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DNA Damaging Effects of Lotion vs Electric Mosquito Repellent Assessed via Chickpea Chromosomal Aberration Assay

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ABSTRACT

Mosquitoes are the potent vectors of malaria, yellow fever and dengue a common hazard in Sindh Pakistan, since decade. Currently variety of mosquito repellent lotions containing hazardous pesticides has been used by people of Sindh. Therefore, preliminary testing for cellular and genetic toxicity five lotion brands was carried out in comparison to Electric mosquito repellent (EMR). The study was based on germination inhibition and chromosomal aberration assay in *Cicer arietinum* L. root tip cells. Seeds of chickpea were incubated with 2.5% solutions of lotion and EMR (at distance of 20 inches) for 20, 40 and 60 minutes. Ethyl methane sulfonate was used as positive control and untreated seeds as negative control. Cytological data was recorded at 400 magnification under light microscope. Statistically significant time dependent ($p \leq 0.01$) differences in germination inhibition of chickpea were found for three lotion brands and electric repellent. For MI and AI highly significant variation ($p \leq 0.01$) were found for all tested lotions specially SMR brand. MI exhibited incubation dependent decrease while reverse the case was for AI. The most frequent chromosomal aberrations induced by all brands of lotion were sticky metaphase and fragmentation. It is concluded that all lotion brands were phyto-genotoxic in plant assay. On the basis of low M.I. and very high A.I. by MMR and SMR were found most genotoxic among the tested lotions and EMR is the safe alternative mosquito repellent. It is recommended to screen repellent lotions in mammalian assay for precise estimation of safe dose for humans.

Key words: Mosquito repellent, Genotoxicity, Cytotoxicity, Chromosomal aberrations.

INTRODUCTION

Mosquitoes transmit different diseases to approximately 700 million people annually. Control of mosquitoes is something of utmost importance in the present day with rising number of mosquito borne illnesses due to floods in Pakistan, with dengue being the most widely disseminated across the country. The total number of dengue cases in Pakistan in 2017, 2018, 2019, and 2020 were 22938, 3204, 24547 and 106 respectively (N.I.H., 2020). Between 1 January and 27 September 2022, a total of 25 932 confirmed dengue cases and 62 deaths (CFR 0.25%) were reported in Pakistan (W.H.O., 2022). In November 2025 more than 10 deaths were reported in Hyderabad and Karachi city.

Mosquito repellents are insecticide that repels mosquitoes. The use of mosquito repellent since last decade has increased in Pakistan due to epidemic of dengue (Patel *et al.*, 2012; Gul *et al.*, 2013). Among mosquito Repellents, lotions are more preferred for outdoor use in Pakistan as most of population sleeps in courtyards. Majority of mosquito repellents lotions basically contain natural Pyrethrins (pyrethrum), and N-diethyl-meta-toluamide (DEET) with combination of other synthetic pyrethrins (Tetramethrin, Dichlorvos (DDVP), Piperonyl butoxide (PBO), transfluthrin and d-phenothrin) (Roger *et al.*, 2026). Other repellent

ingredient includes citronella oil, dimethyl phthalate, lavender, lemon-grass oil, peppermint oil and eucalyptus oil (Enayati *et al.*, 2010; Sah *et al.*, 2010). Prolong usage of DEET (1 mmol/L) is associated with allergic reactions, hypersensitivity (Brooks *et al.*, 1992), hypotension, coma and even deaths (Teinenbein 1988; Ellenhorn, 1997; NCAMP, 1998) therefore its limited use is recommended in young children (Oransky 1991). All the synthetic types of pyrethrins are also proved damaging to cell and DNA via oxidation (Atmaca and Aksoy, 2015; Yan, *et al.*, 2020; Li, *et al.*, 2024), induces apoptosis (Sinha *et al.*, 2011; Sinha *et al.*, 2013), Chromosomal abnormalities (Shin *et al.*, 2024) and tumors (Blair *et al.*, 1976). Citronella oil may cause skin allergies in long term use (Gul *et al.*, 2013).

Keeping the health hazards of pesticide-based mosquito repellents, people of Pakistan start using drug free and ecofriendly electronic mosquito repellents (EMRs) since last decade. Installation of EMR in various public places has been witnessed, although it is not utilized for house use. These mosquito repellent devise are designed to repel mosquitoes by attracting insects with ultraviolet (UV) light and heat, then electrocuting them with a high-voltage internal grid upon contact. Westpoint electric mosquito killer lamps use UV-A light (315 – 400nm) also known as

near UV with a wavelength around **365 nm** to attract insects. If we look at health concerns of UV-A exposure, it is associated with skin ageing, membranes instability and altered functions (Moyal *et al.*, 2000; Yin *et al.*, 2001; Garoli *et al.*, 2014), but no evidence is reported in literature related to DNA damaging effects. Although UV-B and UV-C region with shorter wavelengths and higher energy levels can cause DNA damage which result in cell mutations and cancerous growth (skin cancer) (Gies *et al.*, 1986; Abarca and Casiccia, 2002).

Although mosquito repellent pesticides were evaluated previously for cellular as well as genetic toxicity alone or in mixture but never in mosquito repellent products. As we know that most of product label do not indicate composition or concentrations of active ingredients, making toxicity screening mandatory.

Among various toxicity tests root germination inhibition and plant chromosomal aberration assay are preferred for preliminary studies. Plant assay is cheap and easy to handle with almost sensitivity with that of mammalian cell (Grant, 1978; Gustavino *et al.*, 2015). The chromosomal anomalies due to double stranded breaks in DNA molecule are called abnormal Chromosomal aberrations. Best checkpoint to monitor chromosomal aberration is mitosis. Chromosomal aberrations study of various bioactive compounds in *C. arietinum* L. (Chickpea) is reported by many workers (Sadia *et al.*, 2024; Qureshi *et al.*, 2024). In the light of previous studies there is dearth of information concerning the long-term use of mosquito repellent lotions and EMR and their time dependent cytotoxicity and genotoxicity evaluation. Current work will not only provide base line data for scientific fraternity for precise work in mammalian assay but it will also provide awareness to the about hazardous biological effects mosquito repellent lotions.

Therefore, present investigation will highlight possible time dependent phytotoxicity and genotoxicity of 5 commonly used mosquito repellent lotions (Available at Hyderabad, Sindh), and Electric repellent in the chickpea root tip cells.

MATERIAL METHOD

Assay plants: Chickpea (*Cicer arietinum* L.) was used as standard test plant for phytotoxicity, genotoxicity and oxidative damages as suggested by Grant (1978), Qureshi *et al.* (2014) and Firbasa and Tomez (2014). Seeds of Kabuli chickpea genotype NCS 0530 were obtained from National Agriculture Research Center, Islamabad (NARC).

Treatments: Five most frequently utilized Mosquito repellent brands (Mospel (MMR); Tyfon Good Night (TGN); Serne (SMR); Mortein Natur Gard (MNG); Off Soft and Scented (OSS) and Electric Mosquito repellent (EMR) (Model: WF9112) were purchased from local market.

Five lotion brands were applied in 2.5% solutions in distil water for 20, 40 and 60 minutes. The

concentration was finalized according to the sensitivity, reproducibility of plant assay and it works same for human tissue (Grant, 1987). Ethyl methanesulfonate was used as positive control and untreated seeds as negative control and incubated for 20, 40 and 60 minutes respectively. Incubations with **Electric mosquito repellent (EMR)** were carried out at distance of 20 inches for the same time as liquids.

30 Chickpea seeds per treatment were incubated in Glass beakers with lotions and 10 seeds per incubation time (20, 40 and 60) were collected. To stope reaction treated seeds were washed with dH₂O (water) for 2 to 3 times before sowing. In case of electric repellent six feet distance usually observed in public places and house use was maintained for incubation of dry seeds. The same number of seed per incubation time (20, 40 and 60) were collected for EMR and were soaked for 30 minutes in plain water to facilitate germination.

Phytotoxicity assessment: Phytotoxicity was measured I terms of percentage of roots germinated and MI (%).

Sowing of chickpea seeds and root recovery: The treated seeds were sown in two sand pots per treatment for tap root recovery at 28°C. After two days of sowing the data recording fort tap root emergence was started until the last root germinated. The germination data is expressed in percent increase or decrease as compared to respective negative controls. 2cm long tap roots from all the treatments were carefully removed from seed and fixed in solution of glaciated acetic acid and alcohol solution (3:1) for 24 hours to stope cell division and dehydration for storge. Finally fixed roots are stored in 70% alcohol until used.

Slide preparation: Root tips were spread by using the squash technique (Dill and King 1983; Dill *et al.*, 1986) slides were stained with 2% aceto-carmine.

Microscopy of slide: All the cytogenetic parameters were observed 6 slide per treatment. Per slide 500 cells were analyzed for cytology with the help of Light Microscope at 400 magnifications The photographs were taken with the help of digital camera (USB-2.0) dino eye.

The formula suggested by Racuciu (2009) was used to get MI (%).

$$M.I. = \frac{\text{Total dividing cells}}{\text{Total cells analyzed}} \times 100$$

Genotoxicity Assessment: Genotoxicity analysis is incomplete with number of abnormal cells until supplements with types of chromosomal abnormities. Therefore, initially following formula was used to calculate A.I. (%) Racuciu (2009).

$$A.I. = \frac{\text{Total abnormal dividing cells}}{\text{Total dividing cells}} \times 100$$

The details of mitotic chromosomal abnormalities were recorded stage wise for comparative toxicity between different mosquito repellent used in the study.

Statistical Analysis: Two-way ANOVA followed by Least Square Difference (LSD) test at $p \geq 0.01$ was used to compare treatment mean for M.I. and A.I. using computer software statistics 8.1



Figure1. Incubation arrangement for chickpea seeds in 2.5% aqueous mosquito repellent lotions

RESULTS AND DISCUSSION

The Mosquito lotions have highly inhibitory effect while electric repellent rather promotes germination with increase in incubation time. Lotions exhibited dose dependent inhibition of germination as compared to positive control (Table.1 & Figure 2). Time dependent germination inhibition was observed only for MMR (-73.33 and -94.11) and TNG (-73.33 and -88.23) at 20 and 40 minute incubations, while 60 minute incubation resulted in germination failure (0%). The brand OSS, SMR, MNG exhibited germination only at 20 minutes, whereas 40 and 60 minute incubations were lethal. SMR was the highest phytotoxic among all tested brands.

All the incubations with EMR could not disturb normal germination of chickpea. 20 minutes incubation with electric mosquito repellent germination percentage remained same as that of positive control. While 40 and 60 minutes incubation exhibited increase of 11.76% and 42.85% .

High germination inhibition induced by all the tested mosquito repellent lotions observed in current work is supported by the findings of Kanger *et al.* (2014) working with higher concentration of agriculture pesticide (Hexaconazole and Triazophos) Kanger *et al.*, 2014. Qureshi *et al.*, 2024 working with mosquito repellent coils found similar results in chickpea. Time dependent phytotoxicity observed in our work agrees well with Dubey and Fulekar (2011), who observed concentration dependent reduction and delay in seed germination of grass by agricultural pesticides ((Chlorpyrifos, Cypermethrin and

Fenvalerate). Alteration in germination response is a clear indication of phytotoxicity of tested lotion brands. The germination inhibition obtained for most of lotions in results may be due to the presence of ample amount of chemicals (Given on product labels). Mosquito lotion OSS contain 15% w/w DEET, on MMR packing concentration of DEET is not given. While MNG contain 17% DEET with 1.8% N-octyl bi cycloheptene carboximide. SMR contain DEET with citronella oil. No description about chemical composition of TNG is not provided on product label.

It is clear from the results EMR rather promotes germination with increase in incubation time. It is contained (2x8 watt ultra violet rod) tube +high voltage 315–400 nm (UV-A). UV-A 315 – 400 also known as near UV. It contains higher wavelength, but lower energy level as compared to other radiation. It has also less harmful effects. (Table.2 and 3) Due to UV-A when EMR observe it was mosquito repellents lotions. UV-A radiation is associated with skin ageing, affect membranes stability and functions, persistent pigment darkening (PPD) is darkening or tanning of the skin induced by UVA radiation (Moyal *et al.*, 2000; Yin *et al.*, 2001; Garoli *et al.*, 2014). but no evidence is reported in literature related to mutagenesis and carcinogenesis. Although UV-B region with shorter wavelengths and higher energy levels as compared to UV-A region can cause DNA damage which result in cell mutations and cancerous growths (skin cancer) (Gies *et al.*, 1986; Abarca and Casiccia, 2002). Alteration in germination response is a clear indication of phytotoxicity (Qureshi *et al.*, 2024).

Table 1. Effect of different incubation times of mosquito repellent lotions and electric repellent on germination percentage of *C. arietinum* L.

S.No	Treatment	Incubation Time (Minutes)					
		20 Percentage	Increase/ decrease	40 Percentage	Increase/ decrease	60 Percentage	Increase/ decrease
1.	-tive control	75	100	85	100	70	100
2.	MMR	20	-73.33	5	-94.11	-	-
3.	TGN	20	-73.33	10	-88.23	-	-
4.	MNG	30	-60	-	-	-	-
5.	OSS	10	-86.66	-	-	-	-
6.	SMR	5	-93.33	-	-	-	-
7.	EMR	75	0	95	11.76	100	42.85
8.	+tive control	70	-6.6	42	-52.94	35	-50

(Dashes in cells of table indicate no germination; MMR= Mosphel Mosquito Repellent; TGN= Tyfon Good Night; MNG= Mortein Natur Gard; OSS= Off Soft & Scented; SMR= Serne Mosquito Repellent; EMR= Electric mosquito Repellent)

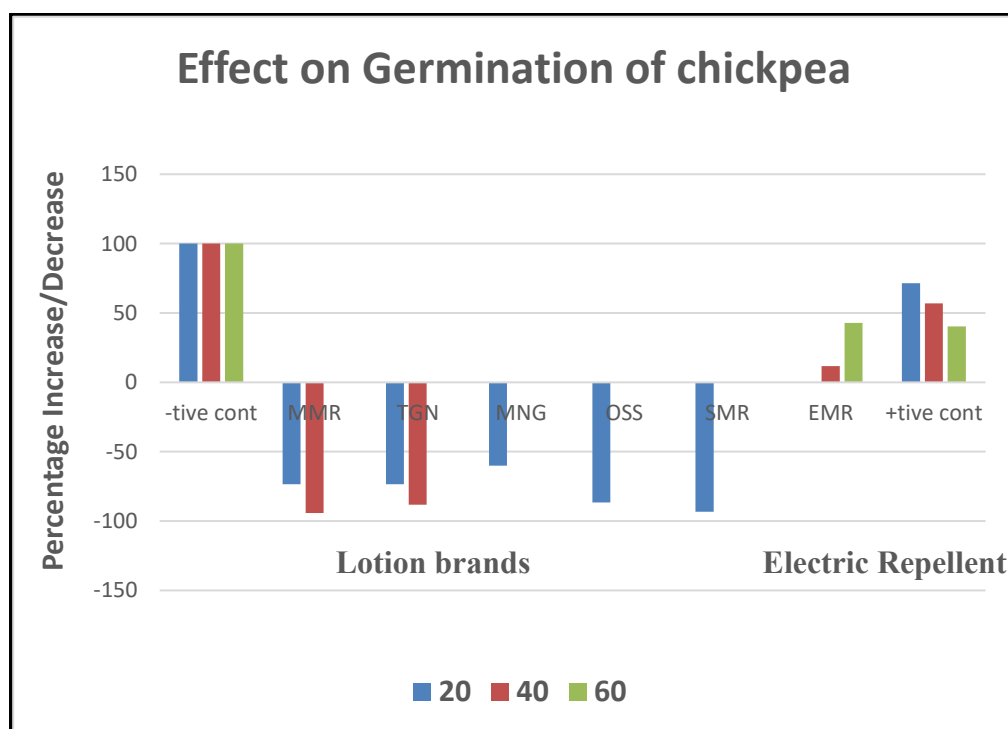


Figure 2. Effect of different incubation times of mosquito repellent lotions and electric mosquito repellent on germination percentage of chickpea

Among five tested mosquito repellent lotions in 20 minutes incubation maximum mitotic index was observed in SMR (82.55%) and minimum in MNG (79.91%). In case of 40 minute incubation maximum mitotic index was scored in TGN (47.5%) followed by MMR (44.35%).

In case of EMR maximum mitotic index was observed in 20 minutes incubation (90.36%) and minimum in 40 minutes incubation (80.09%). (Table 2, 3 and Figure 3) Maximum abnormality index among lotion brands in 20 minutes incubation was observed in SMR (92.95%) and minimum in TGN (26.92%). In case 40 minutes incubation maximum abnormality index was found in MMR (82.07%) followed by TGN (67.10%) (Table 2, 3 and and Figure 4). Time dependent increase in AI was recorded for all the tested lotions. Zeljezic and Vrhovac (2001) also observed pesticide generated incubation

dependent increase in chromosomal abnormalities via comet assay.

In case of EMR maximum abnormality index was observed in 40 minutes incubation (11.79%) and inimum in 20 minutes (4.32%) (Table 4.6). On the basis of mitotic index and abnormality index electric repellent was least genotoxic among all the repellent type tested. In mosquito lotion respective active ingredient was DEET, and much amount of this toxic ingredient in lotions especially MMR and SMR cause reduced number of dividing cells and phosphodiester bond breakage of nuclear DNA creating fragmentation and different type of chromosomal aberrations (Figure 6 and 10). DEET is the most common pesticide in tested mosquito repellent lotions. DEET (15% or lower) is reported to cause cytotoxicity, neurotoxicity, coma and even death. (NCAMP, 1998; Antwi *et al.*, 2008; Lee and Basak, 2021). It is also related with

mammalian germ cell apoptos, induce chromosome abnormalities, gene mutation, through mechanisms involving increased oxidative stress, impaired DNA repair, and disrupted chromatin structure (Shin *et al.*, 2024). Citronella oil was considered safe for adults only in early days of 21st century (Fradin and Day, 2002), later research revealed citronella oil induced DNA double strand breaks in human lymphocytes, at 1000 µg/mL concentration via generation of reactive oxygen species (ROS) and cellular apoptosis (Sinha *et al.*, 2011; Sinha *et al.*, 2013).

The most frequent chromosomal abnormality observed in all incubations of tested mosquito repellent lotions were fragmentation and sticky metaphase, while least common abnormalities were laggard, anaphase bridges, translocation rings, micro-nuclei, di-nuclei

and multi-nuclei (Table 3 and Figure 5 to 11). Current findings are consistent with that of Qureshi *et al.* (2024) while testing mosquito repellent coils in *C. arietinum* L. root tip cells. Many workers recorded.

DNA fragmentation working with different synthetic forms of pyrethrins like β -cyfluthrin (Verma *et al.*, 2013), Dichlorvos (Perocco and Fini, 1980; Mishra *et al.*, 2014), Transfluthrin (Tisch *et al.*, 2005) and natural Pyrethrum extract (Yang, *et al.*, 2020). All these researchers found oxidative stress-based DNA double stranded breaks. Overall results of phytotoxicity and genotoxicity analysis revealed SMR and MMR as the highest genotoxic and TNG as least toxic among lotions. While electric repellent was least genotoxic then all the repellent lotions.

Table 2. Number of non-dividing, normal dividing cells in *C. arietinum* L. root tip cells by mosquito repellent lotions and electric repellent

S.No	Name of treatment	Number of cells Non dividing			Normal			Abnormal dividing		
		20m	40m	60m	20m	40m	60m	20m	40m	60m
1.	-tive control	0	0	0	534	560	501	0	0	0
2.	MMR	257	350	-	160	50	-	85	229	-
3.	TGN	254	420	-	218	125	-	84	255	-
4.	MNG	337	-	-	125	-	-	52	-	-
5.	OSS	250	-	-	150	-	-	89	-	-
6.	SMR	150	-	-	50	-	-	660	-	-
7.	EMR	17	47	85	332	344	310	15	46	32
8.	+tive control	180	315	605	250	5	0	200	410	410
Grand mean		1445	1132	690	1819	1084	811	1185	940	442

(Dashes in cells of table indicate lethal dose; m= Minutes; MMR= Mosphel Mosquito Repellent; TGN= Tyfon Good Night; MNG= Mortein Natur Gard; OSS= Off Soft & Scented; SMR= Serne Mosquito Repellent; EMR= Electric Mosquito Repellent)

Table 3. Effect of mosquito repellent lotions and electric mosquito repellent on Mitotic Index and Abnormality Index in *C. arietinum* L. root tip cells (LSD p<0.01)

S. No.	Name of treatment	M.I (%)			A.I (%)		
		20m	40m	60m	20m	40m	60m
1.	-tive control	100 ^a	100 ^a	100 ^a	0 ^g	0 ^e	0 ^c
2.	MMR	48.80 ^f	44.35 ^e	-	34.69 ^d	82.07 ^b	-
3.	TGN	54.31 ^e	47.5 ^d	-	26.92 ^e	67.10 ^c	-
4.	MNG	34.43 ^g	-	-	44.44 ^b	-	-
5.	OSS	48.87 ^f	-	-	37.23 ^c	-	-
6.	SMR	82.55 ^c	-	-	92.95 ^a	-	-
7.	EMR	90.36 ^b	89.24 ^b	80.09 ^b	4.32 ^f	11.79 ^d	9.35 ^b
8.	+tive control	71.42 ^d	56.84 ^c	40.3 ^c	44.44 ^b	98.79 ^a	100 ^a

(Means with same alphabets are non-significantly different from each other and with different alphabets are significantly different at (p≤0.01); Dashes in cells of table indicate lethal dose; m= Minutes; MMR= Mosphel Mosquito Repellent; TGN= Tyfon Good Night; MNG= Mortein Natur Gard; OSS= Off Soft & Scented; SMR= Serne Mosquito Repellent; EMR= Electric Mosquito Repellent)

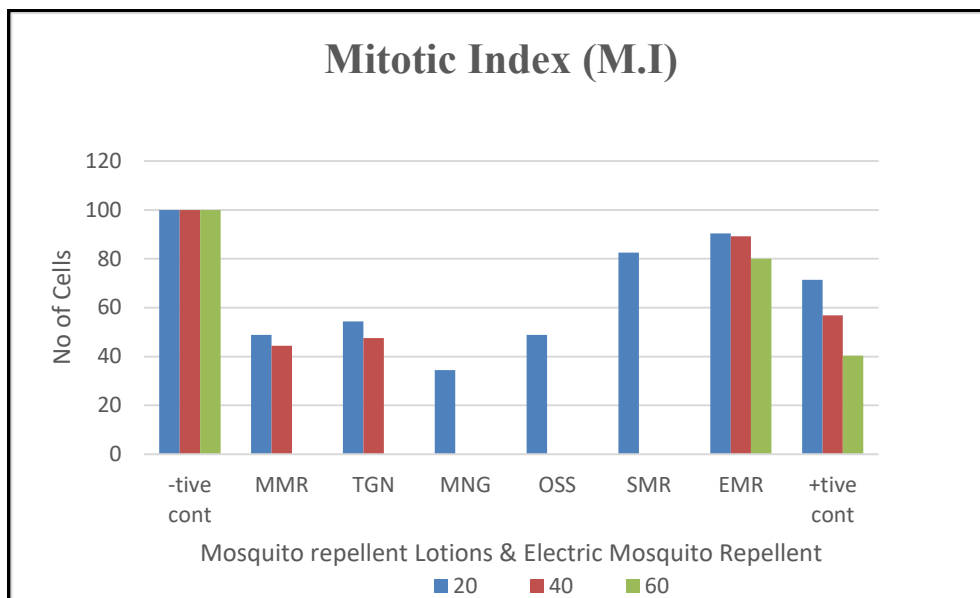


Figure 3. Effect of mosquito repellent lotions and electric mosquito repellent on Mitotic Index in *C. arietinum* L. root tip cells

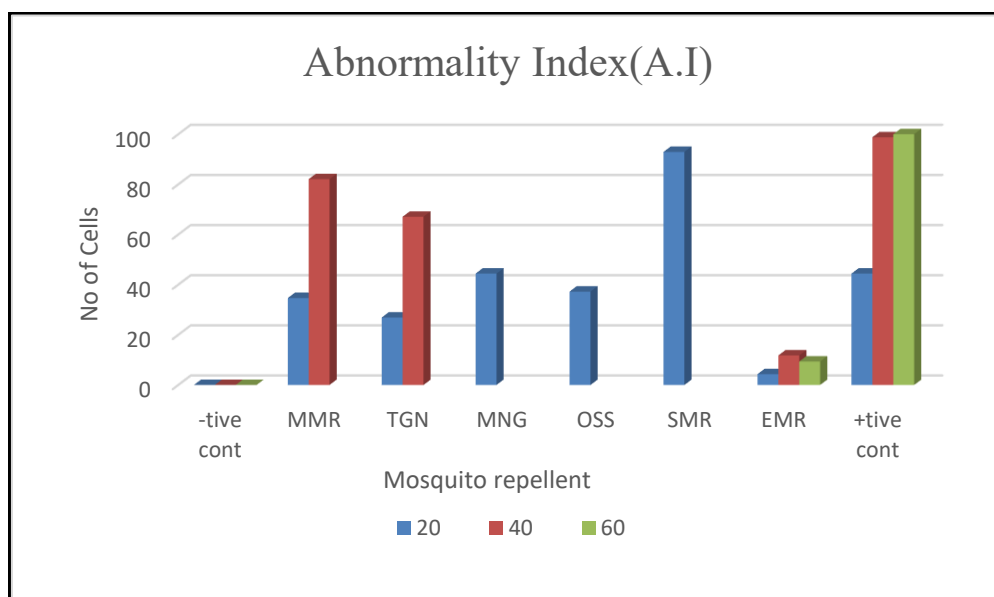


Figure 4. Effect of different incubation times of mosquito repellent lotions and electric mosquito repellent on Abnormality Index in *C. arietinum* L. root tip cells

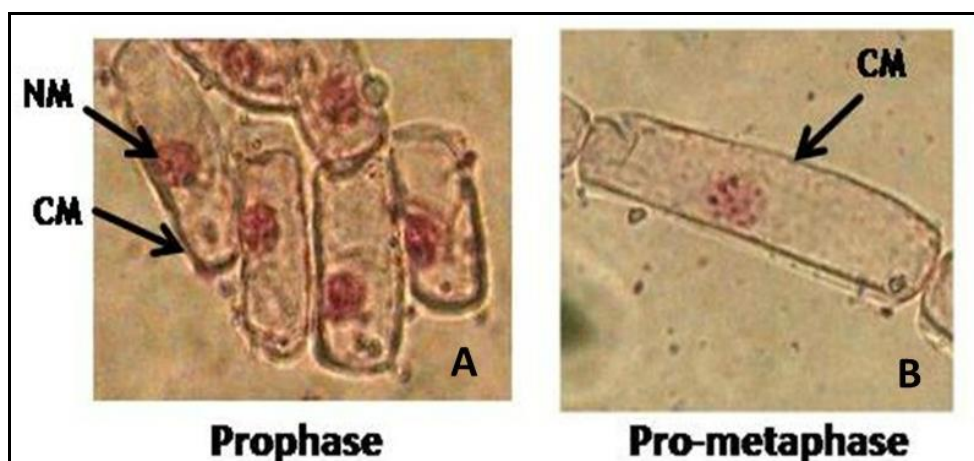


Figure 5a. Photomicrographs of *C. arietinum* L. root tip cells showing (A) normal

prophase cells (B) prometaphase cells (arrows) in Negative control

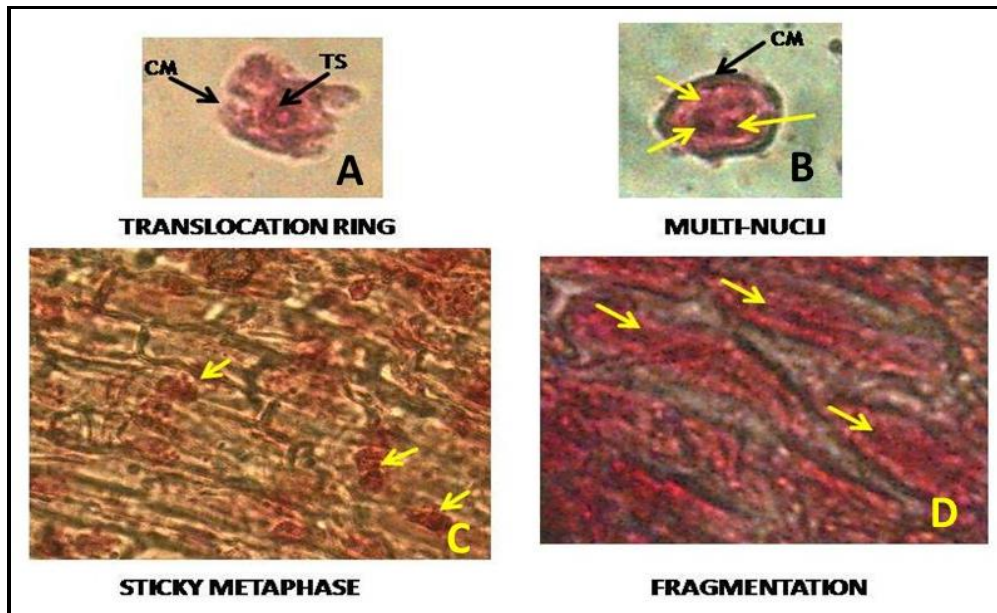


Figure 5b. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Translocation ring (B) multi-nuclei (C) Sticky metaphase (Fragmentations) (arrows) treated with EMS (1%) (positive control)

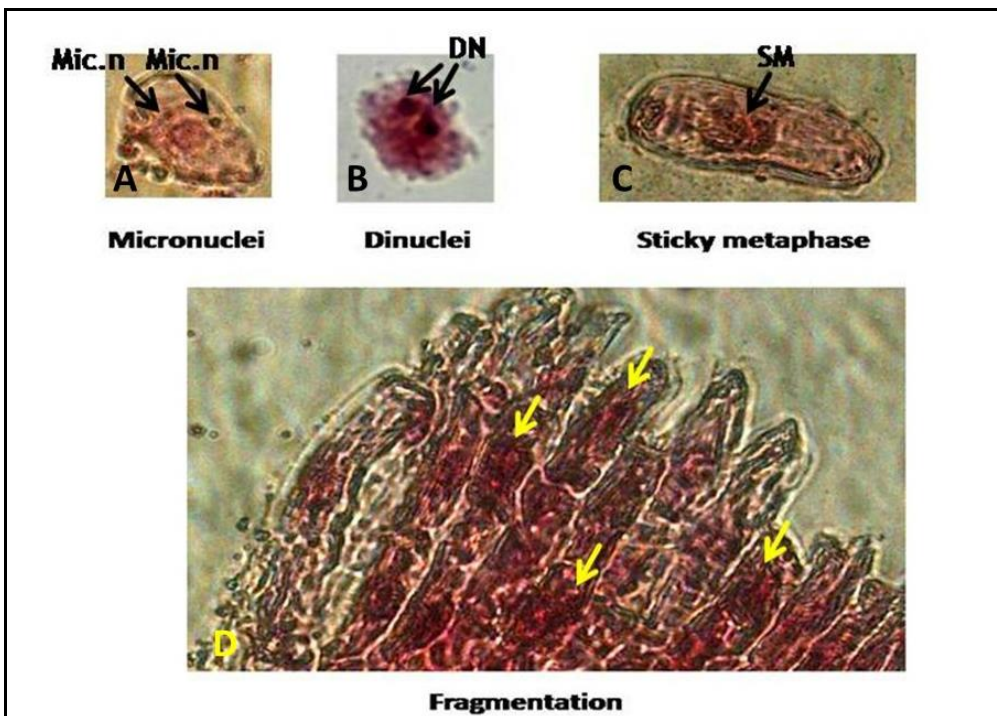


Figure 6. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Micro-nuclei (B) Di-nuclei (C) Sticky metaphase (D) Fragmentations (arrows) treated with repellent MMR

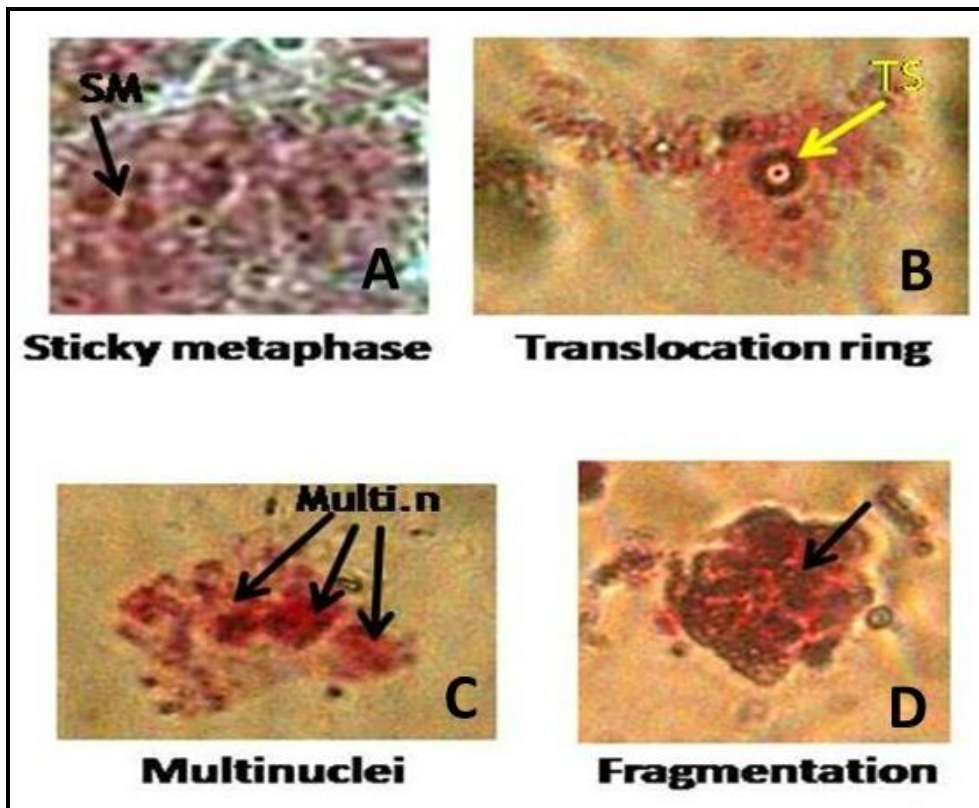


Figure 7. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Sticky metaphase micro-nuclei (B) Translocation ring (C) Multi-nuclei (D) Fragmentations (arrows) treated with repellent TNG

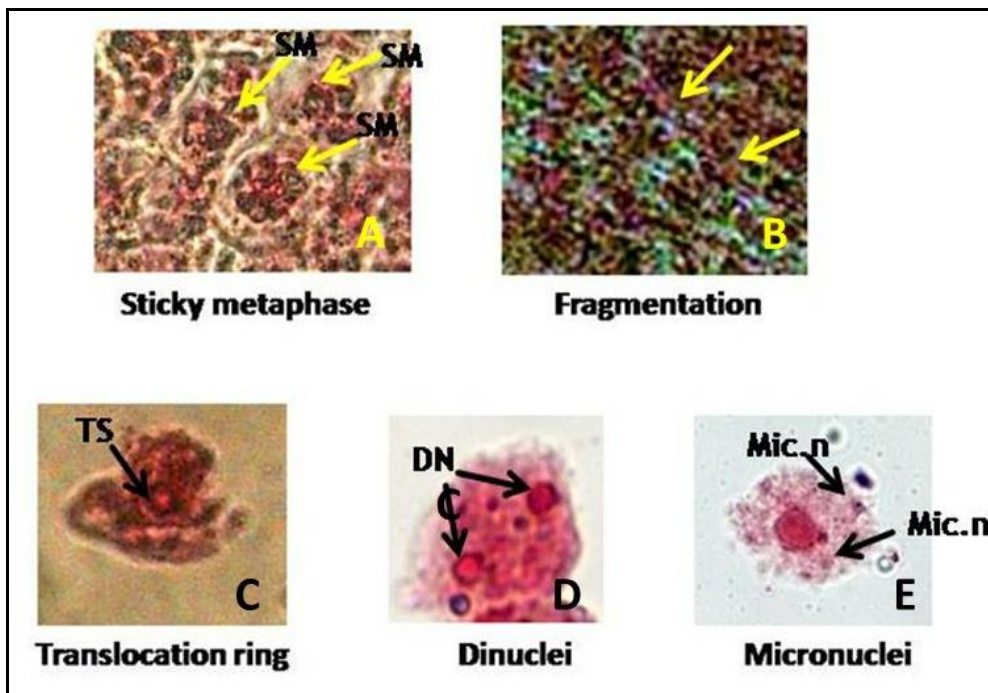


Figure 8. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Sticky metaphase (B) Fragmentations (C) Translocation ring (D) Di-nuclei (E) Micro-nuclei (arrows) treated with repellent MNG

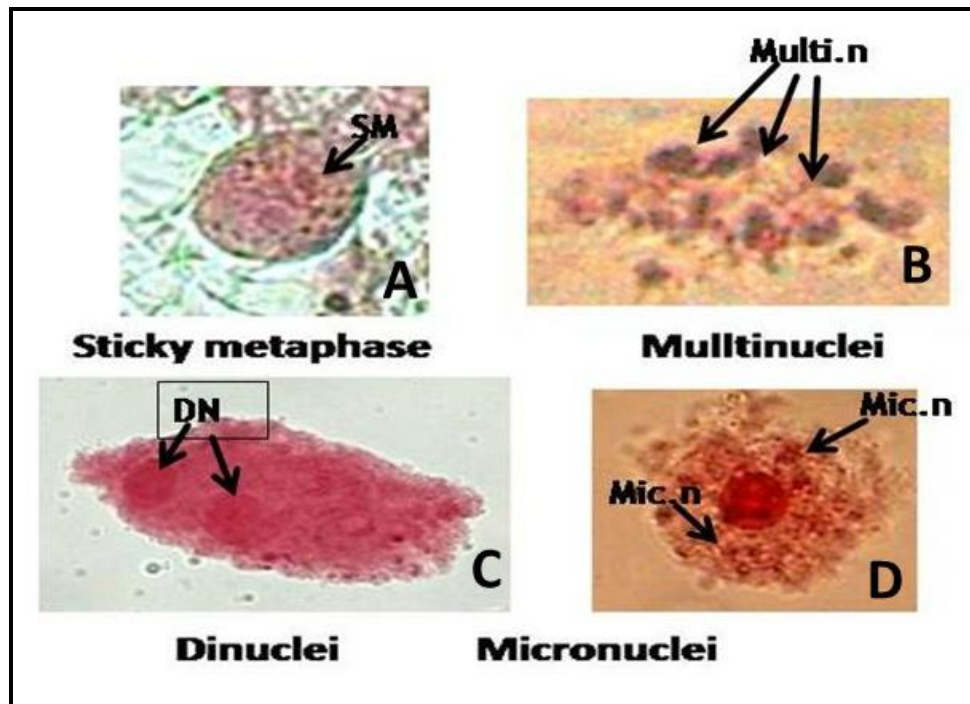


Figure 9. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Sticky metaphase (B) Multi-nuclei (C) Di-nuclei (D) micro-nuclei (E) Micro- nuclei (arrows) treated with repellent OSS

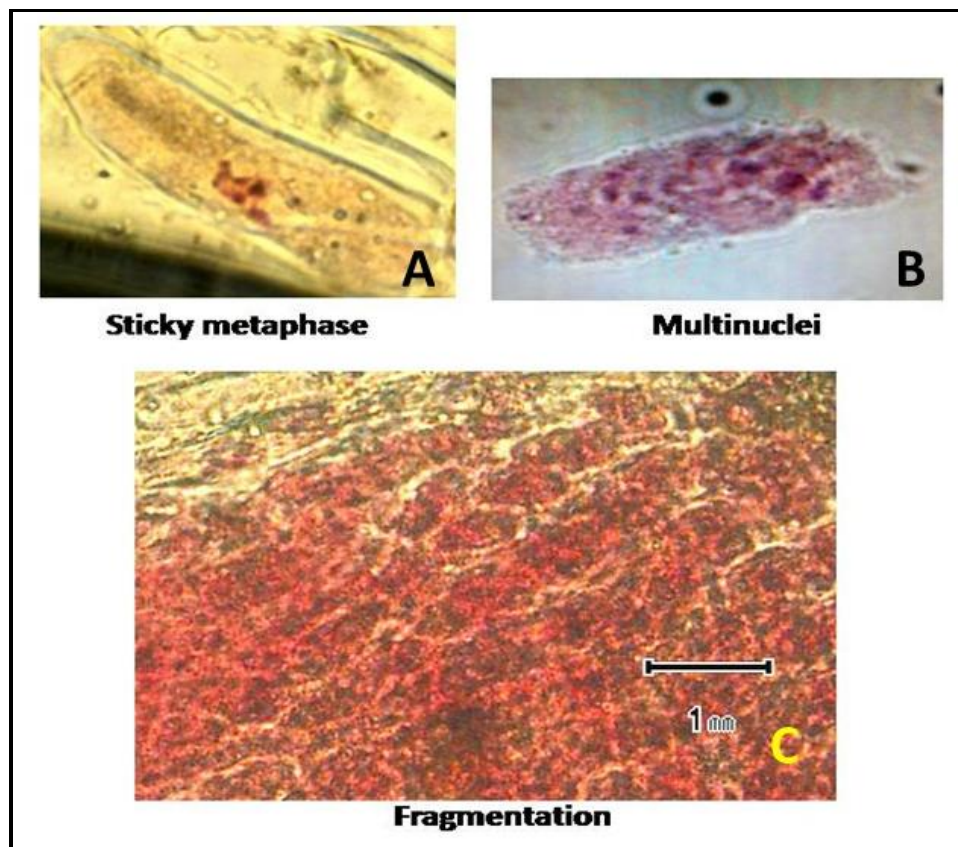


Figure 10. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Sticky metaphase (B) Multi-nuclei g (C) Fragmentations (arrows) treated with repellent SMR

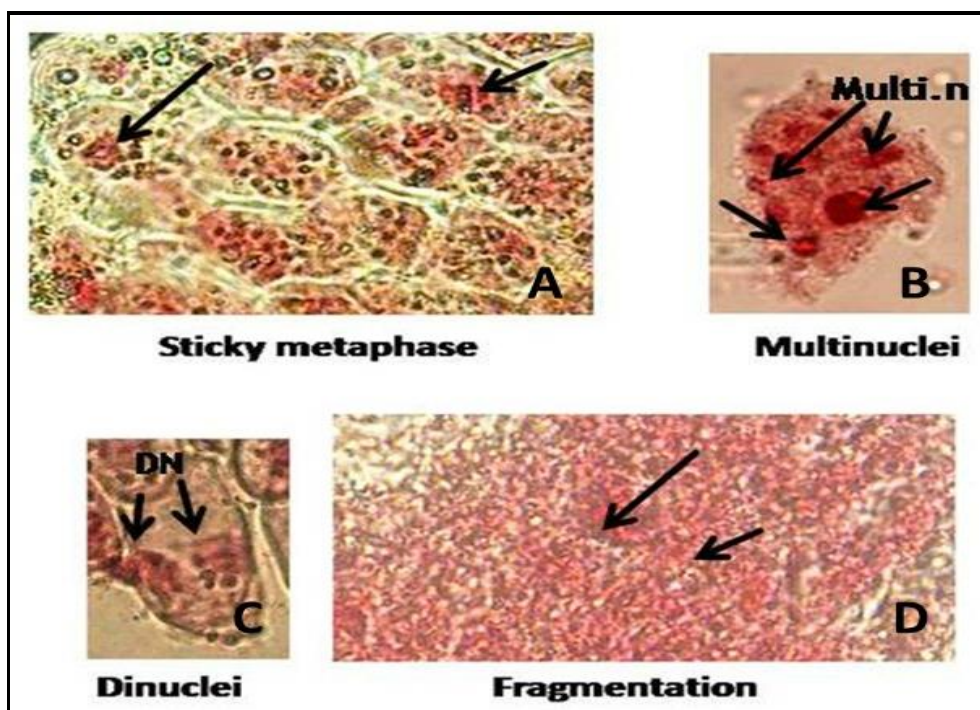


Figure 11. Photomicrographs of *C. arietinum* L. root tip cells showing chromosomal aberration (A) Sticky metaphase (B) Multi-nuclei (C) Di-nuclei (D) Fragmentation (arrows) treated with repellent EMR.

CONCLUSION

It is concluded that all lotion brands were phyto-genotoxic in plant assay. On the basis of low M.I. and very high A.I. by MMR and SMR were found most genotoxic among the tested lotions and EMR is the safe alternative mosquito repellent. It is recommended to screen repellent lotions in mammalian assay for precise estimation of safe dose for humans.

AUTHORS' CONTRIBUTION

APC, designed and conducted the experiment, STQ, edited the manuscript and improve English language, ANS provided critical guidance and AFS carried out statistical analysis and S, oversight throughout the research process.

AUTHORS CONFLICT OF INTEREST

The authors have no conflict of interest.

REFERENCES

- Abarca, J.F. and Casiccia, C.C. (2002). Skin cancer and ultraviolet-B radiation under the Antarctic ozone hole: Southern Chile 1987-2000. *Photodermatology Photoimmunology and Photomedicine*. **18**(6):294-302.
- Yang, Y., Zhang, Y., Gao, J., Xu, W., Xu, Z., Li, Z., Jiagao Cheng, J., Tao, L. (2020). Pyrethrum extract induces oxidative DNA damage and AMPK/mTOR-mediated autophagy in SH-SY5Y cells. *The Science of the Total Environment*. **740**:139925..
- Antwi, F. B., Shama, L. M., & Peterson, R. K. (2008). Risk assessments for the insect repellents DEET and picaridin. *Regulatory Toxicology and Pharmacology*, **51**(1), 31-36.
- Atmaca, E., Aksoy, A. (2015). d-Phenothrin-induced oxidative DNA damage in rat liver and kidney determined by HPLC-ECD/DAD. *Environmental Toxicology*, **30**(5):607-13.
- Blair, D., Dix, K.M., Hunt, P.F., Thorpe, E., Stevenson, D E., Walker, A.I., (1976). Dichlorvos a 2-year inhalation carcinogenesis study in rats. *Archives of Toxicology*. **35**(4):281-294.
- Brooks, B. O., Aldrich, F. D., Utter, G. M., DeBroy, J. A. and Schimke, R. D. (1992). Immune responses to pollutant mixtures from indoor sources. *Annals of the New York Academy of Sciences*. **641**(1): 199-214.
- Dille, J., King, N. and Brighth, M. (1986). Morphological and cytological and cytogenetic effect of 50 tox 25 seed treater (f) (Lindane and Captan) on roots and chromosomes of rye (*S.cereal* L.). *Cytologia*. **51**(3): 489-492.
- Dille, J. and King, N.(1983). Changes in mitotic indexes in roots of cereal exposed to di-methylsulphide (DMJO). *Cytologia*. **48**,659-662. doi: 10.1002/tox.21938.
- Dubey, K.K. and Fulekar, M.H. (2011). Effect of pesticides on the Seed Germination of *Cenchrus setigerus* and *Pennisetum pedicellatum* as Monocropping and Co-cropping System: Implications for Rhizospheric Bioremediation. *Romanian biotechnological letters*. **16** (1): 5909-5918.
- Enayati, A., Hemingway, J. and Garner, P. (2010).Electronic mosquito repellents for preventing mosquito bites and malaria infection. *Cochrane Database of Systematic Reviews*. **2** (CD005434): pp.1-16.
- Fradin, M.S and F. Day J.F (2002). Comparative efficacy of insect repellents against mosquito bites. *The New England Journal of Medicine*. **347** (1): 13-8. <https://api.semanticscholar.org/CorpusID:24270047>.
- Garoli, D., Alaibac, M. and Pelizzo M.G. (2014). Ultraviolet filters for sensors matching biological action spectra. *Optica Applicata*. **44** (4): 611-620.
- Gies, H. P., Roy, C. R. and Elliot, G., (1986). Artificial sun tanning: spectral irradiance and hazard evaluation of ultraviolet source. *Health Physics*. **50** (6):691-703.
- Grant, W.F. (1978). Chromosome aberrations in plants as a monitoring system. *Environmental Health Perspective*. **27** (12): 4-7.
- Gul, S., Ibrahim S, Wasif N, Zafar A and Syed R. (2013) Mosquito repellents: Killing mosquitoes or yourselves.

- Journal of Scientific and Innovative Rresearch*. **2** (6): 1052-1057.
- Ham, J., You, S., Lim, W., Song, G. (2020). Bifenthrin impairs the functions of leydig and sertoli cells in mice via mitochondrion-endoplasmic reticulum dysregulation. *Environmental Pollution*. **266** :115174.
- Kengar, Y.D., Kamble, A. B. and Sabale, A.B. (2014). Effect of hexaconazole and triazophos on seed germination and growth parameters of spinach and gaur. *Annals of Biological Research*. **5**(5): 89-92.
- Kumar, A., Jadhav, A. D., Bagade, R. P. and Parkhe, M. D. (2015). Mosquito a Global Threat: Control by Herbal Approach. *International Journal of Zoological Research*. **5** (4): 1-4.
- Lee, J.T., Basak, S. (2021) Cytotoxic Effects of N,N-Diethyl-Meta-Toluidide (DEET) on Sinonasal Epithelia. *OTO Open*. **5**(2). 2473974X211009232.
- Li, Y., Mijia Li, Shiyi Duan, Sijie Zhang, Huiqiang Lu, Xinchun Guo, Keyuan Zhong, , 2024). d-Tetramethrin causes zebrafish hepatotoxicity by inducing oxidative stress and inhibiting cell proliferation, *Toxicology and Applied Pharmacology*. 483:116817.
- Mishra, M., Sharma, A., Shukla, A.K., Kumar, R., Dwivedi, U.N., Chowdhuri, D. K. (2014). Genotoxicity of dichlorvos in strains of *Drosophila melanogaster* defective in DNA repair, *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*. **766**: 35-41. <https://doi.org/10.1016/j.mrgentox.2014.02.004>.
- Moyal, D., Chardon, A. and Kollias, N. (2000). Determination of UVA protection factors using the persistent pigment darkening (PPD) as the end point: (Part 1) Calibration of the method. *Photodermatology Photoimmunology and Photomedicine*. **16**(6):245–249.
- National Coalition Against the Misuse of Pesticides (NCAMP) 1998. TOXIC WARNING SIGNALS. *Pesticides and You*. **18** (1-2): 1-38.
- National Institute of Health (NIH) Islamabad (2020). *Weekly Field Epidemiology Report*. **2** (2): 1–4.
- Patel, E.K., Gupta A. and Oswal, R.J. (2012). A Review On: Mosquito Repellent Methods. *International Journal of Pharmaceutical, Chemical and Biological Sciences*. **2**(3):10-317.
- Perocco, P., Fini, A. (1980). Damage by Dichlorvos of Human Lymphocyte DNA. *Tumori Journal*. **66**(4):425-430.
- Peterson, C. and Coats, J., Insect Repellents – Past, Present and Future RSC 2001. DOI: 10.1039/b106296b.
- Qureshi, S.T., Channar, A.P., Soomro, A.N. (2024). Phyto-genotoxicity assessment of mosquito repellent coils used in Pakistan via plant chromosomal aberration assay. *Pakistan Journal of Biotechnology*. **21**(2):345-354.
- Racuciu, M. (2009). Effect of radiofrequency radiation on root tip cells of *Zea mays*. *Romanian Biotechnological Letters*. **14** (3): 4365–4369.
- Roger S. Nasci, Emily Zielinski-Gutierrez, Robert A. Wirtz, William G. Brogdon. (2026). Protection against Mosquitoes, Ticks, & Other Insects & Arthropods Chapter 2 - Yellow Book - Travelers' Health – CDC.
- Sadia, Qureshi, S.T., Soomro, A.N., Malik, S., Punar, Z. (2024). Mutational and Carcinogenic Potential of Amaltas Fruit Via Oxidation. *Journal of Applied Research in Plant Sciences*. **5**(2):269-280.
- Sah, M.L., Mishra, D., Sah, S.P. and Rana, M. (2010). Formulation and Evaluation of Herbal Mosquito Repellent Preparations, *Indian Drugs*. **47** (4): 45-50.
- Shin, N., Lascarez-Lagunas, Henderson, A.L.H., Martínez-García, M., Karthikraj, R., Barrera, V., Sui, S.H., Kannan, K. and Colaiacovo, M.P. (2024). Altered gene expression linked to germline dysfunction following exposure to DEET). *iScience*, **27**(108699):1-16. (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).
- Shin, N., Laura, I., Lascarez-Lagunas, Ayana. L., Henderson, Martínez-García, H., Karthikraj, R., Barrera, V., Sui, S.H., Kannan, K., Colaiacovo, M.P. (2024). Altered gene expression linked to germline dysfunction following exposure of *Caenorhabditis elegans* to DEET, *iScience*. **27** (1): 108699,
- Sinha, S., Biswas, D. and Mukherjee, A. (2011). Antigenotoxic and antioxidant activities of palmarosa and citronella essential oils. *Journal of Ethnopharmacology*. **137**(3):1521-7.
- Sinha, S., Jothiramajayam, M., Ghosh, M., Mukherjee, A. (2014.) Evaluation of toxicity of essential oils palmarosa, citronella, lemongrass and vetiver in human lymphocytes. *Food and Chemical Toxicology*. **68**: 71-77.
- Tisch, M., Faulde, M.K., Maier, H. (2005). Genotoxic effects of pentachlorophenol, lindane, transfluthrin, cyfluthrin, and natural pyrethrum on human mucosal cells of the inferior and middle nasal conchae. *American Journal of Rhinology and Allergy*. **19**(2):141-51. PMID: 15921213.
- Verma, R., Awasthi K. K., Soni, I. and John, P.J. (2013). Evaluation of Cytogenetic Effects of β -Cyfluthrin in Swiss Albino Mice. *International Journal of Current Microbiological Applied Sciences*. **2** (6): 30-40.
- WHO, (1993). Research Guidelines for Evaluating the Safety and Efficacy of Herbal Medicines. Published by World Health Organization, Regional Office for the Western Pacific, Manila, pp. 1-10.
- World Health Organization. Reprint 2022. <https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON414>.
- Yin, L., Morita, A. and Tsuji T. (2001) Skin aging induced by ultraviolet exposure and tobacco smoking: evidence from epidemiological and molecular studies. *Photodermatology Photoimmunology and Photomedicine*. **17**(4):178-183.
- Zeljezic, D. and Vrhovac, V.G. (2001). Chromosomal Aberration and Single cell gel electrophoresis (comet) assay in the longitudinal risk assessment of occupational exposure to pesticides. *Mutagenesis*. **16** (4): 359-363

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