Allelochemics Impacts of Leaf Extracts from Vernonia amygdalina and Chromolaena odorata on Germination of Rice

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Abstract

Allelochemics impacts using leaf extract from *Vernonia amygdalina* and *Chromolaena odorata* were compared on Jamila rice seed germination using agronomic characters. A total of forty petri dishes lined with filter paper were arranged in completely randomised design of four treatments in five replicates. Treatments were designated as leaf crude extract V_1 (100% w/v), V_2 (50% w/v), and V_3 (25w/v) for *V. amygdalina* while V_4 (0% w/v) wet with equal volume of distilled water was taken as the control. Similar procedure was used to prepare *C. odorata* and designated as C_1, C_2, C_3 and C_4 at varying concentrations (100%w/v, 50%w/v, 25%w/v, 0%w/v) respectively. Data collected was analysed using SPSS and Duncan multiple test range was used for mean separation at $p \leq 0.05$. The findings showed that both the radicle and plumule lengths of the seedlings were significantly inhibited by the fresh leave aqueous extract. V_{100} radicle/plumule are not statistically different. $V_{0} > V_{50} > V_{100}$. *V. amygdalina* at low concentration significantly increase growth while V_{100} inhibit the growth in both plumule and radicle. *C. odorata* showed the pattern $C_{0\ radicle}$ /$C_{0\ plumule}$ > $C_{25\ radicle}$ / $C_{25\ plumule}$ > $C_{50\ radicle\ /}$ $C_{plumule}$ > $C_{100\ radicle./}$ $C_{100\ plumule}$. $V_{100\ radicle} < V_{0\ radicle} > V_{25\ radicle}$ and $V_{50\ radicle}$ while $V_{100\ radicle} < V_{50\ radicle} < V_{25\ radicle} < V_{0\ radicle}$. This study demonstrates that both *Vernonia amygdalina* and *Chromolaena odorata* extracts can have significant inhibitory effects which are concentration-dependent on the radicle and plumule growth of rice.

Research Highlights

- **Comparative Allelopathic Assessment:** Investigated and compared the concentration-dependent allelochemics impact of fresh leaf aqueous extracts from *Vernonia amygdalina* (bitter leaf) and *Chromolaena odorata* (Siam weed) on the germination dynamics of Jamila rice (*Oryza sativa*).
- **Biphasic (Hormetic) Response of *V. amygdalina*:** Discovered that *V. amygdalina* exhibits a dual agronomic nature; lower concentrations (25% w/v) significantly stimulated radicle and plumule elongation, whereas high concentrations (100\% w/v) exerted severe phytotoxic inhibition (V0 > V{50%} > V{100%}).
- **Linear Inhibition by *C. odorata*:** Demonstrated that *C. odorata* extracts cause a strictly linear, concentration-dependent suppression of early seedling growth parameters, following a distinct statutory decline pattern (C0 > C{25%} > C{50%} > C{100%}) for both radicle and plumule development.
- **Transient Chronological Effects:** Revealed that the allelopathic inhibitory stresses of both botanical extracts are highly prominent during early ontogeny (2 to 11 days after planting) but gradually exhibit a transient nature, showing no statistically significant growth differences ($p \geq 0.05$) by the conclusion of the 21-day bioassay.
- **Agricultural Application Insight:** Highlights the critical threshold dynamics required when harnessing these bioactive weeds as sustainable biofertilizers or botanical pest-control agents without risking autotoxic or non-target crop suppression in rice-cropping systems.

1.0 Introduction

Oryza sativa, commonly known as Asian rice, is one of the most important staple crops globally, providing food for more than half of the world's population. It is extensively cultivated in Asia, Africa, and parts of the Americas, making it crucial for global food security. Despite its significance, rice cultivation faces numerous challenges, including pests and diseases that severely affect yield and quality. One innovative approach to addressing these challenges is the use of plant-derived crude extracts as natural pest control agents. Among these plants, *Vernonia amygdalina* and *Chromolaena odorata* have shown potential due to their bioactive compounds.

Rice is a primary source of carbohydrates and essential nutrients for billions of people, particularly in Asia, where it accounts for a significant portion of daily caloric intake (Khush, 2020). The cultivation of *Oryza sativa* is vital for food security and economic stability in many developing countries. However, rice productivity is threatened by various biotic and abiotic stresses, including pests, diseases, and climate change (Savary et al., 2019). Pests and diseases are among the most critical factors limiting rice production, with common pests including the rice stem borer, rice blast, and brown plant hopper, which can cause significant yield losses. The reliance on synthetic pesticides to control these pests has led to environmental and health concerns, as well as the development of pesticide resistance. Therefore, there is a growing interest in alternative, sustainable pest management strategies (Nwilene *et al*., 2021).

Biopesticides, derived from natural sources such as plants, animals, bacteria, and certain minerals, offer a promising alternative to synthetic chemicals. They are typically less toxic, more biodegradable, and can be highly specific to target pests, thereby reducing non-target effects (Isman and Grieneisen, 2014). Plant-derived crude extracts, in particular, have garnered attention due to their diverse bioactive compounds, which can act as insecticides, fungicides, or herbicides (Dayan et al., 2009).

Vernonia amygdalina, commonly known as bitter leaf, is a shrub native to Africa. It is widely used in traditional medicine for its antimalarial, antimicrobial, and anti-inflammatory properties. The leaves of *V. amygdalina* contain various bioactive compounds, including flavonoids, saponins, and alkaloids, which contribute to its medicinal properties. Recent studies have also highlighted its potential as a biopesticide, with extracts showing activity against a range of agricultural pests (Ijeh et al., 2018).

Chromolaena odorata, also known as Siam weed, is a fast-growing perennial weed native to Central and South America but has become invasive in many tropical regions. Despite its status as a weed, *C. odorata* has been used in traditional medicine for wound healing and anti-inflammatory purposes. The plant contains various secondary metabolites such as alkaloids, flavonoids, and terpenoids, which have been shown to possess insecticidal and antimicrobial properties. Its potential as a biopesticide is gaining recognition, with studies demonstrating its efficacy in controlling several agricultural pests (Uyi et al., 2020).

The exploration of crude extracts from *Vernonia amygdalina* and *Chromolaena odorata* as biopesticides for *Oryza sativa* is significant for several reasons. Utilizing plant-derived biopesticides can promote sustainable agricultural practices by reducing dependence on synthetic pesticides and minimizing environmental pollution. Developing locally sourced biopesticides can be cost-effective for farmers, particularly in developing countries where the high cost of synthetic pesticides can be prohibitive. By providing effective pest management solutions, the study can contribute to improving rice yields and ensuring food security for populations reliant on rice as a staple food. Moreover, biopesticides are generally safer for humans and animals compared to synthetic pesticides, reducing health risks for farmers and consumers (Sparks, 2019).

The extracts from *Vernonia amygdalina* and *Chromolaena odorata* were said to contain phytochemicals that can inhibit or stimulate the growth of other plants. The efTects of the two plants on maize has been established (Chukwuka *et al*., 2014), though with limited information on tested plant. The knowledge of these effects can be harnessed to mitigate the effects of shortage in fertilizers for agronomic practices. The extracts can be used as biofertilizer to enhance good crop yields. *Oryzae sativa* is a staple crop that requires good soil fertilization. This research is therefore imperative since the relative effects of extracts from these two plants on rice seed germination has not been fully explored.

The aim is to explore the effects of crude extracts from *Vernonia amygdalina* and *Chromolaena odorata* as biofertilizer or inhibitor on seed germination of *Oryza sativa*.

2.0 Materials and Methods

2.1 Preparation of the Treatments

The experiment was conducted in the laboratory of the Department of Biological Sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria. This location provided a controlled environment essential for the accurate monitoring of the experiments. This followed the procedure described by Ahn and Chung (2000) and Chukwuka *et al.*, (2014). Viable seeds of *Oryza sativa* (Variety: Jamila or FARO 52 / WITA 4) high yielding, tolerant to iron toxicity were obtained from local farmers at Kontagora at coordinates $10^0$24’N $5^0$28’E, Pandogari, Rafi Local Government who obtained it from National Cereals Research Institute (NCRI), Badeggi, Niger State. Fresh leaves of *Vernonia amygdalina* Delile (voucher number: OAUSTECH/H/1047) at coordinate N0**6**.495^0 E 4.7925 with an approximate elevation 45 meters and *Chromolaena odorata* (L.) R.M. King & H. Rob. (voucher number: OAUSTECH/H/1033) commonly available at coordinate N$06^0$27.388’ E$004^0$45.776’, 37m altitude were harvested from the wild within Igodan Lisa, Okitipupa, and near the Botanical Garden of Olusegun Agagu University of Science and Technology, Campus, Okitipupa, Ondo State, Nigeria using local guideline and were taken to Olusegun Agagu University of Science and Technology, Herbarium, Botany Programme, Biological Sciences, School of Science, Okitipupa, Ondo State, Nigeria where they were identified by the curator, Mr Oluwadamilola Tubosun Aturu and supplied with appropriate voucher specimen numbers. The remaining seeds were kept for future use. Three hundred grams of each of the plant materials were washed thoroughly with tap water, sliced into small pieces, approximately 1 cm in length and ground using ceramic mortar and pestle. The solutions were separately squeezed and filtered through cheesecloth to remove debris. The filtrates were further filtered using Whatman number one filter paper. The final filtrate served as the leaf Fresh Crude Aqueous Extract (FCAE) of *Vernonia amygdalina*. These two filtrates served as 100% w/v aqueous extract of *Vernonia amygdalina* (V_{100}) and 100% aqueous extract of *C. odorata* (C_{100}). Desired solutions of lower concentrations were prepared from each of the stock solutions by adding an equivalent amount distilled water to 40 ml of the stock solution. A total of eight solutions namely aqueous extracts of *V. amygdalina* and *C. odorata* 100%, 50%, and 25% at (V_{100}, V_{50} and V_{25}) and (C_{100}, C_{50} and C_{25}) respectively were used for seed bioassay. V_0 and C_0 served as the control treated with equivalent amount of water. To prevent degradation of its allelochemicals, this filtrate was prepared every three days.

2.2 Germination Experiment

Rice seeds Jamila were carefully soughted and washed with tap water. After which they were sterilized with 1 ratio 4 distilled water to household hypo (5% Sodium Hypochiorite) solution for 5 minutes. They were re-rinsed for five times. Five uniform seeds of *Oryza sativa* were randomly selected and placed in each of sterilized, dry Petri dishes. These Petri dishes were lined with Whatman No. 1 filter paper, which served as an absorbent to keep the seeds moistened and to avoid water stress. 10ml of each aqueous extracts was used to wet the seeds while equal volume of water was applied to the control. The treatments V_{100}, V_{50}, $V_{25,}$ V_0 and C_{100}, C_{50}, C_{25}, C_0 were replicated five times and laid in completely randomized design (Appendix 1a).

The Petri dishes were kept in a cupboard and seeds were examined for germination at room temperature for a duration of experiment. The temperature in the laboratory was maintained within a range of 30 ± 2˚C during the day and 26 ± 2˚C at night, providing optimal conditions for plant growth. Measurements of the plumule and radicle were carried out using meter rule every three days after incubation to monitor germination and growth (Appendix 1b). Then, the germination percentage was calculated using the formula described in Chukwuka *et al.*, (2014).

$$G_p = \frac{N_g}{N_t} \times 100 \quad \text{……Equation 2.1}$$

N_g = final number o emerged seeds, N_t = total number seeds sown. Seeds were considered as germinated where the radicle extended through the seed coat (emergence of 1mm-long radicle).

All the data obtained during the experiment were subjected to one way analysis of variance using the statistical package for social science (SPSS) software version 16 and means were using Duncan multiple range test (DMRT) at p ≤ 0.05.

3.0 Results and Discussion

Table 3.1 shows the effects of aqueous leaf extracts of *Vernonia* amygdalina on the radicle (cm) of *Oryzae sativa at* P ≤ 0.05. From 2 days after planting to 14 days after planting, radicle growth was significantly lower in seeds under 100% concentration of *V. amygdalina*. During this period, the control seeds had the significantly longest radicle. However, there were no significant differences in the treatments at 17 Days after planting (DAP) and 21 DAP. The present study explored the effects of crude extracts from *Vernonia amygdalina* and *Chromolaena odorata* on the germination and early growth stages of rice (*Appendix 1b*). The results demonstrated that radicle growth was significantly inhibited in rice seeds treated with a 100% concentration of *V. amygdalina* extract, especially during the early days after planting (DAP). As the concentration of the extract decreased, radicle growth improved, with the 25% concentration showing better growth, similar to the control group. This suggests that high concentrations of *V. amygdalina* extract may exert a phytotoxic effect on rice seedlings, inhibiting root development.

These findings align with those of Ahmed et al. (2020), who observed a similar inhibitory effect of *V. amygdalina* extract on maize (*Zea mays*) radicle growth, attributing it to the presence of bioactive compounds like sesquiterpene lactones that could induce oxidative stress. Eke and Ibeh (2021) also reported significant reductions in radicle length in cowpea (*Vigna unguiculata*) seedlings treated with high concentrations of *V. amygdalina*, which they linked to the plant's allelopathic properties affecting hormone balance. Similarly, Okpara et al. (2019) found that *V. amygdalina* significantly stunted radicle growth in rice, suggesting that the extract's allelochemicals might interfere with cellular division and elongation processes.

However, not all studies are in agreement. Agu and Eze (2021) found no significant inhibition of radicle growth in rice when treated with *V. amygdalina* extracts, even at high concentrations, suggesting that the rice variety used may possess natural resistance to the allelochemicals. Nwosu *et al*. (2022) observed that the extract could promote radicle growth in tomato seedlings at certain concentrations, possibly by stimulating biochemical pathways that enhance nutrient uptake. Additionally, Obasi and Nwachukwu (2023) noted that in a hydroponic system, *V. amygdalina* extract enhanced radicle growth in lettuce (*Lactuca sativa*), hypothesizing that the extract might contain growth-promoting substances that mitigate any phytotoxic effects.

Table 3.1

Effects of aqueous leaf extracts of *Vernonia* Extracts on the radicle(cm) of *Oryzae sativa*

V_{100}	**2DAP**	**5DAP**	**8DAP**	**11DAP**	**14DAP**	**17DAP**	**21DAP**
	0.05 ± 0.03^a	**0.3 ± 0.1^a**	**0.96 ± 0.33^a**	**2.55 ± 0.76^a**	**3.87 ± 0.98^a**	**5.52 ± 1.41^a**	**6.34 ± 1.42^a**
V_{50}	0.36 ± 0.07^b	1.08 ± 0.17^b	2.94 ± 0.35^b	4.62 ± 0.5^b	6.62 ± 0.92^{ab}	8.09 ± 1.16^a	8.88 ± 1.22^a
V_{25}	0.52 ± 0.11^b	1.29 ± 0.21^b	3.22 ± 0.62^b	5.02 ± 0.63^b	7.29 ± 1.14^b	8.74 ± 1.15^a	9.8 ± 1.15^a
V_0	0.39 ± 0.1^b	1.29 ± 0.29^b	2.66 ± 0.27^b	4.14 ± 0.57^{ab}	5.31 ± 0.66^{ab}	6.29 ± 0.72^a	7.34 ± 0.72^a

Values (Means ± SE) with the same superscript in each column are not significantly different.; V1 = 100% w/v crude extract of *Vernonia amygdalina*, V2 = 50%w/v crude extract of *Vernonia* amygdalina, V3 = 25%w/v crude extract of *Vernonia amygdalina*, V4 = Control; equivalent amount of water; DAP= Days after planting. Mean ± SEM (N = 5). The column with the same letter are not significantly different at P ≤ 0.05 using Duncan Multiple Range Test with the superscripts ^{a} showing the order of significance.

Table 3.2

Effects of aqueous leaf extracts of *Vernonia* on the plumule(cm) of *Oryzae sativa*

V_{100}	2DAP	5DAP	8DAP	11DAP	14DAP	17DAP	21DAP
	0.07 ± 0.03a	**0.49 ± 0.22^{a}**	**1.87 ± 0.57^{a}**	**3.04 ± 0.67^{a}**	**4.22 ± 0.87^{a}**	**5.61 ± 1.19^{a}**	**6.37 ± 1.24^{a}**
V_{50}	0.23 ± 0.05^{b}	0.78 ± 0.07^{a}	2.4 ± 0.32^{a}	3.5 ± 0.28^{a}	4.62 ± 0.52^{a}	5.84 ± 0.42^{a}	7.02 ± 0.57^{a}
V_{25}	0.22 ± 0.03^{b}	0.78 ± 0.11^{a}	2.64 ± 0.34^{a}	4.35 ± 0.49^{a}	5.45 ± 0.51^{a}	6.8 ± 0.64^{a}	7.56 ± 0.69^{a}
V_{0}	0.28 ± 0.05^{b}	0.89 ± 0.14^{a}	2.71 ± 0.24^{a}	3.97 ± 0.31^{a}	5.3 ± 0.46^{a}	6.63 ± 0.5^{a}	7.2 ± 0.42^{a}

Values (Means ± SE) with the same superscript in each column are not significantly different.; V1 = 100% w/v crude extract of *Vernonia amygdalina*, V2 = 50%w/v crude extract of *Vernonia* amygdalina, V3 = 25%w/v crude extract of *Vernonia amygdalina*, V4 = Control; equivalent amount of water; DAP= Days after planting. Mean ± SEM (N = 5). The column with the same letter are not significantly different at P ≤ 0.05 using Duncan Multiple Range Test with the superscripts ^{a} showing the order of significance.

Table 3.2 shows the Mean effects of aqueous leaf extracts of *Vernonia* amygdalina on the plumule(cm) of *Oryzae sativa at* P ≤ 0.05. Significant differences in the plumule growth were found 2 days after planting when seeds treated with 100% extracts of *Vernonia* had the least growth (0.07 ± 0.03 cm) compared to the control (0.28 ± 0.05). However, from 5 days after planting to 21 days after planting, there were no difference in plumule growth across the treatments. Regarding plumule growth, the study showed that *V. amygdalina* extract significantly inhibited growth at 2 DAP in rice seeds treated with 100% extract concentration. However, from 5 DAP to 21 DAP, no significant differences in plumule growth were observed across treatments, suggesting a concentration-dependent and possibly transient inhibitory effect. These findings are consistent with Akinola et al. (2019), who reported that *V. amygdalina* extract significantly inhibited plumule growth in cassava (*Manihot esculenta*) due to the presence of phenolic compounds that disrupt hormonal regulation. Balogun and Onwubiko (2020) found similar delays in plumule emergence in wheat (*Triticum aestivum*), which they attributed to the extract's allelopathic compounds suppressing metabolic processes in seeds. Olatunji et al. (2021) also demonstrated that *V. amygdalina* extracts inhibited plumule elongation in pepper (*Capsicum annuum*) seedlings, potentially due to the disruption of cellular division and elongation processes. Contrarily, Ibrahim et al. (2022) found that plumule growth in rice was not significantly affected by *V. amygdalina* extracts, suggesting that the rice variety might neutralize or resist the extract's inhibitory effects. Ogunleye et al. (2020) reported that the extract enhanced plumule growth in maize seedlings, proposing that certain bioactive compounds might promote growth under specific conditions. Similarly, Olayinka and Ajayi (2023) observed that *V. amygdalina* extract stimulated plumule elongation in cucumber (*Cucumis sativus*) seedlings, possibly due to the extract's nutrient content or a hormetic effect, where low doses stimulate growth. $V_{0\ radicle}$ ratio $V_{0\ plumule}$ (controls) were not signicantly different. $V_{25\ radicle} > V_{25\ plumule} > V_{o}$ (control). $V_{25\ radicle/plumule}$ enhanced significant increase in the radicle/plumule length than V_{50}. V_{100} radicle/plumule are not statistically different (Fig. 3.1).

$V_{0} > V_{50} > V_{100}$. *V. amygdalina* at low concentration significantly increase growth while V_{100} inhibit the growth in both plumule and radicle.

Figure 3.2(a) showed the effects of aqueous leaf extracts of *Chromolaena ododrata* on the radicle (cm) of *Oryzae sativa.* Statistically significant differences were detected in the growth of the radicle of the first half of the experiment. From 2 days after planting to 11 days after planting, the control seeds has the longest radicles compared to all the other treatment group. However, no significant difference were found in the treatment from 14DAP at $P \leq 0.05$ to the end of the experiment. Statistical significant difference were detected in the growth of the plumule only at 2 days after planting $P \leq 0.05$. There were no significant difference across the treatments from 5 DAP to the end of the experiment. radicle growth was significantly lower in treated seeds compared to the control up to 11 DAP, with no significant differences observed from 14 DAP onwards. Plumule growth showed significant differences only at 2 DAP, indicating a potential transient inhibitory effect similar to that observed with *V. amygdalina* (Fig. 3.2b) These findings are supported by Ofoezie et al. (2019), who reported that *C. odorata* extract significantly inhibited radicle and plumule growth as well as in plant growth and development in soybean (*Glycine max*) (Ogungbemi and Chukwuka, 2021), attributing this to allelopathic compounds impeding cellular processes crucial for root and shoot elongation. Udoh and Udo (2022) found that *C. odorata* extract delayed seedling emergence and reduced growth in millet (*Pennisetum glaucum*), suggesting interference with seedling metabolism and hormone signaling. $C_{0\ radicle}/C_{0\ plumule} > C_{25\ radicle}/C_{25\ plumule} > C_{50\ radicle}/C_{plumule} > C_{100\ radicle.}/C_{100\ plumule}$ (Fig. 3.3). Oluwole and Ayodele (2021) also observed reduced radicle and plumule growth in okra (*Abelmoschus esculentus*) seedlings treated with *C. odorata* extract, likely due to the extract's flavonoids and other secondary metabolites.

Figure 3.4 and 3.5 showed the comparative effects of *V. amygdalina* and *C. odorata* on radicle and plumule Growth respectively ($P \leq 0.05$). $V_{0\ radicle}/C_{0\ radicle} < V_{25\ radicle}/C_{25\ radicle}$, $C_{50\ radicle}/C_{50\ radicle}$ and $C_{100\ radicle.}/C_{100\ radicle}$. $V_{100\ radicle} < V_{0\ radicle} > V_{25\ radicle}$ and $V_{50\ radicle}$ while $V_{100\ radicle} < V_{50\ radicle} < V_{25\ radicle} < V_{0\ radicle}$. This implied *V. amygdalina* stimulate radicle growth at lower concentrations which becomes more toxic upon increasing concentrations unlike *C, odorata* with all the treatments lower than the control. *V. amygdalina* induced significant inhibitory effects than *C. odorata* at 100% w/v concentration while at reduced concentrations $C_{25}/V_{25\ radicle}$ and $C_{50}/V_{50\ radicle,}$ *C. odorata* impacted higher significant inhibitory effects on rice radicles. Conversely, Chukwuma and Iheanacho (2020) found no significant effect of *C. odorata* extract on rice seedling growth, proposing that the rice variety might be less sensitive to the allelopathic effects. The Plumule had higher significant inhibitory growth effects between the two plants at all levels (Fig. 3.5).

Nduka and Opara (2021) reported that *C. odorata* extract enhanced radicle and plumule growth in pumpkin (*Cucurbita pepo*) seedlings, possibly due to growth-promoting substances or increased nutrient availability. Eze and Iroegbu (2023) observed no significant impact of *C. odorata* extract on sorghum (*Sorghum bicolor*) seedling development, suggesting natural tolerance in sorghum to the extract's phytochemicals.

Conclusion

This study demonstrates that both *Vernonia amygdalina* and *Chromolaena odorata* extracts can have significant inhibitory effects on the radicle and plumule growth of rice, particularly at higher concentrations. However, the degree of inhibition appears to be concentration-dependent and may vary across different plant species. While some studies support the allelopathic impact of these extracts, others suggest potential growth-promoting effects or tolerance in certain plant varieties. These findings underscore the complexity of plant-plant interactions mediated by allelopathic compounds and highlight the need for further research to fully understand the mechanisms underlying these effects.

Declarations

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Author Contributions

A.O.O. conceived and designed the study, supervised the laboratory analyses and prepared the manuscript. R.O.O. and A.O. participated in data collection, laboratory analyses and data visualization. All authors read and approved the final manuscript.

Data availability statement: All-important data supporting the findings of this study are available within the paper. Any further request will be provided.

Consent to Publish: Not applicable

Ethics approval and consent to participate: Not applicable, as the study does not involve human participants or animals. The plant materials were of the wild origin and harvesting was permitted by peasant farmers. The collection and use of *Vernonia amygdalina* Delile and *Chromolaena odorata* (L.) R.M. King & H. Rob. complied with the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization. Verbal prior informed consent was obtained from landowners. The species are not listed under CITES or Nigerian endangered species laws, and no formal permit was required for non-commercial research collection.

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Figures

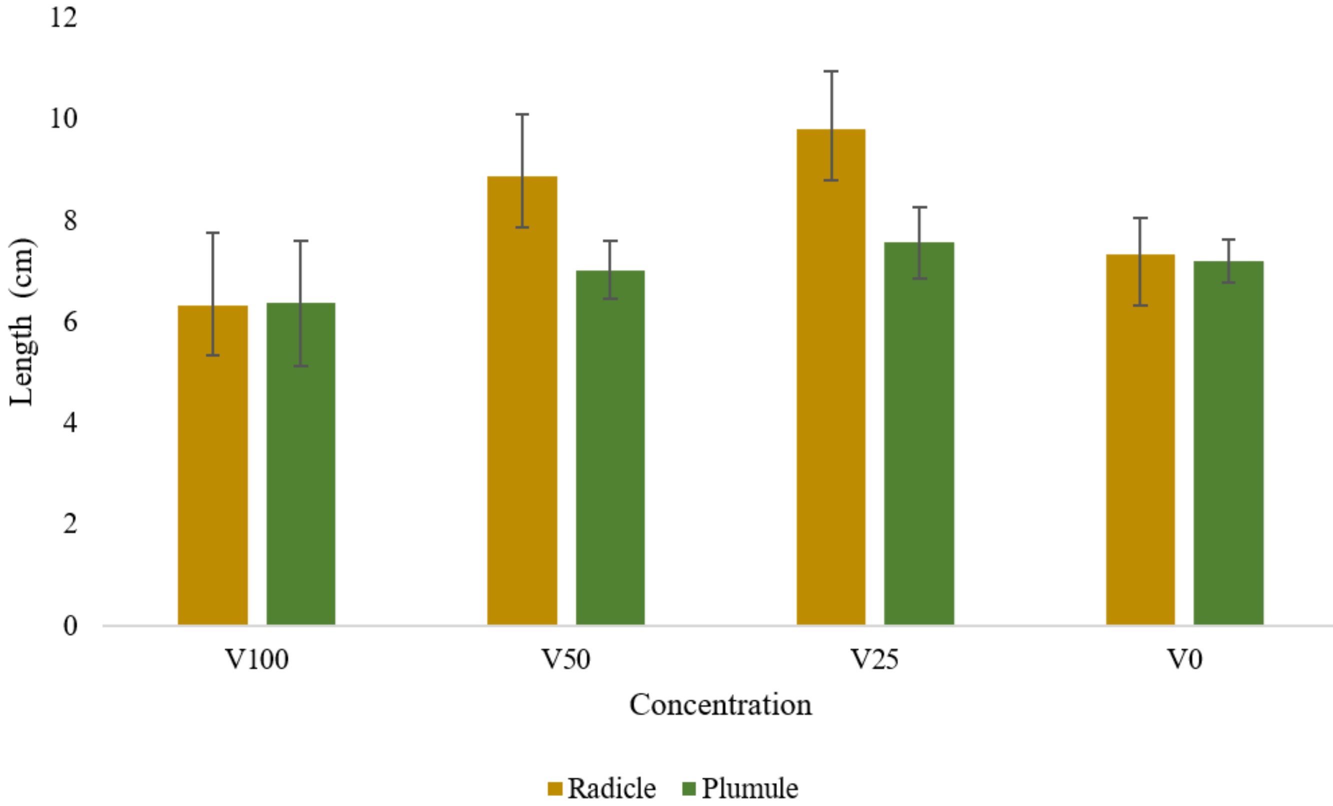

Figure 1

Fig 3.1: Relative effects of *Vernonia* extracts on the radicle and plumule growth

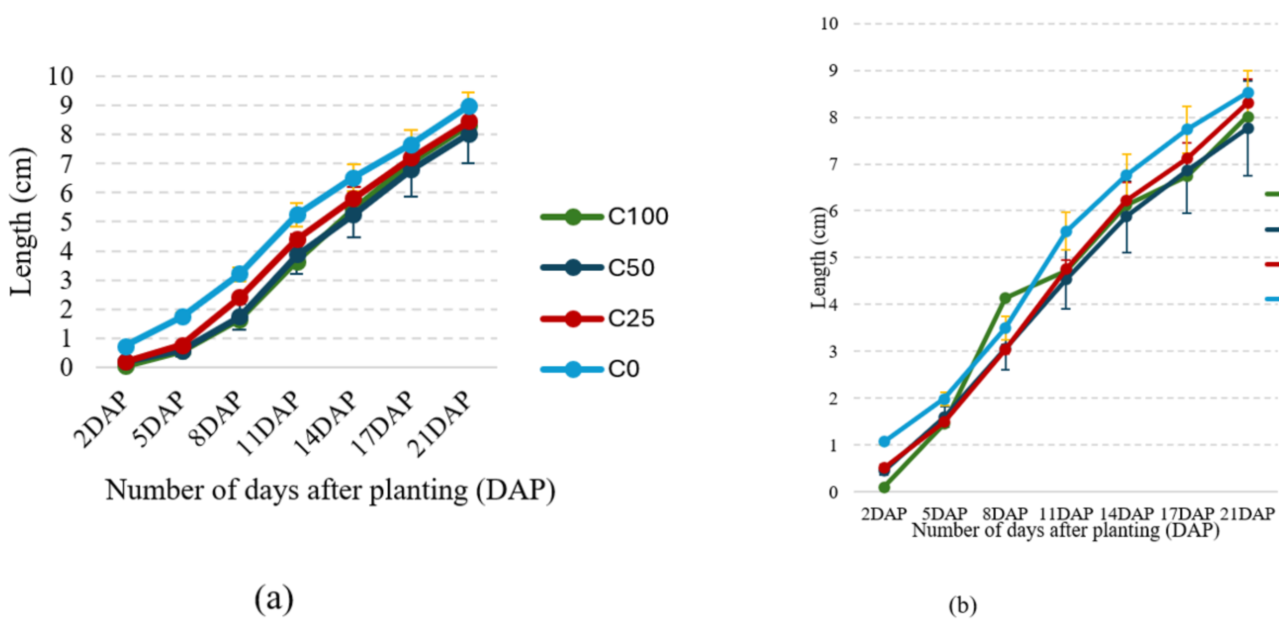

Figure 2

Fig 3.2 (a): Correlative effects of radicle Growth under *Chromolaena* extract.

(b): Correlative effects of plumule Growth under *Chromolaena* extract.

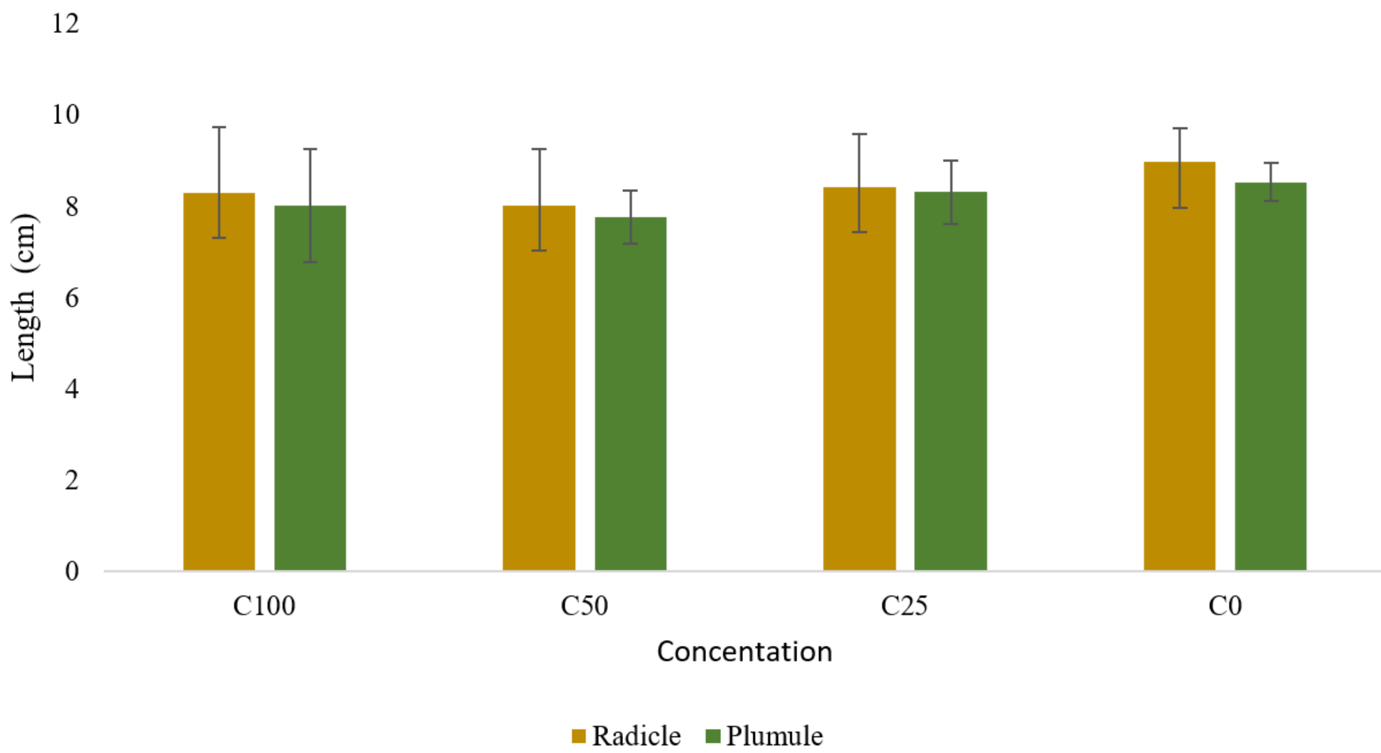

Figure 3

Fig 3.3: Effect of *Chromolaena* extracts on the radicle and plumule growth

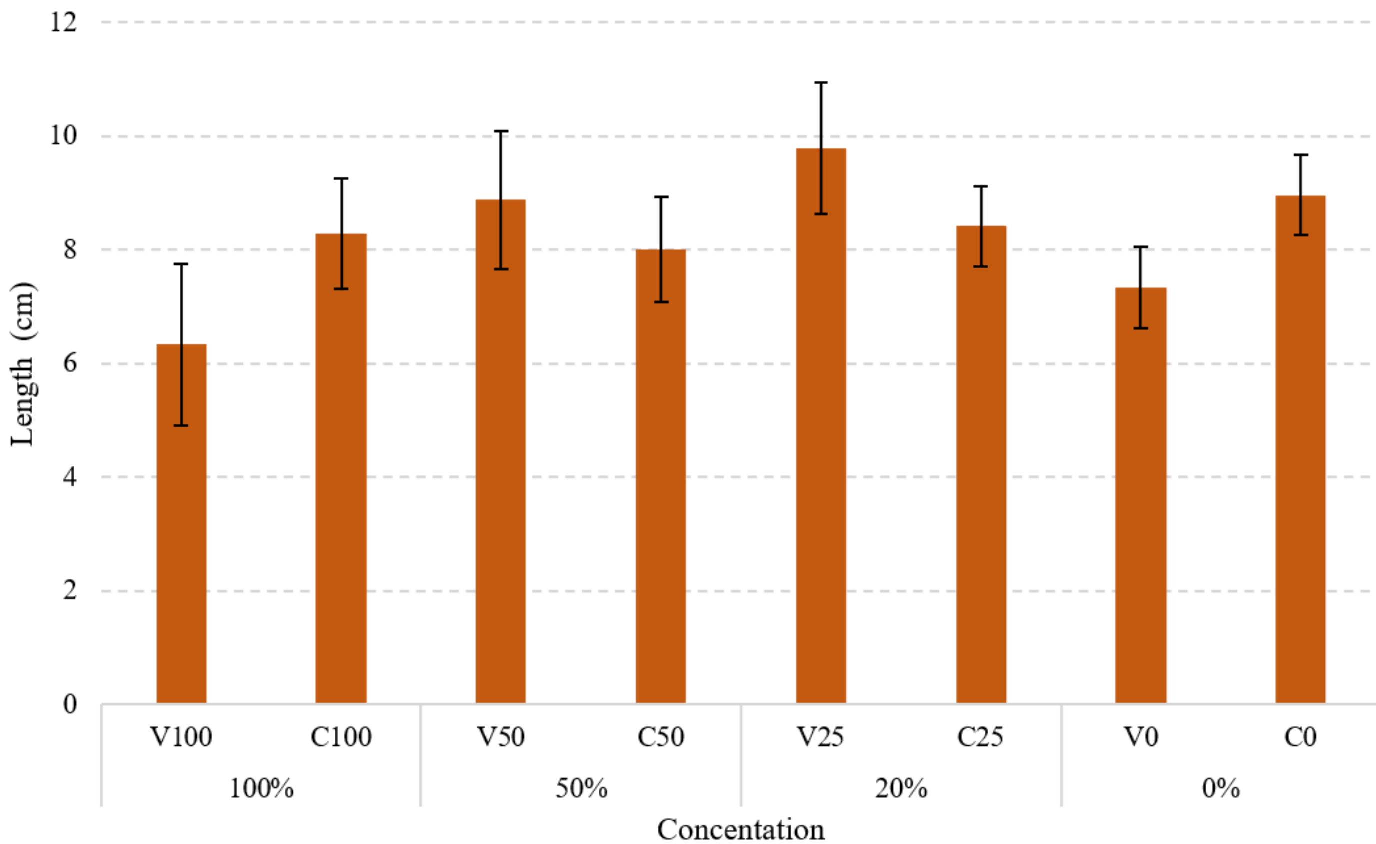

Figure 4

Fig 3.4: Comparative Effects of *V. amygdalina* and *C. odorata* on radicle Growth

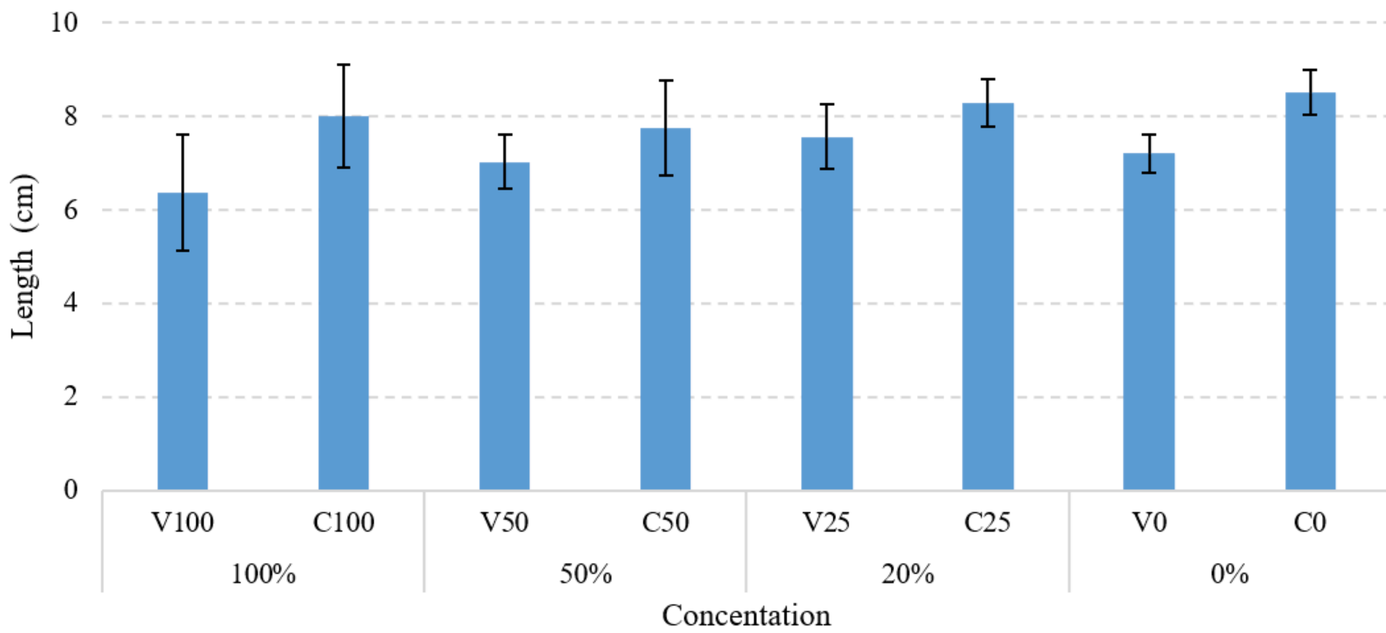

Figure 5

Fig 3.5: Comparative Effects of *V. amygdalina* and *C. odorata* on Plumule Growth

Supplementary Files

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- Appendix1.docx