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RESEARCH ARTICLES

Assessing the Effect of *Chromolaena* odorata on Maize (*Zea mays* L.) Growth and Yield in the Semi-Deciduous Forest Zone of Côte d'Ivoire

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Abstract

Chromolaena odorata is a dominant pioneer species in the successional vegetation following deforestation in humid and sub-humid tropical regions. Despite its prevalence, the specific interactions between *C. odorata* and subsequent food crops remain poorly characterized. This study aimed to evaluate the influence of *C. odorata* on the growth and yield of maize (*Zea mays* L.) under varying nutrient regimes. The experiment employed a randomized complete block design to assess the interaction between shrub presence (present vs. absent) and fertilization (0 or 1× the recommended N–P–K rate). The results indicated that the presence of *C. odorata* significantly increased maize height, stem diameter, and leaf count after anthesis. Furthermore, under high-rainfall conditions, *C. odorata* significantly increased grain yield and yield components. During the long rainy season, grain yields ranged from 8.75 to 10.74 ton/ha in plots integrated with *C. odorata*, compared to 7.63 to 7.84 ton/ha in monoculture plots. These agronomic advantages suggest that *C. odorata* improves productivity through non-thermal biomass management, likely by stabilizing soil pH. Notably, total nitrogen, available phosphorus, cation exchange capacity (CEC), and organic carbon content remained stable across the 0–20 cm and 20–40 cm soil profiles.

Keywords: conservation agriculture, Côte d'Ivoire, crop growth, intercropping, shrub

Introduction

In West Africa, farms are dominated by cash crops, which contribute significantly to the economy. The cultivation and processing of cash crops such as cocoa, peanuts, oil palm, and cashews are carried out by more than 60% of the population (De Haas & Travieso, 2022). The dominance of cash crops led to the degradation of natural resources, resulting in the loss of vegetation and reduced soil fertility, thereby reducing food crop production (Kumar et al., 2022). Food crops are most often grown on newly cleared land, in combination with cash crops, or on marginal land. In addition, crop production is affected by weather variability, including drought years and low crop yields (Connolly-Boutin & Smit, 2016).

In the face of accelerating demand for food, competition for dwindling resources and an increasingly overwhelmed environment, achieving food security is widely recognized as the main challenge of our time (Rahman et al.,

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2025). Unfortunately, most food-crop producers use agrochemicals to increase yields. However, the inappropriate use of agrochemicals, such as pesticides and fertilizers, can lead to significant environmental and health issues (Roy et al., 2025; Srivastav et al., 2024). Furthermore, cut-and-burn farming, widely used in Africa to control weeds during soil preparation, is incompatible with conservation agriculture. This technique affects soil fertility, biodiversity, and physical properties (Arunrat et al., 2024). Using fire together with chemical products has severely reduced the productivity potential of agrosystems.

In recent decades, recurrent crop failures have been attributed to poor soil quality and drought during critical stages of crop development (Dietz et al., 2021; Kouamé et al., 2019). These crop failures are particularly concerning for maize cultivation, the second most important cereal crop in Côte d'Ivoire. Maize is important for human consumption, livestock feed, and baby food production, but its cultivation requires large quantities of chemical fertilizer, ranging from 100 to 250 kg NPK per hectare (Zhang et al., 2022; Zhai et al., 2022). However, multiple studies indicate that using woody species-derived organic inputs in an intercropping management approach can improve crop productivity (Bayala et al., 2022; Bright et al., 2021; Dossa et al., 2012). The invasive nature of *Chromolaena odorata* (CO) makes it a serious weed in Africa and Asia, affecting perennial, arboreal, pasture, and forest reserves (Slaats, 1995). Thus, *C. odorata* poses a significant threat to biodiversity, human well-being, and livelihoods. This species can quickly invade ecosystems due to its rapid growth (Rai & Singh, 2024). It is widely recognized as one of the most pervasive invaders due to its adverse influence on the environment, agriculture, and wildlife. The control of this species indirectly changes soil properties by increasing the intensity and frequency of bush fires. Although prescribed fires can be useful for managing weeds in cultivated areas due to their positive effects on soil pH, total nitrogen, soil organic carbon, and exchangeable calcium, soil texture is still significantly affected (Alcañiz et al., 2018). Amoako and Gambiza (2019) reported that burned soil had lower clay content and smaller soil particles than unburned soil. Due to its negative impact on human activities and the environment, managing or eradicating it has become a challenge for society. To control *C. odorata* in fallow or cropped plots, various manual, mechanical, chemical and biological methods are used, which are more or less effective (Koutika, 2010; Te Beest et al., 2012; Zachariades et al., 2011).

However, burning and grinding down the stumps remain the most common methods of removal. Far from being a calamity in areas where it proliferates, *C. odorata* can be useful in agricultural systems. This has been supported by several studies. *C. odorata* restores soil organic matter, improving soil structure and conserving soil moisture during the dry season (Tondoh et al., 2013). This fallow species can sometimes substitute secondary forests to improve soil fertility (Agbede et al., 2014; Koné et al., 2021; Slaats, 1995; Tondoh et al., 2013). Fallow land cultivated with *C. odorata* can lead to increased levels of organic carbon, total nitrogen, total phosphorus, extractable calcium, and magnesium in the soil (Utama et al., 2024).

Our study focused on the impact of *C. odorata* as a fallow crop (2-5 years) on soil chemical properties and agronomic responses. However, there is very little information on the effect of its continued presence in crop plots. Improving crop productivity, especially maize, in the context of climate variability requires adopting crop practices adapted to local conditions. This necessitates developing a model for agricultural intensification that integrates *C. odorata* with cereal crops to sustainably enhance yields. The objective of this study was therefore to determine the effect of the presence or absence of *C. odorata* on maize growth and yield at varying fertilizer rates.

Materials and Methods

Site Description

The site is located in Sika N'guessankro

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(6.9176781 N, 6.3281935 W), in the centre-west (Haut-Sassandra) region of Côte d'Ivoire, near the Daloa district. The climate is bimodal, with a dry season from November to February and a rainy season from March to October, with a slowdown between mid-July and mid-August. The dry and wet seasons alternate, with average temperatures ranging from 24.78 °C to 28.17 °C (Kouassi et al., 2022).

Soil types are distributed along a smooth toposequence: ferrallitic soils (plinthic lixisols) are located on the upslope plateau; plinthic arenosols are located on the slope; and hydromorphic soils (fluvisols) are located in the lowlands (Konan et al., 2022). Findings on the physical properties reported a bulk density ranging from 1.57 to 1.43 g/cm³ and a texture ranging from loam to sandy loam (Bayala et al., 2025).

Design and Management of Experimental Plots

The experimental design was a completely randomized block design with four replications. The plots were divided into four randomized blocks, each containing four subplots (4 m × 5 m), with a 2 m buffer between subplots and a 3 m buffer between blocks. The experiment used a randomized complete block design with two factors: the presence or absence of *C. odorata* and the fertilizer rate (0 or 1× the recommended NPK rate). Four blocks were established, each with four subplots, with two levels of shrub treatment (shrub-only or crop-and-shrub) and two levels of fertilizer treatment (0 or 1 rate of the recommended NPK). Each block consisted of four treatments: *Chromolaena odorata* only (CO); *C. odorata* plus fertilizer (CO+NPK); fertilizer only (NPK); and control (crop only).

Management of *C. odorata* as a shrub in the plots was based on previous studies involving *Guiera senegalensis and Piliostigma reticulatum* in Senegal (Bayala et al., 2022; Bayala et al., 2025; Bogie et al., 2019; Bright et al., 2021; Dossa et al., 2009; Dossa et al., 2013; Lufafa et al., 2008). Before the cropping season, the *C. odorata* fallow was cut close to the ground. It was not uprooted. The stumps were left in place. The coppiced shoots and leaves were chopped into pieces approximately 5 cm long and spread manually over the plots. The mean *C. odorata* biomass coppiced in each 5 m x 4 m subplot was 9.7 ± 2.5 and 9.5 ± 0.9 t/ha, respectively, for the CO+NPK and CO plots. Additional manual weeding was performed to remove additional weeds.

Maize was planted in early March and in July 2024, with plants spaced 40 cm apart, 80 cm between rows, at a depth of 3–5 cm, with 2–3 seeds per hole and thinned to 1–2 plants per hole after 15 days. Maize was sown between or close to the clumps of *C. odorata*, depending on the position of the seed hole. Subsequent weeding and cutting occurred 15-20 days after crop

Figure 1

Chromolaena odorata, (a) Before Cutting, (b) Cropping Season and (c) After Harvest; bar = 50 cm

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emergence and near the maize flowering stage. In the CO+NPK and CO plots, the coverage of *C. odorata* was managed to remain with less biomass under maize plants. Following cuttings, biomass and soil surface coverage decreased. After the flowering stage, *C. odorata* did not flower until the next cropping season. Figure 1 shows the stand of *C. odorata* before and after the cropping season of maize.

Soil Sampling

Soil samples for chemical analysis were collected on 28 February 2024, during the dry season at the beginning of the experimental design. At each sampling point, soil cores with a diameter of 2.5 cm and a depth of 0–20 cm were randomly taken at five points within each subplot. Two soil profile layers were sampled: 0–20 cm and 20–40 cm. The soil samples were homogenized by layer, air-dried, and sieved to pass through a 2 mm sieve. A 200 g subsample was kept in a sealed plastic bag. The samples were taken to the laboratory of the Agronomic Higher School (ESA) at the National Polytechnic Institute (INPHB) in Yamoussoukro for chemical analysis. The following were analyzed: soil organic matter (OM), carbon, total nitrogen (TN), pH, cation exchange capacity (CEC), available phosphorus (Av. P), Na^+, Ca^{2+}, Mg^{2+}, K^+, and the carbon to nitrogen ratio (C/N). Soil pH was measured using a standard pH meter (Hanna Instruments, the Netherlands) in a soil-to-water suspension at a 1:2.5 (m/v) ratio. The organic carbon content was determined using the modified Walkley and Black method, which measures the oxidation of organic carbon by potassium dichromate ($K_2Cr_2O_7$) in sulfuric acid (H_2SO_4) (Gillman et al., 1986). Total nitrogen was determined using the Kjeldahl method (Goyal et al., 2022).

Crop Phenology and Growth

Phenological observations were conducted daily throughout the maize flowering period. The male and female flowering stages were monitored simultaneously on 70 plants in each plot. The male and female flowering times were defined as the point at which 50% of the plants exhibited tassels and silks, respectively. Crop growth was monitored on 12 maize plants along the two central rows of each subplot. The height of the plants was measured with a tape measure from the ground to the point where the last leaf was inserted, up until the flowering stage of the crop. However, in the second season (August, 2024), these parameters were measured at the maize flowering stage. The number of leaves was counted, and the plant stem diameter near the ground was measured using a digital caliper (Qianyuntong-COD Electronic Vernier Caliper, China).

Statistical Analysis

All collected data were analyzed to determine the effect of different fertilizer types on crop growth and yield. Analysis of variance (ANOVA) was performed in R Core Team (2016) to assess the significance of treatments on the measured parameters, using Tukey's HSD test (p = 0.05).

Results and Discussion

Soil Properties

The variance analysis showed significant differences ($p < 0.05$) only for soil pH (Table 1). All pH values below 6 indicate acidic soil. The 0–20 cm layer of the soil profile has a pH value that is 0.4 units higher than that of the 20–40 cm layer. The exchangeable bases (Mg^{2+}, K^+, Ca^{2+}, and Na^+) were statistically different ($p < 0.05$) between the 0–20 cm and 20–40 cm layers. The Mg^{2+} and Ca^{2+} content in the 20–40 cm soil layer was significantly higher by 10% and 13%, respectively, than in the 0–20 cm layer. In contrast, K^+ and Na^+ were twice as high in the 0–20 cm layer as in the 20–40 cm layer. There were no significant differences ($p > 0.05$) in any of the soil layers for phosphorus, nitrogen, organic matter, or CEC. The availability of phosphorus (AvP) was 3% higher in the 20–40 cm layer than in the 0–20 cm layer. The values of soil carbon,

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total nitrogen, and CEC seem to be equal in the two soil layers. The mean soil carbon content found in our study was 15 g/kg. The soil carbon content is in the medium category, as reported by Mathew et al. (2020), and is higher than the results reported for land-use changes. Previous studies have shown that soil carbon content in savannah areas increased significantly from 10.2 to 14.2 g/kg when the soil was derived from *Chromolaena odorata* fallow (Kassi et al., 2017). In our experiment, the carbon-to-nitrogen ratio (C/N) was between 10 and 20, suggesting that mineralization and the release of nitrogen (N) occur rapidly, making N available for plant uptake (Brust, 2019). However, the Mg^{2+} content was below the required average of 1–1.5 cmol/kg, as were the K^{+}, Ca^{2+}, and Na^{+} contents, which have required averages of 0.2–0.4 cmol/kg, 2.3–3.5 cmol/kg, and 0.3–0.7 cmol/kg, respectively. Although the CEC at different depths is not significantly different ($p > 0.05$), it has the required value for loam soil (10–25 cmol/kg). Available phosphorus content was above the required average (7–15 mg/kg), as was nitrogen content, which averaged between 10 and 15 g/kg. Soil nutrient quality improvement through fallowing or intercropping with *C. odorata* was found by Agbede et al. (2014), Kouadio et al. (2023), and Tondoh et al. (2013). This may be because our experiment was conducted on land that had been fallow for 5 years.

Crop Development

Male flowering occurred significantly earlier ($p < 0.05$) in *C. odorata* plots, both with and without NPK, than in control and NPK plots (Figure 2). Maize intercropped with *C. odorata* reached 50% male flowering 50 days after sowing, while the NPK and control treatments took two days longer (52 days after sowing). Figure 3 shows the mean female flowering rates across the different treatments. Female flowering occurred significantly earlier ($p < 0.05$) in the control treatment (52.7 DAS vs. approximately 53.3 DAS). Fertilization delays silk production in female flowers by one day.

Figure 4 illustrates maize growth between 25 and 53 days after sowing (DAS) during the first rainy season in April 2024. Analysis of variance revealed significant differences between treatments from 39 DAS to the maize flowering stage (53 DAS). Maize growth was compared, and CO and CO+NPK increased in height by 9% to 40%, compared with the control group. Plants from the control plots were shortest between 32 DAS and flowering (ranging from 20 to 140 cm). Plants grown with fertilizer reached 150 cm, which was 6 percent taller than the control. The stem diameter increased for all treatments until day 39. There was a reduction on day 46 across all treatments, but they then increased again by the final measurement on day 53 (Figure 5). Statistical analysis revealed a significant difference ($p < 0.001$) between the treatments from 32 days after sowing (DAS) onwards. Maize plants intercropped with *C. odorata* increased their stem diameter by 15%-38% compared with the control. This trend continued until 53 days after sowing. Maize plants in control plots had the lowest stem diameter, with the diameter of maize fertilized only remaining between the CO

Table 1

Chemical Properties of the Soil of the Experimental Site

Soil layers	pH	Carbon	Total N	OM	C/N	av P	CEC	Mg^{2+}	K^{+}	Ca^{+2}	Na^{+}
			(g/kg)			(mg/kg)			(cmol/kg)		
0-20 cm	5.9 a	15.5 a	1.4 a	26.7 a	10.58 a	90.3 a	10.4 a	0.40 b	0.13 a	1.18 b	0.12 a
20-40 cm	5.5 b	15.1 a	1.4 a	26.0 a	10.44 a	93.9 a	10.9 a	0.44 a	0.07 b	1.34 a	0.06 b
Prob.	0.0 1	0.77	0.94	0.76	0.81	0.70	0.55	0.001	0.011	0.046	0.012

Notes. Means followed by the same letter in the same column do not differ statistically among themselves by the Tukey test ($p < 0.05$). Available phosphorus (Av P), nitrogen (N), carbon (C), organic matter (OM), and cation exchange capacity (CEC).

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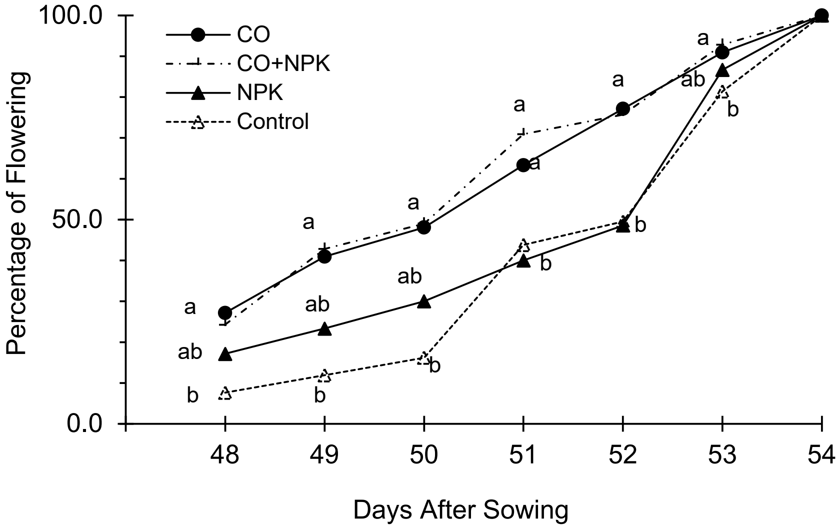
Figure 2

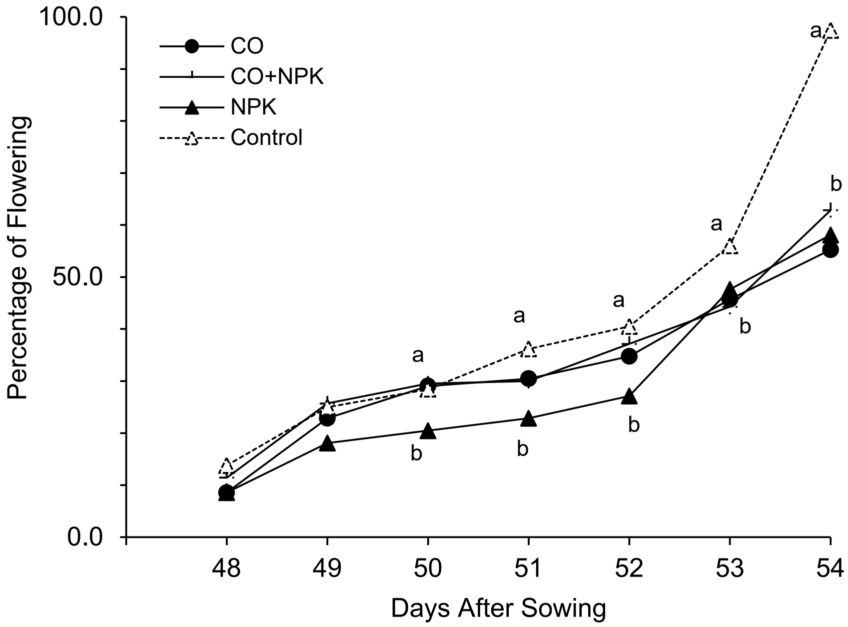
Percentage of Male Flowers Counted in The Flowering Stage of Maize in the April 2024 Rainy Season



Note. Means with the same letter are not significantly different from each other ($p > 0.05$ ANOVA followed by Tukey Test).

Figure 3

Percentage of Female Flowers Counted in The Flowering Stage of Maize in April 2024



Note. Means with the same letter are not significantly different from each other ($p > 0.05$ ANOVA followed by Tukey test).

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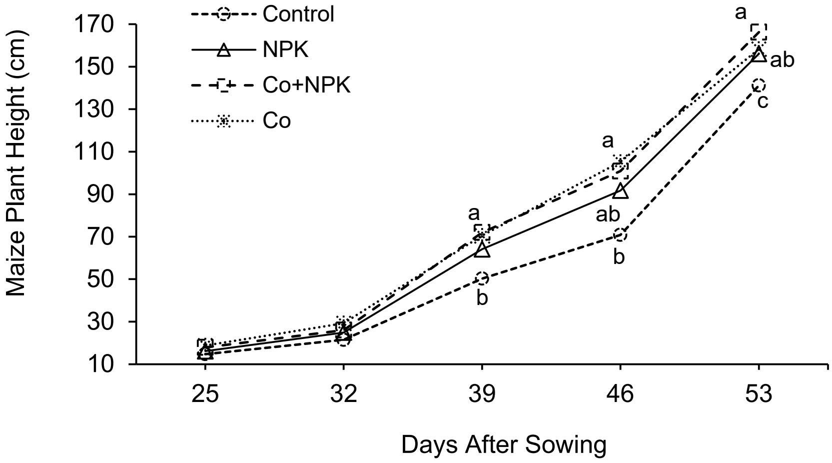
and CO+NPK treatments.

C. odorata significantly affected maize growth during the short rainy season (see Table 3). The number of leaves, plant stem, and height were significantly affected by the intercropping of maize with *C. odorata* ($p < 0.05$). Maize growth in plots with the *C. odorata* was consistently higher than in plots without the shrub. The number of

Figure 4

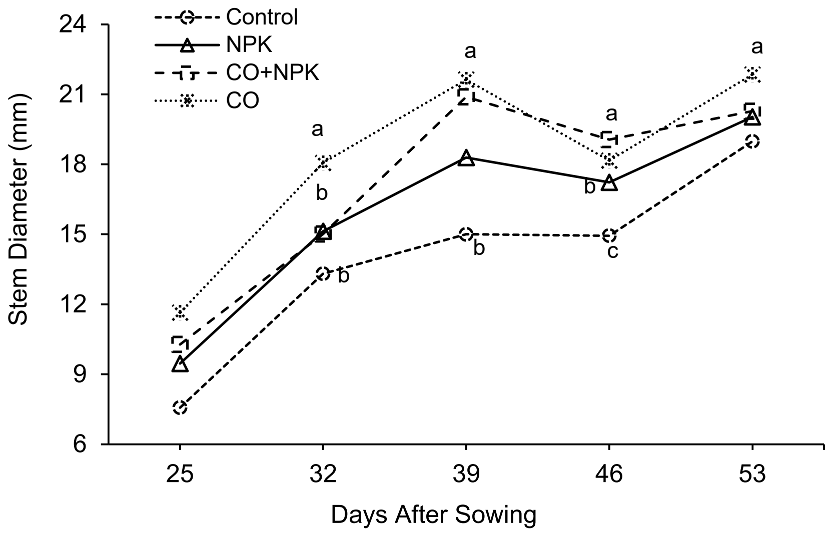
Maize Plant Height Growth During First Rain Season-April 2024



Note. Means with the same letter within the same days after sowing are not significantly different ($p > 0.05$ ANOVA followed by Tukey test).

Figure 5

Maize Stem Diameter Growth During First Rain Season-April 2024



Note. Means with the same letter within the same days after sowing are not significantly different ($p > 0.05$ ANOVA followed by Tukey test).

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leaves was 9% higher in the CO treatment than in plots without a shrub. Stem diameter varied little between treatments, but the CO treatment showed a significant increase of at least 11% compared to all other treatments. The presence of *C. odorata* led to the highest maize growth. The mean plant height was 18% higher in the CO plots than in the other treatments.

In the first rainy season, male flowering in the presence of *C. odorata* was achieved sooner than in sole crop treatments, even without the addition of inorganic fertilizer. This contrasts with female flowering, in which plants in the control plot flowered earlier. In our study, male flowers appeared two days later in the no-shrub plot than in the shrub plus crop plot. This delay is consistent with the work of Mbanyele et al. (2021), who found that, with mulching, the anthesis-silking interval was 4 days shorter than with conventional tillage on sandy soil. A similar situation appears to occur with reduced tillage and mulching, which enhance soil water capture by reducing evaporation (Demo & Asefa Bogale, 2024; Zhang et al., 2025). The presence of *C. odorata* significantly affected maize height. This suggests that the addition of organic matter was beneficial for maize growth, probably by improving soil fertility and physical properties. The gradual release of nutrients from the incorporation and degradation of this biomass boosts maize plant height growth. Other studies have demonstrated that biomass from woody plants or associated shrubs can enhance crop growth, particularly cereals (Begam et al., 2024; Bright et al., 2021). These authors found that intercropping systems can substantially improve the growth attributes of millet and maize, even under drought stress in some cases (Bayala et al., 2022). In our study, fallow land served as a source of green manure for *C. odorata* and other plants, thereby providing better conditions for maize growth and development. This was evident during the first rainy season, when rainfall was abundant. During this period, data on maize plant stem diameter in association with *C. odorata* demonstrated the effectiveness of intercropping. The presence of shrubs and their incorporation into the soil could increase water availability by altering surface infiltration, particularly in the early season (Bogie et al., 2019). This is consistent with the findings of Bright et al. (2017, 2021), who found that shrubs such as *Piliostigma reticulatum* and *Guiera senegalensis* increased the water-use efficiency of millet (*P. glaucum*) and peanuts (*A. hypogea*) in Senegal relative to the no-shrub treatment.

The higher level of organic soil matter accumulated in the optimized *C. odorata* intercropping system could be one way to assist maize (Koutika et al., 2004; Tondoh et al., 2013; Utama et al., 2024). In particular, Koutika et al. (2004) found that the organic matter fraction (2.35%) was higher when soils were under long-term fallow of *C. odorata*. This value is higher than our findings (1.5%), but Nitrogen was equal (0.14%) in the two studies. As a result, the carbon mineralization rate varied, but ranged between 15 and 20. These values suggest that the organic matter has decomposed sufficiently to allow microorganisms and plants to feed on the released nitrogen. The improved soil quality due to mulching biomass during fallow years, as in our current study, would be expected to increase aggregation and porosity for storing water and organisms (Rison & Fuangarworn, 2024) and to make it more readily available for crops.

The depth of rooting could be the reason why there is no competition between the two species. The root formation of *C. odorata* is fibrous and does not penetrate beyond 20-30 cm in most soil (Zahara, 2019). Nyakudya and Stroosnijder (2014) reported that maize root depth varies significantly with soil type, with maximum depths ranging from approximately 0.6 to 2.8 meters or more. Evidence for hydraulic redistribution mechanisms was not provided by our study; however, it could have revealed complementation interactions (Liu et al., 2025; Yin et al., 2020).

Maize Yield and Component

Maize yield parameters during the first rainy season (April–July 2024) showed significant differences between treatments (Table 2). However, the length and diameter of

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the maize ears were significantly lower ($p < 0.05$) in the control plot than in the other treatments. Additionally, CO increased ear length by 21 mm compared to the control. The presence of *C. odorata* alone (CO) increased maize ear weight by 6% to 29% compared with the other treatments. Applying fertilizer had the same effect as CO on maize ear size. The results showed that maize intercropped with *C. odorata* yielded 41% more than the control plot, while the NPK and CO+NPK plots yielded 14% and 3% more than the control, respectively. Maize productivity results in the presence of *C. odorata* suggest a mechanism related to improving soil water retention and availability. The return of biomass to the soil surface reduces evaporation, conserves water, and improves yield. This study suggests that there is no competition for water between *C. odorata* and maize plants. Our findings could be explained by the work of Bogie et al. (2019), who demonstrated that the leaf water potential of millet intercropped with *Guiera senegalensis* was lower than that of the crop-only treatment. There were highly significant differences ($p < 0.0001$) in ear length and grain weight between treatments (see Table 4). Maize length was 7% lower in the CO treatment than in the control and fertilizer treatments. The grain weight of maize per ear in the control plots was 20% higher than in the CO and CO+NPK plots. The maize yields in the fertilized and control plots were not statistically different. There was also no difference between treatments for the middle ear diameter ($p = 0.131$). However, ear weight

Table 2

Yield and Yield Components of Maize as Affected by The Presence of Shrubs (C. odorata) and Fertilizer Rate During the First Rainy Season

Fertilizer treatments	Ear length (mm)	mid-ear diameter (mm)	Ear weight (g)	Yield (t/ha)
Control	141.8b	47.5b	190.3b	7.63b
NPK	157.3a	49.5a	225.6b	7.84b
CO+NPK	159.7a	49.4a	232.1b	8.75 b
CO	162.8a	49.6a	245.2a	10.74a
p value	0.000	0.001	0.000	0.0179

Notes. Means followed by the same letter in the same column do not differ statistically by the Tukey test ($p < 0.05$). CO: *Chromolaena odorata* only, CO+NPK: *Chromolaena odorata* + NPK fertilizer; NPK: 300 kg/ha fertilizer rate and control.

Table 3

Effect of Fertilizer on Maize Plant Growth at Flowering Stage During the Second Rainy Season

Fertilizer treatments	Number of leaves	Plant stem diameter (mm)	Plant height (cm)
Control	10.1 ± 0.3^{b}	18.2 ± 0.7^{b}	128.3 ± 6.8^{c}
NPK	10.2 ± 0.3^{b}	18.3 ± 0.6^{b}	137.5 ± 6.5^{bc}
CO+NPK	10.9 ± 0.3^{b}	18.5 ± 0.7^{b}	153.1 ± 5.5^{b}
CO	11.8 ± 0.2^{a}	20.5 ± 0.6^{a}	181.8 ± 4.3^{a}
p value	0.0004	0.033	0.000

Notes. Means followed by the same letter in the same column do not differ statistically by the Tukey test ($p < 0.05$). CO: *Chromolaena odorata* only, CO+NPK: *Chromolaena odorata*+ NPK fertilizer; NPK: 300 kg/ha fertilizer rate and control.

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Table 4

Yield and Components of Maize as Affected by the Presence of Shrubs (C. odorata) and Fertilizer Rate During the Second Rainy Season

Fertilizer treatments	Ear length(mm)	mid-ear diameter (mm)	Ear weight (g)	Yield (t/ha)
Control	150.6[a]	43.8 [a]	193.1[a]	2.3[a]
NPK	150.6[a]	44.3 [a]	176.7[ab]	2.3[a]
CO+NPK	143.0[b]	43.9 [a]	152.0[b]	1.9[b]
CO	140.6[b]	48.8[a]	153.2[b]	1.9[b]
P value	0.000	0.131	0.0042	0.014

Notes: Means followed by the same letter in the same column do not differ statistically by Tukey test ($p < 0.05$). CO*: Chromolaena odorata only,* CO+NPK: *Chromolaena odorata* + NPK fertilizer; NPK: 300 kg/ha fertilizer rate, and Control.

was significantly affected by the treatments ($p < 0.005$). Residue mulching of *C. odorata* dramatically increases maize yield, suggesting a mechanism related to soil quality improvement and nutrient availability (Kassi et al., 2017; Koné et al., 2021; Kouadio et al., 2023; Tondoh et al., 2013).

The response of maize to fertilizer, with or without *C. odorata*, with yields varying with the rainy season, higher in the long rainy season (April–June) than in the short rainy season (September–October). This was probably due to differences in rainfall. The total rainfall registered during the short or second rainy season was 205.6 mm. Based on this rainfall value, maize growth was classified as drought-stressed by Djaman et al. (2018), who reported that the net irrigation requirement ranged from 606.8 to 678.6 under local conditions. Therefore, the presence of *C. odorata* near maize could reduce water availability for both crops, given maize's water sensitivity.

In the second rainy season, maize intercropped with *C. odorata* had larger leaves but a low yield. This result suggests that the most critical stages of maize growth for which water should be available to ensure optimal yields are the blooming and seed ripening stages. Previous findings have shown that water scarcity before and after flowering also affects maize yield. Specifically, drought stress due to moisture deficits affects maize's photosynthetic capacity, reproductive growth, fertilization, seed formation, and yield (Desclaux & Roumet, 1996; Kim & Lee, 2023; Sah et al., 2020). This suggests that there could be competition for water between the maize and the intercropped *C. odorata*. However, Bayala et al. (2022), Bayala et al. (2025), Bogie et al. (2019), and Bright et al. (2021) found that the presence of shrubs positively affected millet's water supply. They found no competition between the two crops for water resources. This study showed that the effect of *C. odorata* on maize growth and yield is greater than that of fertilizer. This is particularly beneficial in areas where this species is widespread, as integrating *C. odorata* into cropping systems could reduce chemical input costs.

Conclusions

The objective of this study was to determine the effect of the presence of *C. odorata,* compared with its absence*, at* zero and recommended fertilizer rates on crop phenology and growth. The results of this study indicate that *C. odorata* is delivering agroecosystem services. This was true for the temporal results, which showed a significant trend: maize reached reproductive stage 1-2 days earlier with *C. odorata* than in the control. After two trials, the impact of intercropping on maize stem diameter was greater in the zero-fertilizer treatment (21

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mm) than in the NPK treatment (20 mm) and the control (15 mm). Also, the number of leaves was 9% higher in the *C. odorata* treatment than in the control. In the season with lower rainfall, treatment with *C. odorata* had the greatest impact on maize growth and yield. Maize productivity in the presence of *C. odorata* suggests a mechanism related to improved soil water retention and availability. Future research should be conducted over longer periods and examine stump densities, water use, and nutrient uptake to determine the relative benefits of these two species in promoting crop productivity.

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