH levels and the peripheral blood of mice exposure to 5.0 Gy gamma radiation with (experimental) or without (irradiated control) TCE, respectively. Statistical analysis: normal v/s irradiated control, irradiated control v/s experimental, significance levels: ^{a}p 0.05, ^{b}p 0.01, and ^{c}p 0.001

age to these cells impairs normal physiological processes, with a drastically adverse impact on the survival rate. At the same time, TCE-pretreated animals experienced a substantial increase in survival time by the 30th day, which may possibly be attributed to TCE's protective effect on the bone marrow stem cell component which continued to supply the requisite number of cells in the survivors [19].

The findings on blood constituents presented here demonstrate that a continuous and gradual decline in RBC, Hb, and Hct was recorded in whole-body irradiated mice, with a maximum fall on day 3rd of postexposure, which may be attributed to the direct damage caused by radiation. Such a decrease in RBC might be due to the inhibition of new cells entering the blood, loss through hemorrhage and the direct killing of cells/ indirect effects on them *via* vessel trauma, as suggested earlier [20, 21]. However, TCE-administration before irradiation showed a significant increase in RBCs that could be a result of the stimulation and production of bone marrow progenitor cells and the inhibition of radiation-induced bone marrow suppression that might have significantly contributed to the radioprotective effect of RBC.

Likewise, the depletion in hemoglobin and hematocrit levels may be related to the direct cytotoxic effects of radiation on the dividing cells of the hemopoietic system, due to the disturbances in steady-state mechanisms of erythropoiesis, resulting in an altered hemoglobin synthesis, decreased erythropoiesis, loss of RBC in circulation, a decreased hematocrit value and an increase in the plasma volume. A similar decrease in hemoglobin and hematocrit counts after exposure to gamma radiation has also been reported by others [22, 23]. Furthermore, the immunosuppressive action of radiation also causes a significant reduction in the weight of the liver and spleen (unpublished data) which might have sequestered the defective RBC, resulting in the initial decrease of hemoglobin. *Tinospora cordifolia* has been reported as an immunomodulator which may possibly act by removing the defective and damaged RBC from peripheral blood circulation through the stimulation of the liver and the spleen. Whereas the higher level of Hb at the remaining intervals could be a result of a feedback-mechanism-stimulated hemopoiesis in the bone marrow. The increase in hemoglobin and hematocrit counts is closely related with the protection of RBC and erythropoiesis by TCE.

As opposed to this, ESR (erythrocyte sedimentation rate) continuously rose over the normal up to day 7th of irradiation, whereupon it is influenced by the size and number of erythrocytes; therefore, its rise is possibly due to the radiation-mediated destruction of mature cells, internal bleeding and inflammation. Such an elevation in ESR is in accordance with the findings of [24, 25].

In the present study, the total number of leucocytes and non-neutrophilic granulocytes (eosinophils and basophils) exhibited their minimum level on day 7th, whereas the maximum decline in lymphocytes, monocytes and neutrophil counts was recorded on day 3rd following irradiation. Similarly, some other investigators have also reported a significant fall in TLC (total leucocytes counts) and DLC (differential leucocytes counts) in mice after exposure to different doses of gamma rays [26, 27]. The initial phase of rapid decline in all such cellular counts may be due to the direct killing by radiation of hematopoietic stem cells, resulting in an insufficient release of mature cells in the peripheral blood, as also suggested by others [28, 29].

Irradiation leads to neutropenia and results in an increased phagocytosis for a number of postirradiation hours [30]. This increased phagocytic activity is associated with the elevated level of cytokine (IL-1β and GM-CFS) activity in the serum [31]. The administration of *Tinospora cordifolia* before irradiation has been reported to increase the endogenous production of cytokinines to higher values, leading to an increase in the phagocytic activity of peritoneal macrophages [32, 33]. The said effect of TCE may be efficient and hasten the clearance of dead cells and microorganisms and the replenishment of damaged cells by new ones, thus leading to a faster recovery of hemopoitic tissues. A significant increase in leucocytes counts after TCE-administration and the enhancement of cell proliferation may also be associated with the increased CFU counts in the spleen, as reported earlier, indicating an immunomodulatory role of TCE in the present study [13].

Radiation-mediated, large-scale biological destructions are manifested by an enhanced production of

free radicals as a result of oxidative stress. The crucial outcome of radiation is judged by the peroxidation of membrane lipids which ultimately lead to DNA damage and cell death. However, two factors blur the association between radiation exposure and its biological consequences, *i*. *e*. individual variability (due to genetic and environmental factors) and the presence of various defensive mechanisms which counteract the oxidative stress resulting from after radiation exposure.

The 5-day supplementation of *Tinospora cordifolia* presented in this study might be responsible for the elevated concentrations of phyto antioxidants which could subsequently restore the radiation-mediated elevation in lipid peroxidation towards the normal, the said phenomenum being a radiorecovery effect. As glutathione is one of the major components of the cellular antioxidant system [34], the significant reduction of GSH in the blood after irradiation in the present study is, hence, possibly attributable to its enhanced ability to detoxify the free radicals generated by radiation. TCE-pretreatment has contributed significantly to the protection of endogenous glutathione levels against irradiation, also mirrored in terms of reduced levels of LPO. The increase in GSH levels is a confirmation of our belief that TCE exerts its radioprotectove properties, principally, through free radical scavenging and the protection from radiation-induced lethality, as well. Similar alterations in LPO and GSH levels were also reported by other investigators using different plant extracts [35, 36].

Tinospora cordifolia owes its powerful radioprotective effects of enhancing antioxidant activities in plasma to the free radical scavenging capacity of polyphenol (3- glucosides, gallic acid, tannins), flavonoids (quercetin), alkaloids (berberine), and triterpenoids compounds which elicit the protection against radiation and other pathological states [37, 38]. For a long time, polyphenolic compounds have been recognized to possess many potentially significant benefits, including anticarcinogenic, antioxidant, antiviral and antiproliferative properties [39, 40].

The radioprotective properties of medicinal plants such as Ginko biloba, and Mentha piperita have also been attributed to the presence of polyphenols capable of stopping the propagation of lipid peroxidation and chelate transitional metal ions and, hence, of inhibiting the formation of free radicals [41, 42]. The ability of flavonoids to scavenge free radicals and block lipid peroxidation introduces the possibility that the TCE extract may act as protective agent against radiation-mediated damage, as earlier reported by [43, 44]. Thus, the enhancement of cell proliferation, immunomodulation, stimulation of hematopoisis and protection against radiation-induced genotoxicity and the activation of the endogenous antioxidant defense system could, together, contribute to the radioprotective efficacy of TCE, as presented in this study.

CONCLUSIONS

Based on the results obtained, it can be concluded that the administration of TCE before irradiation significantly reduces postirradiation alterations of peripheral blood constituents, indicating its radioprotective influence on the hemopoitic system.

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AUTHOR CONTRIBUTIONS

The experiments were conducted and the manuscript was written by P. Sharma. The experiments was planned and the manuscript was corrected by P. K. Goyal. Both the authors analyzed and discussed the results.

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СПРЕЧАВАЊЕ ХЕМАТОЛОШКИХ И БИОХЕМИЈСКИХ ПРОМЕНА ИЗАЗВАНИХ ЗРАЧЕЊЕМ ПОМОЋУ ЕКСТРАКТА КОРЕНА БИЉКЕ *TINOSPORA CORDIFOLIA* (ЛЕКОВИТЕ ИНДИЈСКЕ БИЉКЕ)

Овај рад бави се радиомодуларним утицајем екстракта корена биљке *Tinospora Cordifolia* на периферни крвни систем швајцарских албино мишева после озрачивања гама зрачењем од 5 Gy у присуству (експериментална група) или одсуству (контролна група) *Tinospora Cordifolia* (75 mg по килограму телесне масе животиње). Првог, трећег, седмог, петнаестог и тридесетог дана по озрачивању, животиње из различитих група жртноване су и њихова крв је сакупљена. Регистрован је значајно смањен број еритроцита и укупан број леукоцита. Уочени су облици опоравка код животиња из експерименталне групе, али до краја експеримента нису достигнути нормални нивои опоравка. Такође, *Tinospora Cordifolia* значајно доприноси повећању нивоа холестерола и липидне пероксидације уз уочено смањење глутатина и укупне концентрације протеина.

Кључне речи: гама зрачење, Tinospora Cordifolia, глутатин, хематологија, липидна пероксидација, швајцарски албино миш