


ORIGINAL RESEARCH ARTICLE

Concentration-Dependent Effects of Dimethoate, Lambda-Cyhalothrin and their Mixture on Germination, Vegetative Growth and Yield of Cowpea (*Vigna unguiculata*)

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ABSTRACT

Cowpea is frequently treated with pesticides to alleviate pest pressure; however, these chemicals can adversely affect seed germination, growth, and yield. Farmers often use pesticides such as Dimethoate and Lambda-Cyhalothrin on cowpeas, but studies on the effects of different doses on germination, growth, and yield are limited. This research evaluated the impacts of Dimethoate (A), Lambda-Cyhalothrin (B), and their combination (A+B) on cowpea in both in vitro and in vivo settings. Different concentrations of the treatments were administered, and the resulting germination rate, vegetative parameters, reproductive traits, and yield components were compared to an untreated control using standard procedures. Lambda-Cyhalothrin consistently enhanced early seedling performance, with peak germination occurring at 30 mL/L in vitro (3.50 ± 0.501 days) and at 40 mL/L in vivo (3.00 ± 0.000 days). Conversely, Dimethoate delayed germination, requiring up to 7.50 ± 2.290 days at a concentration of 50 mL/L. The response in vegetative growth reflected these findings: the tallest plants (67.75 ± 16.912) were recorded under Lambda-Cyhalothrin at 50 mL/L, while the combination treatment (A+B) at the same concentration resulted in the shortest plants (34.25 ± 1.921). Mean leaf production peaked at (38.5 ± 26.900) leaves under Lambda-Cyhalothrin (20 mL/L), whereas Dimethoate (40 mL/L) produced the lowest count at (14.75 ± 2.590) leaves. The Leaf Area Index (LAI) reached 50% under Lambda-Cyhalothrin but dropped to 1% with the combination treatment. Reproductive traits varied based on the pesticide type. Dimethoate (10 mL/L) led to the highest number of flower buds (16.00 ± 2.833) but also the highest abortion rate (8.00 ± 0.711). Yield performance was strongest in both the control group and with Dimethoate (10 mL/L), yielding (25.00 ± 1.001) pods, while Dimethoate (50 mL/L) resulted in only (4.25 ± 2.283) pods. Lambda-Cyhalothrin (10 mL/L) achieved the highest seed count per pod (92.60 ± 9.202) and seed weight (14.15 ± 0.642 g). In conclusion, Lambda-Cyhalothrin improved germination, growth, and yield, whereas Dimethoate and the combination treatment displayed inhibitory effects.

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INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.), a member of the Fabaceae family, is one of humanity's oldest food sources (Tazerouni *et al.*, 2019). It was brought from Africa to various parts of the world around 2000 to 3500 years ago (Kébé *et al.*, 2017). This legume is widely cultivated worldwide (Xiong *et al.*, 2016). In recent times, it has gained significance as a crop in numerous countries throughout tropical Africa, Asia, and South America (Mahalakshmi *et al.*, 2007). Cowpea is an essential legume

that thrives in arid and semi-arid regions (Oyewale and Bamaïyi, 2013). Nevertheless, pesticides can contaminate both soil and groundwater, posing toxicity risks to beneficial plants and causing significant adverse effects on plant growth and development and on human health (Özkara *et al.*, 2016). When misused, pesticides have the potential to poison humans, pets, and livestock, as well as beneficial insects, birds, fish, and other wildlife (Ogbonnaya *et al.*, 2022). Cowpea is vulnerable to a range

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of pests and diseases that can affect the crop at all growth stages, including insects, bacteria, fungi, and viruses. If pest populations grow too high and no control measures are implemented, it can lead to complete crop yield loss (Omoigui *et al.*, 2018).

Farmers in Katsina State frequently utilize pesticides such as Dimethoate and Lambda-Cyhalothrin to protect their cowpea crops from pests. However, surprisingly little research has examined how different dosages of these chemicals affect local agricultural practices. Most existing studies have not thoroughly examined the impact of varying pesticide levels on germination, growth, and overall yield. This study aims to address this gap by investigating how Dimethoate and Lambda-Cyhalothrin, individually and in combination, influence cowpea growth. The objective is to assist farmers in using pesticides more effectively, thereby enhancing crop yields while minimizing any adverse effects. Exposure to these pesticides is known to cause significant alterations in plant characteristics, including height, leaf structure, flower development, and pollen viability. Such changes can impede plant growth and reproductive success, ultimately affecting yield quality and the long-term health of the crops. These potential challenges underscore the importance of careful pesticide application to promote sustainable farming practices and protect both the environment and human health (Saad-Allah *et al.*, 2021).

Description of Study Area/Site

The experiment was carried out at the Katsina Bioresources Development Centre (BIODEC) in Katsina State, Nigeria. This region is characterized by a warm subtropical climate, receives an average annual rainfall of approximately 700 to 800 mm. During the dry season, the mean monthly temperature hovers around 30 °C. Humidity levels peak in August and September, while they are at their lowest in February and March (Aminu, 2020). The experimental site featured an insect-controlled environment within a screen house, with a temperature range of 27-35 °C and a relative humidity of 65% (Ntombela, 2024).

Sample Collection and Identification

Cowpea seeds (573-1-1) were obtained from the International Institute for Tropical Agriculture (IITA) Kano office.

Sample Processing (Seed Quality/Viability) Tests

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

Table 1. Chemical Identity and Technical Purity of Dimethoate and Lambda-Cyhalothrin

Parameter	Dimethoate	Lambda-cyhalothrin
Chemical class	Organophosphate	Pyrethroid
CAS Number	60-51-5	91465-08-6
Molecular formula	C ₅ H ₁₂ NO ₃ PS ₂	C ₂₃ H ₁₉ ClF ₃ NO ₃
Mode of action	Acetylcholinesterase (AChE) inhibitor	Voltage-gated sodium channel modulator
TMP (FAO/WHO)	94–98% a.i.	92–98% a.i.
Common impurities	Omethoate, O-methyl dimethoate	Isomeric cyhalothrin mixtures, acid chlorides
Physical state (technical)	Amber to brown liquid	Off-white crystalline solid

Key: TMP = Technical material purity

Experimental Design, Potting Procedure, and Effluent Treatments

The experiment was arranged in a pot design (PD) according to Javed *et al.* (2022) and Ahmad *et al.* (2007) with two treatment factors: pesticides Dimethoate (A), Lambda-Cyhalothrin (B) and the combination of Dimethoate and Lambda-Cyhalothrin (A+B). Concentrations (Five levels: 10, 20, 30, 40, and 50 mL/L) along with a control of 100% water and a variety (one level – Cowpea seed) (Meng *et al.*, 2021). An *in vitro* pilot study was initially conducted to assess the effect of pesticides on cowpea seed germination. The experimental setup was arranged as indicated in Table 2. Each pot was labelled with the treatment: 0, 10, 20, 30, 40, and 50 mL/L. Each concentration was replicated three times with 60 treatments and 15 pots as controls, giving a total of 75 pots. Each pot was filled with 10 kg of soil (Ilunga, 2014; Alfadil *et al.*, 2021). Three Cowpea seeds were then sown in each pot, irrigated with pesticide-contaminated water, and allowed to germinate. Seed germination time was recorded to assess the influence of different

concentrations of pesticides, and the seeds were allowed to grow. Then aerial parts of the plants were sprayed with pesticide-contaminated water at two-week intervals. The experiment was monitored by measuring morphological parameters every two weeks after sowing; all parameters were recorded (Alfadil *et al.*, 2021).

Data collection

After sowing the seed every day, the experiment was monitored. Germination was recorded daily, and the number of leaves and branches was counted. Plant height was measured using a graduated ruler from the soil surface up to the base of the top leaf. Leaf area (LA) and Leaf Area index (LAI) were assessed in the field using the Petiole Pro app on a smartphone. Healthy, fully expanded leaves from comparable canopy positions were selected from each plant. The device's camera was positioned parallel to the leaf surface, with a calibration scale placed adjacent to it, and images were captured according to the app's instructions. The app automatically calculated the area of each leaf, which was then recorded. To ensure representative sampling, multiple leaves per plant, across

several plants per treatment, were measured. The total leaf area for each plot was summed and divided by the ground area occupied to determine LAI. Measurements were performed under consistent lighting conditions, avoiding shadows; the camera distance and angle were standardized to minimize variability. Flower buds and aborted flowers were counted and measured every two weeks after emergence. The development was observed through full vegetative growth. Yield components, including biomass (root and shoot) and seed mass per plant, were measured using a digital weighing scale. Pods and seed numbers were determined after harvesting (Ilunga, 2014).

Table 2: Experimental Design and Potting Procedure with Effluent Treatment

A(mL/L)	B(mL/L)	A+B(mL/L)	CONTROL (0mL/LH ₂ O)
10	10	5+5	10
20	20	10+10	20
30	30	15+15	30
40	40	20+20	40
50	50	25+25	50

(Meng *et al.*, 2021).

RESULT AND DISCUSSION

In the *in vitro* trial, the result shows that Lambda-cyhalothrin (B) at 30mL/L concentration shows the best rate of germination at three and a half days (4) while Dimethoate (A) at 50mL/L concentration takes longer days of germination (8) days when compared with the control. Across all the Treatments, Dimethoate (A) and combinations of Dimethoate and Lambda-Cyhalothrin (A+B) indicated a longer germination day when compared with the Lambda-Cyhalothrin (B) (Figure 1), this could be due to the presence of Dimethoate in the combination which can take a long time 8-18 weeks before saturation in the soil or aqueous solution as reported by Vijay, (2014). In the *In vivo* trial, soil treated with Lambda-Cyhalothrin (B) at 40mL/L concentration shows the best rate of germination at three days (3), while Dimethoate (A) at 10mL/L concentration takes longer days of germination (7) days when compared with the control. Across all the Treatments, Dimethoate (A) indicated a longer germination day when compared with the Lambda-Cyhalothrin (B) and combinations of Dimethoate and Lambda-Cyhalothrin (A+B) (Figure 1). The results suggest that lambda-cyhalothrin (B) has a stimulatory effect on seed germination, while Dimethoate (A) has an inhibitory effect, and that the combination of A and B (A+B) also shows longer germination times.

In plant height, soil treated with Lambda-Cyhalothrin (B) at 50mL/L shows the highest plant height (67.75cm), while those treated with the combination of Dimethoate and Lambda-Cyhalothrin (A+B) at 50mL/L show the least (34.25cm) when compared to the control. Similar findings have been reported in previous studies. Research has shown that lambda-cyhalothrin (B) can enhance crop growth and development, resulting in higher plant heights (Oladapo *et al.*, 2021). In contrast, Dimethoate (A) has been shown to have negative effects on crop growth and development in the research, leading to lower plant

heights, as shown in Figure 2. The combination of A and B has also been shown to negatively affect crop growth and development, resulting in lower plant heights. The results suggest that lambda-cyhalothrin (B) has a positive effect on cowpea plant height, while Dimethoate (A) and the combination of Dimethoate and lambda-cyhalothrin (A+B) have negative effects. Soil treated with Lambda-Cyhalothrin (B) at a 20 mL/L concentration shows the highest leaf number (38.5) eight weeks after germination. In contrast, those treated with Dimethoate (A) at 40 mL/L show the least (14.75) compared to the control. Across all the Treatments, Lambda-Cyhalothrin (B) indicated the best performance when compared with Dimethoate (A) and combinations of Dimethoate and Lambda-Cyhalothrin (A+B), as shown in Figure 2. Similar findings have been reported in previous studies. Research has shown that lambda-cyhalothrin (B) can enhance crop growth and development, resulting in higher leaf numbers (Oladapo *et al.*, 2021). In contrast, Dimethoate (A) has been shown to negatively affect crop growth and development in the research, leading to lower leaf numbers. The combination of Dimethoate and lambda-cyhalothrin (A+B) has also been shown to negatively affect crop growth and development, leading to lower leaf numbers (Tallapragada, 2022). The results suggest that lambda-cyhalothrin (B) has a positive effect on leaf number, while Dimethoate (A) and a combination of Dimethoate and lambda-cyhalothrin (A+B) have negative effects.

Soil treated with Lambda-Cyhalothrin (B) at 10mL/L concentration shows the highest plant branch number, while those treated with Dimethoate (A) at 40mL/L concentration show the least when compared with the control (Figure 2). Oladapo *et al.* (2021) reported that Lambda-Cyhalothrin (B) can increase crop growth and development, leading to higher plant branch numbers.

Soil treated with Lambda-Cyhalothrin (B) shows the best performance (50%) in terms of leaf area index. Similarly, the same soil combinations show the least (1%) performance compared to Dimethoate (A) and the Combination of Lambda-Cyhalothrin (A+B), as shown in Figure 3. Overall, Lambda-cyhalothrin (B) appears to perform best. The results suggest that Lambda-Cyhalothrin (B) has a positive effect on leaf growth and canopy development, leading to a higher LAI. Dimethoate (A) has a moderate effect on leaf growth and canopy development; this result contradicts the findings of Singh *et al.* (2014), who reported that Dimethoate has a stimulatory effect to trigger plant leaf development. The combination of Dimethoate and Lambda-Cyhalothrin (A+B) impairs leaf growth and canopy development, resulting in a lower LAI. The result contradicts the findings of Oladapo *et al.* (2021), who reported that soil was treated with combined pesticides. Lambda-cyhalothrin and dimethoate treatments elicited diverse responses from the cowpea plant. Overall, the results indicate that Lambda-Cyhalothrin (B) is the best treatment for promoting leaf growth and canopy development. The result is in agreement with the findings of Tong *et al.* (2021), which showed that lambda-cyhalothrin can

increase plant leaf growth. While the combination of (A+B) is the least effective in the first row, the percentage of leaf coverage in between rows is significantly lower than the control, ranging from 32% to 28%. This suggests that

there may be more open space between plant rows. In the second row, the difference between treatments and the control narrowed to 4% to 27%, indicating relatively denser growth between rows under treatments (B).

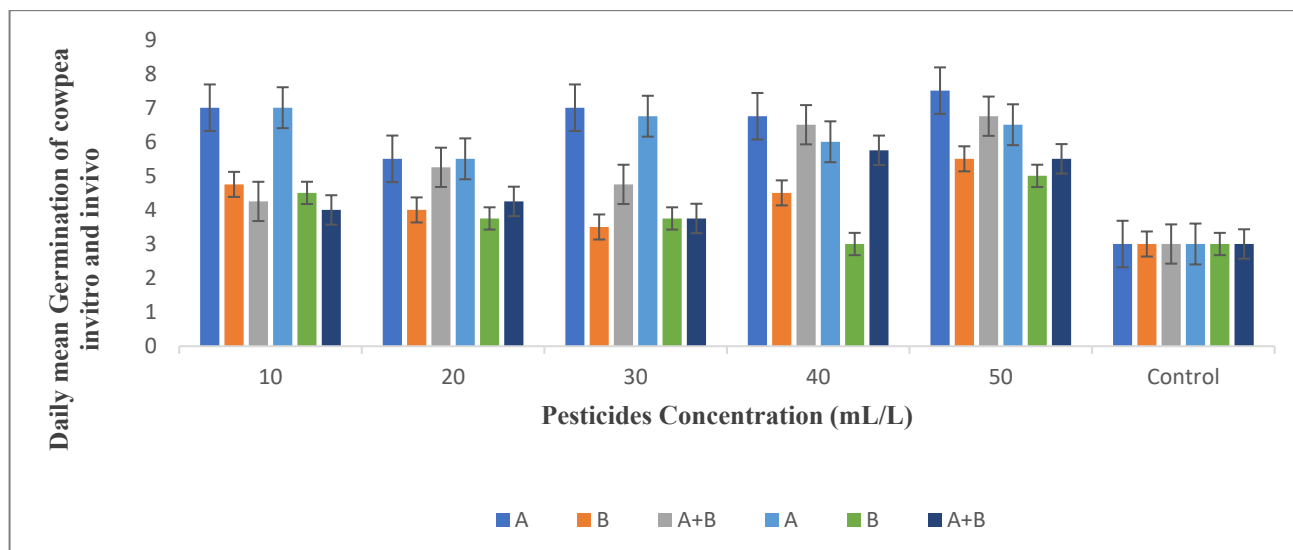


Figure 1: Daily Mean Value of Cowpea Germination *In vitro* and *In vivo*

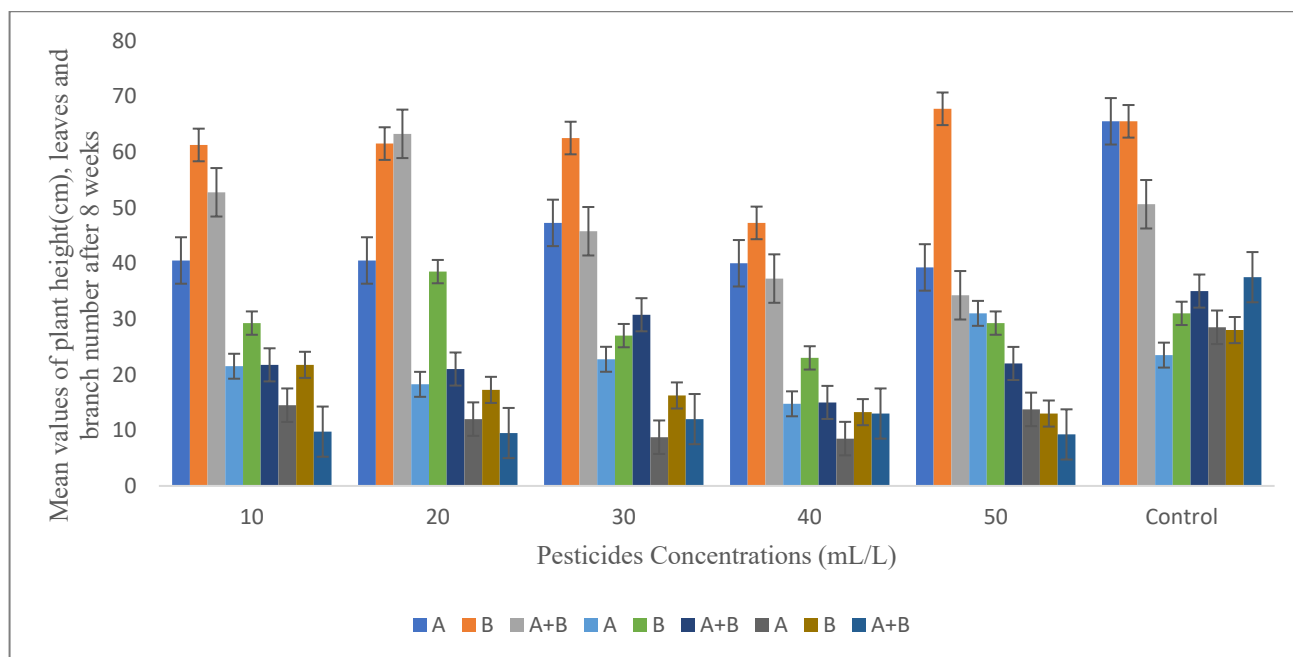


Figure 2: Mean values of the Plant Height(cm), Leaf and Branch number 8 weeks after sowing.

The results indicate that soil treated with Dimethoate (A) at 10mL/L concentration showed the highest number of flower buds (16), while the combination of Dimethoate and Lambda-Cyhalothrin (A+B) at 20mL/L concentration showed the least number of flower buds (9.25), compared to the control, as shown in Figure 4. However, there seems to be a competing behaviour in terms of flower buds/plants across all Treatments and concentrations. Additionally, soil treated with Dimethoate (A) at 10mL/L concentration showed the highest number of aborted flowers (8), while the combination of Dimethoate and lambda-cyhalothrin (A+B) at 50mL/L concentration showed the least number of aborted flowers (5), compared to the control, as shown in Figure 4. Similar findings have been reported in

previous studies. The research has shown that Dimethoate (A) can increase flower bud formation, but may also lead to flower abortion as reported by Sridhar (2022). In contrast, lambda-cyhalothrin (B) has been shown to have a positive effect on flower development and reduction of flower abortion (Franceschinelli et al., 2023). The combination of A and B (A+B) has also been shown to impair flower development and increase flower abortion (Boukar et al., 2019). The results suggest that Dimethoate (A) has a positive effect on flower bud formation but may also lead to flower abortion, whereas lambda-cyhalothrin (B) has a positive effect on flower development and reduces flower abortion. The combination of A and B (A+B) hurts flower development and increases flower abortion.

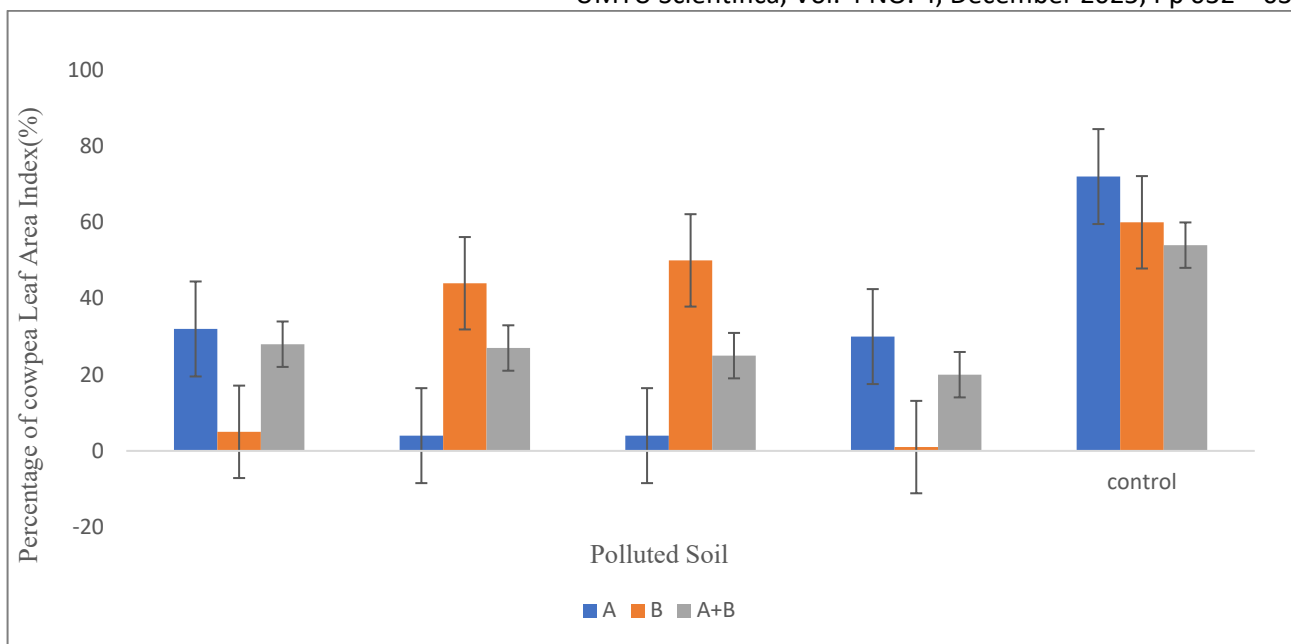


Figure. 3: Percentage values of cowpea Leaf Area Index (LAI) (%)

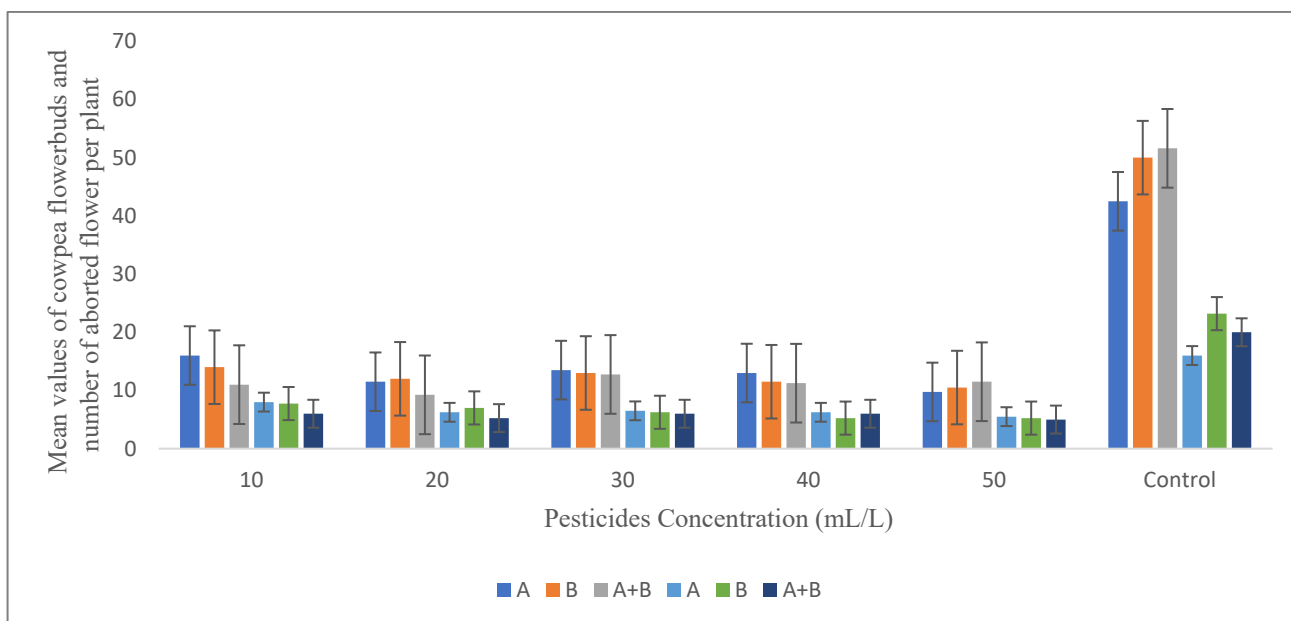


Figure. 4: Mean value of the number of cowpea flower buds and number of aborted flowers per plant

Soil treated with Dimethoate (A) at a 10 mL/L concentration shows the highest number of pods (8 pods). In contrast, those treated with the combination of Dimethoate and Lambda-Cyhalothrin (A+B) at a 20 mL/L concentration show the least (4 pods) compared with the control (Figure 5). In the seed number per pod, Soil treated with the combination of Dimethoate and Lambda-Cyhalothrin (A+B) at 30mL/L concentration shows the highest seed number per pod (45.25 seeds), while those treated with Lambda-Cyhalothrin (B) at 50mL/L concentration show the least (17.25 seeds) when compared to the control (Figure 5). As the concentration increases from (10mL/L to 50mL/L) the seed number per plant decreases. This indicates that the combination of Dimethoate and lambda-cyhalothrin at 30mL/L might produce more pods in cowpea plants when applied. The research is in line with the findings of Ahemad and Khan (2010), who stated that pesticides can decrease pod yield,

seed yield, and grain yield in pea plants. The number of pods produced by the treatments was significantly different ($P>0.05$) when compared with the control. Sartaj *et al.* (2010) reported that varying concentrations of pesticides increased cowpea yields. Additionally, Jackai and Adalla (1997) found that treating cowpeas with Dimethoate alone resulted in higher yields compared to untreated plots. This is contrary to the current report, which observed higher yields with increased combined concentrations of dimethoate and Lambda-Cyhalothrin in the protected area compared to the control, as depicted in Figure 5. In the seed weight, soil treated with Dimethoate (A) at 10mL/L concentration shows the highest seed weight per plant (7.1g), while those treated with Lambda-Cyhalothrin (B) at 50mL/L concentration show the lowest (2.2g) when compared with the control, as shown in Figure 5. Across all the concentrations, Dimethoate (A) showed a uniform decrease in seed weight per plant, while

Lambda-Cyhalothrin (B) and a combination of Dimethoate, Lambda-Cyhalothrin (A+B) showed alternating features of seed weight per plant across all concentrations. Similar findings have been reported in previous studies.

Research by *Oladapo et al. (2021)* showed that dimethoate and lambda-cyhalothrin applications increased pod weight at three concentrations. The research has shown that Dimethoate (A) can increase pod number and seed weight, but may also decrease seed number per pod (*Yang et al., 2023*). A study on Environmental Pollution found that

Lambacyhalothrin (B) applications resulted in higher seed numbers per pod and seed weight per plant than Dimethoate (A) applications (*Majumder et al., 2024*). The combination of Dimethoate and Lambda-Cyhalothrin (A+B) has also been shown to hurt pod number and seed weight per plant (*Bird et al., 2018*). The results suggest that Dimethoate (A) positively affects pod number and seed weight per plant, but may also decrease seed number per pod. Lambda-cyhalothrin (B) positively impacts seed number per pod and seed weight per plant. The combination of Dimethoate and Lambda-Cyhalothrin (A+B) hurts pod number and seed weight per plant.

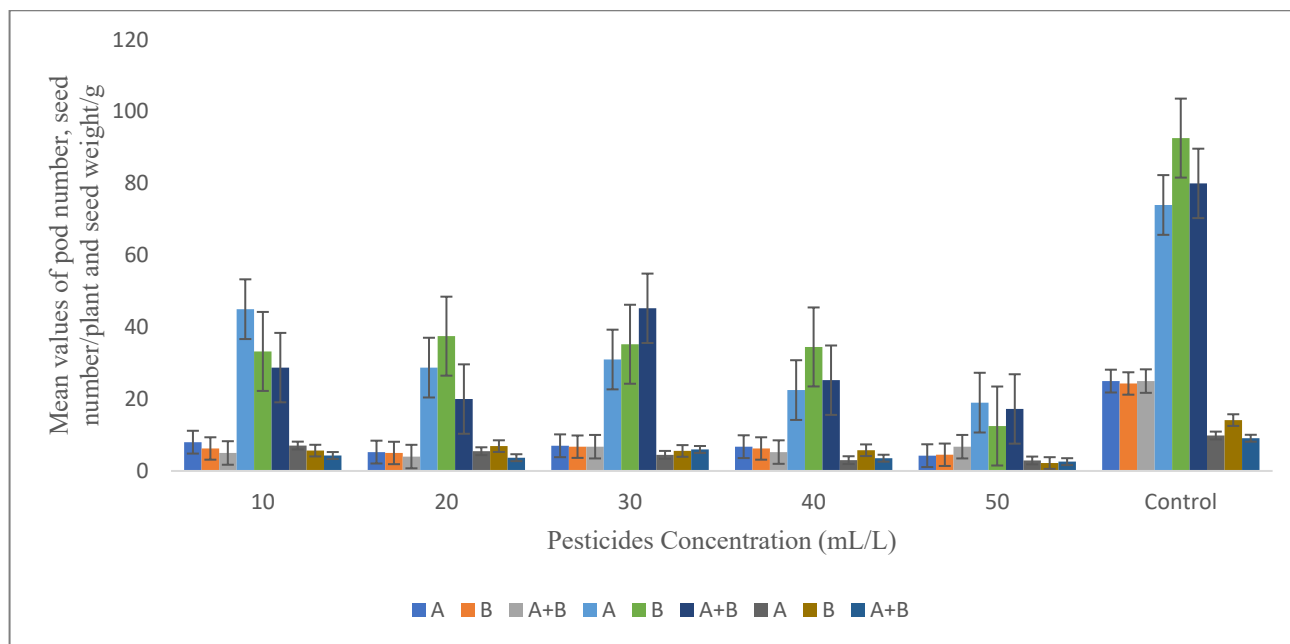


Figure. 5: Mean values of Effects of Different Pesticide Concentrations on the Yield of Cowpea

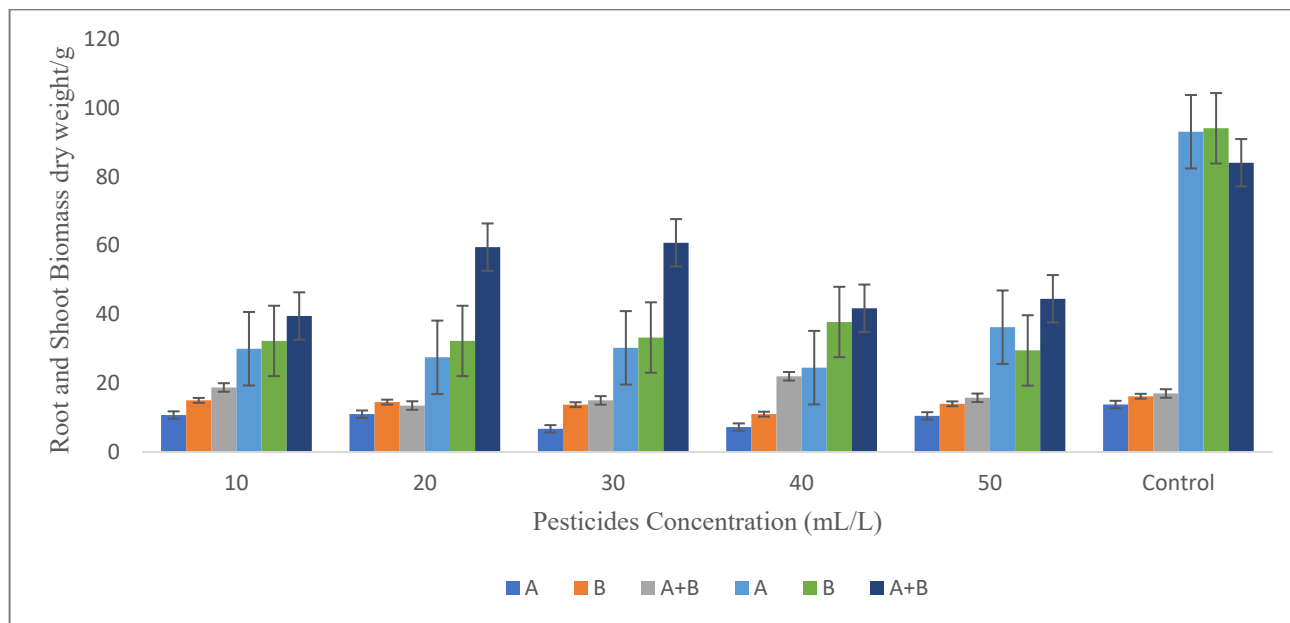


Figure. 6: Mean values of the biomass of Cowpea Plant weight(g)

Soil treated with the combination of Dimethoate and lambda-cyhalothrin (A+B) at 40mL/L concentration shows the highest (22g) weight of root dry biomass, while Dimethoate (A) at 30mL/L concentration shows the lowest (6.75g) compared to the control, as shown in *Figure 6*. Across all concentrations (10mL/L to 50mL/L),

Lambda-Cyhalothrin (B) showed a good performance when compared with Dimethoate (A). In the shoot dry biomass, soil treated with the combination of Dimethoate and lambda-cyhalothrin (A+B) at 30mL/L concentration shows the highest (60.75g) dry weight of shoot biomass, while Dimethoate (A) at 40mL/L concentration shows

the lowest (24.5g) compared to the control, as shown in Figure 6. Across all concentrations (10mL/L to 50mL/L), a combination of Dimethoate and Lambda-Cyhalothrin (A+B) showed an overall performance compared with Lambda-Cyhalothrin (B) and Dimethoate (A).

The analysis of variance (ANOVA) (Table 3) indicated highly significant treatment effects ($p \leq 0.0001$) on all measured growth and yield parameters, except for the Leaf

Area Index (LAI). The germination percentage showed significant differences among treatments ($F = 16.69$), indicating that the applied treatments significantly influenced early seed establishment. Vegetative growth characteristics, including the number of leaves ($F = 39.90$), number of branches ($F = 11.10$), and plant height ($F = 49.97$), also showed strong variation due to treatment, highlighting how these treatments substantially affected canopy development and structural growth.

Table 3: ANOVA Summary Tables for Plant Vegetative Growth and Yield Parameters

SOURCE	DF	ADJ SS	ADJ MS	F- VALUE	P- VALUE
Germination	6	136.66	22.777	16.69	0.0001
Leaves No,	12	8808	734.00	39.90	0.0001
Branch No,	12	2542	211.87	11.10	0.0001
Height (Cm)	12	21172	1764.35	49.97	0.0001
Flower Bd No,	4	62382	1559.56	248.19	0.0001
Aborted F, No,	4	1048.70	262.176	140.44	0.0001
Pod Number	4	1491.36	372.841	185.15	0.0001
Seed No/Pod	4	6465	2155.1	5.08	0.0001
Seed Mass (g)	4	143.3	47.760	6.71	0.0001
Roots weight (g)	4	961.34	320.447	67.08	0.0001
Shoot weight (g)	4	10208	3402.7	8.54	0.0001
LAI (%)	2	0.000060	0.000030	0.96	0.496

Reproductive traits showed pronounced responses to the treatments, with flower bud number ($F = 248.19$), aborted flowers ($F = 140.44$), pod number ($F = 185.15$), and seed number per pod ($F = 5.08$) all revealing statistically significant differences ($p \leq 0.0001$). Additionally, seed mass ($F = 6.71$), root weight ($F = 67.08$), and shoot weight ($F = 8.54$) were significantly affected, indicating clear treatment effects on biomass accumulation and reproductive output. In contrast, the Leaf Area Index (LAI) did not show significant variation across treatments ($F = 0.96$; $p = 0.496$), suggesting minimal or inconsistent effects of treatments on canopy coverage. Overall, the ANOVA results indicate that the treatments significantly influenced most physiological, morphological, and yield-related traits, with LAI being the only trait unaffected.

CONCLUSION

Lambda-Cyhalothrin (B) is the most effective treatment for enhancing germination, vegetative growth, reproductive development, and biomass accumulation in cowpea. Its use at appropriate concentrations stimulates physiological functions without imposing significant stress. Dimethoate (A) has mixed effects: while it promotes flowering and early reproductive traits at low concentrations, it also delays germination and inhibits biomass and yield at higher concentrations. Combination treatments (A+B) tend to show additive or synergistic negative effects, particularly on LAI, flower development, and seed yield, possibly due to combined phytotoxicity or stress overload on plant systems. Overall, pesticide concentration is a critical determinant of outcome; lower levels may exhibit beneficial effects, whereas higher doses tend to be inhibitory.

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