

SOME AGRONOMIC INDICES DYNAMICS IN SELECTED VEGETABLES CULTIVATED IN SPENT ENGINE OIL POLLUTED SOIL

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ABSTRACT

Impacts of spent oil pollution on agronomic traits of *Celosia argentea*, *Amaranthus hybridus*, and *Corchorus olitorius* were studied. Plants were cultivated within a controlled screen house environment in soil (1 Kg) treated with varying quantities of spent oil; 0 mL (0% v/w), 10 mL (1% v/w), 20 mL (2% v/w), 30 mL (3% v/w), and 40 mL (4% v/w). Key indices including shoot height, number of leaves, chlorophyll content were measured over six weeks. Results indicate a significant reduction in agronomic indices with increasing spent oil contamination, with *A. hybridus* exhibiting the most sensitivity, particularly at 4% v/w, where the plants were unable to survive till sixth week. The findings indicate that spent oil severely impacts key growth indices, biomass, and photosynthetic traits of the vegetables and suggests *C. argentea*, and *C. olitorius* could thrive on spent engine oil polluted soil at low or moderate levels.

KEY WORDS: vegetables; physiological drought; pollution; contamination; soil.

INTRODUCTION

A large portion of spent oil is usually dumped into the ground after lubricating oil from cars or generator engines has been serviced and drained (Anoliefo & Vwioko, 2001). Spent lubricating oil is any oil that has been contaminated by physical or chemical contaminants and has thus expired, regardless of whether it was refined from crude oil or synthetic components (James & Douglas, 2014). The used oil has a comparatively high concentration of hydrocarbons, including the extremely hazardous polycyclic hydrocarbons (Wang *et al.*, 2000). The majority of heavy metals, including V, L, Al, Fe, and Ni, which are often below the detection level in unused lubricating oil, are usually present in high concentration in spent oil (Whisman *et al.*, 1974). It is environmentally unfriendly when used oil is dumped into open, abandoned plots, farms, gutters, and water drains. Spent engine oil is one prevalent and harmful

environmental contaminant that is not present in nature. The heavy metals contained in the oil may bind with organic matter in the soil or remain in the soil as oxides, hydroxides, carbonates, or exchangeable cations (Dominguez-Rosado & Pitchel, 2004).

Since spent oil is liquid, it can move around with ease and eventually contaminate water and soil (Olugboji & Ogunwole, 2008). Soil pollution with spent engine oil results in a considerable decrease in soil moisture, a significant inhibition of soil catalase and dehydrogenase activities, delayed seed germination, and a loss in plant growth (Akoachere *et al.*, 2008). In addition, when spent engine oil is disposed, it displaces water and air, creates anaerobic conditions, and reduces aeration propensity, bulk density and water-holding capacity of the soil (Chukwu *et al.*, 2024). Numerous studies have also documented the negative impacts of petroleum products on plants, which include decreased seed germination, decreased plant survival, and decreased plant yields (Akinola *et al.*, 2004; Andrade *et al.*, 2004; Komolafe *et al.*, 2015). The majority of these studies have concentrated on gasoline, diesel, and crude oil that accidentally leak into the environment (Inoni *et al.*, 2006). The effects of discharged engine oil are poorly understood, particularly on agronomic and photosynthetic attributes.

Environmental pollution arising from petroleum derived-products, especially spent oil disposal into gutters, water drains, vacant plots, and farmlands, depletes biodiversity by forming an oil film on water and killing plants and animals that come into contact with it due to its toxic effects. Over the years, there have been several reports of gradual disappearance and significant decrease in yield and growth quality of vegetable crops grown in regions exposed to oil pollution (Inoni *et al.*, 2006; Essien & John, 2010; Correa *et al.*, 2022; Obada *et al.*, 2024).

Despite indiscriminate disposal of spent engine oil being a common practice, with hazardous effects on agricultural land and plants, the specific physiological impacts on plant agronomic traits are not as well understood as those of other petroleum products such as crude oil and diesel. In this study, the aim was to elucidate the effects of different concentrations of spent oil pollution on some agronomic indices of three important vegetables: *Celosia argentea*, *Amaranthus hybridus*, and *Corchorus olitorius*. This study offers important information regarding the susceptibility, tolerance, and suitability of these crops in spent engine oil polluted soils.

MATERIAL AND METHOD

The Department of Crop Production and Protection at Obafemi Awolowo University in Ile-Ife, Nigeria, provided the seeds for *C. argentea*, *A. hybridus*, and *C. olitorius*. A local mechanic shop in Ile-Ife (Ife Central), Osun State, Nigeria, provided the used oil. The experiment was conducted in a screen house in the Department of Botany, at Obafemi Awolowo University, Ile-Ife, Nigeria. To ensure adequate water drainage, the planting pots were appropriately pierced. They were labeled with the corresponding level of spent engine oil pollution: 0 mL (0% v/w), 10 mL (1% v/w), 20 mL (2% v/w), 30 mL (3% v/w), and 40 mL (4% v/w) mixed with 1 kilogram of topsoil each.

To ensure homogeneity, the used oil was completely combined with soil and water at field capacity. The mixture was then left to stand for a week, with daily addition of water to prevent leaching. The study lasted six weeks, and key indices, including biomass (fresh weight and dry weight), photosynthetic traits (chlorophylls a and b, and carotenoids), and vegetative growth indices (shoot height, leaf area, number of leaves, and leaf area ratio), were evaluated using previously established standard procedures (Coombs *et al.*, 1990; Vile *et al.*, 2005; Olowolaju *et al.*, 2023). The biomass and photosynthetic parameters were assessed at the end of the experimental period (week 6), while vegetative growth indices were evaluated on a fortnightly basis.

Statistical analysis. Statistical Analytical Software (SAS) version 9.2 was used to carry out the statistical analysis. The effects of spent engine oil pollution on the growth, yield, and accumulation of photosynthetic pigments in *C. argentea*, *A. hybridus*, and *C. olitorius* were examined using Analysis of Variance (ANOVA). The significant mean values at the 0.05 confidence level (alpha level) were separated using Fisher's LSD. Python was used for the principal component analysis (PCA).

RESULTS AND DISCUSSIONS

Shoot height of *C. argentea*: Table 1 shows the shoot heights of *C. argentea* as a function of spent engine oil pollution levels. *C. argentea* grown in unpolluted soil (0% v/w) had highest shoots at 4 (24.50) and 6 (50.30) weeks after sowing (WAS) than plants cultivated in polluted soil. There is significant difference in the shoot height of *C. argentea* among the treatments, with 4 % v/w treatment recording the lowest shoot height while those grown in unpolluted soil (0% v/w) had significantly higher shoot height compared to others ($p \leq 0.05$).

Number of leaves *C. argentea*: The number of leaves of *C. argentea* in each treatment increased gradually from 2 to 6 WAS. At 2 WAS, the number of leaves of *C.*

argentea grown in unpolluted soil (0% v/w) and 2% v/w treatments were the same and recorded a higher average number of leaves (7.00) than other treatments. 0% v/w treatment yielded the most leaves (28.00) at 6 WAS, while the 4% v/w treatment had the fewest. The number of *C. argentea* leaves varied significantly between treatments at $p < 0.05$ (Table 1).

Leaf area of *C. argentea*: At 2 WAS, *C. argentea* under 2% v/w treatment had the highest leaf area (8.19), whereas those cultivated in soil contaminated with 4% v/w spent oil recorded the lowest (4.37). The control treatment (0% v/w) had the highest leaf area (29.53) at 6 WAS, while the 4% v/w treatment had the lowest leaf area (3.59). The leaf area of *C. argentea* varied significantly between treatments at $p \leq 0.05$ (Table 1).

TABLE 1. Effects of spent oil pollution on some growth indices of *C. argentea*

	Contamination level (% v/w)	Weeks after sowing (WAS)		
		2	4	6
Shoot Heights (cm)	0	6.00c	24.50a	50.30a
	1	7.20a	17.90c	38.30b
	2	7.20a	19.00b	31.50c
	3	6.60b	17.50d	38.30b
	4	4.30d	6.60e	13.20d
Number of leaves	0	7.00a	22.00a	28.00a
	1	6.00b	19.00b	22.00c
	2	7.00a	14.00d	21.00d
	3	6.00b	15.00c	26.00b
	4	4.00c	8.00e	11.00e
Leaf Area (cm ²)	0	6.57c	12.14d	29.53a
	1	4.76d	10.28c	10.94c
	2	8.19a	9.57b	16.90b
	3	6.39b	7.55a	6.75d
	4	4.37e	4.68e	3.95e

At $p \leq 0.05$, means that share the same letter along the column do not differ significantly.

Shoot height of *A. hybridus*: There was gradual increase in the shoot height of *A. hybridus* from the beginning till the end of experimental period. At 2, 4 and 6 weeks after sowing (WAS), the shoot height of *A. hybridus* grown in unpolluted soil (0% v/w) was taller compared to plants grown under different spent engine oil pollution levels. At the end of the experiment (6 WAS), *A. hybridus* grown in soil polluted with 4% v/w spent oil had significantly shortest shoots. There was significant difference in the shoot height of *A. hybridus* among the treatments at $p \leq 0.05$ (Table 2).

Number of leaves of *A. hybridus*: From two to six WAS, the number of *A. hybridus* leaves in each treatment progressively increased. At 2 WAS, the number of

leaves of *A. hybridus* of 2% v/w and uncontaminated (0% v/w) treatments were equal and higher than that of other treatments. *A. hybridus* cultivated on uncontaminated soil (0% v/w) had the most leaves at 6 WAS, while 4% v/w treatment had the fewest. The number of *A. hybridus* leaves varied significantly across the treatments at $p \leq 0.05$ (Table 2).

Leaf area of *A. hybridus*: At 4 and 6 WAS, the leaf area of *A. hybridus* grown in unpolluted soil (0% v/w) was highest while 4% v/w treatment had the lowest leaf area. There was significant difference in the leaf area of *A. hybridus* among the treated plants at $p \leq 0.05$ (Table 2). All *A. hybridus* of 4% v/w treatment died out before week 6 of the experiment.

TABLE 2. Effects of spent oil pollution on some growth indices of *A. hybridus*

	Contamination level (% v/w)	Weeks after sowing (WAS)		
		2 WAS	4 WAS	6 WAS
Shoot Heights (cm)	0	8.30a	16.00a	26.28a
	1	7.00b	10.50b	15.05b
	2	4.50c	7.00d	9.10c
	3	4.50c	8.21c	15.40b
	4	3.70d	5.20e	0.00d
Number of leaves	0	8.60a	13.00a	18.00a
	1	8.60a	10.00c	12.00b
	2	6.00b	11.00d	12.00c
	3	6.00b	9.00b	9.00b
	4	3.00c	2.00e	0.00d
Leaf Area (cm ²)	0	5.64a	12.10a	26.125a
	1	4.15b	7.62d	14.625b
	2	3.25e	8.23b	15.47c
	3	4.79c	6.55c	10.40d
	4	4.12d	4.41e	0.00d

At $p \leq 0.05$, means that share the same letter along the column do not differ significantly.

Shoot height of *C. olitorius*: At 2, 4 and 6 weeks after sowing (WAS), the shoot height of *C. olitorius* grown in unpolluted soil (0% v/w) was taller compared to plants grown under different levels of spent oil pollution. At the end of the termination of the experiment (6 WAS), *C. olitorius* grown in soil polluted with 4% v/w had the shortest shoot height. The shoot height of *C. olitorius* varied significantly between treatments at $p \leq 0.05$ (Table 3).

Number of leaves of *C. olitorius*: In all treatments, the number of *C. olitorius* leaves progressively increases from two to six WAS. Compared to other treatments, the 0% v/w, 1% v/w, and 2% v/w treatments recorded the same and more leaves at 2 WAS compared to other treatments. The 2% v/w treatment had the most leaves at 6

WAS, while the 4% v/w treatment had the fewest leaves. The quantity of *C. olitorius* leaves varied significantly between treatments at $p < 0.05$ (Table 3).

Leaf area of *C. olitorius*: At 2, 4, and 6 WAS, *C. olitorius* of 0% v/w treatment had the most leaf area, whereas those cultivated in soil contaminated with 4% v/w of spent oil had the smallest leaf area. The *C. olitorius* leaf area varied significantly across the treated plants ($p < 0.05$).

TABLE 3. Effects of spent oil pollution on some growth parameters of *C. olitorius*

	Contamination level (% v/w)	Weeks After Sowing		
		2 WAS	4 WAS	6 WAS
Shoot Heights (cm)	0	17.90a	38.50a	56.00a
	1	14.30b	34.20c	47.80b
	2	13.10c	36.90b	45.50c
	3	11.50d	29.10d	34.50d
	4	6.70e	12.20e	17.30e
Number of leaves	0	7.00a	12.00a	15.00c
	1	7.00a	12.00a	6.00b
	2	7.00a	12.00a	9.00a
	3	6.00b	8.00b	4.00d
	4	5.00c	6.00c	2.00e
Leaf Area (cm ²)	0	3.26a	16.67a	25.01a
	1	2.57b	13.06c	12.51b
	2	1.52d	16.30b	14.89d
	3	2.23c	7.13d	8.80c
	4	1.52e	2.67e	3.21e

Mean with same letter along the column are not significantly different at $p \leq 0.05$.

Biomass (fresh weight and dry weight): Total fresh and dry weight of *C. argentea*, *A. hybridus* and *C. olitorius* were highest in plants grown in uncontaminated soil (0% v/w) while 4% v/w treatment recorded the lowest. There was significant difference in chlorophyll a content of among the treatments in all the vegetables at $p \leq 0.05$ (Table 4).

Leaf area ratio (LAR): LAR as affected by spent oil pollution is presented in Table 6. The results indicate that LAR of *C. argentea*, *A. hybridus*, and *C. olitorius* varied significantly with different levels of spent oil pollution, with *A. hybridus* showing the highest LAR at 2% v/w of spent oil (45.50 cm²g⁻¹), while *C. olitorius* had the highest LAR at 3% v/w (55.33 cm²g⁻¹), and the LAR of *C. argentea* was highest in the control treatment (0% v/w). There was a significant difference among the treatments in all the vegetables at $p \leq 0.05$.

TABLE 4. Effects of spent oil pollution on fresh and dry weights of *C. argentea*, *A. hybridus* and *C. olitorius*

	Level of contamination (% v/w)	Plant Biomass	
		Fresh Weight (g)	Dry Weight (g)
<i>C. argentea</i>	0	77.10a	10.40b
	1	69.81b	12.05a
	2	51.10d	6.19c
	3	52.01c	5.57d
	4	21.49e	1.65e
<i>A. hybridus</i>	0	31.98a	4.89a
	1	5.94c	0.82c
	2	1.57d	0.34d
	3	24.13b	3.37b
	4	0.00e	0.00e
<i>C. olitorius</i>	0	3.37c	0.52a
	1	3.71a	0.45b
	2	3.51b	0.44c
	3	0.88d	0.16d
	4	0.24e	0.08e

Mean with same letter along the column are not significantly different at $p \leq 0.05$.

TABLE 6. Effects of spent oil pollution on the Leaf Area Ratio of *C. argentea*, *A. hybridus* and *C. olitorius*

	Level of contamination (% v/w)	LAR (cm ² g ⁻¹)
<i>C. argentea</i>	0	2.80a
	1	0.97c
	2	2.70a
	3	1.21c
	4	2.39b
<i>A. hybridus</i>	0	5.34c
	1	17.84b
	2	45.50a
	3	3.10d
	4	0.00e
<i>C. olitorius</i>	0	48.15b
	1	27.85e
	2	33.84d
	3	55.33a
	4	40.13c

Mean with same letter along the column are not significantly different at $p \leq 0.05$.

Photosynthetic pigment: Chlorophyll a content of *C. argentea*, *A. hybridus* and *C. olitorius* were highest in *C. argentea*, *A. hybridus* and *C. olitorius* grown in unpolluted soil (% v/w) and lowest in those grown in soil polluted with 4% v/w of spent oil. There was significant difference in chlorophyll a content of *C. argentea*, *A. hybridus* and *C. olitorius* among the treatments in all the vegetables at $p \leq 0.05$.

Accumulation of Chlorophyll b in *C. argentea*, *A. hybridus* and *C. olitorius* were highest in *C. argentea*, *A. hybridus* and *C. olitorius* grown in unpolluted soil (0% v/w) and lowest in those grown in soil polluted with 4% v/w of spent oil. There was significant difference in chlorophyll a content of among the treatments in all the vegetables at $p \leq 0.05$.

Total Chlorophyll content of *C. argentea*, *A. hybridus* and *C. olitorius* were highest in *C. argentea*, *A. hybridus* and *C. olitorius* grown in soil polluted with no spent oil (0% v/w) and lowest in those grown in soil polluted with 4% v/w of spent oil. There was significant difference in chlorophyll a content among the treatments in all the vegetables at $p \leq 0.05$.

TABLE 5. Effects of spent oil pollution on the chlorophyll content of *C. argentea*, *A. hybridus* and *C. olitorius*

	Contamination level (v/w)	Photosynthetic Pigments			Carotenoids (mgg ⁻¹ FW)
		Chl a (mgg ⁻¹ FW)	Chl b (mgg ⁻¹ FW)	Total Chl (mgg ⁻¹ FW)	
<i>C. argentea</i>	0	18.78a	29.26a	53.22b	13.51a
	1	17.15d	29.16b	53.73a	13.54a
	2	18.40b	26.46c	50.26c	9.70b
	3	18.22c	25.83d	48.17d	8.35c
	4	6.12e	1.97e	8.09e	7.18d
<i>A. hybridus</i>	0	16.16a	27.03a	50.33a	8.59a
	10	14.88b	23.53b	33.55c	6.93c
	20	6.35c	14.27c	37.39b	7.82b
	30	2.40d	3.24d	6.32d	5.48d
	40	-	-	-	-
<i>C. olitorius</i>	0	19.65a	27.54a	50.59a	15.97a
	10	19.24b	10.23b	21.25c	15.02b
	20	17.61c	4.15d	33.39b	13.55c
	30	17.19d	3.14e	15.61d	10.63d
	40	14.93e	4.92c	11.09e	8.45e

Mean with same letter along the column are not significantly different at $p \leq 0.05$. **Legend:** Chl = Chlorophyll

The carotenoid content of the three plants decreased as spent engine oil quantity increased. 4% v/w, *C. argentea*'s decreased from 13.51 to 13.54 mgg⁻¹ in the control to 7.18 mgg⁻¹. At 3% v/w, *A. hybridus* dropped from 8.59 mgg⁻¹ in the control to 5.48 mgg⁻¹. The carotenoid levels in *C. olitorius* were the highest. Although *C. olitorius* maintained comparatively greater levels under stress, *A. hybridus* suffered the harshest effects of oil pollution, which overall considerably decreased carotenoid accumulation. There is significant difference in the carotenoids among the treatments ($p \leq 0.05$).

Principal component analysis (PCA): By effectively separating treatments based on spent oil levels, the PCA showed that the first two principal components (PC1 and PC2) accounted for the majority of the dataset's variance. Shoot height, leaf number, and photosynthetic pigments were all highly correlated with PC1, suggesting that these characteristics were the main drivers of treatment differentiation. Plants grown in 4% v/w treatments were clearly separated on the negative side, indicating severe growth inhibition, whereas control plants (0% v/w) clustered distinctly on the positive axis of PC1, reflecting superior agronomic performance. While *A. hybridus* at 4% v/w formed a distinct outlier cluster, confirming its high sensitivity and mortality under severe oil stress, intermediate treatments (1% v/w –3% v/w) occupied transitional positions (Figure 1).

Engine oil comprises a blend of performance-enhancing additives and base oils, which represent the non-volatile fraction of crude oil acquired through vacuum distillation. Additives such as amines, phenols, benzene, calcium, zinc, barium, magnesium, phosphorus, sulfur, and lead are commonly found. Most plant species encounter growth inhibition and metabolic disorders as a result of the heavy metal concentration in oil-contaminated soil. This study observed a gradual reduction in the agronomic traits of *C. argentea*, *A. hybridus*, and *C. olitorius*, including shoot height, leaf area, and leaf count, correlating with elevated levels of wasted oil pollution. This reduction may result from modified soil conditions that induce growth inhibition and metabolic issues in the examined plant species. In soils contaminated by waste oil, growth retardation and inhibition of *Solanum melongena*, *Ricinus communis*, and *Solanum incanum* seedling emergence have been reported (Vwioko & Fashemi, 2005).

The death of *A. hybridus* at 4% v/w contamination level before the sixth week might be attributed to interference in water and gaseous intake, a condition known as physiological drought. According to Okonokhua *et al.* (2007), oil-polluted soils become waxy when wet and usually stop water from penetrating from above. It has been shown that the decreased oxygen concentration of the soil is a result of this waxy nature and this may be attributed a significant reduction in key growth, biomass, and photosynthetic indices. Other studies on plants grown in high concentrations of hydrocarbon-polluted soils have also reported the death of some plant species at a certain stages growth and development (Vwioko & Fashemi, 2005; Omosun *et al.* (2008).

The significant decrease in the fresh and dry weight of *C. argentea*, *A. hybridus*, and *C. olitorius* grown at certain concentrations (2% v/w, 3% v/w, and 4% v/w) may be caused by a decrease in the amount available nutrients or an increase in

the levels of certain elements, like iron and zinc, to toxic levels that prevent these plant species from accumulating dry matter. This outcome is consistent with the earlier research by Omosun *et al.* (2008), who observed a gradual decline in *A. hybridus* plant biomass as crude oil content increased and linked this to unfavorable changes in the ideal soil conditions for plant growth. Ikhajiagbe *et al.* (2013) state that oil contamination of the soil lowers crop yields and results in early plant death in tomatoes and peppers.

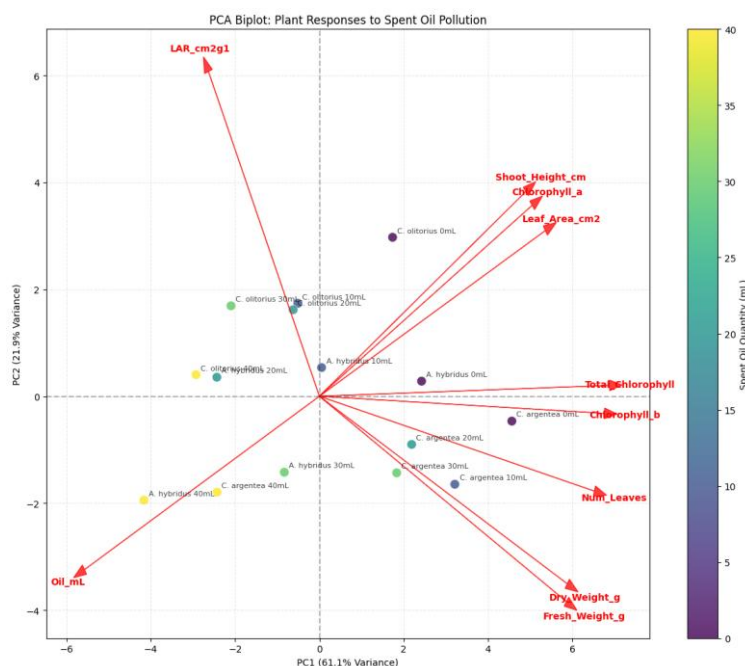


FIG. 1. PCA Biplot of Growth, Biomass, and Photosynthetic Indices in Spent Oil-Polluted Soil

The significant decrease recorded in leaf photosynthetic pigments of *C. argentea*, *A. hybridus* and *C. oleraceus* grown under different concentrations of spent oil might be attributed to a rise in toxic levels of elements such as manganese and copper which interferes with chlorophyll biosynthesis. For instance, copper and manganese plays an important role in photosynthetic pigments accumulation. However, at excess of specific limits, these metals adversely affect photosynthetic pigment production (Ikhajiagbe *et al.*, 2013). This result corroborate the results obtained by Ikhajiagbe *et*

al. (2013) who stated that oil polluted soil significantly reduced the leaf photosynthetic activity of African Yam Bean (*Sphenostylis stenocarpa*) due to lower absorption of light as a result of poor biosynthesis of photo-assimilates.

The study indicates that LAR is not impaired in these plants under the influence of spent oil pollution. This finding agrees with Olowolaju *et al.* (2020) who reported increase in LAR of tomatoes under certain levels of exogenous application of boric acid. On the other hand, this finding is in contrast with the work of Osuntoki *et al.* (2022) which reported a significant reduction in LAR of cassava in cultivated in crude oil polluted soil. This suggests specie-specific response and different adaptive mechanisms by plants in response to a polluted environment.

The PCA indicates that spent oil pollution exerts significant directional pressure on vegetable growth parameters, with variations in the indices evident along oil concentration gradients. Unpolluted plants cluster distinctly, revealing that shoot growth and pigment accumulation are key indicators of stress resilience. Treatments at 4% v/w highlight a threshold where hydrocarbon toxicity severely affects plant metabolism, in line with the ANOVA. The 1% v/w–3% v/w treatments show partial tolerance, particularly in *C. argentea* and *C. olitorius*, suggesting some species adapt to moderate pollution. Overall, PCA confirms *A. hybridus* as the most susceptible species, while *C. argentea* and *C. olitorius* exhibit relative tolerance under moderate contamination.

CONCLUSIONS

From the findings of this study, spent oil pollution significantly impaired key growth and biomass indices of *C. argentea*, *A. hybridus*, and *C. olitorius*, and also inhibited their photosynthetic pigments accumulation. These impairments could be attributed to interference with water uptake, gaseous exchange resulting in a condition of physiological drought, and decreased biosynthesis of photosynthetic pigments, as well as leaf water relations through cellular osmotic adjustment. These results showed that *C. argentea* and *C. olitorius* could thrive on spent engine oil-polluted soil at low or moderate levels.

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