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Original Research Article (Experimental)

Improved anticancer efficacy of plant leaf extracts from *homa* environment: A preliminary study

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ABSTRACT

Background: Medicinal plants have been the most important component of agro-ecosystems and the natural environment from the very beginning of life. Air, water, and soil have been significantly contaminated, adversely affecting the production and development of plants. Homa therapy, based on traditional Vedic knowledge, purportedly restores balance to nature and eliminates environmental pollutants. However, this approach must be comprehended in light of current scientific findings.

Objective: This study examined the comparative efficacy of leaves extracted from plants in Homa and non-Homa (control) environments for their anticancer potential in a cervical cancer cell line.

Materials and methods: The leaves of the selected medicinal plants–*Murraya koenigii* (curry), *Ocimum sanctum* (tulsi), *Aegle marmelos* (bael), and *Azadirachta indica* (neem), were collected from both locations, subsequently dried, and extracted using Soxhlet apparatus. The leaf extracts were examined for cytotoxicity in HeLa cells using the MTT assay. The rate of cell migration was assessed with a wound healing assay. Subsequently, intracellular reactive oxygen species (ROS) generation was evaluated using DCFDA. Additionally, gene expression was checked using quantitative polymerase chain reaction.

Results: Our findings indicate that Homa environment plants are significantly ($p < 0.05$) more effective against cervical cancer, as their IC_{50} values were comparatively low. The intracellular ROS generation assay demonstrated that Homa environment plants produced more ROS ($p < 0.05$) in cancer cells than those of non-Homa plants. Moreover, inhibited cell migration was more noticeable ($p < 0.05$) in Homa plants than non-Homa plants. The genes, *SOD1*, *CAT*, and *MMP9* were found to be significantly ($p < 0.05$) downregulated in Homa grown leaf extracts. The study's findings offer promising preliminary trends that the Homa farming environment may improve certain plants' therapeutic qualities, including their capability to fight against cancer.

1. Introduction

Medicinal plants have been a source of biologically active phytochemicals for ages, employed as raw materials or purified compounds to cure various diseases. Alkaloids, flavonoids, terpenoids, and polyphenols from these medicinal herbs have antioxidant, anti-inflammatory, antibacterial, and anticancer effects [1]. Medicinal plants support sustainable healthcare practices since their production and usage are less harmful to the environment than synthetic pharmaceuticals [2,3]. However, urbanization, increasing environmental pollution, and stress have reduced the efficacy of these medicinal plants.

Plants adapt to environmental stress by using their antioxidant properties, which protect chloroplasts and other photosynthesis-related cellular components from damage due to oxidative stress. But environmental factors, including extreme temperatures, radiation, and pollution, can reduce antioxidant levels in medicinal plants [4]. These stresses can cause an increase in reactive oxygen species (ROS), which can overwhelm the plant's antioxidant defenses. Environmental pollutants, including pesticides, industrial chemicals, and heavy metals, may accumulate in the soil and water where medicinal plants are cultivated.

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These pollutants are assimilated by the plant and sequestered in its tissues, thereby modifying its chemical makeup and diminishing its health benefits [5]. In addition to pollutants, pesticides and herbicides may significantly affect the soil and water quality and increase toxic substances in medicinal plants [6].

The convention on biological diversity, often known as the Rio Convention, suggests using all methods, including traditional knowledge, to solve these challenges [7]. Homa therapy, based on vedic wisdom, purifies the atmosphere by restoring nature. This method used by Rishis and Maharishis was successful in ancient times. Homa farming employs a straightforward approach known as 'Agnihotra,' where 'Agni' signifies 'fire' and 'hotra' denotes 'healing' (a detailed description of Homa therapy following Agnihotra is provided in Supplementary File 1). It involves the recitation of a Sanskrit mantra at a specific time of day before a holy fire [8]. Agnihotra ash is believed to balance pH and enhance the soil's essential bacterial flora along with purifying water from pathogenic bacteria [9]. Experts believe that Homa farming is a scientific approach that emphasizes atmospheric fumigation, a crucial element in maintaining crop health against diseases [10]. This therapy serves to restore the natural balance and produce a type of microclimate surrounding the farm. It has been demonstrated to help purify the atmosphere and enhance product output and quality by utilizing the most fundamental Yagya, known as Agnihotra, which is synchronized with the biorhythm of dawn and sunset [9].

During photosynthesis, Photosystem II (PSII), a protein complex that splits water molecules using light energy, is the compartment most prone to abiotic stresses. This stress diminishes the electron transport chain, thereby resulting in a decrease in photosynthesis [11]. Homa organic farming (Agnihotra atmosphere) has been shown to improve PSII efficiency by minimizing damage and helping in repair and protection processes [12]. The Agnihotra was also found to dramatically improve photochemical efficiency, vegetation morphology, and the amount of active reaction center processes [12].

Although Homa therapy has demonstrated improved environmental conditions and more substantial plant quality, there is currently no evidence to suggest that Homa therapy promotes the therapeutic properties of plants cultivated in a Homa environment. Hence, an *in vitro* study on the cervical cancer cell line, HeLa, was designed to investigate the enhanced therapeutic (anti-cancerous) properties of some medicinal plants from Homa organic farming in comparison to those collected from 4 to 5 km away in a non-Agnihotra atmosphere.

2. Materials and methods

2.1. Collection and details of plant samples

The selected plants for this study have natural therapeutic properties and require the same climatic and soil conditions for their optimum growth (Table 1). Four different plant species types selected for this study were *Murraya koenigii* (curry), *Ocimum sanctum* (tulsi), *Aegle marmelos* (bael), and *Azadirachta indica* (neem). The samples were collected from two locations: one from Homa Therapy Goshala in Maheshwar, Madhya Pradesh, India, and the other from a site located 4–5 km away in a non-Agnihotra environment. After collection, the samples were encoded and sent for identification: CB (Control Bael), CC (Control Curry), CN (Control Neem), CT (Control Tulsi), HB (Homa Bael), HC (Homa Curry), HN (Homa Neem), and HT (Homa Tulsi).

Table 1
Detail of plants selected for the study.

Plant species	Common name	Therapeutic Property	References
Murraya koenigii	Curry	Antitumor, antioxidant, anti-inflammatory, antihyperglycemic, and hypoglycaemic effects	[13–15]
Ocimum sanctum	Tulsi	Anti-cancer,antioxidant, antidiabetic, anti-inflammatory, and antimicrobial	[16–19]
Aegle marmelos	Bael	Antidiarrheal, antioxidant, antidiabetic, hepatoprotective, anti-cancer, antiulcer	[20–22]
Azadirachta indica	Neem	Anti-cancer, antioxidant, antiviral, antibacterial, antifungal, antimalarial, antiulcer, antidiabetic, and anti-inflammatory	[23–28]

All collected plant samples were preliminarily identified with the help of a species key available in published flora, based on taxonomic characters and the traditional knowledge system. To get quality plant material, herbarium voucher specimens of each species were collected and processed to prepare herbarium sheets following the standard herbarium techniques proposed by Jain and Rao (1977) and finally deposited in the herbarium of the CSIR-Institute of Himalayan Bioresource Technology (CSIR-IHBT), Palampur, Himachal Pradesh, India, as recognized by the New York Botanical Garden (acronym –PLP, 2007) for authentication of reference material. Samples were identified as *Aegle marmelos* (Bael), *Murraya koenigii* (Curry), *Azadirachta indica* (Neem), and *Ocimum sanctum* (Tulsi) with herbarium numbers PLP-108921, PLP-108922, PLP-108923, PLP-108924, PLP-108925, PLP-108926, PLP-108927, and PLP-108928 for CB, CC, CN, CT, HB, HC, HN, and HT, respectively.

2.2. Description of site

The Homa Therapy Goshala, covering a 36,422 m^2 area in Maheshwar, M.P., India, was selected as a site to examine the impact of Agnihotra on naturally occurring vegetation. It is located in Khargone district, Madhya Pradesh, India, between Maheshwar and Mandleshwar (75.6210° East, 22.1736° North). Agnihotra has been conducted there consistently since 2001 [9,29,30]. For comparison, the same plants were chosen at a non-Agnihotra location situated 4–5 km away from the Homa Therapy Goshala.

2.3. Reagents

Dulbecco's modified Eagle's medium (DMEM), antibiotic-antimycotic (Ab/Am) solution, fetal bovine serum (FBS), trypan blue, and 0.25 % trypsin-EDTA solution were provided by Gibco (Thermo Fisher Scientific, USA). Dichlorofluorescein diacetate (DCFDA), 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide tetrazolium salt (MTT), dimethyl sulfoxide (DMSO), and phosphate buffered saline (PBS) were obtained from Sigma Chemical Co. (St. Louis, MO, USA), and molecular-grade ethanol and Methanol from Lab Chem Quality Solution. RevertAid First Strand cDNA Synthesis kit, RNAiso Plus (Takara, Japan), and DyNAmo ColorFlash SYBR Green qPCR kit were obtained from Thermoscientific.

2.4. Preparation of plant extracts

Leaves were cleaned thoroughly with running tap water and were allowed to soak in water for 15 min to remove mud and other particles. Leaves were then cleaned with distilled water and dried for 8–10 days in shade at room temperature (Fig. 1) and then ground into a powder. The extracts were prepared using the solvents methanol (for *O. sanctum* and *A. marmelos*) and 75% ethanol (for *M. koenigii* and *A. indica*) in a Soxhlet apparatus [21,31–33]. The extraction procedure was carried out in 6–8 working hours for two to three days at a temperature of 60–70°C using a heating mantle. The leaf extracts formed were then concentrated using a rotary evaporator. To determine the extraction yield, the following formula was used:

$$\%Yield\ of\ extract = \frac{Weight\ of\ extract\ from\ plant}{Weight\ of\ dried\ plant\ sample} \times 100$$



Fig. 1. Different plant samples after being dried in the shade for 7–8 days. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2.5. Maintenance of HeLa cell line

The HeLa (HPV18+) human cervical cancer cell line was acquired from the National Centre for Cell Science (NCCS) in Pune, India. HeLa cells were grown in DMEM with 10 % FBS and 1 % antibiotic-antimycotic solutions in an incubator with 5 % CO_2 and 95 % humidity at 37 °C. The presence of mycoplasma contamination was monitored by routine evaluation. Cells with 12–15 passages were employed in subsequent experiments.

2.6. Cell viability via MTT assay

The DMEM-cultured HeLa cells were allowed to reach confluency (70–80%). The cells were separated with trypsin and seeded into 96-well plates at 5×10^3 cells/well in triplicate. Following a 24-h incubation period at 37°C to promote adhesion, the HeLa cells were exposed to several concentrations of different leaf extracts of both environments: *M. koenigii* (curry), *O. sanctum* (tulsi), *A. marmelos* (bael), and *A. indica* (neem) at 10, 20, 30, 40, 50, 60, 70, and 80 μg/ml. After an incubation of 24 h, 10 μl of MTT (5 mg/ml) was added and incubated for another 3 h. After aspirating the medium, 100 μl of DMSO was added to each well to dissolve the formazan crystals, and live cell proportions were estimated using a BioTek Epoch 2 microplate reader at 540 nm [34]. Similarly, the cytotoxicity of plant extracts from Homa environment was checked on normal cell line, HaCaT. The following formula, mentioned in the equation, is used to evaluate cell viability:

$$\textit{Viable cells}\ (\%) = \frac{\textit{Absorbance of exposed cells}}{\textit{Absorbance of unexposed cells}} \times 100$$

2.7. Wound healing assay

Cancer cell migration was assessed using the wound healing assay [35]. Cells were cultured for 24 h in 6-well plates. When cells reached 70–80% confluency, a 200 μl sterile tip was used to scratch at the center of each well. The cells were exposed to *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica* extracts from both environments at a concentration of 60 μg/ml for 24 h. Images from the scratch site recorded migratory area variation from 0 to 24 h. The images were taken at magnification × 200 using inverted phase contrast microscopy (Nikon Eclipse Ti2, Japan). Measurements of the wound area were taken using the ImageJ (Fiji) program.

2.8. Intracellular ROS measurement

Intracellular ROS production was measured using

dichlorodihydrofluorescein diacetate DCFDA [35,36]. In 12-well plates, 1×10^5 cells per well were seeded with fresh medium for 24 h. Cells were treated at a concentration of 60 μg/ml with all the leaf extracts from Homa and non-Homa environments (*M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica*) and incubated for another 24 h. The medium was carefully removed, and wells were washed with 1 × PBS. Plates were incubated at 37°C for 30 min in the dark after adding 10 μM DCFDA to each well. The cells were examined under a fluorescence microscope (Nikon Eclipse Ts2, Japan) after washing twice with 1 × PBS. Magnification × 200.

2.9. RNA isolation and real-time polymerase chain reaction (RT-PCR)

Total RNA was extracted from HeLa cells using the TRIzol reagent (Invitrogen, USA). RNA purity and concentration were assessed with a NanoDrop spectrophotometer (Wilmington, DE, USA). Complementary DNA (cDNA) was synthesized using the RevertAid First Strand cDNA Synthesis Kit (Thermo Fisher Scientific, USA) following the manufacturer's instructions. Real-time PCR was performed using the DyNAmo Flash SYBR Green 2X master mix (Thermo Fisher Scientific, USA) along with gene-specific primers for *SOD1*, *CAT*, *MMP9*, and *GAPDH* (primer sequences provided in Supplementary file 2). Fold changes were calculated using the ΔΔCt method using *GAPDH* as an endogenous control for the relative measurement of gene expression [37]. All reactions were conducted using three duplicates each.

2.10. Statistical analysis

The IC_{50} values were calculated by nonlinear regression analysis using GraphPad Prism 8.0. The percent cell viability was fitted to a four-parameter logistic (4PL) model (log[inhibitor] vs. response - variable slope). The curve estimated the top and bottom plateaus, hill slope, and logIC_{50}. The fitted parameters were used to automatically calculate the IC_{50}. Results are displayed as mean ± SEM. All treatment groups were compared with their respective controls using the analysis of variance (ANOVA) with a Tukey Multiple Comparison Test and unpaired two-tailed Student's t-test (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ indicating significant differences). The software programs used to perform statistical analysis were ImageJ (Fiji) software, Microsoft Excel, and GraphPad Prism v. 8.0.

3. Results

3.1. Total yield of different plant extracts

Percentage yields of control and Homa environment plants are shown in Table 2.

3.2. MTT assay analysis

Results of the MTT assay revealed that treatment of HeLa cells with the leaf extracts of plants from the Homa environment showed significantly more cytotoxicity as compared to those from the control environment treatments (Fig. 2). Whereas no toxicity was observed in the normal HaCaT cell line. The methanolic extracts of *O. sanctum* and *A. marmelos* of Homa environment were found to have lower half-maximal inhibitory concentration (IC_{50}) values than those of their respective control sites, indicating their better efficacy against the HeLa cervical cancer cell line. Similarly, the ethanolic extracts of *M. koenigii* and *A. indica* of Homa site resulted in enhanced anticancer potential against the cervical cancer cell line compared to that of the control environment plants. As mentioned in Table 3, lower IC_{50} values were observed in the case of extracts prepared from plants grown in the Homa environment than those of control environment plants. The IC_{50} curves of all plant extracts have been provided in supplementary file 3.

Table 2
Total percentage yield of all plant sample extracts and the respective solvents use.

Plant sample (Leaves)	Environment	Dry weight (g)	Extract weight (g)	Percentage yield (%)	Solvent used
M. koenigii	Control	20	1.41	7.05	Ethanol
	Homa	20	1.57	7.85	
O. sanctum	Control	24	1.53	6.37	Methanol
	Homa	25	1.71	6.84	
A. marmelos	Control	11.9	1.61	13.53	Methanol
	Homa	11.9	1.66	13.94	
A. indica	Control	20	3.15	15.75	Ethanol
	Homa	20	2.95	14.75	

3.3. Evaluation of wound healing assay

The capacity of the cells to migrate was assessed by means of an inverted phase contrast microscope. For the wound-healing potential of HeLa cells, plant extracts from Homa and control environments were compared after 24 h of scratching. Consequently, the results indicate a significant inhibition of wound healing or migration in HeLa cells treated with Homa environment plant extracts, in contrast to the plant samples acquired from the control environment (Fig. 3). As seen in Fig. 3b, the percentage scratch area of leaf extracts from control environment showed lower scratch percentage than those of leaf extracts collected from Homa farming environment.

3.4. Intracellular ROS generation in HeLa cell line

Cellular reactive oxygen species (ROS) levels were monitored after 24 h in both control and Homa environment-treated cells. After treatment with 60 μg/ml of *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica* of control and Homa environment, the DCF-fluorescence intensity in the HeLa cells was found to be significantly higher in the cells treated with Homa environment plant extracts. As shown in Fig. 4, leaf extracts from both environments generated intracellular reactive oxygen species (ROS) in the HeLa cells; however, extracts from the Homa environment exhibited substantially higher ROS production than those from non-Homa(control) environment.

3.5. Effect of homa environment on expression of SOD1, CAT and MMP9 genes

The gene expression analysis was performed to determine the fold change of antioxidants and migratory gene in control and Homa environment. As shown in Fig. 5, the genes *SOD1* and *CAT* were found to be altered in Homa grown *M. koenigii*, *O. sanctum*, *A. marmelos* leaf extracts. Likewise, the expression of *MMP9* was found to be significantly affected by Homa grown *M. koenigii* and *A. marmelos* leaf extracts.

4. Discussion

Pollution is a major issue that impacts all living forms, including animals and plants. It alters the morphology and chemical composition of plants, leading to a reduction in their medicinal effectiveness. Homa organic farming approaches solve this problem by purifying the atmosphere and increasing the productivity of plants grown in these areas [9,11,12]. The present work was a comparative study to evaluate whether the leaves of four medicinal plants, *viz., Murraya koenigii* (curry), *Ocimum sanctum* (tulsi), *Aegle marmelos* (bael), and *Azadirachta indica* (neem), grown in Homa environment enhanced the anti-cancerous property.

Plant samples were extracted using two different solvents in order to maximize the yield. Literature indicated that the solvent employed for the leaf extract of *Ocimum sanctum* (tulsi) and *Aegle marmelos* (bael) was

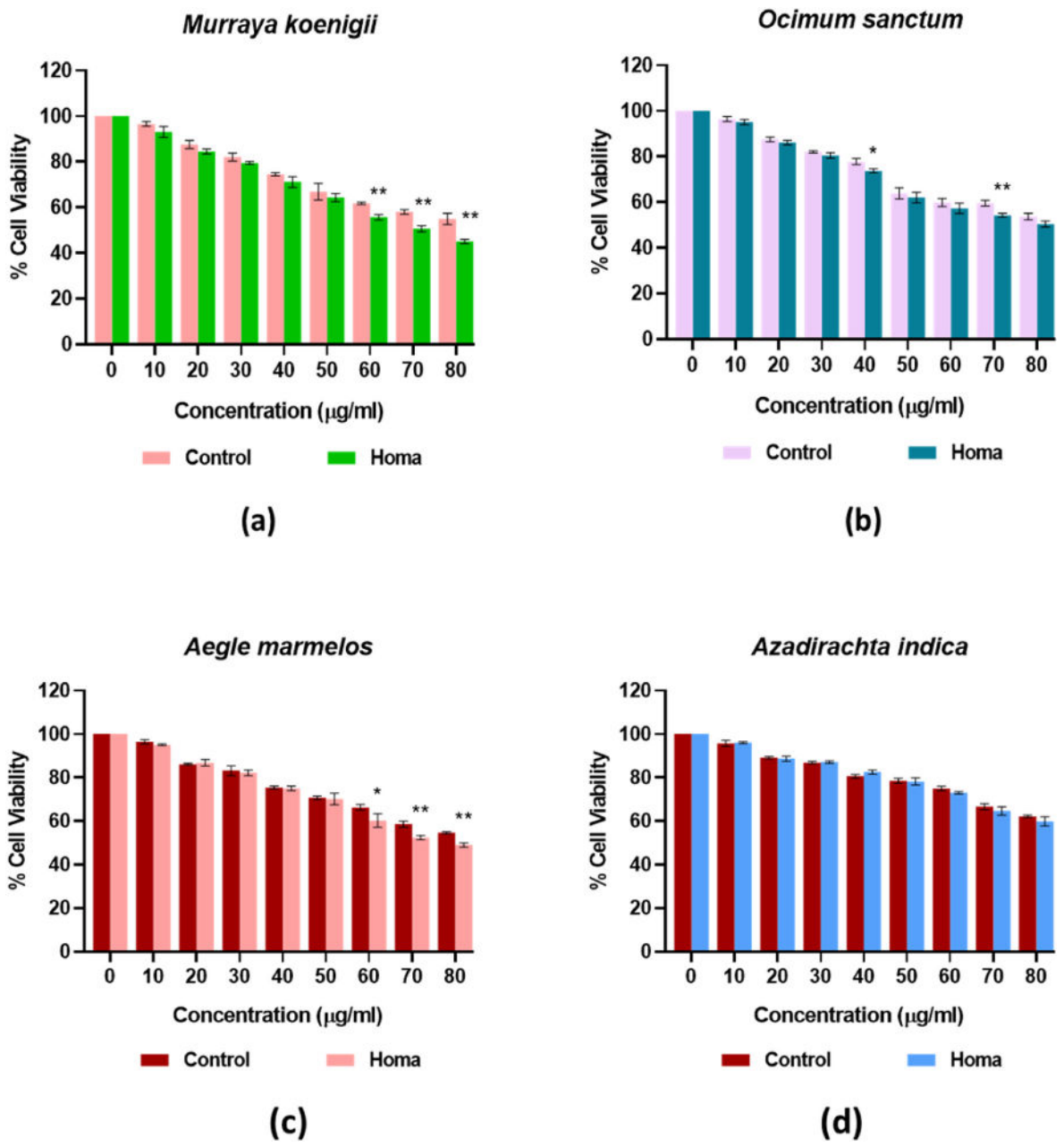


Fig. 2. Graphs showing percent cell viability of HeLa cells after MTT assay following 24-h treatment with the leaf extracts of *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica* taken from Control and Homa environments. The results of three separate experiments in triplicate are presented as mean ± SEM (statistical significance, *p < 0.05, **p < 0.01 relative to the control group of each leaf extract). (a) *M. koenigii*; (b) *O. sanctum*; (c) *A. marmelos*; (d) *A. indica*.

Table 3
Calculated IC_{50} values of leaf extracts of plants grown in control and Homa and control environment against cervical cancer cell line.

Plants	Half-maximal inhibitory concentration (IC_{50}) in µg/ml	
	Control	Homa
M. koenigii (Curry)	59.7	52.1
O. sanctum (Tulsi)	58.57	54
A. marmelos (Bael)	68.3	57.2
A. indica (Neem)	79.26	75.74

methanol, while ethanol was used for *Murraya koenigii* (curry) and *Azadirachta indica* (neem), since these solvents demonstrated better yield compared to others [21,31–33]. Based on the calculated percentages of total yield from all extracts, a higher yield was noted in the plants cultivated under Homa organic farming compared to the control, with the exception of *Azadirachta indica* (neem) extract.

The cytotoxic effects of *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica* leaf extracts of both collection sites were assessed on human HeLa cells for a 24-h period at varying concentrations. Our results indicated that the plants collected from the Homa-therapy environment, where Agnihotra is routinely practiced, showed significantly enhanced anti-cervical cancer efficacy, particularly in *M. koenigii* and *A. marmelos,* as evidenced by their lower IC_{50} values in comparison to those from control (non-Homa) environments. The anticancer effects may be possibly due to enhancement of phytochemical constitution, like alkaloids, flavonoids, and phenolics, in the plants grown in Homa environment [38,39].

Cancer cells produce ROS due to their greater metabolic rate and its increased concentration is crucial for the growth, proliferation, and

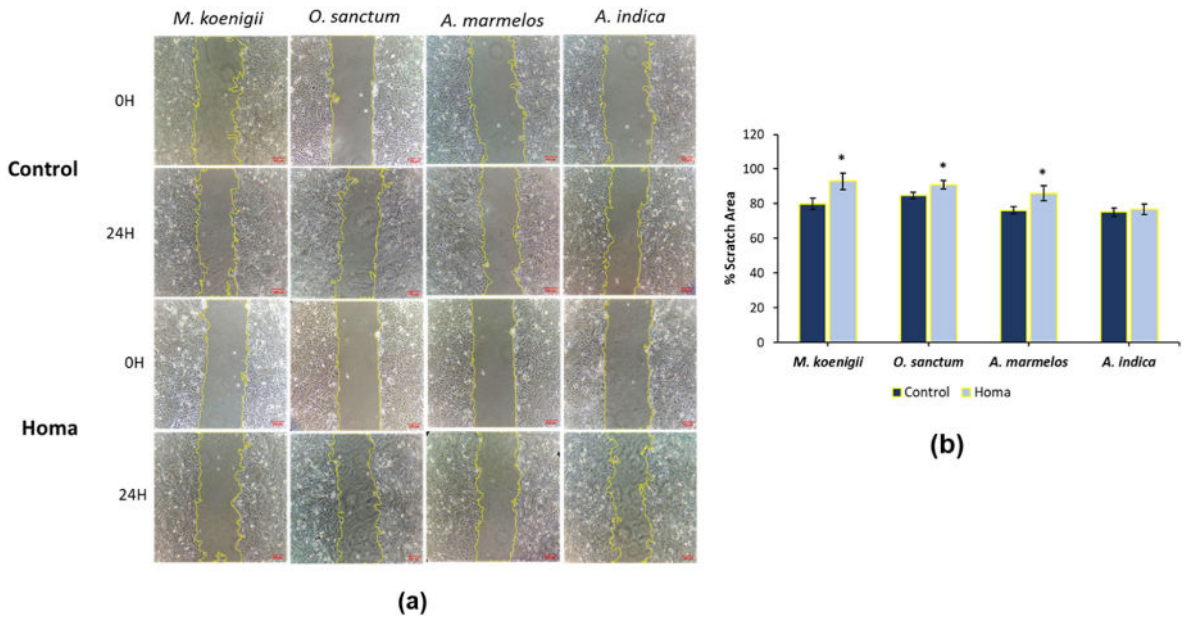


Fig. 3. HeLa cells showing wound healing in (a) a control group with no treatment and in groups treated with leaf extracts of different plants: *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica*, at a concentration of 60 μg/ml at 0 h and 24 h. (b) A quantitative comparison between the scratch area percentage of leaf extracts from two different environments (Homa and Control). Data presented as mean ± SEM from three different experiments (statistical significance, *p < 0.05 relative to control group of each leaf extract).

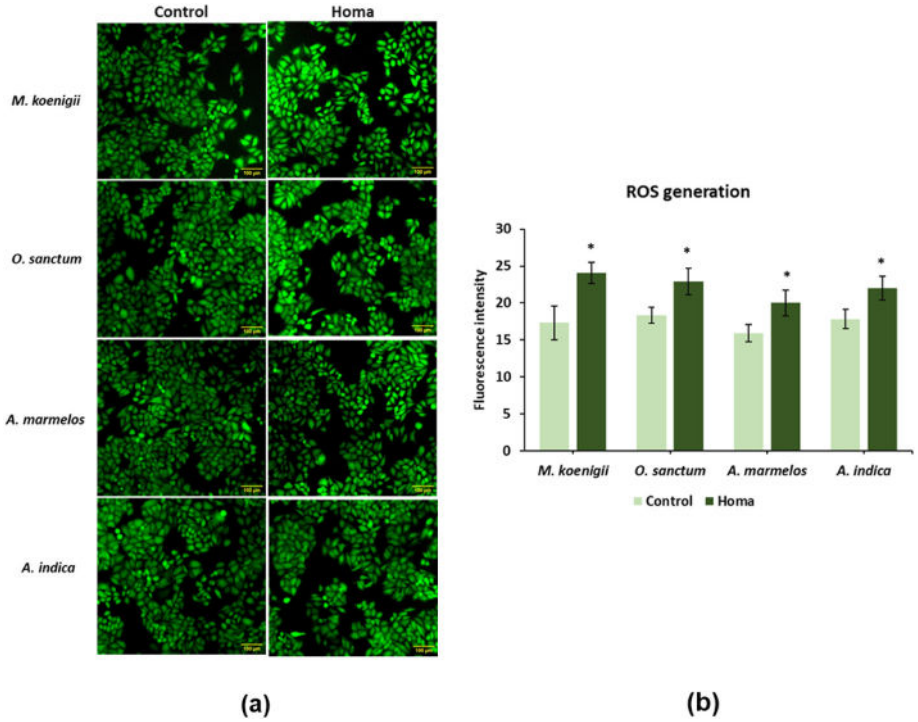


Fig. 4. HeLa cells treated with *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica* in both control and Homa environments at a concentration of 60 μg/ml showed enhanced ROS generation under a fluorescence microscope. (a) ROS production in HeLa cells with different leaf extracts: *M. koenigii*, *O. sanctum*, *A. marmelos*, and *A. indica*. (b) ROS levels in HeLa cells as a percentage of DCFDA fluorescence. Data represent the mean ± SEM from three independent experiments. (statistical significance, *p < 0.05).

metastasis of cancer cells [40]. Excessive ROS may induce oxidative stress in cancer cells, potentially resulting in cell death [41]. The current study demonstrates that treatment with Homa organic farming plant samples results in significant elevation in the production of ROS in cervical cancer cells (Fig. 4). Cancer cells, unlike normal cells, have a deficient antioxidant system necessary for mitigating excess ROS and preventing related cellular damage [41]. In this study, the antioxidants like *SOD1* and *CAT* were also found to be downregulated in Homa-treated groups as compared to non-treated groups particularly in *M. koenigii*, *O. sanctum,* and *A. marmelos.*

This study also assessed the impact of Homa environment plants on the migratory capability of cervical cancer cells by using the "wound

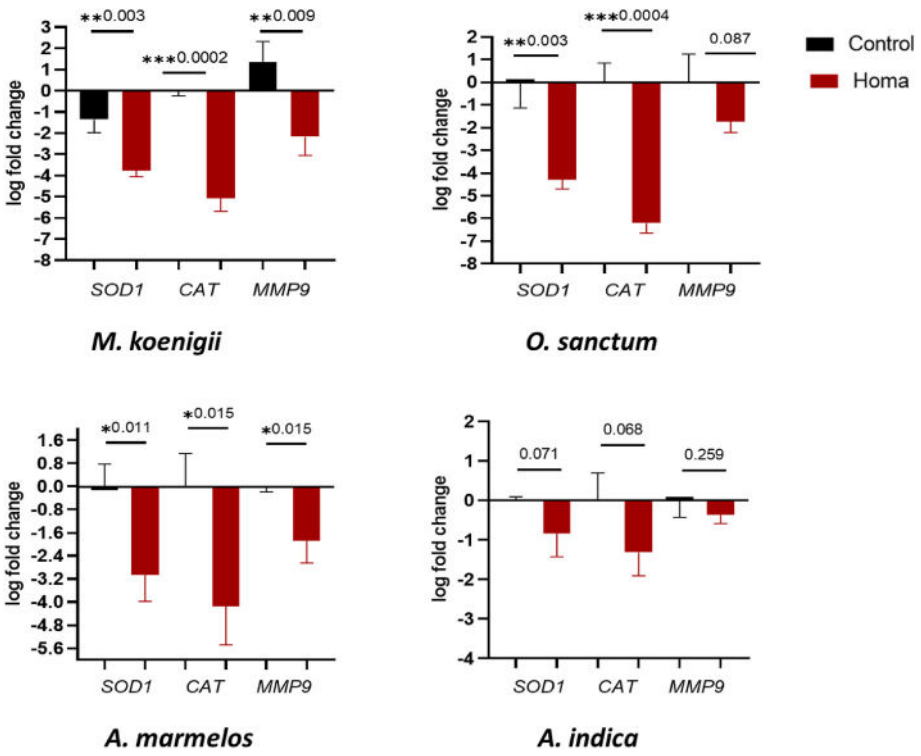


Fig. 5. Real-time PCR data showing altered expression levels of *SOD1*, *CAT* and *MMP9* genes in Homa treated group. (statistical significance, *p < 0.05, **p < 0.01, ***p < 0.001).

healing" assay [42]. Results indicated that plants from Homa organic farming markedly inhibited the migratory capacity of cervical cancer cells. According to the observations, *M. koenigii* and *O. sanctum* of Homa environment exhibited a maximum scratch area of 92.83% and 90.91%, demonstrating their ability to block the migration of cervical cancer cells (Fig. 3b). Moreover, *M. koenigii* and *O. sanctum* in a controlled environment have higher scratch area compared to *A. marmelos* and *A. indica*. The significant downregulated expression of *MMP9* in Homa grown *M. koenigii* leaf extracts also supported its enhanced anti-migration ability.

Our observations indicated that plants from Homa organic farming may be more effective than those from non-Homa environments in decreasing cell proliferation, reducing cell viability, increasing ROS levels, and preventing cell migration in cervical cancer cells. Further study may be required to substantiate the efficacy of the therapeutic properties of these plants in the Homa environment.

The drugs and treatment options currently available do not fully cure or reverse the adverse effects of the disease [43,45]. Additionally, current cancer therapies have socioeconomic costs associated with prolonged attendance, and hospital expenses escalate each year [44]. This necessitates the formulation of safer alternative medicines that have been utilized since antiquity. Homa method of cultivation is low-cost and its results in cancer inhibition may yield a low-input, non-chemical means of enhancing plant extract biomedical application.

5. Limitations

Since, it was a preliminary study, it did not evaluate the specific bioactive compounds in the extracts. The study also does not evaluate the anti-cancer potential and combinatorial effects in *in vivo* models and long-term toxicities to draw conclusive results.

6. Conclusion

The Homa habitat has shown an improvement in the anticancer effects particularly in *M. koenigii* and *A. marmelos*. However, the effect of other environmental factors like soil nutrients, pollutants or microclimatic conditions remain untested. Future research may be undertaken to identify and quantify specific bioactive compounds and include other cancer models for anti-cancerous validation.

Data statement

Data supporting the findings of this study are accessible within the article and supplementary materials.

Author contributions

PS: Conceptualization, Formal analysis and investigation, Methodology, Writing – original draft. SM: Conceptualization, Methodology, Writing-review and editing. OM: Methodology, Writing-review and editing. AK: Formal analysis and investigation, Writing-review and editing UB: Formal analysis and investigation, Writing – original draft. MB: Conceptualization, Funding acquisition, Resources, Supervision, Writing – review and editing.

Declaration of generative AI in scientific writing

The authors declare that this article did not use generative AI or AI-assisted technologies.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaim.2025.101316.

References

[1] Mapeka T, Sandasi M, Ncube E, Viljoen A, Van Vuuren S. Enhancing the antimicrobial efficacy of common herbs and spices through an optimized polyherbal approach. South Afr J Bot 2024;164:91–9. https://doi.org/10.1016/j.sajb.2023.11.030.

[2] Trifunovic-Momcilov M, Krstic-Milosevic D, Trifunovic S, Ciric A, Glamoclija J, Jevremovic S, et al. ANTIMICROBIAL ACTIVITY, ANTIOXIDANT POTENTIAL AND TOTAL PHENOLIC CONTENT OF TRANSGENIC ATCKX1 CENTAURY (Centaurium erythraea Rafn.) PLANTS GROWN IN VITRO. Environ Eng Manag J 2019;18:2063–72. https://doi.org/10.30638/eemj.2019.196.

[3] Theodoridis S, Drakou EG, Hickler T, Thines M, Nogues-Bravo D. Evaluating natural medicinal resources and their exposure to global change. Lancet Planet Health 2023;7:e155–63. https://doi.org/10.1016/S2542-5196(22)00317-5.

[4] Zargoosh Z, Ghavam M, Bacchetta G, Tavili A. Effects of ecological factors on the antioxidant potential and total phenol content of Scrophularia striata boiss. Sci Rep 2019;9:16021. https://doi.org/10.1038/s41598-019-52605-8.

[5] Husen A. Plants and their interaction to environmental pollution: damage detection, adaptation, tolerance, physiological and molecular responses. Amsterdam Oxford Cambridge, Mass: Elsevier; 2023.

[6] Shentu J, Fang Y, Wang Y, Cui Y, Zhu M. Bioaccessibility and reliable human health risk assessment of heavy metals in typical abandoned industrial sites of southeastern China. Ecotoxicol Environ Saf 2023;256:114870. https://doi.org/10.1016/j.ecoenv.2023.114870.

[7] Morgera E, Tsioumani E. Yesterday, today, and tomorrow: looking afresh at the convention on biological diversity. Yearb Int Environ Law 2010;21:3–40. https://doi.org/10.1093/yiel/yvr003.

[8] Bhatia S, Rohilla A, Kaushal S. A review on homa farming – a vedic touch to modern agriculture. IJAAST 2022;9:14–25. https://doi.org/10.47856/ijaast.2022.v09i05.003.

[9] Berk U. Impact of homa organic farming in mitigating soil, water, and other environmental crises. Int J Power Eng 2020;6:56–67. https://doi.org/10.18811/ijpen.v6i01.07.

[10] S KC, Srivastava S, Rashmi I, R TK, Rosin KG, Kumar S. Homa Farming- science behind concepts and methodologies. 2016.

[11] Gururani MA, Venkatesh J, Tran LSP. Regulation of photosynthesis during abiotic stress-induced photoinhibition. Mol Plant 2015;8:1304–20. https://doi.org/10.1016/j.molp.2015.05.005.

[12] Singh H, Agrawal SB, Agrawal M, Berk U. Comparative evaluation of dynamic photosynthetic performance of plants by chlorophyll fluorescence related parameters in and outside of agnihotra atmosphere. Int J Power Eng 2023;9:333–42. https://doi.org/10.18811/ijpen.v9i04.05.

[13] Dineshkumar B, Mitra A, Mahadevappa M. Antidiabetic and hypolipidemic effects of mahanimbine (carbazole alkaloid) from Murraya koenigii (Rutaceae) leaves, 2; 2011. https://doi.org/10.5138/ijpm.2010.0975.0185.02004.

[14] Muthumani P, Venkatraman S, Ramseshu KV, Meera R, Devi P, Kameswari B, et al. Pharmacological studies of anticancer, anti inflammatory activities of Murraya koenigii (Linn) spreng in experimental animals. J Pharmaceut Sci Res 2009;1:137–41.

[15] Tembhurne S, Sakarkar D. Hypoglycemic effects of fruit juice of Murraya koenigii (L) in alloxan induced diabetic mice. Int J PharmTech Res 2009;1:1589–93.

[16] Khan N, Xia K, Perveen N. Phytochemical analysis, antibacterial and antioxidant activity determination of Ocimum sanctum. Pharm & Pharmacol Int J 2018;6. https://doi.org/10.15406/ppij.2018.06.00223.

[17] Luke AM, Patnaik R, Kuriadom ST, Jaber M, Mathew S. An in vitro study of Ocimum sanctum as a chemotherapeutic agent on oral cancer cell-line. Saudi J Biol Sci 2021;28:887–90. https://doi.org/10.1016/j.sjbs.2020.11.030.

[18] Malairaman U, Mehta V, Sharma A, Kailkhura P. ANTIOXIDANT, anti-inflammatory, and antidiabetic activity of hydroalcoholic extract of ocimum sanctum: an in-vitro and in-silico study. Asian J Pharmaceut Clin Res 2016;9:44. https://doi.org/10.22159/ajpcr.2016.v9i5.12713.

[19] Manaharan T, Thirugnanasampandan R, Jayakumar R, Kanthimathi MS, Ramya G, Ramnath MG. Purified essential oil from Ocimum sanctum linn. Triggers the apoptotic mechanism in human breast cancer cells. Pharmacogn Mag 2016;12:S327–31. https://doi.org/10.4103/0973-1296.185738.

[20] Ahmad W, Amir M, Ahmad A, Ali A, Ali A, Wahab S, et al. Aegle marmelos leaf extract phytochemical analysis, cytotoxicity, in vitro antioxidant and antidiabetic activities. Plants 2021;10:2573. https://doi.org/10.3390/plants10122573.

[21] Monika S, Thirumal M, Kumar P. Phytochemical and biological review of *Aegle Marmelos* linn. Future Sci OA 2023;9. https://doi.org/10.2144/fsoa-2022-0068. FSO849.

[22] Rahman S, Quader M, Khan I. Prevention of peptic ulcer by aqueous extract of Aegle marmelos leaf in rats. IMC J Med Sci 2018;12:11. https://doi.org/10.3329/imcjms.v12i1.35171.

[23] Azhagu M. Phytochemical analysis and anticancer activity of Azadirachta indica ethanolic extract against A549 human lung cancer cell line. J Biomed Res Environ Sci 2021;2:280–5. https://doi.org/10.37871/jbres1225.

[24] Biney E, Nkoom M, Darkwah W, Puplampu J. High-performance liquid chromatography analysis and antioxidant activities of extract of Azadirachta indica (Neem) leaves. Phcog Res 2020;12:29. https://doi.org/10.4103/pr.pr_14_19.

[25] Deshpande PK. Phytochemical analysis and evaluation of antimalarial activity of Azadirachta indica. Pharm Innov 2014;2(3):12–6.

[26] Ezeigwe O, Ezeonu F, Ngozi N. Phytochemistry and antidiabetogenic property of aqueous extract of Azadirachta indica leaf in streptozotocin-induced diabetic rats. J Phytopharmacol 2020;9:155–63. https://doi.org/10.31254/phyto.2020.9301.

[27] Hikaambo CN, Kaacha L, Mudenda S, Nyambe MN, Chabalenge B, Phiri M, et al. Phytochemical analysis and antibacterial activity of *Azadirachta indica* leaf extracts against *Escherichia coli* PP, 13; 2022. p. 1–10. https://doi.org/10.4236/pp.2022.131001.

[28] Leontopoulos S, Skenderidis P, Anatolioti V, Kokkora M, Tsilfoglou S, Petrotos K, et al. Antifungal activity of Azadirachta indica aqueous and non-aqueous extracts on Colletotrichum gloeosporioides, Botryodiplodia theobromae and fusarium solani. A first approach. Int J Food Biosyst Eng 2017;6:38–50.

[29] Berk U, Johnson B. Research paper agnihotra and homa therapy for sustainable living. Int J Glob Sci Res 2022;9:1804–30. https://doi.org/10.26540/ijgsr.v9.i2.2022.210.

[30] Singh H, Agrawal SB, Agrawal M, Berk U. Comparative evaluation of dynamic photosynthetic performance of plants by chlorophyll fluorescence related parameters in and outside of agnihotra atmosphere. Int J Power Eng 2023;9:333–42. https://doi.org/10.18811/ijpen.v9i04.05.

[31] Sasidharan I, Menon AN. Effects of temperature and solvent on antioxidant properties of curry leaf (Murraya koenigii L.). J Food Sci Technol 2011;48:366–70. https://doi.org/10.1007/s13197-010-0134-x.

[32] Chaudhary A, Sharma S, Mittal A, Gupta S, Dua A. Phytochemical and antioxidant profiling of Ocimum sanctum. J Food Sci Technol 2020;57:3852–63. https://doi.org/10.1007/s13197-020-04417-2.

[33] Hashim N, Abdullah S, Hassan LS, Ghazali SR, Jalil R. A study of neem leaves: identification of method and solvent in extraction. Mater Today Proc 2021;42:217–21. https://doi.org/10.1016/j.matpr.2020.11.726.

[34] Sachan A, Mishra RK, Shweta Avinashi SK, Sharad P, Masood S, et al. Synthesis of Al2O3-Reinforced SrO–SiO2–K2O glasses with enhanced optical, and biological properties for biomedical applications. Sci Rep 2025;15:36607. https://doi.org/10.1038/s41598-025-20343-9.

[35] Parveen S, Masood S, Kumar S, Banerjee M. Phytonanomedicine: a therapeutic approach for cervical cancer. OpenNano 2023;13:100178. https://doi.org/10.1016/j.onano.2023.100178.

[36] Kumar S, Parveen S, Swaroop S, Banerjee M. TNF-α and MMPs mediated mucus hypersecretion induced by cigarette smoke: an in vitro study. Toxicol Vitro 2023;92:105654. https://doi.org/10.1016/j.tiv.2023.105654.

[37] Masood S, Kushwah AS, Srivastava K, Banerjee M. Association of CDH1 gene variant C > A (rs16260) with expression and treatment outcomes in cervical cancer patients receiving chemoradiotherapy. Gene Reports 2025;41:102344. https://doi.org/10.1016/j.genrep.2025.102344.

[38] Samanta SK, Kandimalla R, Gogoi B, Dutta KN, Choudhury P, Deb PK, et al. Phytochemical portfolio and anticancer activity of Murraya koenigii and its primary active component, mahanine. Pharmacol Res 2018;129:227–36. https://doi.org/10.1016/j.phrs.2017.11.024.

[39] Manandhar B, Paudel KR, Sharma B, Karki R. Phytochemical profile and pharmacological activity of Aegle marmelos linn. J Integr Med 2018;16:153–63. https://doi.org/10.1016/j.joim.2018.04.007.

[40] Liou G-Y, Storz P. Reactive oxygen species in cancer. Free Radic Res 2010;44:479–96. https://doi.org/10.3109/10715761003667554.

[41] Qian Q, Chen W, Cao Y, Cao Q, Cui Y, Li Y, et al. Targeting reactive oxygen species in cancer via Chinese herbal medicine. Oxid Med Cell Longev 2019;2019:1–23. https://doi.org/10.1155/2019/9240426.

[42] Kim D, Xing T, Yang Z, Dudek R, Lu Q, Chen Y-H. Epithelial mesenchymal transition in embryonic development, tissue repair and cancer: a comprehensive overview. JCM 2017;7:1. https://doi.org/10.3390/jcm7010001.

[43] Kushwah AS, Masood S, Sharad P, Nema R, Banerjee M. Recent advances in porous silicon–based technology for biomedical applications. Drug delivery and

biomedical applications of porous silicon-based nanocarriers. Elsevier; 2025. p. 399–426. https://doi.org/10.1016/B978-0-443-24802-3.00012-3.

[44] Masood S, Kushwah AS, Yadav A, Singh P, Srivastava K, Banerjee M. A study on socio-demographic-based knowledge and awareness for cervical cancer among women from Uttar Pradesh, India. Clinical Epidemiol Global Health 2024;30: 101825. https://doi.org/10.1016/j.cegh.2024.101825.

[45] Masood S, Sharad P, Kushwah AS, Masood O, Banerjee M. MicroRNAs and HPV oncogenes crosstalk, their biomarker potential and therapeutic utility in cervical cancer. Biomark Med 2025:1–13.