Cancers are known through unlimited and uncontrolled cell divisions, which can cause death. Although different methods have been introduced to treat cancers, the number of cancer patients increases annually. It is estimated that nearly 16,000,000 human bodies on the earth will develop this illness by the next ten years, of which about 12,000,000 cases are fatal. Accordingly, this is one of the important factors of humans dying. In addition, this disease is reported to be due to the lack of the regulation of important activities of the cell, including development pathways, anti-cell programmed death processes, immune responses, and cellular microenvironment.

In addition, damages and genetic alterations including modifications in the DNA sequence and coherence and other genetic elements have a high impact on carcinogenesis. Cancer treatment has been applied to reset cellular processes. So far, several clinical experiments have studied potential treatments for cancer through radiotherapy, chemical treatment, and immunotherapy although the first two methods have harmful and lethal effects against natural
tissues. Although the third method offers highly particular and targeted therapy, it is limited and highly expensive. Further, cancers recur after treatment. Recently, new methods have been used to find new compounds with anticancer effects from difficult resources for controlling the harmful effects of anticancer medicines and finding better compounds.

Medicinal plants have long been a natural resource for the treatment of many ailments. According to the World Health Organization report, many plants are currently used for medical purposes.

Additionally, the metabolites of plants are useful for different therapeutic aims, and plant compounds have biological roles such as pain reliever, along with anti-inflammatory and antimicrobial activities. Furthermore, they are the resources of nearly 25% of therapeutic drugs and more than 60% of anticancer drugs are derived from the plants.

As discussed earlier, it is essential to develop newer, safer, and more effective substances for treating cancer. Plant compounds are beneficial materials for developing other medicines with high performance while fewer side effects.

The Verbenaceae plant family includes various plant genus and species, most of which have been traditionally utilized as remedies for some disease. Lantana camera from the plant Verbenaceae family is endemic of Africa and America. The leaves of this plant are effective on the treatment of bellyache, wounds, rheumatism, pain in a tooth, pneumonia, and other ailments. Furthermore, L. camara has several biologically active compounds. Moreover, many terpenes, fatty acids, and flavonoids have been extracted from this plant in phytochemical studies. Additionally, this plant is claimed to have anti-protozoal, anti-bacterial, anti-fungal, anti-oxidant, insecticidal, and anti-viral activities, as well as allelopathic properties. Similarly, the major essential compounds of L. camera are γ-curcumin (6.3%), Davanone (7.3%), germacrene D (10.9%), α-humulene (11.5%), and β-caryophyllene (23.3%).

Considering the above-mentioned explanations, this research aimed to investigate the anti-mutagenic activities of the L. camera extract applying mutant Salmonella typhimurium through the Ames test.

Materials and Methods

Plant Material
Different parts of L. camara were prepared from the National Botanical Garden of Iran (Tehran Iran) in Spring 2018.

Plant Extract
Different parts of the plant were prepared and dried in the shadow. Then, they were powdered, and 50 g of them were converted to the extract by adding alcohol (Methanol 80%) using the percolation method. In addition, the extracts were concentrated by a rotary system at 40°C (the concentrated extract was about 5 g), dehydrated in the oven (40°C), and finally, their anti-mutagenic activities were investigated based on the aim of the study.

Bacterial Strains
The histidine auxotrophic mutant strains (His-) of Salmonella typhimurium (TA100) were obtained from the Laboratory of Microbiology of Kharazmy University (Tehran, Iran) and used to determine the occurrence of base-pair mutations. These mutant strains cannot grow on a minimal mineral medium, and only those bacteria having mutated to wild (His+) type by the reverse mutation in the presence of a mutagen (Sodium azide, NaN₃) can grow on this medium. Therefore, the presence of an anti-mutagenic substance (e.g., a plant methanolic extract), along with the mutagen (i.e., NaN₃) can reduce the rate of the reverse mutation.

Anti-mutagenic Activity Assay
The anti-mutagenic effect of the extract was evaluated by the Ames method using the mutant strain of Salmonella typhimurium (TA100) in the presence of NaN₃ and counting grown colonies indicating the incidence of a reverse mutation. The mutant Salmonella typhimurium strain (TA100) that requires histidine for growing in minimal media is suitable for measuring the anti-mutagenic activity of mutagenic substances.

In this phase, the anti-mutagenic effect of the extract was evaluated by adding S₉ (The sterile extract of the mouse liver containing microsomal enzymes). The cytochrome oxidase enzyme (P450), which inactivates oxidant and toxic compounds, can be found in the membrane of liver cells, especially the endoplasmic reticulum membrane. Thus, the metabolic and antimutagenic activities of compounds are strengthened in the presence of the microsomal extract of the liver (S₉).

The concentration of 1% or 1 μg/mL of the concentrated extract was used because of its suitability for assaying anti-mutagenic activity without killing the bacteria. Then, the anti-microbial activity of the methanolic extract against Salmonella typhimurium was assessed by the microbial culture and the disk diffusion method to obtain the minimum inhibitory concentration, which was obtained 6.25 μg/mL for both leaf and flower extracts. Further, Dimethyl sulfoxide was considered as the solvent.

Next, the anti-mutagenic test was performed by adding the plant extract (0.5 mL) to the fresh overnight culture (0.5 mL) and the Histidine-Biotin solution (0.5 mL) containing top agar (10 mL) and NaN₃ (1.5 μg) in a test tube. The contents of this tube were shaken for 3 seconds by a shaker and then evenly spread on the entire surface of the minimal glucose agar medium. Then, the experiment was repeated three times, and petri dishes were placed in an incubator (at 37°C for 24 hours). The positive control contained NaN₃ (1.5 μg) as a
mutagen per plate, and plates without any NaN₃ or the plant extract, which only consisted of 0.5 mL sterile distilled water, were considered as the negative control. After the incubation, grown colonies were counted per plate.²¹-²³

In the second experiment, 0.5 mL of the S₉ compound (prepared from the laboratory complex of the Islamic Azad University of Tehran, Science and Research Branch) was added to all plates.

**Calculating the Percentage of Mutation Inhibition**

The average number of grown colonies per plate was determined, and the mean mutation inhibitory activity was calculated by the “Ong” formula.²⁴ This formula computes the percentage of mutation inhibition based on the number of the grown colonies per plate as follows:

\[
\text{Percentage of inhibition} = \left[1 - \frac{T}{M}\right] \times 100
\]

where \( T \) denotes the numbers of the grown colonies each petri with the mutagen and the plant extract, and \( M \) represents the number of grown colonies in the plates of the positive control. The mutagenicity of NaN₃ without the extract (positive control) was considered as 100% growth (i.e., 0% mutation inhibitory activity).²¹ Finally, the anti-mutagenic activity was categorized as moderate (25%-40%) or strong (>40%).²¹,²²,²³

**Analysis of Data**

The findings were presented as the mean ± standard deviation of three replications per sample in each experiment. Furthermore, any significant difference between the mean of the grown colonies per petri dish was analyzed by SPSS statistical software (version 22) using the one-way analysis of variance, and the significance level was considered as \( P < 0.05 \).

**Results**

The present study assessed the anti-mutagenic activities of plant extracts applying the mutated *Salmonella typhimurium* (TA100) strain.

Positive control plates, including sodium azide (NaN₃), were used to induce reverse mutations. NaN₃ converts several mutant bacteria into wild types (these bacteria can grow on the minimal mineral medium without histidine). Moreover, negative control plates, including distilled water without the presence of NaN₃, were applied to induce spontaneous mutations, and the resulting colonies indicated that several bacteria in the medium spontaneously mutated and became wild. In this case, the number of colonies is extremely low compared to the positive control (Figure 1, a-b) and is negligible.

The number of the grown colonies in plates containing the extracts was lower compared to the positive control due to the anti-mutagenic activities of the plant extracts that inhibited the reverse mutations of bacteria in the presence of NaN₃ (Figure 1, c-f).

The number of the grown colonies and the percentage of mutation inhibition calculated by the Ong formula²⁴ are presented in Table 1.

**Anti-mutagenic Activity of Lantana camara Leaf Methanolic Extract**

The statistical results of the anti-mutagenic activities of the leaf methanolic extract in the absence of S₉ showed that the number of the colony-forming unit (CFU) of the mean grown colonies (201.66 ± 4.83) significantly decreased compared to the control (\( P<0.05 \), and

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**Table 1.** The Effects of the Leaf and Flower Methanolic Extracts of Lantana camara on the Number of the Grown Colonies of *Salmonella typhimurium* TA100 (by Reverse Mutations) and Mutation Inhibition Percentage With or Without S₉

| Sample          | Mutation inhibition percentage | Mean number of grown colonies | Mutation inhibition percentage | Mean number of grown colonies |
|-----------------|--------------------------------|-------------------------------|--------------------------------|-------------------------------|
| Positive control| -                              | 826.33 ± 3.02                 | -                              | 826.33 ± 3.02                 |
| Negative control| -                              | 102.66 ± 4.98                 | -                              | 102.66 ± 4.98                 |
| Leaves extract  | 84.79 ± 0.17*                  | 125.66 ± 1.37                 | 75.59 ± 0.73**                 | 201.66 ± 4.83                |
| Flower extract  | 62.32 ± 0.23*                  | 311.33 ± 1.68                 | 49.57 ± 0.55**                 | 416.66 ± 3.38                |

Note: S₉: Sterile extract of the mouse liver containing microsomal enzymes.

* A significant difference was at \( P=0.026 \), at the level of 5% ** Significant difference was at \( P=0.018 \) at the level of 5%.

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**Figure 1.** Anti-mutagenic Activity of the Lantana camara Extract. The images of the grown colonies in the positive control (a), negative control (b), treatment with the leaf extract in the presence of S₉ (c), treatment with the leaf extract without S₉ (d), treatment with the flower extract in the presence of S₉ (e), and treatment with the flower extract without S₉ (f).
mutation inhibition percentage was calculated as $75.59 \pm 0.73$. Additionally, strong anti-mutagenic activity (above 40%) was observed according to the standard “Ong” formula.24

In addition, the mean number of the grown colonies of this extract in anti-mutagenic studies in the presence of $S_9$ demonstrated a significant decrease ($125.66 \pm 1.37$ CFU, $P < 0.05$) compared with the positive control, showing a percentage of mutation inhibition of $84.79 \pm 0.17$ (Figures 2 and 3). As shown in Figure 2, the anti-mutagenic effect with $S_9$ was higher compared to the absence of $S_9$.

**Anti-mutagenic Activity of Lantana camara Flower Methanolic Extract**

Based on the results, the mean grown colonies significantly decreased ($416.66 \pm 3.38$ CFU) in the presence of the flower methanolic extract and the absence of $S_9$ ($P < 0.05$) compared with the positive control. Further, the mutation inhibition percentage was $49.57 \pm 0.55$ and anti-mutagenic was above 40% although it was significantly lower compared to the leaf extract ($P = 0.018$).

In the presence of $S_9$, the mean number of the grown colonies of the flower extract showed a significant decrease ($311.33 \pm 1.68$ CFU and $P < 0.05$) compared with the control. Furthermore, the percentage of mutation inhibition was $62.32 \pm 0.23$, and anti-mutagenic activity was also above 40% although it was significantly lower than that of the leaf extract ($P = 0.026$).

**Discussion**

The bacterial reverse mutation assay is a simple, rapid, and inexpensive assay for the detection of the mutagenic and anti-mutagenic activities of different substances. The damage of DNA by mutagens may be the main cause of most genetic defects and cancer. In addition, the anti-mutation and anti-cancer activities of plants are due to their secondary metabolites.25 Further, the plant structures of *L. camara* have many of these compounds which are accountable for several medical properties for treating diseases such as cancers, measles, chickenpox, asthma, edema, blood pressure, eczema, eye infections, tetanus, and malaria.27

These research findings represented that *L. camara* methanolic extracts had anti-mutation activities by applying the *Salmonella* typhimurium reverse mutation assay and the Ames test, which is in line with the results of Zare et al on the anti-mutation and anti-cancer activities of two species from the Verbenaceae family (*Lippia* genus), namely, *Lippia citriodora* and *Lippia nodiflora*, which were attributed to their flavonoids and essential oil components.28 Furthermore, Begum et al reported the existence of flavonoids as the components of *L. camara*.29

Our results are also in conformity with those of Ghasemian et al, demonstrating the effects of secondary metabolites on the anti-mutagenic and anti-oxidant activities of the pomegranate peel extracts of two cultivars (from Iran) using the Ames test. They also suggested that the existence of flavonoid compounds in these plants was responsible for these activities.31 Additionally, Ruberto and Baratta reported the anti-oxidant and anti-cancer activities of phenolic compounds.30 Meanwhile, phenolic compounds are found to be the major constituents in the plants of the Verbenaceae family, including *L. camara*,31 which can explain its anti-mutagenic activity.

In another study, Vicaña et al concluded that essential oils or fatty compounds (e.g., terpenoids) in the Verbenaceae family are responsible for anti-tumor and anti-carcinogenic effects by augmenting DNA repair mechanisms.32 Moreover, Sefidkon indicated

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**Figure 2.** Comparison of the Mean Number of Grown Colonies Between the Extracts of *Lantana camara* With the Control With $S_9$ (+ $S_9$) and Without $S_9$ (-$S_9$) ± Standard Error.

**Note.** The comparison was made at the 0.05 level. $S_9$ is a sterile extract of the mouse liver containing microsomal enzymes such as the cytochrome oxidase enzyme (P450) which causes the antitoxic action and inactivates oxidant and cancer compounds. In addition, the positive control contained sodium azide (NaN$_3$) as a mutagen per plate, and plates consisting of only sterile distilled water without any NaN$_3$ or the plant extract were considered as negative control.

**Figure 3.** Comparison of the Percentage of Mutation Inhibition Between the Extracts of *L. camara* With the Control With $S_9$ (+ $S_9$) and Without $S_9$ (-$S_9$) ± Standard Error.

**Note.** *L. camera: Lantana camera*. The comparison was made at the 0.05 level. $S_9$ is a sterile extract of the mouse liver containing microsomal enzymes such as the cytochrome oxidase enzyme (P450) which causes the antitoxic action and inactivates oxidant and cancer compounds. Further, the positive control contained sodium azide (NaN$_3$) as a mutagen per plate, and plates consisting of only sterile distilled water without any NaN$_3$ or the plant extract were considered as negative control.
that the vegetative and reproductive parts of *L. camara*, which were planted in Iran, contained essential oils and fatty compounds including β-caryophyllene (14.0% and 22.5%), sabinene (16.5% and 7.3%), 1,8-cineole (10.0% and 6.0%), humulene (6.0% and 10.8%), and bicyclogermacrene (8.1% and 18.5%). Therefore, the existence of the essential oils can partly be involved in the observed anti-mutagenic and anti-cancer activities of *L. camara* as well.

According to our results, the leaf extract demonstrated the highest anti-mutagenic effects in the presence of **S**<sub>1</sub>(+S<sub>2</sub>). Effective compounds (i.e., essential oil, flavonoid, and the like) are probably more abundant in the leaves as compared to the flowers of the plant, or the types of the compounds in the flowers probably differ from those of the leaves, which needs to be studied and analyzed in the future.

**Conclusion**

Generally, the findings of the research showed that the *L. camara* methanolic extracts of its flowers and leaves had potent anti-mutagenic activity against *Salmonella* typhimurium. These activities are probably related to the existence of flavonoids and different fatty compounds in this plant. The findings revealed that anti-mutagenic activity was higher in the leaf extract compared to the flowers. Thus, it is suggested that future studies directly investigate the anti-cancer activities of this plant on human and animal cancer cell lines.

**Ethical Approval**

Not applicable. There was no need for moral confirmation considering that bacterial samples were used in this study.

**Conflict of Interest Disclosure**

The authors declare that there is no conflict of interests.

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