

Cytotoxicity Assessment of Chlorpyrifos and Azadirachtin through *Allium cepa* Assay

Parshotam Singh Tyagi, Shalu Vyas

Received 22 June 2025, Accepted 14 August 2025, Published on 11 September 2025

ABSTRACT

It is known fact that while pesticides can effectively protect crops from pests, they often come with significant drawbacks, including harm to the environment, soil health, and overall ecosystem balance. Organophosphates represent a class of highly toxic pesticides that pose significant risks to flora, fauna, beneficial insects, and agricultural workers. Among these, Chlorpyrifos - marketed under the trade name Kemtrek is one of the extensively utilized organophosphate within agricultural practices and food production. In contrast, Azadirachtin, derived from the Neem plant, is frequently employed as a robust pesticide for crop protection. The present study is aimed to evaluate the cytotoxic effects of both Chlorpyrifos and Azadirachtin at concentrations of 0.25%, 0.50%, 0.75%, and 1.0%. The experimental design involved applying pesticide treatments during both the seed germination phase and the flowering stage. Cytotoxicity was assessed during early seedling development by measuring seed germination rates, radicle length,

seedling survival rates, and the mitotic index. The cytotoxicity was evaluated by microscopic examination of meiotic cells obtained from aceto-carmine squashes of anthers collected from young floral buds. The basic purpose of the research was to evaluate the ill effects of selective pesticides- one organic and one inorganic, on cytological level and at early growth and development of the seedlings. Results demonstrated that both pesticides exhibited cytotoxic properties; however, the toxicity associated with Azadirachtin, as a natural pesticide, was found to be minimal. Conversely, Kemtrek (Chlorpyrifos) significantly impeded seed germination, reduced primary root length, diminished seedling survival, and decreased the mitotic index across all tested concentrations. A general trend of increasing toxicity was noted with rising concentrations. A similar pattern was observed in the analysis of meiotic cells, where Chlorpyrifos induced a range of chromosomal abnormalities that escalated with higher concentrations. Frequently observed chromosomal aberrations included chromosomal stickiness, chromosome fragmentation, univalents and trivalents, anaphase and telophase bridges, unequal second meiotic divisions, and lagging chromosomes. The findings of this research suggest that farmers ought to refrain from utilizing chemical pesticides in order to preserve the environment and mitigate potential genetic harm to their crops. Instead, they should prioritize the application of organic pesticides, such as neem oil, to effectively safeguard their crops from pest infestations.

Keywords Chlorpyrifos, Trivalents, Lagging chromosomes, Aceto-carmine squash, Assay, Chromosomal stickiness.

Parshotam Singh Tyagi^{1*}, Shalu Vyas²

^{1,2}Associate Professor

Department of Agriculture, Sant Baba Bhag Singh University,
Jalandhar, Punjab, India

Email: psbons@yahoo.com

*Corresponding author

INTRODUCTION

The agricultural sector heavily relies on pesticides to enhance crop yields, particularly in response to the rapid growth of the global population and the consequently increasing demand for food resources (Atmaca *et al.* 2019). This urgency has resulted in the escalated application of pesticides, which play a key role in managing pests and diseases to boost agricultural productivity. Among various pesticide classes, organophosphates are prominently utilized in India for pest control due to their efficacy in inhibiting acetylcholine esterase activity in insects. Chlorpyrifos, one of the most widely employed organophosphates, is available under numerous trade names and is frequently employed for controlling a range of agricultural and household pests (Wexler 2014). Since its registration in India under the Insecticides Act of 1977, chlorpyrifos accounts for approximately 9.4% of the nation's total insecticide consumption. While pesticides offer immediate agricultural benefits through enhanced productivity, their overuse raises significant concerns regarding human health risks. Exposure to organophosphate pesticides, such as chlorpyrifos, can lead to adverse health effects, including nausea, dizziness, confusion, tachycardia, respiratory distress, and potentially fatal outcomes. Despite awareness of these dangers, many farmers continue to apply pesticides excessively in pursuit of short-term gains. Recent discussions have highlighted the latent risks associated with pesticides, suggesting the potential for genetic harm to humans due to their widespread use (Kaur and Kaur 2018).

Cytotoxicity of chemical pesticides refers to their ability to cause damage to cells, potentially leading to cell death or dysregulation of cellular functions. Many commonly used pesticides, including organophosphates, have been shown to exert toxic effects on human and animal cells, impacting vital processes such as cell division, apoptosis, and gene expression. Chromosomal aberrations caused by pesticides represent a significant area of concern in toxicology and environmental health, reflecting the genetic damage that these chemicals can inflict on living organisms. Pesticides, particularly those classified as genotoxic, can induce structural and numerical changes in chromosomes, such as deletions, duplications, breaks, and

translocations. These aberrations disrupt normal cellular functions. Historical research has long focused on evaluating the detrimental effects of chemical pesticides on a variety of crops (Kihlman 1966). Studies have demonstrated the impacts of pesticides on plant cell division, chromosomal morphology, and overall crop yield (Pandey 2008, Singh *et al.* 2009, Pandey 2015). Despite extensive research into the mutagenic and toxic effects of chlorpyrifos in animal models, there remains a lack of comprehensive studies concerning its cytological effects in plants.

In response to mounting health concerns, there is a significant shift among farmers towards organic farming practices, which utilize pesticides derived from biological sources rather than synthetic chemicals. The neem tree (*Azadirachta indica*) is notable in this context; its leaves and seeds contain azadirachtin, a bioactive compound with proven fungicidal, bactericidal, and insecticidal properties, which presents minimal toxicity risks (Roshan and Verma 2015). Literature is abundant regarding the pesticidal effects of azadirachtin from neem seed oil on plant health (Adhikari *et al.* 2020). Given the critical importance of this topic, the current study aims to investigate the mutagenicity of chemical pesticides compared to organic alternatives by employing the *Allium cepa* assay. Numerous studies, including those by Singh *et al.* (2009) and Datta *et al.* (2018), have verified the effectiveness of the *Allium* test in detecting potentially genotoxic substances, establishing a foundation for the present investigation.

MATERIALS AND METHODS

The experimental study was conducted at the Horticulture Laboratory and Agricultural Farms within the Faculty of Agriculture at Sant Baba Bhag Singh University, Khiala, Jalandhar, Punjab. For the experimentation, Gentex Nasic Red N-53 onion seeds were utilized. The pesticides selected for this study were Kemtrek (active ingredient Chlorpyrifos 20% EC, C9H11Cl3NO3PS), produced by Sumitomo Chemicals, and neem oil (active ingredient Azadirachtin) sourced from Katyani Organics. Four concentrations for each pesticide—0.25%, 0.5%, 0.75%, and 1.0%—were established as indicated in Table 1.

Table 1. Treatments.

Sl. No.	Notations	Treatments	Concentration
1	To	Control	Distilled water
2	T1	Neem oil (Azadirachtin)	0.25%
3	T2	Neem oil (Azadirachtin)	0.5%
4	T3	Neem oil (Azadirachtin)	0.75%
5	T4	Neem oil (Azadirachtin)	1.0%
6	T5	Kemtrek (Chlorpyrifos)	0.25%
7	T6	Kemtrek (Chlorpyrifos)	0.5%
8	T7	Kemtrek (Chlorpyrifos)	0.75%
9	T8	Kemtrek (Chlorpyrifos)	1.0%

Seed treatment protocol

The concentrations of pesticides were determined based on existing literature and preliminary trials, utilizing the LD50 value as a reference for dose formulation. Initially, the seeds were immersed in distilled water for a duration of 48 hours, followed by treatment with the respective pesticide concentrations (0.25%, 0.5%, 0.75%, and 1.0%) for a period of 6 hours. Post-treatment, the seeds underwent thorough washing with distilled water. Subsequently, 100 seeds from each treatment group were placed on moist blotting paper within petri dishes, arranged in triplicate, to facilitate germination in a controlled seed germinator environment. The germination rate was recorded after 5 days and expressed as a percentage of germinated seeds. After a subsequent period of 12 days, the primary root lengths were measured using a centimeter scale. The seedlings were allowed to grow for an additional 20 days, at which point the number of surviving seedlings was quantified and reported as a percentage survival rate. The remaining treated seeds were designated for seedling development for subsequent field transplantation.

Mitotic index evaluation

The mitotic index was calculated as the ratio of cells undergoing mitotic division to the total number of cells observed in the microscope field. For each treatment group, root tips of newly emerged seedlings were fixed in Carnoy's fluid (a mixture of ethanol, chloroform, and glacial acetic acid in a 6:3:1 ratio).

Cytological analysis employed the Aceto-carmine squash technique for staining meristematic cells of the root tips. Fixed root tips were placed in a watch glass, to which acetocarmine stain and 1N HCl were added at a 9:1 ratio. The mixture was warmed to 60 degrees Celsius. Subsequently, 2-3 root tips were placed on a clean glass slide, a drop of stain was added, and the root tips were covered with a cover slip. The slide was compressed between filter paper folds and tapped gently to prepare a squash for observation. Analysis was conducted using a binocular microscope, where the number of dividing and non-dividing cells was counted from approximately 100 cells sampled from four distinct corners of the slide. This procedure was replicated across different treatments and replicates.

Meiotic studies

To investigate meiotic abnormalities, seedlings treated with pesticides were established in the field, with five random plants from each treatment group marked for observation. These marked plants were subsequently sprayed with the corresponding concentrations of neem oil and chlorpyrifos as applied in the mitotic index assessment, with the application occurring just prior to the flower initiation phase. Young flower buds from the labelled plants were harvested and fixed in Carnoy's fluid. During the preparation of slides for the analysis of chromosomal aberrations induced by pesticides, selected anthers were excised from the fixed buds, and the aceto-carmine squash technique was employed as previously described for mitotic analysis. Chromosomal evaluations were performed at various stages of cell division, analyzing approximately 400 pollen mother cells (PMCs) collected from randomly selected fixed buds in Carnoy's fluid. Any observed PMCs exhibiting abnormalities such as chromatin stickiness, lagging chromosomes, chromatin bridges, or multivalents were classified as aberrant. The discriminatory impact of pesticides on gamete production and functionality was assessed through the evaluation of pollen sterility via microscopic examination. The sterile pollen grains appeared either colorless or faintly stained with aceto-carmine.

Statistical analysis

All research findings were subjected to statistical

analysis utilizing the one way ANOVA test, executed through OPSTAT, HAU software, to determine the significance of results.

RESULTS AND DISCUSSION

Results

Developmental abnormalities

The investigation of developmental abnormalities during the early phases of seed germination is detailed in Table 2. The findings indicate that all tested concentrations of pesticides adversely influenced the meristematic cells of germinating seeds, resulting in decreased germination rates, reduced radical elongation, and diminished seedling survival. Notably, Chlorpyrifos exhibited pronounced toxicity, which escalated with increasing pesticide concentration, peaking at a 0.75% concentration. Beyond this point, at the 1.0% concentration, no significant increase in

Table 2. Toxic effects of pesticides on early developmental stages and mitotic index.

Sl. No.	Treatment	(%) Seed germination	Length of radicle (mm)	Survival rate (%)
1	Control	91.33± .88	40.0± 0.15	86.66± 1.20
2	Neem oil 0.25%	82.33± .88	37.0± .05	83.33± 0.33
3	Neem oil 0.50%	72.33± 1.70	34.30± .12	81.66± 2.33
4	Neem oil 0.75%	69.00± 2.08	31.60± .08	81.00± 0.57
5	Neem oil 0.1.0%	68.33± 1.45	31.0± .05	79.33± 0.66
6	Kemtrek 0.25%	72.00± 1.73	28.0± .05	60.00± 1.15
7	Kemtrek 0.50%	65.66± 1.76	25.0± .11	50.66± 1.45
8	Kemtrek 0.75%	59.66± 0.88	23.0± .05	41.33± 1.76
9	Kemtrek 0.1.0%	55.00± 0.57	19.3± .08	40.66± 0.66
	CD (p<0.05)	5.35	0.28	4.03
	SE (m)	1.77	0.09	1.33

Note: Figures marked with red show maximum toxicity.

Table 3. Comparison of cytotoxicity of Chlorpyrifos and Neem oil on % Mitotic index.

Sl. No.	Treatment	Neem oil (Azadirachtin)		Chlorpyrifos	
		Mitotic Index Percent	Toxicity (%)	Mitotic Index Percent	Toxicity (%)
1	0% (control)	37.30± .018	-	37.30± .018	-
2	0.25%	32.70± .009	11.62	24.30± .015	34.85
3	0.50%	30.30± .009	18.76	20.00± .006	46.38
4	0.75%	27.30± .009	26.80	18.00± .012	51.74
5	1.00%	26.00± .012	30.29	16.00± .012	57.10

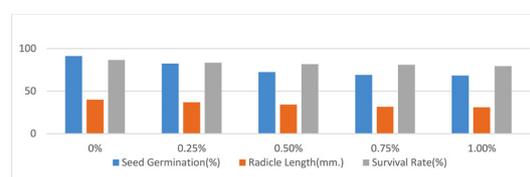


Fig. 1. Effect of neem oil on developmental parameters compared with control.

toxicity was observed (Fig.1). Conversely, the organic pesticide neem oil (Azadirachtin) demonstrated minimal toxicity compared to its chemical counterpart. Its impact on seed germination rates, seedling survival, and radical growth was negligible, suggesting its relative safety for agricultural use. Though a slight increase in toxicity was noted with elevated concentrations, it remained within non-lethal limits. The data represented in Table 2 and Fig. 1 substantiate that neem oil (Azadirachtin) has a minimal effect on seed germination, radical growth, and seedling survival.

Table 4. Comparison of cytotoxicity of Chlorpyrifos and Neem oil.

Sl. No.	Treatment	Neem oil (Azadirachtin)		Chlorpyrifos	
		(%) Chromosomal aberrations induced by Azadirachtin (AZC)	(%) Chromosomal Toxicity	(%) Chromosomal aberrations induced by Chlorpyrifos (ChIC)	(%) Chromosomal Toxicity
1	0% (Control)	7.30± 0.17	-	7.30± 0.17	-
2	0.25%	7.60± 0.17	3.94	8.60± 0.11	15.11
3	0.50%	7.90± 0.05	7.59	11.03± 0.12	33.81
4	0.75%	8.63± 0.17	15.41	14.10± 0.15	48.22
5	1.0%	9.23± 0.12	20.91	15.36± 0.12	52.47

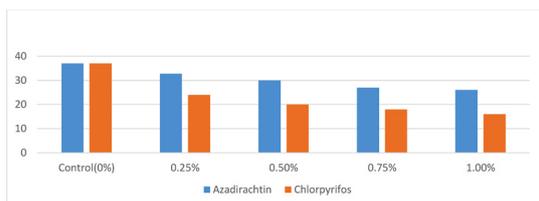


Fig. 2. Comparison of cytotoxicity of chlorpyrifos and azadirachtin on % mitotic index.

Note: Toxicity of chlorpyrifos is very high as compared to Azadirachtin at all concentrations as depicted by orange color, which shows that mitotic index is being progressively decreased.

Mitotic index

A comparative analysis of the effects of the chemical pesticide Chlorpyrifos and the organic pesticide neem oil on the mitotic index is illustrated in Table 3 and Fig. 2. The data show a consistent decline in the mitotic index correlating with increasing pesticide concentrations. The most pronounced effect was observed with Kentrek (Chlorpyrifos) at concentrations of 0.75% and 1.0%, where the reduction in the mitotic index exceeded two-fold at the 1.0% concentration, closely followed by the 0.75% concentration. More-

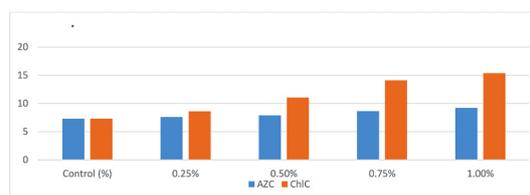


Fig. 3. Comparison of cytotoxicity of chlorpyrifos (Chl C) and Azadirachtin (AZC) on % chromosomal aberrations at meiosis.

Note: Chromosomal aberrations are progressively increasing with increasing conc of chlorpyrifos.

over, the percentage toxicity reached its zenith with Kentrek (Chlorpyrifos) at the 1.0% concentration, followed by the 0.75% concentration. In stark contrast, neem oil (Azadirachtin) exhibited significantly lower toxicity levels, with minimal impact on the mitotic index even at a 0.50% concentration.

Meiotic abnormalities

Meiotic abnormalities resulting from pesticide treatments were assessed through the observation of dividing pollen mother cells (PMCs) at various mei-

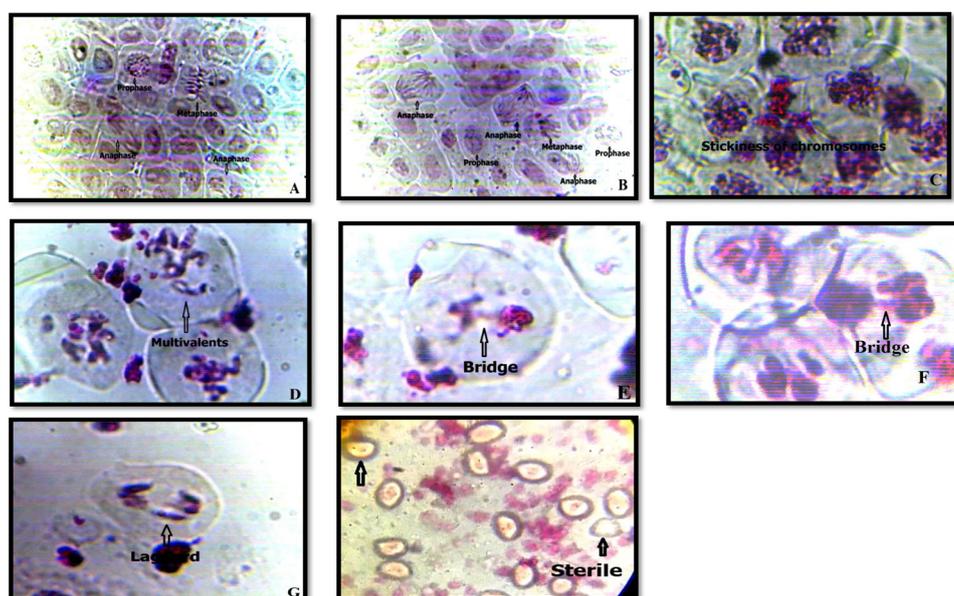


Plate 1. Mitotic and meiotic stages.

A: Mitotic index (Metaphase, Prophase, Anaphase), **B:** Mitotic index (Anaphase), **C:** Chromosome stickiness **D:** Formation of multivalent in meiosis, **E:** Anaphasic bridge, **F:** Telophasic bridge, **G:** Laggard chromosome at anaphase, **H:** Pollen sterility.

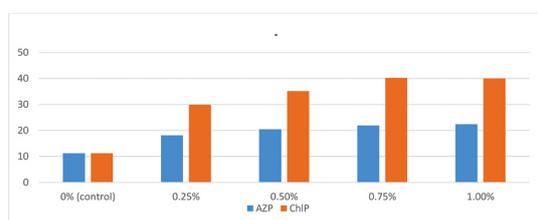


Fig. 4. Comparison of cytotoxicity of Chlorpyrifos (Chl P) and Azadirachtin (AZP) on % Pollen sterility at meiosis.

otic stages, with the findings summarized in Table 4, Fig. 3, and Plate 1. A range of chromosomal aberrations was identified, including sticky chromosomes, chromosome laggards at anaphase, multivalents, and chromosome bridges at both anaphase and telophase. Table 4 indicates that Azadirachtin had a negligible impact on the induction of chromosomal aberrations and percent toxicity. Conversely, Kemtrek (Chlorpyrifos) was responsible for significant chromosomal aberrations (Plate 1) and induced higher levels of toxicity at elevated concentrations, with maximum toxicity recorded at 1.0%. Toxicity levels were calculated in relation to control samples. Consistent with these findings, Chlorpyrifos also induced a high rate of pollen sterility, ranging from 2% to 5% in comparison to the minimal effects observed with Azadirachtin (Table 5, Fig. 4). Overall, the results highlight the marked disparities in toxicity and developmental effects between chemical and organic pesticides, underscoring the potential advantages of using Neem oil (Azadirachtin) in agricultural practices while raising concerns regarding the extensive toxicity associated with Chlorpyrifos.

DISCUSSION

In contemporary agriculture, maximizing crop yield is critical to meet the food demands of an ever-growing population. Pesticides are widely employed across agricultural systems, and their application has escalated significantly in recent years due to their capacity to enhance agricultural output by effectively targeting and eliminating pests as well as pathogens. While acknowledging the benefits of pesticides in bolstering food security through increased crop production, it is essential to consider the phytotoxic effects that these chemicals may exert. Such effects can manifest as cytological and morphological damage, ultimately

impairing the viability and yield of crop plants.

The present study elucidates the cytotoxic effects induced by pesticides, specifically highlighting their detrimental impact on seed germination rates, radical elongation, seedling survival, and the mitotic index. These findings are consistent with earlier research, such as that conducted by Gogoi *et al.* (2016). It can be deduced that pesticides penetrate meristematic cells, significantly disrupting cellular division processes. This disruption may explain the observed reduction in radicle elongation and subsequent lower survival rates of seedlings. In this study, exposure to the chemical pesticide Kemtrek (Chlorpyrifos) resulted in a notable reduction in the mitotic index across various concentrations, underscoring the pronounced cytotoxic consequences of this pesticide. This finding is similar to work published by Kumar and Prasad (2024). In contrast, the organic pesticide Azadirachtin (Neem oil) exhibited comparatively low cytotoxicity, suggesting that the chemical nature of the pesticide plays a crucial role in determining its genotoxicity and overall impact on plant physiology (Chaudhary *et al.* 2017).

The cell cycle, particularly during the S phase where DNA synthesis occurs, is significantly vulnerable to pesticide interference. Such interference may lead to a reduction in the mitotic index (Sudhakar *et al.* 2001) or could result from a blockage during the G2 phase, inhibiting the transition to mitotic division (Yekeen & Adebayo 2013). Furthermore, the genotoxic potential of pesticides was evidenced in meiotic cells, where various chromosomal aberrations were observed alongside decreased pollen fertility. Prominent chromosomal abnormalities noted in meiotic cells included chromosome stickiness, anaphase and telophase bridges, lagging chromosomes, and the formation of univalents and multivalents. Chromosomal stickiness is theorized to arise from improper condensation and folding of chromatin into single chromatids. The occurrence of multivalents, particularly trivalents, can be attributed to the formation of univalents due to weakened synapsis between homologous chromosomes, which may lead to non-homologous pairing or interfere with normal homologous pairing, subsequently resulting in multivalent configurations. Additionally, pesti-

Table 5. Comparison of cytotoxicity of Chlorpyrifos and neem oil on pollen sterility.

Sr. No.	Treatment	Azadirachtin (Induction of pollen sterility) (AZC)		Chlorpyrifos (Induction of pollen sterility) (ChC)	
		1	0% (control)	11.20± 0.17	-
2	0.25%	18.13± 0.24	38.22	29.90± 0.24	62.54
3	0.50%	20.46± 0.28	45.25	35.13± 0.28	68.11
4	0.75%	21.93± 0.14	48.92	40.23± 0.14	72.16
5	1.00%	22.46± 0.17	50.13	42.16± 0.17	73.43

cide-induced chromosomal breakage and reciprocal translocations may also contribute to the formation of multivalents. The presence of lagging chromosomes in the current study may stem from chromosomal fragmentation, as segments lacking centromeres fail to attach to spindle fibers, causing them to lag during cell division. This lagging can also be compounded by delayed terminalization or stickiness at chromosome ends. The observed anaphase and telophase bridges are likely consequences of chromosomal fusions, where connections between two chromosome segments, both possessing centromeres, create dicentric chromosomes that attach to spindle fibers of opposite poles, resulting in bridge formations.

Ultimately, the reduction in fertile pollen grains and subsequent increase in pollen sterility due to pesticide exposure is a direct consequence of chromosomal aberrations occurring during meiosis. This correlation between the percentage of chromosomal aberrations and the observed sterility underscores the detrimental effects of pesticides on plant reproductive capabilities, thus emphasizing the need for a more judicious approach to pesticide use in agricultural practices.

CONCLUSION

The present study has proved that the chemical pesticide Kemtrek containing active ingredient Chlorpyrifos is highly toxic at early seed germination stage, meristematic cell division stage and flower developmental stage. The toxicity is manifested in the form of mitotic index inhibition, inhibition of

seedling survival and induction of chromosomal aberrations. However the study also demonstrates that the use of organic pesticide neem oil containing active ingredient Azadirachtin is safe for use in agriculture as it induces minimum abnormalities. In agriculture the un-decomposed residues of the pesticides used in the previous crops are absorbed by germinating seeds resulting in abnormalities in the meristematic cells. This interferes with seed germination rate, radical elongation, seedling survival and reduces mitotic index. Similarly spray of pesticides like Chlorpyrifos at higher concentrations by farmers before flower developmental stage interfere with the normal development of flower primordia, resulting in chromosomal aberrations in meiotic cells along with reducing pollen fertility. Looking at the toxicity of Chlorpyrifos, it was banned for use on all food crops by US Environment Protection agency in 2021. But the ban lasted for a brief period as it was overturned by US federal appeal court.

ACKNOWLEDGMENT

The authors are thankful to Sant Baba Bhag Singh University for providing necessary materials and land for accomplishing this research work.

REFERENCES

- Adhikari, K., Bhandari, S., Niraula, D., & Shrestha, J. (2020). Use of Neem (*Azadirachta indica* A. Juss) as a biopesticide in Agriculture: Review. *Journal of Agriculture and Applied Biology*, 1(2), 100-117.
- Atmaca E., Das, Y. K., Yavuz, O., & Aksoy. (2019). An evaluation of the levels of organochlorine compounds (OCPs and PCBs) in cultured freshwater and wild sea fish eggs as an exposure biomarker for environmental contamination. *Environmental Science and Pollution Research*, 26(7), 7005-7012.
- Chaudhary, S., Kanwar, R. K., Sehgal, A., Cahill, D. M., Bar-row, C. J., Sehgal, R., & Kanwar, J. R. (2017). Progress on *Azadirachta indica* based biopesticides in replacing synthetic toxic pesticides. *Frontiers in Plant Science*, 8, 610. <https://doi.org/10.3389/fpls.2017.00610>
- Datta, S., Singh, J., Singh, J., & Singh, S. (2018). Assessment of genotoxic effects of pesticide and vermicompost treated soil with *Allium cepa* test. *Sustainable Environment Research*, 28 (4), 171-178.
- Gogoi, P., Das, S., Das, S., & Khan, M. Z. A. (2016). Effect of Organophosphorus Insecticide, Malathion on the Division of Meristems of *Allium cepa* L. *International Journal of Pure and Applied Bioscience*, 4(4), 114-122.
- Kaur, K., & Kaur, R. (2018). Occupational Pesticide Exposure,

- Impaired DNA Repair, and Diseases. *Indian Journal of Occupational and Environmental Medicine*, 22(2), 74–81.
- Kihlman, B. A. (1966). Action of Chemicals on dividing cells. Prentice-Hall INC., New Jersey.
- Kumar, P., & Prasad, V. (2024). Study of cytogenetic effect of pesticide chlorpyrifos using chromosomal behavior of root meristem in *Allium cepa* L. *International Journal of Biology Pharmacy and Allied Sciences*, 13(6), 2678-2692
- Pandey, R. M. (2008). Cytotoxic effects of pesticides in somatic cells of *Vicia faba* L. *Cytology and Genetics*, 42, 373–377.
- Pandey, V. (2015). Cytological effects of insecticides on onion (*Allium cepa* L.). AIJRA, Vol IV, Issue II
- Roshan, A., & Verma, N. K. (2015). A brief study on neem (*Azadirachta indica*) and its application—A review. *Research Journal of Phytomedicine*, 1(1), 01-03
- Singh, J., Singh, P. K., Singh, V., & Singh, Y. P. (2009). Toxicity evaluation of pesticide waste leachate by *Allium cepa* root (growth and cytogenetic) assay. *International Journal of Applied Environmental Sciences*, 4(1), 71-83
- Sudhakar, C., Surabhi, G. K., & Lakshmi, A. (2001). Changes in the antioxidant enzyme efficacy in two high yielding genotypes of mulberry (*Morus alba* L.) under NaCl salinity. *Plant Science*, 161(3), 613-619
- Wexler, P. (Ed.). (2014). Chlorpyrifos In: Encyclopedia of Toxicology. 3rd edn. vol 1. Elsevier Inc., Academic Press, pp 930-934.
- Yekeen, T. A., & Adeboye, M. K. (2013). Cytogenotoxic effects of cypermethrin, deltamethrin, lambda-cyhalothrin and endosulphan pesticides on *Allium cepa* root cells. *African Journal of Biotechnology*, 12(41), 6000-6006.