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Cytological effects of Dimethoate and Lambda-Cyhalothrin on Pollen Grain Cells Reproduction and Development

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Abstract

This study investigates the effects of Dimethoate (A) and Lambda-Cyhalothrin (B) on pollen grain cells in the soil at various concentrations. Lowest exine thickness was observed in soil treated with a combination of Dimethoate and Lambda-Cyhalothrin (A+B) at 10mL/L. Dimethoate (A) at 40mL/L increased exine thickness, while Lambda-Cyhalothrin (B) and the combination (A+B) enhanced pollen grain size and circumference. Pollen grain width was largest in soils treated with Lambda-Cyhalothrin (B) at 10mL/L. Additionally, cellular abnormalities, including stickiness, surface deformation, shrinkage, irregular shapes, and size variation, increased with an increase in pesticide concentration. Dimethoate (A) induced the most severe cellular abnormalities, particularly at 50mL/L, with a peak of 31% abnormal cells, compared to 27.3% in Lambda-Cyhalothrin (B) and 20.5% in the combination (A+B). The results indicate significant alterations in exine thickness, pollen grain circumference, and pollen grain width. These findings suggest a dose-response relationship between pesticide concentration and cellular disruption. The study emphasises the potential cytotoxic effects of Dimethoate and Lambda-Cyhalothrin on plant reproduction and development, highlighting the need for sustainable agricultural practices to mitigate pesticide-induced harm. Further research is necessary to explore the molecular mechanisms of these cytological changes and develop strategies to minimise pesticide toxicity in crops.

Keywords: Cytology; Cowpea; Pesticides; Pollen grain

INTRODUCTION

Cowpea (*Vigna unguiculata* L. WALP) (Fabaceae) is one of the most ancient human food sources and has probably been used as a crop plant since Neolithic times (Tazerouni *et al.,* 2019). Cowpea was introduced from Africa to many regions in the world approximately 2000 to 3500 years ago (Kébé *et al.,* 2017). It is a widely adapted legume grown worldwide (Xiong *et al.,* 2016). Recently, it has become an essential crop in many countries in tropical Africa, Asia, and South America (Lazaridi and Bebeli, 2023). Cowpea is a significant leguminous crop that is commonly produced in arid and semi-arid areas (Oyewale and Bamaiyi, 2013). However, pesticides may contaminate soil and groundwater, which can be toxic to desirable plants and cause a substantial impact on the growth and development of plants and humans (Özkara *et al.,* 2016). If used improperly, pesticides can poison people, pets, and livestock, and also beneficial insects, birds, fish, and other wildlife (Ogbonnaya *et al.,* 2022). Cowpea is susceptible to a wide range of pests and diseases that attack the crop at all stages of growth. These include insects, bacteria, fungi, and viruses. High pest densities can cause a complete loss of grain yield if no control measures are taken (Setiawati *et al.,* 2022).

Farmers in Katsina typically use pesticides in their agricultural fields, among which are dimethoate and lambda-cyhalothrin (A and B). Based on the consulted literature, prior research has not examined the genotoxic effects of dimethoate and lambda-cyhalothrin (A and B) up to the cytological stage in the State. Cowpea, despite its multifunctionality as a nutritious crop, often remains overlooked in terms of genetic enhancement efforts. This lack of focus has contributed to its relatively low yield potential compared to other legumes. Research and investment into improving the genetic traits of cowpea could significantly boost its productivity and establish it as a more prominent staple in agriculture. Enhancing traits such as disease resistance, drought tolerance, and overall yield can help to maximize the benefits of this valuable crop, both for farmers and consumers alike. It is essential to exercise caution when dealing with pesticides as they can cause alterations in crop growth performance and pollen grains, which can disrupt the cytological nature of the plant, leading to mutations. This can have serious implications for future generations. It is recommended to take measures to minimize pesticide exposure and ensure the safety of all those involved (Saad-Allah *et al.*, 2021).

Materials and Methods

Description of Study Area/Site

The experiment was conducted at the Katsina Bioresources Developments Centre (BIODEC), Katsina State, Nigeria. Katsina, with a warm subtropical climate, receives an average annual rainfall of approximately 700-800 mm. The mean monthly dry season temperature is approximately 30°C. The highest humidity levels occur in August and September, while the lowest occur in February and March (Aminu, 2020). The experimental study site was an insect-controlled environment (35/27°C Day/night; 65% RH) screen house at the Bioresources Development Centre, Katsina, Katsina State, Nigeria. The temperature of the screen house was based on the ecological characteristics (environment) of the semi-arid tropics where cowpea is commonly grown.

Plate 1: The Experimental Site Insect-controlled Screen House

Sample Collection and Identification

A variety of cowpea seeds (573-1-1) was obtained from the International Institute for Tropical Agriculture (IITA) Kano office. The seeds were taken to the herbarium unit for identification at the Department of Biological Sciences, Umaru Musa Yar'adua University, Katsina, Katsina State.

The seeds' viability was tested by placing them in water using the flotation method (Daneshvar *et al.*, 2017). The non-viable seeds floated on the water, signifying the cotyledons were destroyed and discarded. The seeds that did not float were collected and used for this research.

METHODOLOGY

The pesticide applications for the soil contamination and plant spray were prepared in varying concentrations (10, 20, 30, 40, and 50 mL/L) and applied to the cowpea plants. The applications were done four times at two-week intervals using a hand sprayer between 7:00 am and 9:00 am (Laane, 2018). Early spikelets of the flower samples for pollen analyses were collected based on different concentrations (10, 20, 30, 40, and 50 mL/L) between 10:30 am and 11:30 am, starting the day after the treatment and continuing until the day of the next treatment (Nateghi *et al.*, 2013). These samples were preserved in a fixative solution (3:7 ratio of ethyl alcohol-water). According to Bhagyawant and Srivastava (2015), and refrigerated until used. After removing the flowers from the fixative, the anthers were extracted from the floral buds using a dissection needle and mounted on glass slides. Two drops of acetocarmine were added, and glycerin was applied to prevent drying (Bhagyawant and Srivastava, 2015). To measure the thickness, circumference, and width of the pollen grains, a total of 100 flowers were taken from each group. The stickiness of pollen grains, surface deformation, shrinkage, unusual forms, and size fluctuation are other pesticide impacts that have been studied. Pollen cells were captured on camera using a Pixel Pro and a Motic image microscope under x400 magnification. The pollen measurement and properties were ascertained using stage and ocular micrometre calibrations based on the pesticides and the experimental setup (A, B, and A+B), the pollen cells were seen, and the observations were documented according to Sivaguru *et al.* (2012).

RESULTS

The results show that soil treated with Lambda-Cyhalothrin (B) at concentrations of 20mL/L, and the combination of Dimethoate and Lambda-Cyhalothrin (A+B) at concentrations of 20mL/L and 40mL/L, exhibited the largest pollen grain circumference diameter (1µm). Soil treated with Dimethoate (A) at a 50mL/L concentration showed the smallest diameter (0.275µm). This may be due to the stimulatory factor lambda-cyhalothrin and the inhibitory factor of dimethoate, compared to the control, as illustrated in (Figure 1).

The results show that soil treated with a combination of Dimethoate and Lambda-Cyhalothrin (A+B) at a concentration of 10mL/L exhibited the lowest exine thickness of (0.0525µm), while soil treated with Dimethoate (A) at a concentration of 40mL/L showed the highest exine thickness of (0.09µm), this may be due to stimulatory factor of lambda-cyhalothrin and the inhibitory factor of dimethoate, compared to the control, as illustrated in (Figure 1).

The data suggest that soil treated with Dimethoate (A) at a concentration of 50mL/L exhibited the smallest pollen grain width (0.4µm), whereas soil treated with Lambda-Cyhalothrin (B) at a concentration of 10mL/L showed the widest pollen grain width (0.875µm). The decrease in pollen grain width as a result of dimethoate treatment may be attributed to its ability to impede cell growth and division, whereas the increase in pollen grain width due to Lambda-Cyhalothrin treatment might be more pronounced at lower concentrations because of its capacity to enhance cell size and division compared to the control, as illustrated in (Figure 1). Moreover, across all concentrations ranging from 10mL/L to 50mL/L, Lambda-Cyhalothrin (B) demonstrated a consistent decrease in pollen grain width. The combination of Dimethoate and Lambda-Cyhalothrin (A+B) shows a synergistic impact on pollen grain width across all tested concentrations.

The regression analysis (Table 1) shows the Pearson correlation coefficients between pesticide concentration variables A, B, A+B, and the control group. The highest positive correlation is observed between concentrations and A+B ($r = 0.884$, $p = 0.023$), indicating a strong linear association between pesticide levels and the combined effect of variables A and B. This suggests that as pesticide concentration rises, the overall impact of A and B also escalates. The correlation between concentrations and the control group ($r = 0.577$, $p = 0.154$) is moderate, though it does not reach statistical significance at the 0.05 level, indicating some association level. The relationship between A and B is negative ($r = 0.244$, $p = 0.346$), which means that as A increases, B tends to decrease slightly; the correlation is weak and not statistically significant. The correlation between concentrations and A+B ($p = 0.023$) is statistically significant, highlighting a meaningful relationship between pesticide concentration and the interaction of A and B.

This analysis implies that pesticide concentration has a strong and significant connection with the interaction of variables A+B, while its associations with the individual variables A, B, and the control group are moderate or weak and lack statistical significance (Plate 3). These findings suggest that the interaction between A and B is pivotal to exine changes as a response to pesticide concentration, more so than the separate impacts of A or B.

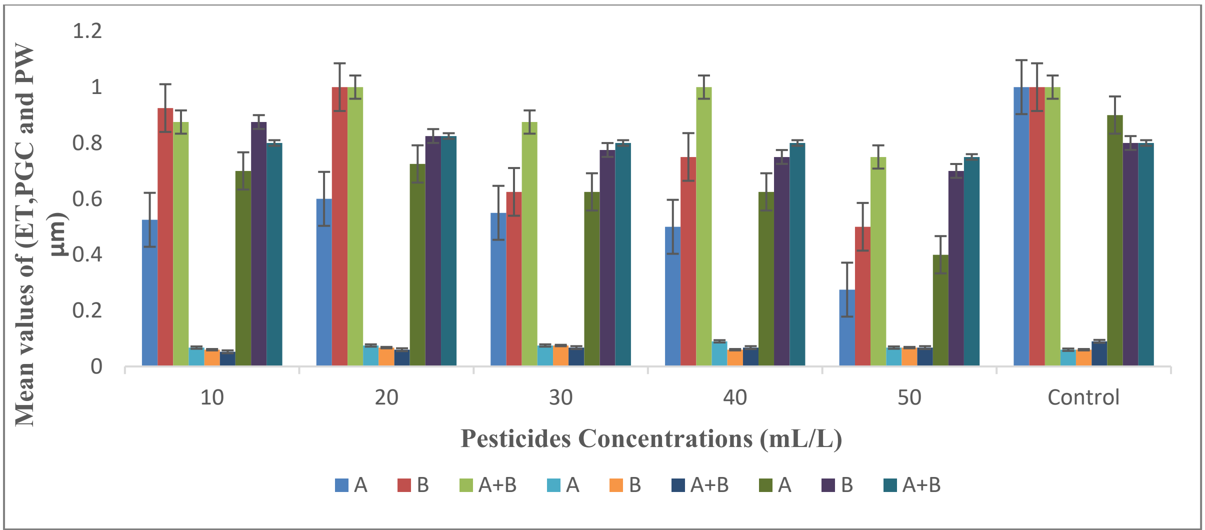

Figure 1: Showing the Mean values of Pollen Grain Circumference, Exine Thickness, and Pollen Grain Width (µm)

The regression analysis (Table 2) assesses the Pearson correlation coefficients (r) between pesticide concentration, variables A and B, their interaction (A+B), and the control group regarding changes in pollen grain circumference. The correlation between concentrations and B (r =-0.842, p = 0.037) reveals a strong negative relationship between pesticide concentration and variable B. This implies that as pesticide levels increase, the effects of variable B also rise considerably. In a similar vein, the correlation between concentrations and variable A also shows a strong negative association (r = -0.754, p = 0.070). Still, this relationship is slightly weaker and does not achieve statistical significance at the p < 0.05 threshold. The correlation between concentrations and A+B (r = -0.378, p = 0.265) is weaker and statistically insignificant, suggesting that the interaction effect of A and B does not significantly influence changes in pollen grain circumference to pesticide concentration. Notably, the correlation between A and B (r = 0.769, p = 0.064) is both strong and positive, indicating that as A rises, B also tends to increase. Additionally, A and A+B (r = 0.796, p = 0.054) and B and A+B (r = 0.709, p = 0.090) demonstrate strong positive correlations, meaning that the interaction effect (A+B) is impacted by both A and B. The results suggest that pesticide concentration substantially and negatively affects B while having a moderately strong impact on A.

The regression analysis (Table 3) investigates the Pearson correlation coefficients (r) connecting pesticide concentrations, variables A, B, A+B, and the control group concerning changes in pollen grain width. The most substantial correlation is found between concentrations and B (r = -0.995, p< 0.001), signifying a very strong negative association. This suggests that as pesticide concentration increases, B's effects increase almost perfectly. There is also a strong negative correlation between concentrations and A (r = -0.863, p = 0.030), indicating that rising pesticide concentrations significantly elevate the effects of A. The correlation between concentrations and A+B (r = -0.722, p = 0.084) is moderately strong, but it does not reach statistical significance at the 0.05 level. A and B display a strong positive correlation (r = 0.862, p = 0.030), suggesting that as A increases, B similarly increases. A and A+B show a high positive correlation (r = 0.961, p = 0.005), indicating a strong link between A and the interaction effect. Additionally, B and A+B display a moderately strong positive correlation (r = 0.710, p = 0.090), though they do not achieve statistical significance at $p < 0.05$. This extremely strong inverse correlation between pesticide B and width ($r = -0.995$, $p < 0.001$). This suggests B severely compromises pollen grain development, possibly via oxidative stress or microbiome dysbiosis, both of which disrupt cellular integrity during pollen formation.

Pesticide A: Also negatively correlated ($r = -0.863$, $p = 0.030$), though less severe than B.

Combined A+B: $r = -0.722$, $p = 0.084$, again highlighting that individual applications may pose greater harm than dual exposures under some biological thresholds.

Table 1: Regression Analysis between Pesticide Concentrations and Exine Changes

		CONC	A	B	A_B	CONTROL
Pearson Correlation	CONC	1.000	.258	.189	.884	.577
	A	.258	1.000	-.244	.456	-.373
	B	.189	-.244	1.000	.468	.764
	A_B	.884	.456	.468	1.000	.612
	CONTROL	.577	-.373	.764	.612	1.000
Sig. (1-tailed)	CONC	.	.337	.380	.023	.154
	A	.337	.	.346	.220	.268
	B	.380	.346	.	.213	.066
	A_B	.023	.220	.213	.	.136
	CONTROL	.154	.268	.066	.136	.

Table 2: Regression Analysis between Pesticide Concentrations and Pollen Grain Circumference Changes

		CONC	A	B	A_B	CONTROL
Pearson Correlation	CONC	1.000	-.754	-.842	-.378	.
	A	-.754	1.000	.769	.796	.
	B	-.842	.769	1.000	.709	.
	A_B	-.378	.796	.709	1.000	.
	CONTROL	.	.	.	.	1.000
Sig. (1-tailed)	CONC	.	.070	.037	.265	.000
	A	.070	.	.064	.054	.000
	B	.037	.064	.	.090	.000
	A_B	.265	.054	.090	.	.000
	CONTROL	.000	.000	.000	.000	.

Table 3: Regression Analysis between Pesticide Concentrations and Pollen Grain Width

		CONC	A	B	A_B	CONTROL
Pearson Correlation	CONC	1.000	-.863	-.995	-.722	.354
	A	-.863	1.000	.862	.961	-.480
	B	-.995	.862	1.000	.710	-.331
	A_B	-.722	.961	.710	1.000	-.612
	CONTROL	.354	-.480	-.331	-.612	1.000
Sig. (1-tailed)	CONC	.	.030	.000	.084	.280
	A	.030	.	.030	.005	.207
	B	.000	.030	.	.090	.293
	A_B	.084	.005	.090	.	.136
	CONTROL	.280	.207	.293	.136	.

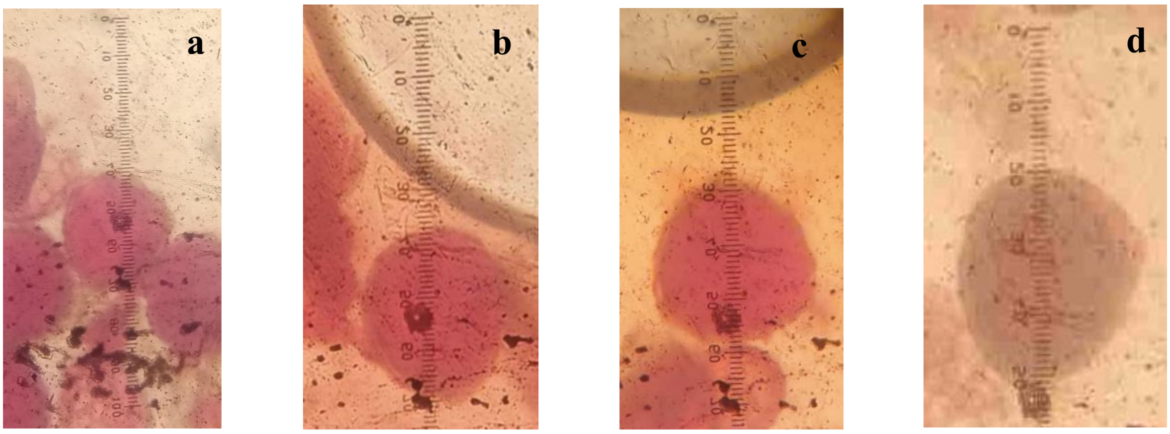

Plate 2: Cytological Effects of (a) Dimethoate (A), (b) Lamba-Cyhalothrin (B)(c) Combination of Dimethoate and Lamba-Cyhalothrin (A+B),and (d) Control. On Pollen Grain Circumference (PGC), Exine Thickness (ET), and Pollen Grain Width (PGW). Observed at 40x magnification.

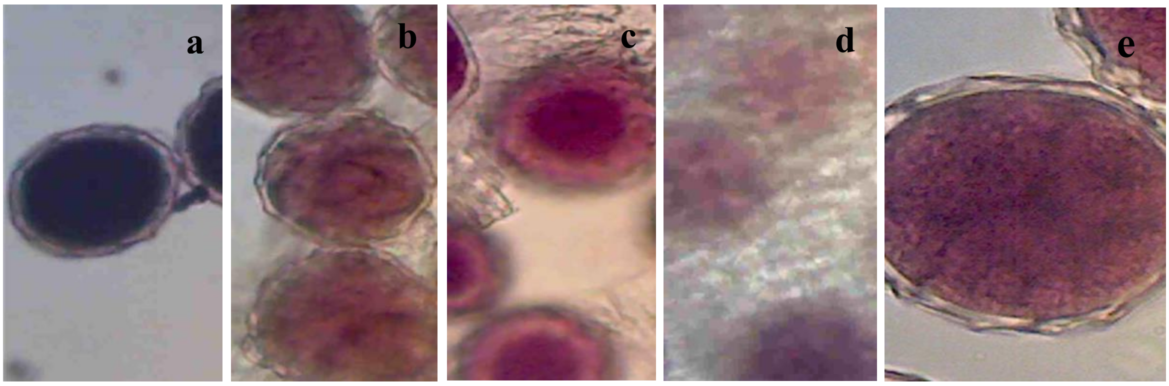

Plate 3: Effects of Pesticides on Pollen Grain (a) Stickiness, (b) Surface Deformation, (c) Size Variation, (d) Shrinkage/Irregular Shapes and (e) Control Observed at 40X magnification.

The information in (Table 4) describes the impact of different levels of Dimethoate (A), Lambda-Cyhalothrin (B), and their combination (A+B) on pollen grain cells. The outcomes display various irregularities in cellular structure, such as stickiness, surface deformations, shrinkage, irregular shapes, and variations in size. The total cells examined (TCE) remained constant at 498 in all scenarios. Stickiness (ST) increased with higher concentrations of Dimethoate (A) (20-50mL/L). Lambda-Cyhalothrin (B) showed moderate stickiness at lower concentrations (10-20mL/L) and a rise in stickiness at higher concentrations (30-50mL/L). The combined (A+B) treatment exhibited increased stickiness across all concentrations. Surface deformations (SD) were moderately observed at lower concentrations of Dimethoate (A) (10-20mL/L) and increased with higher concentrations (30-50mL/L). Conversely, Lambda-Cyhalothrin (B) displayed moderate surface deformation at all concentrations, while the combination (A+B) showed increased surface deformation across all concentrations. Shrinkage (SR) increased with higher concentrations of Dimethoate (A) (30-50mL/L). Lambda-Cyhalothrin (B) exhibited moderate shrinkage at lower concentrations (10-20mL/L) and increased shrinkage at higher concentrations (30-50mL/L). The combination (A+B) showed increased shrinkage across all concentrations. Irregular shapes (IS) increased at higher concentrations of Dimethoate (A) (30-50mL/L) and higher concentrations of Lambda-Cyhalothrin (B) (30-50mL/L), with the combination (A+B) displaying increased irregular shapes across all concentrations. Size variation (SV) increased with higher concentrations of Dimethoate (A) (30-50mL/L), while Lambda-Cyhalothrin (B) showed moderate size variation at all concentrations. The combination (A+B) demonstrated increased size variation across all concentrations.

The percentage of cellular irregularities peaked at (31%) for Dimethoate (A) at 50mL/L, whereas (27.3%) for Lambda-Cyhalothrin (B) at 50mL/L was observed, and (20.5%) for the combination (A+B) at 50mL/L. As a result, the data suggest that all pesticides and their combination induced cellular abnormalities in pollen grain cells (Plates 1 and 2), with higher concentrations resulting in increased abnormalities. The combination (A+B) led to more severe cellular abnormalities than individual pesticides did. Dimethoate (A) induced more severe cellular abnormalities than Lambda-Cyhalothrin (B) at higher concentrations. These findings indicate that exposure to Dimethoate, Lambda-Cyhalothrin, and their combination can cause significant cytological changes in pollen grain cells, potentially impacting plant reproduction and development. The results of this research demonstrate a substantial influence of Dimethoate (A), Lambda-Cyhalothrin (B), and their combination (A+B) on pollen grain cells, resulting in diverse cellular irregularities. The consistent total cells examined (TCE) across all treatments ensures the reliability of the results. Pesticide exposure increases adhesiveness, surface distortion, shrinkage, irregular shapes, and size disparity, which indicate cytological changes.

Table 4: Effects of Different Concentrations of Pesticides on Pollen Grain Cells

Pest, Conc,	Tce	ST	SD	SR	IS	SV	(%)
A							
Cnl	166	0	1	0	0	1	1.2%
10	498	492	2	1		1	1.2%
20	498	490	3	2	2	1	2.0%
30	498	477	7	7	6	1	4.2%
40	498	443	43	2	8	2	11.0%
50	498	346	75	57	19	1	31.%
B							
Cnl	166	0	0	0	0	1	0.6%
10	498	486	8	1	2	1	2.4%
20	498	480	11	2	3	2	4%
30	498	474	16	4	3	1	5%
40	498	458	28	7	4	1	8%
50	498	362	69	42	21	4	27.3%
A+B							
Cnl	166	0	3	1	0	1	3.0%
10	498	464	19	11	3	1	7%
20	498	446	26	19	6	1	10.4%
30	498	437	32	21	7	1	12.2%
40	498	413	48	27	9	1	17.1%
50	498	396	55	34	11	2	20.5%

KEY: PEST CONC: Pesticide Concentration, **TCE:** Total Cells Examined, **ST**: Stickiness, **SD**: Surface Deformation, **SR**: Shrinkage, **IS**: Irregular Shapes, **SV**: Size Variation, **A**: Dimethoate Pesticide, **B**: Lambda-Cyhalothrin Pesticide, **A+B**: Combination (Dimethoate and Lambda-Cyhalothrin Pesticide).

DISCUSSION

These findings align with previous studies indicating that Lambda-Cyhalothrin can increase pollen grain size and diameter (Ward *et al.*, 2024). The research has also shown that Dimethoate can adversely impact pollen grain size and diameter, while the combination of Dimethoate and Lambda-Cyhalothrin can have a synergistic effect on pollen grain size and diameter (Rajak *et al.*, 2023). The increase in pollen grain circumference (diameter) with Lambda-Cyhalothrin treatment may be attributed to its ability to enhance cell size and division. Conversely, the reduction in pollen grain circumference (diameter) with Dimethoate treatment may be due to its capacity to inhibit cell growth and division. The findings imply that Lambda-Cyhalothrin (B) and the combination of Dimethoate and Lambda-Cyhalothrin (A+B) have a positive impact on pollen grain circumference (diameter), while Dimethoate (A) has negative effects. These findings are in line with the previous studies, which indicated that Lambda-Cyhalothrin could enlarge pollen grain size and width (Garcia *et al.*, 2022), while Dimethoate could reduce them (Simon-Delso *et al.*, 2017).

Previous studies indicate that Dimethoate can increase pollen grain exine thickness (Candan and Ozatrk, 2015), while Lambda-Cyhalothrin can decrease pollen grain exine thickness (Nevein *et al.*, 2014). Wrońska-Pilarek *et al.* (2023) also reported that pesticides can reduce the thickness of pollen exine. The combination of Dimethoate and Lambda-Cyhalothrin (A+B) may have a synergistic effect on pollen grain exine thickness, as reported by Tonfack (2019), who showed that pesticides can reduce pollen viability, resulting in the lowest exine thickness even at lower concentrations. The increase in exine thickness with Dimethoate treatment may be attributed to its ability to enhance cell wall thickness and deposition, while the decrease in exine thickness with Lambda-Cyhalothrin treatment may be due to its ability to inhibit cell wall thickening and deposition.

The findings of the regression analysis (Table 1) reveal a statistically significant and strong positive correlation between pesticide concentration and the combined impact of variables A and B. This indicates that the interaction between these variables is a pivotal factor in mediating the biological response, which may encompass alterations to pollen exine structure. The elevated Pearson correlation coefficient (r = 0.884, p = .023) signifies a robust linear relationship, thereby reinforcing the notion that increasing pesticide levels amplify the collective biological effect of A and B. This finding supports the hypothesis that synergistic or additive effects may arise when both variables function in concert, aligning with existing literature that underscores the compounded influence of multiple stressors on pollinators and plant reproductive traits (Tosi *et al.*, 2018). This may imply microbial interference by the pesticide (Memela, 2022). However, negative pesticide impacts are more prevalent than significant ones, with few confirmed effects on soil organisms. Research by Bawa *et al.* (2025) has demonstrated that Dimethoate can adversely affect soil bacteria and fungi. The substance is known to decrease the population of these microorganisms in the soil, and can even lead to the demise of certain bacterial species.

In contrast, the moderate correlation observed between pesticide concentration and the control group (r = 0.577, p = .154) suggests a potential trend; however, it does not achieve statistical significance. Likewise, the weak and non-significant negative correlation identified between variables A and B (r = 0.244, p = .346) indicates minimal direct interaction when evaluated independently. These patterns imply that although individual variables may exert limited influence, their combined effect (A+B) significantly modulates the response, which is consistent with findings in toxicology that reveal mixture effects often diverging from single-exposure outcomes (Bawa *et al*,2025).

The findings of the regression analysis (Table 2) indicate that elevated pesticide levels decrease pollen grain circumference, primarily through their influence on these variables, especially B. Furthermore, the strong positive correlation between A and B indicates that these variables are likely interdependent regarding their effects on pollen grain circumference, suggesting that both A and B should be considered together rather than separately when evaluating the impacts of pesticide exposure. (Ayaz *et al.*, 2019).Control shows zero correlation, reinforcing that observed effects are linked to pesticide treatments.

The findings of the regression analysis (Table 3) Indicate That Pesticides, particularly organophosphates and neonicotinoids, impair soil microbial biodiversity, affecting key functions such as Nitrogen fixation, mycorrhizal interactions, and the degradation of allelochemicals. As plant-microbe interactions regulate plant reproductive traits, including pollen morphology, microbial suppression can lead to abnormal tapetum activity (pollen coat), impaired sporopollenin synthesis, which is critical to exine, reduced nutrient availability affecting pollen hydration and germination (Parween *et al.*, 2016).

The data presented in Table 4 indicate that exposure to Dimethoate (A), Lambda-Cyhalothrin (B), and their combination (A+B) results in various cytological abnormalities in pollen grain cells, with the severity escalating by pesticide concentration. Each treatment demonstrated a dose-dependent increase in stickiness (ST), surface deformation (SD), shrinkage (SR), irregular shapes (IS), and size variation (SV), signifying progressive cellular stress and structural damage.

Dimethoate (A) induced the highest percentage of abnormalities, reaching a peak of 31% at a concentration of 50 ml/l. This was followed by Lambda-Cyhalothrin (B), which exhibited a percentage of 27.3%, and the combination of both agents (A+B), which demonstrated a percentage of 20.5%. The elevated toxicity of Dimethoate is aligned with recent research indicating that organophosphates present a greater reproductive risk in plants than pyrethroids (Martin-Reina *et al.*, 2017). It is noteworthy that, although the combination (A+B) resulted in abnormalities across all concentrations, the maximum percentage observed was lower than that recorded for Dimethoate alone. This observation suggests a potential antagonistic interaction at higher concentrations, a phenomenon that has been documented in recent studies regarding pesticide interactions (Ngoula *et al*., 2014).

The consistent total number of cells examined (TCE = 498) across treatments enhances the reliability of these observations. Cellular abnormalities, including shrinkage and surface deformation, may impair pollen viability, thereby reducing fertilisation efficiency and ultimately impacting plant reproduction and crop yield (Singh *et al*., 2021). These findings emphasise the detrimental effects of commonly used agricultural pesticides on non-target reproductive structures, even at relatively low concentrations.

Given the critical role of pollen in plant reproduction, these findings highlight the need for stricter regulation of pesticide use and a shift toward more sustainable, pollinator-safe pest management strategies.

The escalation of cellular irregularities, depending on the concentration, suggests a dose-response correlation (Tables 1, 2, 3, and 4), implying that higher concentrations of pesticides lead to more severe cellular effects. The combination (A+B) exhibited more severe cellular abnormalities than individual pesticides, implying a synergistic effect. Therefore, combining **dimethoate** (an organophosphate) and **lambda-cyhalothrin** (a pyrethroid) in a plant like cowpea could lead to a range of cellular aberrations due to their distinct toxic mechanisms (Watts, 2010; Ranz, 2022). This is disconcerting, given the common practice of using pesticides in combination in agriculture (Hatamleh *et al*., 2022). Dimethoate is an organophosphate pesticide that contains compounds inhibiting the enzyme acetylcholinesterase, leading to toxicity in both pests and plants (Agrawal and Sharma, 2010). Lambda-cyhalothrin is a pyrethroid pesticide. Its compounds work by disrupting insects' nervous systems (Ali, 2012). In plants, these compounds can interfere with various metabolic processes, potentially resulting in cellular abnormalities. This enzyme inhibition can disrupt plant cellular processes, potentially leading to abnormal cell structures or functions. (Araujo *et al*., 2023). Dimethoate (A) demonstrated more severe cellular irregularities than Lambda-Cyhalothrin (B) at higher concentrations, indicating a greater potential for cytological disruption.

CONCLUSION

In conclusion, this study highlights the significant impact of Dimethoate, Lambda-Cyhalothrin, and their combination on pollen grain cells, leading to diverse cellular irregularities. The cytological changes observed have implications for plant reproduction and development, potentially leading to reduced crop yields and altered plant cytology. The mechanisms underlying these cytological changes are not entirely understood but may involve pesticide-induced oxidative stress, DNA damage, and disrupted cell signalling pathways. The findings highlight the need for careful consideration of pesticide use in agriculture and underscore the importance of developing sustainable agricultural practices that minimise harm to plant cells and the environment. Further research is required to elucidate the molecular mechanisms and to devise strategies to mitigate the harmful effects of Dimethoate, Lambda-Cyhalothrin, and their combination on plant cells.

REFERENCES

Agrawal, A., & Sharma, B. (2010). Pesticides induce oxidative stress in mammalian systems. *International Journal of Biology and Medical Research, 1*(3), 90–104.

Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M.-Q. (2021). Heavy metals and pesticide toxicity in agricultural soil and plants: Ecological risks and human health implications. *Toxics, 9*(3), 1–42. [Crossref]

Ali, Z. Y. (2012). Neurotoxic effect of lambda-cyhalothrin, a synthetic pyrethroid pesticide: Involvement of oxidative stress and protective role of antioxidant mixture. *New York Science Journal, 5*, 93–103.

Aminu, H. A. (2020). Arbuscular mycorrhizal fungi as a potential biocontrol agent against vascular wilt of cowpea (Vigna unguiculata L. Walp) in Katsina Nigeria [Master's dissertation, Unpublished].

Araújo, M. F., Castanheira, E. M., & Sousa, S. F. (2023). The buzz on insecticides: A review of uses, molecular structures, targets, adverse effects, and alternatives. *Molecules, 28*(8), 3641. [Crossref]

Ayaz, M., Ullah, F., Sadiq, A., Ullah, F., Ovais, M., Ahmed, J., & Devkota, H. P. (2019). Synergistic interactions of phytochemicals with antimicrobial agents: Potential strategy to counteract drug resistance. *Chemico-Biological Interactions, 308*, 294–303. [Crossref]

Bawa, Y. M., Kalimullah, S., & Wagini, N. H. (2025). The effects of pesticide application on soil microbiota and weed dynamics in cowpea cropping systems. *UMYU Scientifica, 4*(1), 150–159. [Crossref]

Bhagyawant, S. S., & Srivastava, N. (Eds.). (2015). *Plant biotechnology*. Horizon Books.

Candan, F., & Öztürk, Ç. (2015). Studies on the comparison of pollen morphology and viability of four naturally distributed and commercial varieties of Anemone coronaria L. *Pakistan Journal of Botany, 47*(2), 517–522.

Daneshvar, A., Tigabu, M., Karimidoost, A., & Odén, P. C. (2017). Flotation techniques to improve viability of Juniperus polycarpos seed lots. *Journal of Forestry Research, 28*, 231–239. [Crossref]

García, M. G., Sánchez, J. I. L., Bravo, K. A. S., Cabal, M. D. C., & Pérez-Santín, E. (2022). Presence, distribution, and current pesticides used in Spanish agricultural practices. *Science of the Total Environment, 845*, 157291. [Crossref]

Hatamleh, A. A., Danish, M., Al-Dosary, M. A., El-Zaidy, M., & Ali, S. (2022). Physiological and oxidative stress responses of Solanum lycopersicum (L.) (tomato) when exposed to different chemical pesticides. *RSC Advances, 12*(12), 7237–7252. [Crossref]

Kébé, K., Alvarez, N., Tuda, M., Arnqvist, G., Fox, C. W., Sembène, M., & Espíndola, A. (2017). Global phylogeography of the insect pest Callosobruchus maculatus (Coleoptera: Bruchinae) relates to the history of its main host, Vigna unguiculata. *Journal of Biogeography, 44*(11), 2515–2526. [Crossref]

Laane, H. M. (2018). The effects of foliar sprays with different silicon compounds. *Plants, 7*(2), 45. [Crossref]

Lazaridi, E., & Bebeli, P. J. (2023). Cowpea constraints and breeding in Europe. *Plants, 12*(6), 1339. [Crossref]

Martin-Reina, J., Duarte, J. A., Cerrillos, L., Bautista, J. D., & Moreno, I. (2017). Insecticide reproductive toxicity profile: Organophosphate, carbamate and pyrethroids. *Journal of Toxins, 4*(1), 7. [Crossref]

Memela, U. (2022). The physiological effects of heat stress on anthesis and pollination in domesticated sunflowers (Helianthus annuus L.) [Doctoral dissertation, University of Pretoria].

Nateghi-A, F., & Rezaei-Tabrizi, A. (2013). Nonlinear dynamic response of tall buildings considering structure-soil-structure effects. *The Structural Design of Tall and Special Buildings, 22*(14), 1075-1082. [Crossref]

Nevein, M. A., Gamil, M. A., & Nagi, F. I. (2014). Biological verification and quality assessment of a natural hepatoprotective recipe. *International Journal of Pharmacy and Pharmaceutical Sciences, 6*(6), 641-647.

Ngoula, F., Watcho, P., Kenfack, A., Manga, J. N. Z., Defang, H. F., Pierre, K., & Joseph, T. (2014). Effect of dimethoate (an organophosphate insecticide) on the reproductive system and fertility of adult male rat. *American Journal of Pharmacology and Toxicology, 9*(1), 75. [Crossref]

Ogbonnaya, E., Ahmad, A. R., Ile, E. B., & Ayuba, V. (2022). Assessment of phytotoxicity of selected botanical insecticides on treated cowpea (*Vigna unguiculata*) seed. *Bulletin of the National Research Centre, 46*(1), 171. [Crossref]

Oyewale, R., & Bamaiyi, L. (2013). Management of cowpea insect pests. *Scholars Academic Journal of Biosciences, 1*(5), 217–226.

Özkara, A., Akyil, D., & Konuk, M. (2016). Pesticides, environmental pollution, and health. In *Environmental Health Risk - Hazardous Factors to Living Species*. IntechOpen. [Crossref]

Parween, T., Bhandari, P., Jan, S., & Raza, S. (2016). Interaction between pesticide and soil microorganisms and their degradation: A molecular approach. In *Plant, Soil and Microbes: Volume 2: Mechanisms and Molecular Interactions* (pp. 23–43). Springer. [Crossref]

Raina, A., Tantray, Y. R., & Khan, S. (2023). Assessment of bio-physiological damages and cytological aberrations in cowpea varieties treated with gamma rays and sodium azide. *PLoS ONE, 18*(7), e0288590. [Crossref]

Rajak, P., Roy, S., Ganguly, A., Mandi, M., Dutta, A., Das, K., Nanda, S., Ghanty, S., & Biswas, G. (2023). Agricultural pesticides—friends or foes to the biosphere? *Journal of Hazardous Materials Advances, 10*, 100264. [Crossref]

Ranz, R. E. R. (2022). *Insecticides: Impact and benefits of its use for humanity*. BoD-Books on Demand.

Saad-Allah, K. M., Hammouda, M., & Kasim, W. A. (2014). Effect of sodium azide on growth criteria, some metabolites, mitotic index, and chromosomal abnormalities in *Pisum sativum* and *Vicia faba*. *International Journal of Agronomy and Agricultural Research, 4*(4), 46-61.

Saroop, S., & Tamchos, S. (2024). Impact of pesticide application: Positive and negative side. In *Pesticides in a Changing Environment* (pp. 155–178). Elsevier. [Crossref]

Setiawati, W., Muharam, A., Hasyim, A., Prabaningrum, L., Moekasan, T. K., Murtiningsih, R., & Mejaya, M. J. (2022). Growth, and yield characteristics as well as pests and diseases susceptibility of chili pepper (*Capsicum annuum* L.) under different plant densities and pruning levels. *Applied Ecology and Environmental Research, 20*(1). [Crossref]

Simon-Delso, N., San Martin, G., Bruneau, E., Delcourt, C., & Hautier, L. (2017). The challenges of predicting pesticide exposure of honey bees at landscape level. *Scientific Reports, 7*(1), 3801. [Crossref]

Singh, A., Sharma, A., Singh, O., Rajput, V. D., Movsesyan, H. S., Minkina, T., & Ghazaryan, K. (2024). In-depth exploration of nanoparticles for enhanced nutrient use efficiency and abiotic stress management: Present insights and future horizons. *Plant Stress, 11*, 100576. [Crossref]

Sivaguru, M., Mander, L., Fried, G., & Punyasena, S. W. (2012). Capturing the surface texture and shape of pollen: A comparison of microscopy techniques. *PLoS ONE, 7*(6), e39129. [Crossref]

Srivastava, A. K., & Singh, A. K. (2009). Effects of insecticide profenophos on germination, early growth, meiotic behaviour and chlorophyll mutation of barley (*Hordeum vulgare* L.). *Acta Physiologiae Plantarum, 31*, 1-8. [Crossref]

Tazerouni, Z., Ali, A. T., & Mehran, R. (2019). *Cowpea: Insect pest management* (pp. 1-48). Agricultural Research Center.

Tonfack, L. B., Foamouhoue, E. N., Tchoutang, D. N., & Youmbi, E. (2019). Application of pesticide combinations on watermelon affects pollen viability, germination, and storage. *Journal of Applied Biology and Biotechnology, 7*(6), 35–39. [Crossref]

Tosi, S., Burgio, G., & Nieh, J. C. (2018). A common neonicotinoid pesticide, thiamethoxam, impairs honey bee flight ability. *Scientific Reports, 7*, 1201. [Crossref]

Ward, S. E., Hoffmann, A. A., Van Helden, M., Slavenko, A., & Umina, P. A. (2024). The effects of insecticide seed treatments on the parasitism and predation of *Myzus persicae* (Homoptera: Aphididae) in canola. *Journal of Economic Entomology, 117*(1), 102–117. [Crossref]

Watts, M. (2010). *Pesticides: Sowing poison, growing hunger, reaping sorrow*. Pesticide Action Network Asia and the Pacific.

Wrońska-Pilarek, D., Maciejewska-Rutkowska, I., Lechowicz, K., Bocianowski, J., Hauke-Kowalska, M., Baranowska, M., & Korzeniewicz, R. (2023). The effect of herbicides on morphological features of pollen grains in *Prunus serotina* Ehrh. in the context of the elimination of this invasive species from European forests. *Scientific Reports, 13*(1), 4657. [Crossref]

Xiong, H., Shi, A., Mou, B., Qin, J., Motes, D., Lu, W., Ma, J., Weng, Y., & Yang, W. (2016). Genetic diversity and population structure of cowpea (*Vigna unguiculata* (L.) Walp). *PLoS ONE, 11*(8), e0160941. [Crossref]