Variations in Growth Performance of Amaranthus cruentus and Celosia argentea in Response to Leaf Allelopathy of Anacardium occidentale

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Variations in Growth Performance of *Amaranthus cruentus* and *Celosia argentea* in Response to Leaf Allelopathy of *Anacardium occidentale*.

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ABSTRACT

The study was conducted to evaluate the allelopathic influence of leaf powder of *Anacardium occidentale* under various treatments of 20 g, 40 g, 60 g and 80 g on the growth performance of *Amaranthus cruentus* and *Celosia argentea*. Data generated from the measurement of growth parameters were subjected to Analysis of Variance and DMRT after the eighth week of growth. Results showed variations in the height, stem girth, number of leaves, leaf area and chlorophyll contents were observed in the test crops. Significant reduction ($P<0.05$) in stem height were recorded as from 20 g till 60 g treatments in *A. cruentus* but no significant difference was observed between 60 g and 80 g at 2 WAT. The variations in stem girth at 2 WAT was similar to that 4 WAT in *C. argentea* and *A. cruentus* at 4 WAT. At 6 WAT, significant reduction in the number of leaves started in 40 g treatment in *C. argentea* while in *A. cruentus* significant reduction started in the 20 after the eighth week of growth after the eighth week of growth g treatment and progressively reduced in all the treatments at $P<0.05$. Chlorophyll A of *C. argentea* leaves increases significantly ($P<0.05$) as the mass of leaf powder increased while chlorophyll A content in *A. cruentus* leaves reduced progressively at $P<0.05$ in all the treatments. The findings of this study revealed that the inhibitory effects of *A. occidentale* on the growth performance of the two vegetables were concentration-dependent and the pronounced inhibitory effects observed weeks after transplanting was adduced to the complete release of allelochemicals from the leaves after their total decomposition.

Keywords: Allelopathy, inhibitory, *Anacardium occidentale*, *Amaranthus cruentus*, *Celosia argentea*

INTRODUCTION

Allelopathy is the direct influence of chemicals released from one plant on the development and growth of another plant (Olofsdotter, 1998). Allelopathic interaction involves the production and release of chemical substances (allelochemicals) by certain plants that inhibit the growth and development of the individuals of the neighboring species (Shaukat *et al*., 2003). The phenomenon of allelopathy in relation to weed-crop interaction has been reported by Ito *et al*. (1998) and Tajuddin *et al*. (2002). According to them, toxic allelochemicals may inhibit shoot/root growth, nutrient uptake, or attack a naturally occurring symbiotic relationship thereby destroying the plant's usable source of a nutrient. The consequent effects may be inhibited or retarded germination rate, reduced root or radicle and shoot or coleoptile extension, lack of root hairs, swelling or necrosis of root tips, curling of the root axis, increased number of seminal roots, discolouration, reduced dry weight accumulation and lowered reproductive capacity (Ayeni *et al*., 1997). Plants release allelochemicals into the environment via root exudation, leaching by rains, or decomposition of plant residues (Rice, 1984; Inderjit and Dakshini, 1995; Inderjit, 1996; Inderjit and Duke, 2003). Allelochemicals are present in almost all plants' tissues including leaves, stems, roots, flowers, seeds bark and buds (Weston and Duke, 2003).

Anacardium occidentale belongs to the family Anacardiaceae. According to Frankel (1999), *A. occidentale* is native to the northern part of Africa and now distributed in many tropical parts of Africa with great economic and medicinal values. Due to its several values, it has become a common sight around homesteads, providing shades for home gardens, and also employed in agroforestry sites in Nigeria, especially in southern Nigeria. Litters from this tree species can be embedded into soil in form of mulch or as green/organic manures in homestead garden. Reports have it that leaves are the most potent sources of allelochemicals (Bhatt and Todaria, 1990) and without understanding the environmental implications of the presence of such tree species on farmlands, crop production may be in the dwindling trend. Therefore, this study was aimed at assessing the inhibitory effects of *A. occidentale* on commonly garden-grown vegetables (*C. argentea* and *A. cruentus*) around homesteads.

MATERIALS AND METHODS

Study Area

This study was conducted at the Screen House of the Department of Plant Biology, University of Ilorin (N 08º 28′ 53.3″ and E 04º 40′ 28.9″), Ilorin, Nigeria.

Plant Materials

Leaves of *Anarcadium occidentale* Linn. were collected from matured tree stands on the University campus while viable seeds of the test crops (*Celosia argentea* and *Amaranthus cruentus*) were obtained from the State Ministry of Agriculture, Ilorin. The plant materials and soils were collected in July, 2012.

Preparation of Extracts and Experimental Set up

Fresh leaves of *Anarcadium occidentale* were cut into small pieces, air dried at room temperature and made into powder using an electric blender. Four different regimes (20g, 40g, 60g and 80g) of the powdered leaves were prepared as treatments. Thirty (30) experimental plastic containers were filled with 2 kg of loamy soil each and randomly allocated to the following regimes; Control, 20 g, 40 g, 60 g and 80 g of powdered leaves in three replicates for each test crop respectively. The soil in the experimental plastic containers was moisture to saturation with fresh water (from borehole) and left for thorough agglomeration of the powdered leaves with the soil matrices for three days. Few seeds of each test crop of *Celosia argentea* and *Amaranthus cruentus* were germinated in a nursery and after two weeks, three young seedlings of the same height and vigour of each test crop were transplanted into each plastic container. The experiment was set-up for two months with regular irrigation under ambient condition of photo-periodism.

Measurement of Growth parameters

Measurements started two (2) weeks after transplanting (WAT) and lasted for eight (8) weeks with an interval of two weeks. The morphological parameters scored include: Plant Stem Height, Leaf Length and Breadth, Stem Girth and Leaf Area. The Stem Height, Leaf Length and Breadth were measured with a standard meter rule while the Stem Girth was measured with an Electronic Digital Caliper (Titan 23175 model). The Leaf Area was calculated according to Pearcy *et al*. (1989):

$$\text{Leaf Area} = (L \times B)\, K$$

Where L= length of leaf, B=maximum width and K= 0.5

Leaf chlorophyll content

The chlorophyll contents of *A. cruentus* and *C. argentea* were estimated after eight weeks of transplanting (WAT) according to the method of Hipkins and Baker (1986), modified by Adenipekun *et al.* (2009). Two grams of the fresh leaves were weighed using an electric Metler balance and made into a fine pulp by grinding in a ceramic mortar with 5ml of 80% v/v aqueous acetone. The mixture was extracted with another 20ml of 80% v/v aqueous acetone in dim light and filtered with Whatman No. 1 filter paper. Three ml of filtrate was taken into a cuvette and the absorbance (A) was read in a spectrophotometer at 645, 653 and 663nm. The readings were taken three times for each treatment and the chlorophyll content (mg/l) in each of the samples was calculated using the following equations:

Chlorophyll (Chl. a) = $12.7^{(A663)} - 2.69^{(A645)}$

Chlorophyll b (Chl. b) = $22.9^{(a645)} - 4.68^{(A665)}$

Total Chlorophyll ($Chl._t$) = $20.2^{(A645)} + 8.02^{(A663)}$

Statistical analysis

Data generated were analyzed using Statistical Package for Social Science (SPSS) 16.0 for Windows. Duncan Multiple Range Test [DMRT] was used to separate mean differences at $P<0.05$.

RESULTS

Effect of Leaf Powder of *A. occidentale* on Stem Height

The variations in the stem height of the test crops (*C. argentea* and *A. cruentus*) are shown in Figure 1. Except for the 20 g treatment of *C. argentea*, there were significant decreases ($P<0.05$) in stem height with increasing mass of *A. occidentale* powder in the treatments with the two test crops at 2 WAT and 4 WAT. This effect in height was more in *A. cruentus* than *C. argentea*, as deviation of the treatments from the Control was widest. There was no significant difference in height between the 20 g and 40 g treatments as well as between the 60 g and 80 g treatments of *C. argentea* at 2 WAT and 4 WAT. At 6 WAT, stem height of 40 g and 60 g treatments of *C. argentea* were at par. The variations in height of *A. cruentus* at 6 WAT was similar to 8 WAT, with the 20 g treatment shorter than 40 g treatment although not significant. The trend of height in *C. argentea* at 8 WAT was similar to those obtained at 4 WAT (Fig. 1).

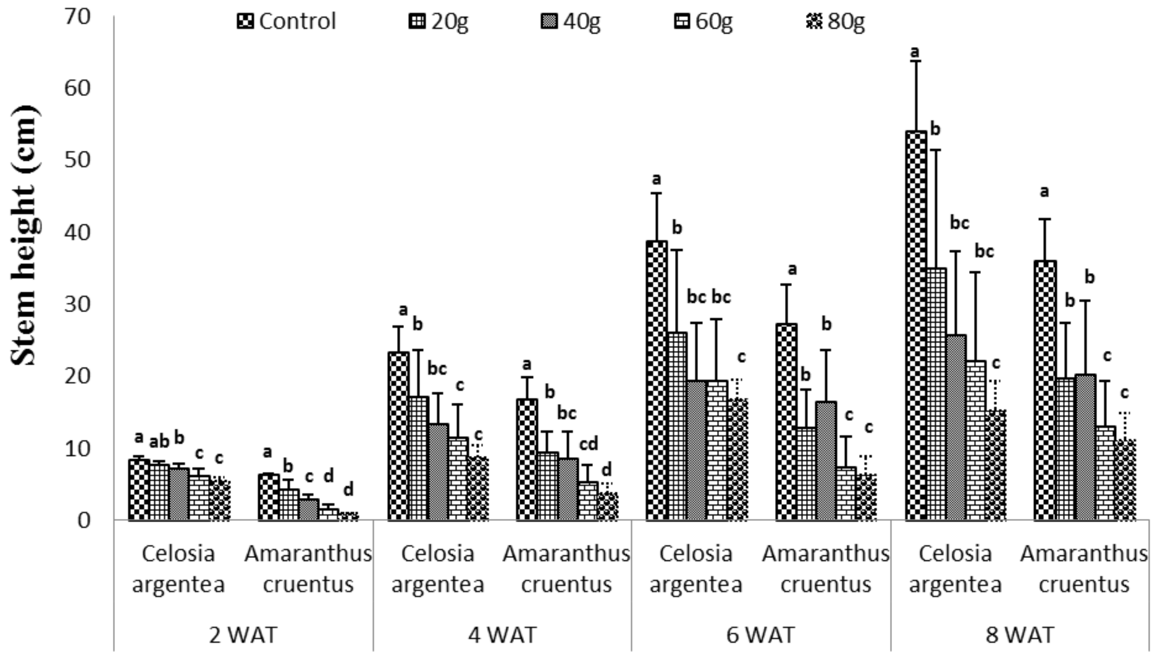

Figure 1: Variations in the stem height of *C. argentea* and *A. cruentus* as influenced by leaf powder of *Anarcadium occidentale*.

Values with same letter are not significantly different at the 0.05 probability level.

<u>Effect of Leaf Powder of *A. occidentale* on Stem Girth</u>

At all weeks after transplanting (WAT), there were significant reduction ($P<0.05$) in stem girth due to treatments with *A. occidentale* powder of the two test crops, except for the 20 g treatment on *C. argentea*. Marked differences were observed in *C. argentea* compared to *A. cruentus*, as the effect of increased levels of the powder in *A. cruentus* was not significant at 2, 6 and 8 WAT, and inconsistent throughout the weeks. The order of stem girth (control > 20 g > 40 g > 60 g > 80 g) for *C. argentea* was consistent throughout the experiment (Fig. 2).

<u>Effect of Leaf Powder of *A. occidentale* on Leaf Number</u>

The trends in the number of leaves of the two test crops were similar throughout the periods of the experiment, with the control plants producing more leaves. There were no significant differences in the number of leaves in the control and the 20 g treatment of *C. argentea*, as well as the 20 g and 40 g treatments of *A. cruentus* at various periods after transplanting (Fig. 3)

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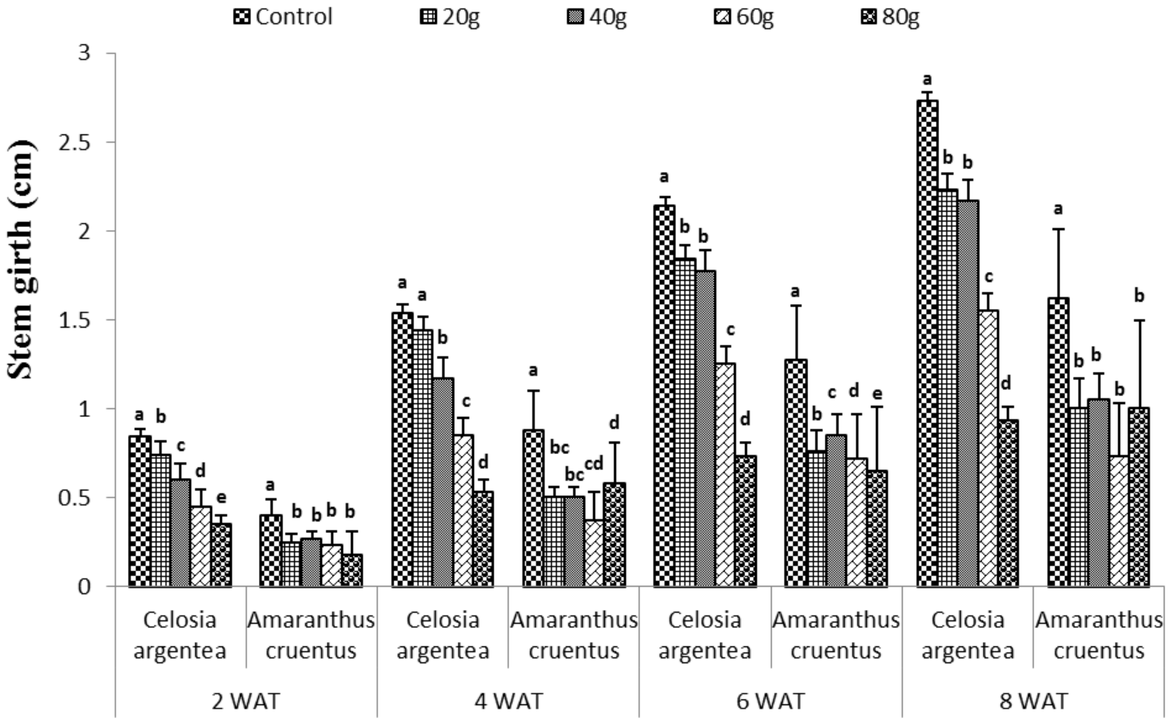
Figure 2. Variations in the stem girth of *C. argentea* and *A. cruentus* as influenced by leaf



powder of A*narcadium occidentale*.

Values with same letter are not significantly different at P< 0.05.

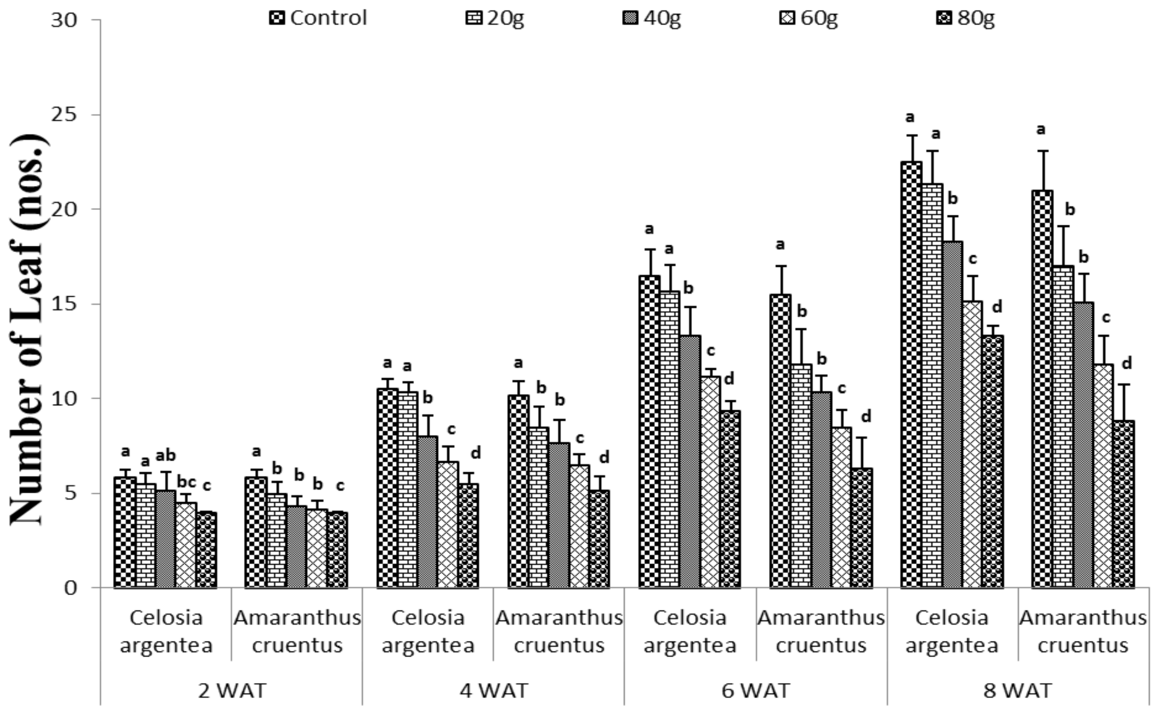


Figure 3. Variations in the number of leaf of *C. argentea* and *A. cruentus* as influenced by leaf powder of *Anarcadium occidentale*.

Values with same letter are not significantly different at P< 0.05.

Effect of Leaf Powder of *A. occidentale* on Leaf Area

The trends of leaf area in *C. argentea* were consistent was the order Control > 20 g > 40 g > 60 g > 80 g. Thus, indicating a reduction in leaf area with increasing mass of *A. occidentale* powder. The leaf areas of all treated plants were significantly lower than those of the control, although no marked reduction was observed in the leaf area at 2 WAT due to increasing levels of the leaf powder. At 6 WAT and 8 WAT, the leaf area in *A. cruentus* was in the order Control > 40 g > 20 g > 60 g > 80 g, but the 20 g and 40 g treatments were not significantly different (Fig. 4).

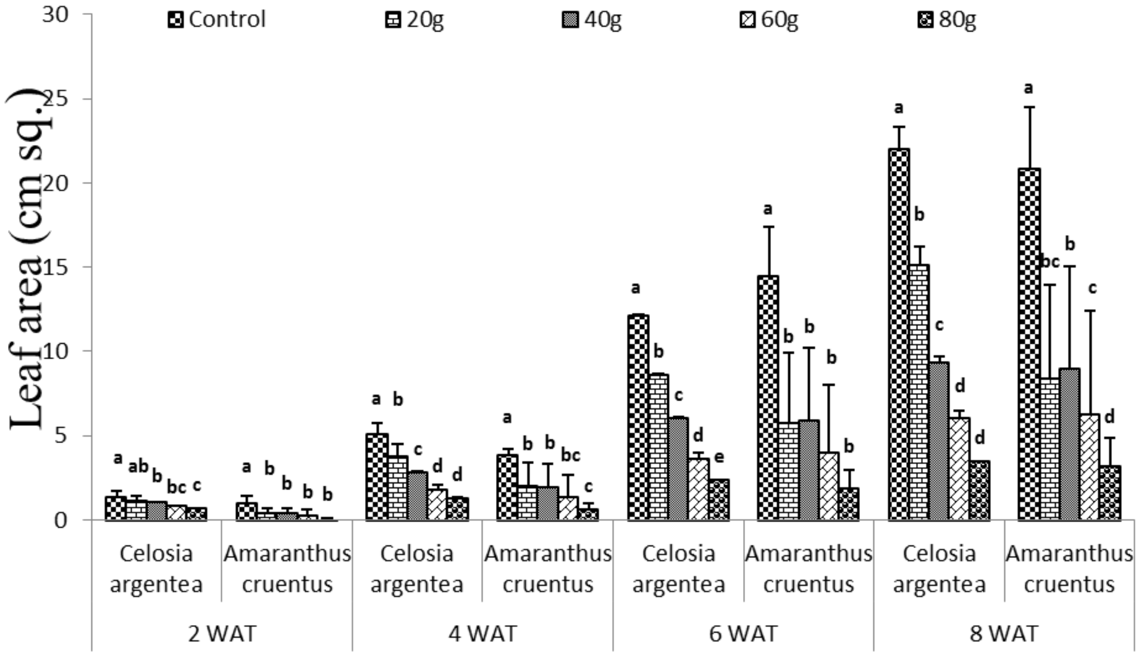


Figure 4. Variation in the leaf area of *C. argentea* and *A. cruentus* as influenced by leaf powder of *Anarcadium occidentale*.

Values with same letter are not significantly different at P< 0.05.

<u>Effect of Leaf Powder of *A. occidentale* on Chlorophyll contents</u>

Table 1 presents the Chlorophyll contents of *C. argentea* as influenced by leaf powder of *A. occidentale*. Chlorophyll a of *C. argentea* leaves increased significantly (P<0.05) as the mass of leaf powder treatment increased whereas Chlorophyll b reduced significantly (P<0.05) as the mass of leaf powder increased. The amount of total Chlorophyll in *C. argentea* was highest in the 20 g treatment and significant reductions that were progressive were recorded as the mass of leaf powder treatment increased in the treatments (Table 1). In *A cruentus*, Chlorophyll a content of the leaves reduced progressively at P<0.05 in all the treatments and the least amount was recorded for 80 g treatment while Chlorophyll b content was highest in 80 g treatment and least in 20 g treatment (Table 2). The amount of total Chlorophyll in *A cruentus* was highest in 80 g treatment and least in both 20 g and 60 g treatments

Table 1. Effect of *A. occidentale* leaves on the chlorophyll contents of *C. argentea*

	Chlorophyll a	Chlorophyll b	Total Chlorophyll
Control	21.267^{a}	23.913^{d}	45.153^{b}
20g	18.232^{e}	32.421^{a}	50.635^{a}
40g	19.281^{d}	25.352^{b}	44.618^{c}
60g	19.507^{c}	24.360^{c}	43.852^{d}
80g	19.782^{b}	15.980^{e}	35.939^{e}

Means with same lettes superscripts along the same column are not significantly different at P<0.05

Table 2. Effect of *A. occidentale* leaves on the chlorophyll contents of *A. cruentus*

	Chlorophyll a	Chlorophyll b	Total Chlorophyll
Control	21.358^{a}	26.339^{a}	47.682^{a}
20g	20.294^{b}	10.464^{e}	30.751^{d}
40g	19.609^{c}	12.371^{c}	31.971^{c}
60g	19.100^{e}	11.682^{d}	30.774^{d}
80g	19.495^{d}	16.291^{b}	35.775^{b}

Means with same letter superscripts along the same column are not significantly different at P<0.05

DISCUSSION

Previous research revealed that various concentrations of leaf extract of *Metapium brownie* (Family: *Anacardiaceae*) inhibits radicle growth of *Amaranthus hypochondriacus* (Anaya *et al.*, 1999). The findings from this study showed that there probably were some phytochemical compounds in the leaf tissues of *Anacardium occidentale* which showed significant phytotoxic effects on of *C. argentea* and *A. cruentus.* This experiment showed many trends of inhibition from the two trees leaf extracts obtained. The trend showed that with the increasing concentration of leaf extract, the growth parameters (stem height, number of leaves, stem girth and leaf area) of each bioassay test vegetable species decreased respectively. *C. argentea* and *A. cruentus* responded morphologically to the phytotoxicity of *A. occidentale* but at varying degree. The effects of the inhibitory potentials of *A. occidentale* on the vegetables in this study increased as the mass of leaf powder increase and in conformity with the assertion of Raoof and Siddiqui (2012) and Sirawdink *et al*. (2011) that allelopathy is a concentration-dependent phenomenon whereby its effect increases as the concentration of the extracts increased. In the same vein, it was generally noticed that the phytotoxic effects of *A. occidentale* observed in the morphological parameters of the two vegetables were progressively pronounced after the fourth week of transplant and this evidently indicate that most of the allelochemicals in the leaves were totally released into the soil through mineralization after 4 WAT and thereby available for uptake by the roots. The increased concentrations of the available phytochemicals at 4 WAT may have enhanced their synergistic inhibitory effects on the vegetables as Einhelling (2008) reported that phytotoxicity displayed by most allelopathic trees might be due to synergistic effects of allelochemicals rather than the single effect of Phenolic acid on germination and plant growth processes. The inhibitory effects reduced at the 8 WAT probably due to leaching away of most of the allelochemicals from the soil especially the toxic phenol and thereby not readily available to exert phytotoxic effects. Phenolic acids have been reported by Sirawdink *et al*. (2011) to be toxic to germination and, plant growth processes and activities of many enzymes due to their interference with vital growth processes and activities of many enzymes and phyto-hormones.

The inhibitory effects of *A. occidentale* on the morphological parameters in. *C. argentea* and *A. cruentus* was accompanied by a reduction in the biochemical parameters of the test crops. Total chlorophyll decreased as the mass of leaf powder in the treatment increased and this was in accordance with the findings of Singh and Rao (2003) for rice. The reduction in chlorophyll content in all the concentrations could probably be due to the degradation of chlorophyll pigments or reduction in their synthesis and the action phytochemicals present in leaf leachate as opined by Bora *et al*. (1999). Being the most important component of the pigment system, chlorophyll molecules play a major role in photosynthesis. The significant reduction of chlorophyll b and total chlorophyll content seen with all concentrations of the powder in *C. argentea* may be due to the inhibition of chlorophyll biosynthesis, the stimulation of chlorophyll-degrading substances, or both (Yang *et al*., 2007). Patterson (1981) found a marked reduction in the concentration of chlorophyll in leaves of soybean plants following treatment with a number of allelopathic compounds. The progressive reduction in the chlorophyll b contents of the leaves of the two vegetables than chlorophyll a indicates their susceptibility due to stress possibly initiated by the allelochemicals released by the decomposed leaves (Djanaguiraman *et al*., 2003).

CONCLUSION

The inhibitory effects of *A. occidentale* on the growth performance of the two vegetables were concentration-dependent and pronounced inhibitory effects observed some weeks after transplanting was adduced to the complete release of allelochemicals resident in the leaves after decomposition. It is also observed that *C. argentea* was more resistant to the inhibitory effects of *A. occidentale* and could be grown in association with the tested tree species in agroforestry system with least harmful effects.

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