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Determination of the Allelopathic effects of Fresh Leaf Segments of *Lantana Camara* and *Tithonia Diversifolia* on Maximum Quantum Yield, Effective Quantum Yield, Chlorophylls and Carotenoids Concentrations in Selected Soybean Varieties

Khavere E. K., Musyimi D.M., Netondo G.W., and Mmayi M.P.*

Department of Botany, Maseno University, Kisumu, Kenya

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Corresponding Author: **Mmayi M.P.** | E-Mail: **(patrick.mmayi734@gmail.com)**

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ABSTRACT

The use of forest tree species and weeds as green manure has exacerbated soil fertility issues, potentially due to the allelopathic chemicals present in these organic materials. Information available on their allelopathic potential on photosynthetic pigment, chlorophyll fluorescence and growth of soybean is not exhaustive. The objective was to determine the allelopathic effects of fresh leaf segments of L. camara and T. diversifolia on chlorophyll pigments and chlorophyll fluorescence of SB97 and SB19 soybean varieties. The experiment was carried out in the laboratory and greenhouse at Maseno University. In the lab, different concentrations of aqueous extracts, (25%, 50%, 75%, and 100%) and the control- tap water was used. Chlorophyll fluorescence and chlorophyll concentrations in plants were determined within a green house. Fresh leaf material of T. diversifolia and L. camara of 4g, 8g, 12g and 16g was added to soil in pots. The control only composed soil. This was replicated four times and laid out in Completely Randomized Design. Data on Chl a, a/b ratio, total chl, carotenoids, leaf maximum quantum yield and leaf effective quantum yield were recorded weekly. Data were subjected to analysis of variance using SAS 9.1 then treatment means were separated using LSD at P = 0.05. Chlorophyll fluorescence and chlorophyll concentration analyses revealed that both leaf biomass materials impacted negatively on photosynthetic activity of the soy bean varieties. Allelochemicals in the fresh leaf segments of these plants decreased maximum photochemical efficiency and quantum efficiency, potentially reducing photosynthetic activity. Farmers are therefore advised not to incorporate Lantana camara and Tithonia diversifolia leafy biomass in farms where soy bean varieties SB 19 and SB 97 are growing.

Keywords: *Camara, Tithonia, allelopathy Chl a, carotenoids, Chlorophyll & photosynthetic activity.*

Introduction

A substantial portion of Kenya's population resides in rural areas, relying mainly on agriculture-related activities for their livelihoods [16]. Among this population, a significant majority are small-scale farmers who own less than 5 acres of land. These smallholder households are particularly vulnerable to food insecurity due to the uncertainties surrounding their daily food provision as manifested through frequent famine, malnutrition and poverty [6]. In Kenya, soybean stands out as a vital leguminous crop, serving as a significant source of protein and oil in the human diet. Additionally, it plays a crucial role in enhancing soil fertility through the process of biological nitrogen fixation, as evidenced by studies such as those conducted by [4] and [19]. The cultivation of soybean is primarily undertaken by smallholder farmers, who face limitations in addressing various challenges associated with crop production.

Soybeans varieties selected for drought tolerance have the potential of improving agricultural productivity and hence livelihoods if adopted by farmers [5] Soybean varieties mature early and are drought tolerant hence a food security crop.

Soybean grains serve as raw materials in livestock feed industries, edible vegetable, oil processing industries and other human manufacturing outfits [29]. Small scale home processing of soybeans into various products also creates employment and enables households to increase their access to cash income thereby effectively contributing to poverty alleviation [6]. Studies indicate that consumption of soybeans reduces cancer, blood serum cholesterol osteoporosis and heart disease [4]. Soyabeans are also appropriate for people with lactose intolerance and are known to ease the symptoms of menopause [25]. People who suffer from digestive problems or diabetes also stand to benefit from soybean-based food [10].

Lantana camara is one of the top ten invasive weeds on earth [24]. It belongs to the family *verbenaceae* [3]. This weed grows well on nutrient deficient and barren soils and in places with increased light availability [3]. It forms dense non-specific thickets with individuals reaching up to 2 to 4 meters in height and spreading up to 4 meters in diameter. *Lantana camara* has several important uses to human beings, it has beautiful flowers and hence it is an ornamental plant, used for erosion control, twigs are used as a fuel wood and the seeds are used as livestock feeds, its straw is mixed with dung for biogas production and it has medicinal value in that the leaf extracts are used in curing wounds [11]. Despite its use there remains limited knowledge on the allelopathic effects of aqueous extracts and leaf segments on chlorophyll concentration and chlorophyll fluorescence on soybean varieties hence this study comes handy.

However, [27] explored the allelopathic impact of *T. diversifolia*, revealing that its presence in soil previously used for cultivation of maize led to a reduction in shoot and root growth of the tested plant species. Additionally, the application of soil-water separated from the same soil and water extracts from *T. diversifolia* leaves resulted in diminished shoot and root growth. These plants have thus, depicted allelopathy. Allelopathy is the chemical inhibition of one plant species by another and represents a form of chemical warfare between neighbouring plants [26]. Allelopathy is believed to be involved in many natural and manipulated ecosystems, and plays a role in the evolution of plant communities [17]. Most plant species including crops are capable of producing and releasing biologically active compounds (allelochemicals) into the environment to suppress the growth of other plants [20].

Tithonia diversifolia contain allelochemicals which inhibit germination and growth of some plants as demonstrated by [20], that aqueous shoot extracts of *Tithonia diversifolia* has inhibitory effects on germination and growth of *Amaranthus cruentus. Tithonia diversifolia* among other plant species such as *Chromolaene odorata* and *Helianthus annus* have been reported to compete with crops. [13] and [21] investigated the allelopathic effects of *Tithonia diversifolia* on maize and found out that the stimulatory functions of *Tithonia diversifola* significantly enhanced growth of older *Amaranthus cruentus* plants. It inclusively affected shoot height, fresh weight, dry weight and leaf area parameters[21]. However, no similar study has been carried out to investigate its effects on growth parameters of soybeans, a crop now popular in Western Kenya. According to[21], *Tithonia diversifolia* does not affect the germination of the *Zea mays* but studies have not been carried out to investigate whether it has similar effects on Soybean.

Chlorophyll fluorescence and photosynthetic pigments parameters are the most reliable indicators of plant stress[31]. However, naturally available allelochemicals regulators in biomass of *Lantana and Tithonia* act as either stimulation or suppression in growth[14]. It was therefore of an importance to determine how allechemical from these plant`s biomass affect biosynthesis and accumulation of photosynthetic pigments and chlorophyll fluorescence of soybeans. According to[9], photosynthetic pigments and chlorophyll fluorescence provide basic frameworks in photosynthesis. Stressful conditions negatively affect chlorophyll and can drastically reduce it in plant leaves[31]. The reduction of chlorophyll content in plants due to the application of allelopathic plant extracts was reported in many studies[14]. On the other hand, in a review by[31] the effects of sunflower leaf, stem, and root extracts on chlorophyll accumulation in two varieties of wheat and found that sunflower leaf and root aqueous extracts significantly increased chlorophyll content in both varieties. It has been reported that allelopathic compounds have inhibitory effects on plant growth by influencing chlorophyll content and photosynthesis[14]. Photosynthesis is reduced in most studies reduced as higher percentage aqueous extracts concentrations of 50% to 75% are applied. High percentages inhibit root formation making the plants have difficulties in water uptake and nutrient absorption as found in pea plants.

Findings of[12]stated that there was remarkable reduction caused in plant physiological traits due to inhibitory phytotoxic compounds accumulated in donor plant parts.

Changes in the photosynthetic pigments and chlorophyll fluorescence of plants under the influence of allelopathic compounds have been reported by[14]. Parameters such as ɸPSII, FV/FM, stomatal conductance (gs) and net photosynthetic rate were highly reduced with increasing concentrations of sunflower extract[14]. However it is not documented on how the chlorophyll fluorescence parameters of soybean plant varieties are affected by extracts from both *lantana camara* and *Tithonia diversifolia*. Therefore, it is necessary for a continual detailed research on the allelopathic effects of biomass from certain plant species to growth, yield, photosynthetic pigment concentration and chlorophyll fluorescence of soybean plants. Knowledge on allelopathic effects to soybeans and interactions between *Tithonia and Lantana* plant biomass could be used in sustainable crop management and production.

The objectives of this study was to determine allelopathic effects of various amounts of fresh leaf segments of *L. camara* and *T. diversifolia* on maximum quantum yield, effective quantum yield, chlorophyll *a*, *b*, *a/b*, *a+b* and carotenoid concentrations in SB97 and SB19 soybean varieties. The reduced land size means farmers are unable to produce enough soybeans to feed rapidly growing population[27]. Soybeans current yields in traditional cropping systems are still low (0.6t /ha) yet yield potential in the range of 3-4t/ha were reported way back by[6] and[8]. Given that beans take 2-4 months to mature, they provide the best avenue to increase productivity thus reducing nutritional as well as income deficit problems among the rural people in Western Kenya. Therefore, a growing interest to develop farming technologies that would boost yields of Soybeans on these small sized pieces of land is evident. For instance, to improve soil fertility for soybean yield, green manures from selected agroforestry shrub species from natural lands can be introduced in the soy bean growing farm system. Organic residues from plants such as *Lantana camara* and *Tithonia diversifolia* have been found to contain high N and P concentration, which is mineralized rapidly from organic material[28]. The study also improves our knowledge on the allelopathy of potentially useful agroforestry shrubs like *L. camara* and *T. diversifolia* and enable farmers make informed choices on their use. Further, studies indicated that when green manure from *Lantana camara* and *Tithonia diversifolia* are used, there is allelopathic effects to most crops. This calls for thorough investigation into allelopathic potential of these shrub species since they may have negative effects on the crops.

Materials and Methods

Experimental site; The research was carried out in the green house and laboratory at Maseno university botanic garden. Maseno area is approximately 1500 m above sea level and receives annual mean precipitation of 1750 mm with bimodal pattern of distribution[17]. The yearly average temperature of Maseno is 28.7 ^{0}C The soils in Maseno are classified as acrisol, deep reddish brown friable clay with pH ranging from 4.5 to 5.5[17]. Greenhouse temperatures varied 25±3 ^{0}C (day/night). With 27-99% relative humidity.

Experimental Materials; Fresh leaves of *Lantana camara* and *Tithonia diversifolia* was collected from Maseno university field near Botanic garden.

The leaves were taken to the laboratory and immediately separated into leaf and stem parts. Seeds of two locally adopted soybean varieties SB19 and SB97 were obtained from International Centre for Tropical Agriculture (CIAT) Maseno centre.

Preparation of fresh extracts of *Lantana* and *Tithonia*; One hundred and eight grams of fresh leaf extracts of *Lantana camara* and *Tithonia diversifolia*, respectively were harvested at the vegetative stage and cut into small chips of about 4 cm length, according to[18] and finely ground with pestle and motor and then soaked in 1 litre of water in a large beaker for 24 hours. The resultant extract was filtered through cheese cloth to remove debris and finally filtered using Watman No. 1 filter paper to have 100% concentration. The aqueous extracts of 25%, 50% 75% and 100% concentration were made by diluting original extract with distilled water.

Green house experiment on growth; Growth test was carried out in a greenhouse at the university botanic garden. The cut leaf tissues of *Lantana camara* and *Tithonia diversifolia*, respectively were incorporated in the soil contained in 4.5 litre plastic pots at five different rates namely 0 grams (control), 4 grams, 8 grams, 12 grams and 16 grams of fresh weight per pot according to[23] and[18]. The soybean seeds SB 19 and SB 97 were sown in soils within different pots at a rate of 10 seeds per pot and at a depth of 1 cm. The seeded pots were irrigated with tap water daily. The seedlings were thinned to 5 plants per pot after two weeks. Completely randomized design (CRD) with treatments replicated four times was used.

Determination of allelopathic effects of various amounts of fresh leaf segments of *L. camara* and *T. diversifolia* on maximum quantum yield, effective quantum yield, chlorophyll *a*, *b* concentration, *a+b*, *a/b ratio*, and carotenoids concentrations

Maximum quantum yield and effective quantum yield; Chlorophyll fluorescence parameters were determined using a portable florescent monitoring system (Hansatech Model FMS 2, Hansatech instruments, Germany). Leaves used were dark adapted for 30 minutes using the dark adaptation clips and then illuminated for 6 seconds to induce fluorescence, according to[20]. The fluorescence parameters estimated included; automatically calculated maximum quantum yield of the PSII (Fv/Fm) and effective quantum yield (ΦPSII). Effective quantum yield (ΦPSII) was manually calculated as (Fm' – Fs)/Fm' and is the indicator of the effective quantum yield of PSII.

Chlorophyll *a*, *b* concentration, *a+b*, *a/b* ratio and carotenoid concentrations; Chlorophyll content was extracted the methods of Arnon (1949) and Combs (1985) as described by[17]. In the laboratory 0.5 g of fresh leaf tissue was placed in 10 ml of 80% acetone in dark for 3 days for full chlorophyll extraction. The extract was diluted with 20ml of 80% acetone and read on a spectrophotometer (Nova spec II, Pharmacia Biotech, Cambridge, England) at wavelengths 480 nm, 645nm and 663 nm in order to determine chlorophyll *a* and *b,* chl. *a+b* and chl. *a/b* and Carotenoids. The respective chlorophyll concentration in milligrams (mg) per gram (g) of leaf tissues collected was calculated using the formula of Arnon (1949) while carotenoid concentration was then calculated using the formula of [14]

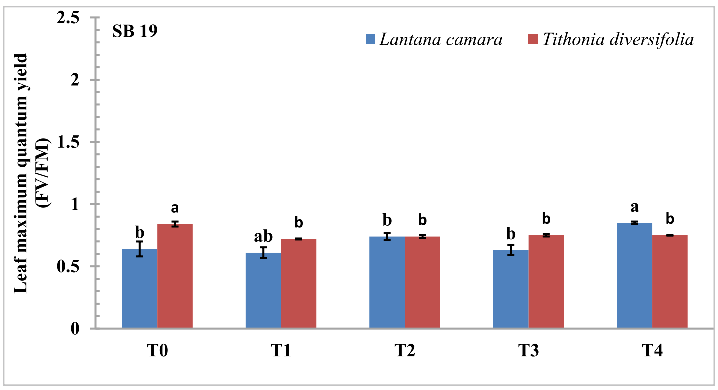
Statistical Data Analysis; Data collected was subjected to analysis of variance (ANOVA) to establish significant difference among treatments, varieties and plant materials using statistical computer package (SAS Software version 9.1). The treatment means were separated using Least Significant Difference (LSD) test at 5% significance level.

Results

Allelopathic effects of various amounts of fresh leaf segments of *L. camara* and *T. diversifolia* on maximum quantum yield, effective quantum yield, chlorophyll *a*, *b*, *a+b*, *a/b*, and carotenoids concentrations

Leaf maximum quantum yield (FV/FM); Variety SB 97 showed treatment means to be reducing with increased amount of fresh leaf segments from T1 to T3 for both *L. camara* and *T. diversifolia* while for SB19 they reduced with increasing amount of fresh leaf segments from T0 to T1 for both *L. camara* and *T. diversifolia* (Fig. 1). Variety SB19 showed that mean for T0 was significantly higher compared to T1, T2, T3 and T4 respectively for *T. diversifolia*. The leaf maximum quantum yield differed significantly under varying amount of fresh leaf segments ($p<0.05$).
Varieties interacted with both amount of fresh leaf segments and the type of fresh leaf segments from *Lantana camara* and *Tithonia diversifolia* with significant differences (Fig. 1). The interaction among varieties, type of fresh leaf segments from *Lantana camara* and *Tithonia diversifolia,* and amount of fresh leaf segments was also significant ($p<0.05$). Mean of SB 19 (0.73) variety was significantly higher than that of SB 97 (0.68).

Leaf effective quantum yield (PS II); Varieties SB 19 and SB 97 showed that treatment means were reducing with increased amount of fresh leaf segments after T2 for both *L. camara* and *T. diversifolia* (Fig. 2). Hence the leaf effective quantum yield differed significantly under varying amounts of leaf segments of each plant type ($p<0.05$). Leaf effective quantum yields were significantly different ($p<.05$) for the interactions between type of leaf segments from *Lantana camara* and *Tithonia diversifolia* plants, and amount of fresh leaf segments. Varieties also interacted with both amount of fresh leaf segments from plants and the type of fresh leaf segments from *Lantana camara* and *Tithonia diversifolia* plants with significant differences ($p<0.05$).



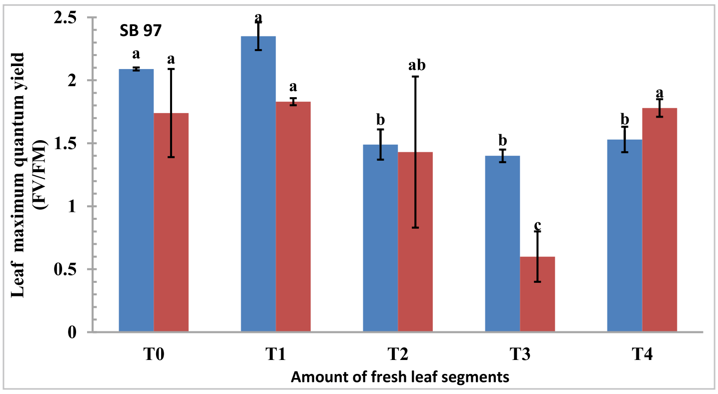


Fig. 1. Leaf maximum quantum yied in two soy bean varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.

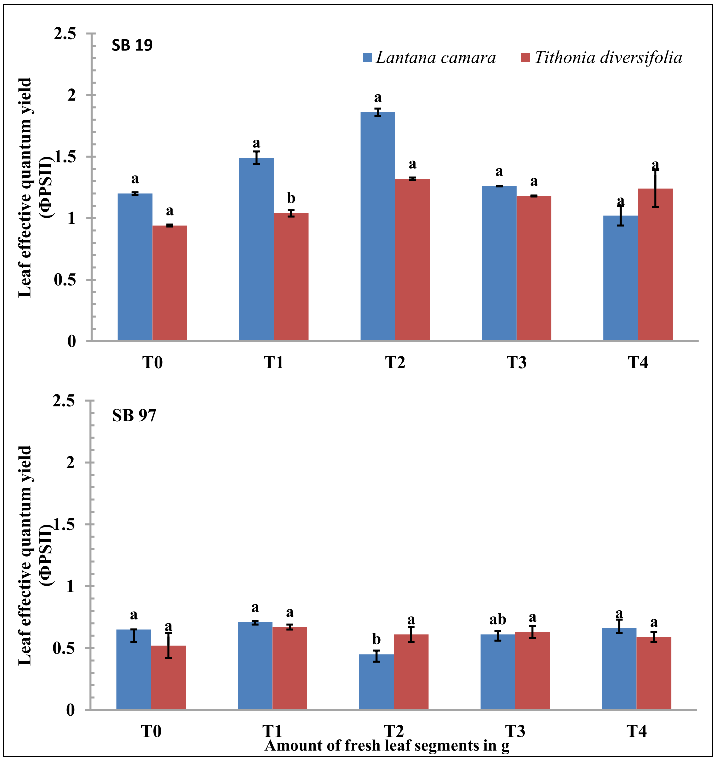
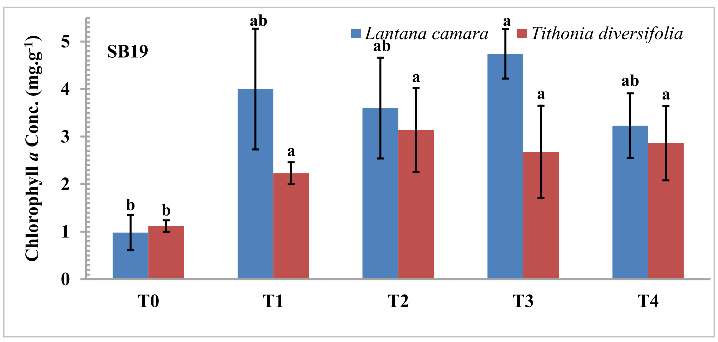


Fig. 2. Leaf effective quantum yied in two soy bean g varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.



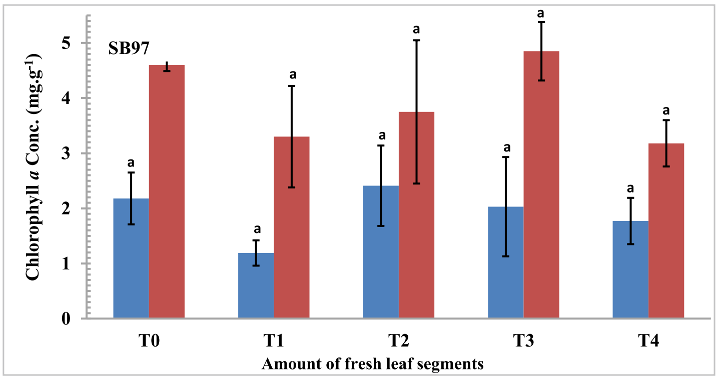


Fig. 3 Chlorophyll a concentrations in two soy bean varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.

Chlorophyll *a* concentration; There was no consistency in decrease in means as the amount of fresh leaf segments were increased for varieties SB 19 and SB 97 for both *L. camara* and *T. diversifolia* (Fig. 3). Therefore *chl.a* differed significantly under increasing amount of leaf segments of each plant type ($p<0.05$). Chlorophyll *a* concentrations were significantly different ($p<0.01$) for the interaction between type of fresh leaf segments from *Lantana camara* and *Tithonia diversifolia* plants*.* Chl. *a* showed amount of fresh leaf segments from plants interacted with varieties with a significant difference ($p<0.05$).

Chlorophyll *b* concentration; There was no consistency in decrease in means as amount of fresh leaf segments were increased for varieties SB 19 and SB 97 for both *L. camara* and *T. diversifolia* (Fig. 4).

Chlorophyll b concentration differed significantly under varying amount of green leaf segments of each plant type ($p<0.05$). Similarly, there was significant interaction between the amount of leaf segments and plant type on chlorophyll b concentration. Interaction between the amount of fresh leaf segments, plant type and variety of soy bean significantly influenced chlorophyll b concentration.

Chlorophyll *a/b* ratio; There was no consistency in decrease in means as the amount of fresh leaf segments were increased for varieties SB 19 and SB 97 for both *L. camara* and *T. diversifolia* (Fig. 5).

Hence Chlorophyll *a/b* ratio differed significantly under varying amount of leaf segments of each plant type ($p<0.05$). The interaction between the amount of fresh leaf segments and plant type significantly influenced chlorophyll a/b ratio. There was also significant interaction between the amount of fresh leaf segments, varieties and plant type on chlorophyll a/b ratio.

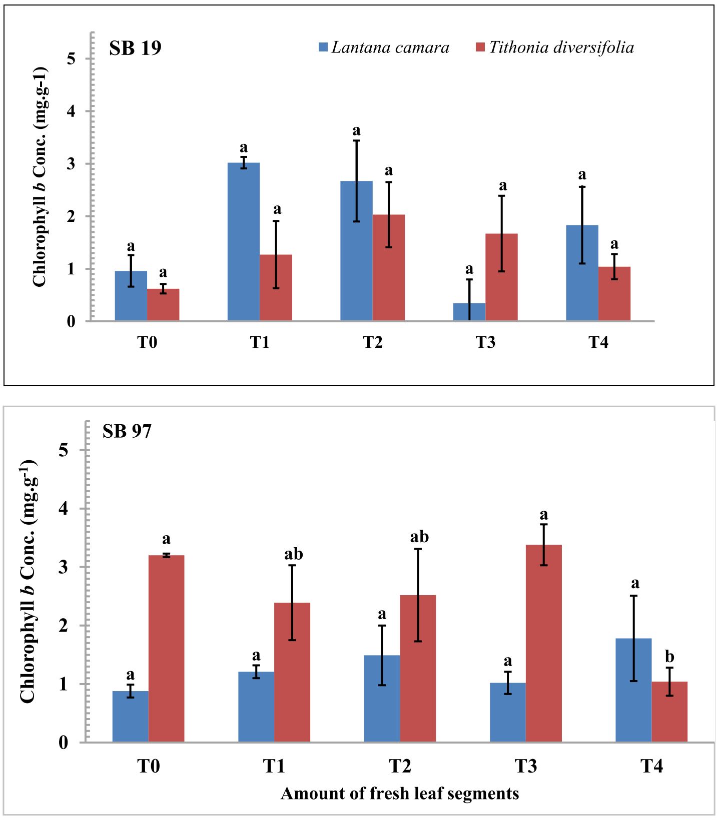


Fig. 4. *Chlorophyll b concentrations in two soy bean varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.*

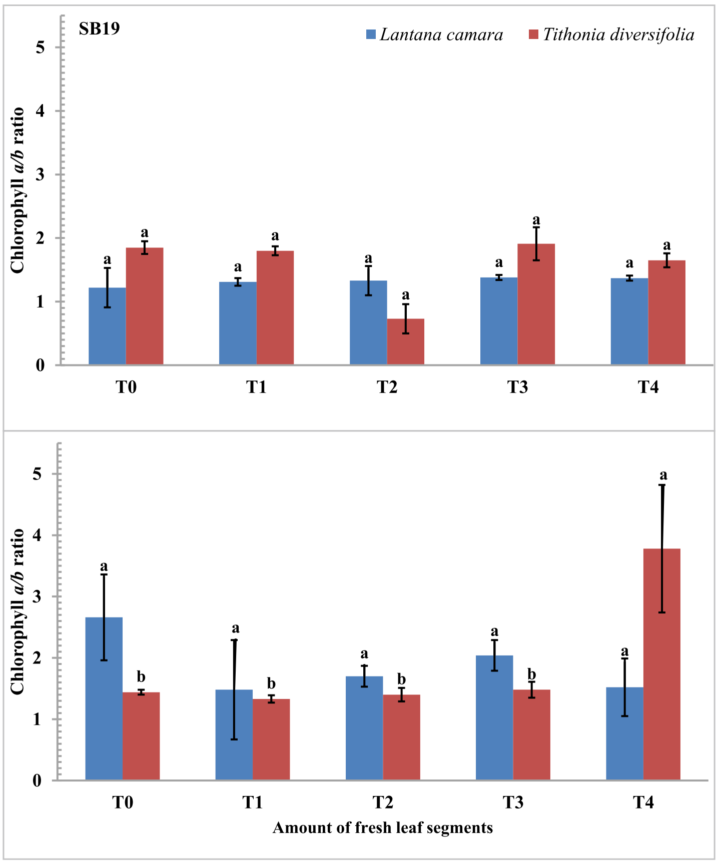


Fig. 5 *Chlorophyll a/b concentrations in two soy bean varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.*

Total chlorophyll concentrations; There was no consistency in decrease in total chlorophyll as the amount of fresh leaf segments were increased for varieties SB 19 and SB 97 for both *L. camara* and *T. diversifolia* (Fig. 6). Total chlorophyll concentration differed significantly under varying amount of green leaf segments of each plant type ($p<0.05$).

Similarly there was a significant interaction between the amount of leaf segments and plant type on total chlorophyll concentration at ($p<0.01$). The interaction between plant type, amount of fresh leaf segments and soy bean variety significantly influenced total chlorophyll concentration.

Carotenoids concentrations; The consistent increase was observed in means as amount of fresh leaf segments were increased for variety SB 97 for both *L. camara* and *T. diversifolia* (Fig. 7).

Carotenoids concentration differed significantly with increase in amount of fresh leaf segments of each plant type ($p<0.05$). There was also a significantly interaction between the amount of leaf segments and plant type on carotenoids concentration ($p<0.01$). The interaction between plant type, amount of fresh leaf segments and soy bean variety significantly influenced the amount of carotenoids concentration.

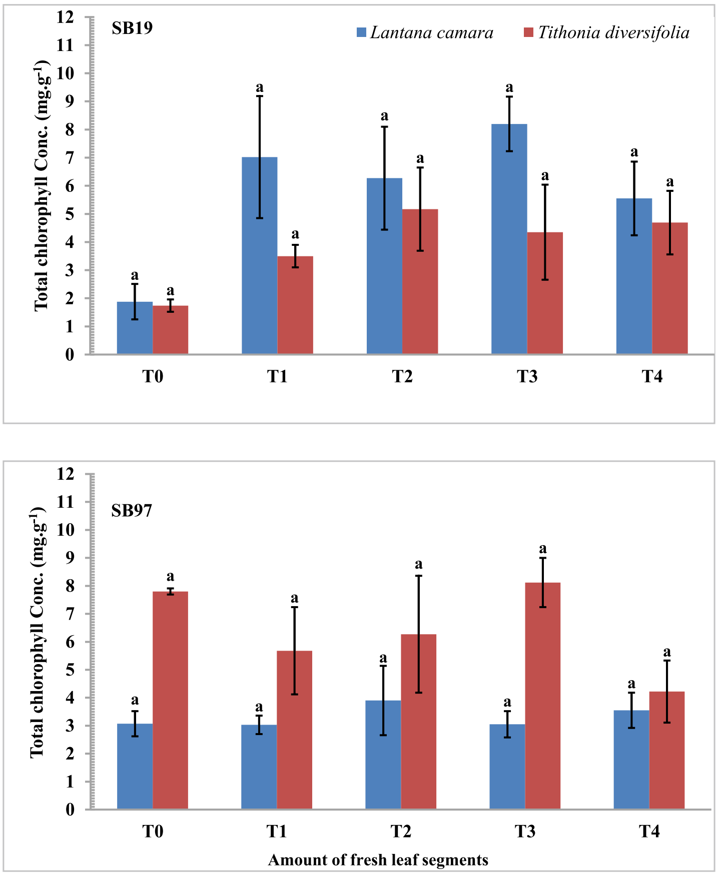


Fig. 6 *Total chlorophyll concentrations in two soy bean varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.*

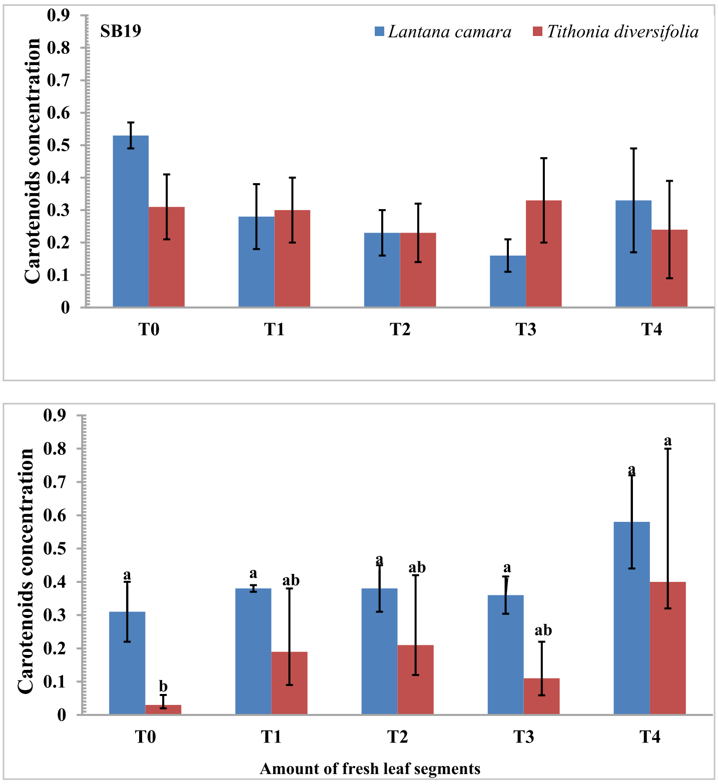


Fig. 7 Carotenoids concentrations in two soy bean varieties subjected to various treatments of fresh leaf segments. Values are means of four replicates±SEs. Control (T0), 4g of fresh leaf segments (T1), 8g of fresh leaf segments (T2), and 12g of fresh leaf segments (T3) and 16g of fresh leaf segments (T4) from both L. camara and T. diversifolia. Means with the same latter are not significantly different among treatments for every variety.

Discussion

Allelopathic effects of various amounts of fresh leaf segments of *L. camara* and *T. diversifolia* on on maximum quantum yield, effective quantum yield, chlorophyll *a*, *b*, *a*/*b*, *a*+*b* and carotenoid concentrations of SB 19 and SB 97 soybean varieties

Chlorophyll fluorescence in this study was significantly inhibited with an increase in amount of leaf segments. Leaf maximum quantum yield was significantly reduced but the leaf effective quantum yield appeared to have significantly increased initially in both varieties (Fig. 1 and Fig. 2). According to[14], this can be explained in relation to allelochemicals ability to increase initial fluorescence, but decreased maximum photochemical efficiency of PS II (Fv/Fm), quantum efficiency of non-cyclic electron transport of PS II (phi(PSII)), photochemical quenching and antenna conversion efficiency (Fv'/Fm'). This is in agreement with the study by[30] whose study on effects of two allelochemicals on the photosynthesis and chlorophyll fluorescence characteristics of eggplant seedlings, showed that the two allelochemicals were the barriers of chlorophyll content, net photosynthetic rate, and stomatal conductance. The initial non significant increase from T1 to T2 in leaf effective quantum in SB19 and for all extracts was followed by sudden non significant fall from T2 to T4 (Fig. 1). Concurrently, there was an overall significant reduction for leaf maximum quantum yield in SB 97 fromT1 to T3 (Fig. 2). These two occurrences may be explained as due to the allelochemicals in the extracts making non-photochemical quenching (qN) increase first and later decrease. According to[30] and[9], 1, 2-benzodicarboxylic dimethyl ester decreased qN, which was harmful to the photosynthesis structure.

[2] conducted a study where they found that exposure to cafferic acid led to notable changes in leaf properties. After 12 days of treatment, there was a significant increase in leaf diffusive resistance and transpiration rate, while after 28 days, there was a significant decrease in chlorophyll fluorescence (Fv/Fm). Similar results were observed in leaf spurge after treatment with hydroxyquinone in their previous study[1].The researchers concluded that the primary mechanism behind the growth inhibition was the disruption of plant water relations. They suggested that chronic reduction in available CO_2 and water stress might be the possible reasons for the decline in chlorophyll fluorescence (Fv/Fm). In the current study, there might be a slight reduction in Fv/Fm at the later stage of soybean plant growth due to increased leaf extract concentration. However, the reductions in photosynthetic rate and plant growth were evident right after subjecting the plants to *Lantana* and *Tithonia* fresh leaf segments treatments.

The study indicated that the disruption of PSII electron transport in vivo doesn't necessarily imply that it is the primary or direct mechanism of allelochemical-mediated photosynthesis inhibition. There is need for evidence showing whether allelochemicals reach chloroplasts and accumulate in significant amounts. Arguably, allelochemicals may have limited activity beyond the rhizosphere. Therefore, obtaining such evidence is crucial before concluding the role of allelochemicals in chlorophyll fluorescence.

Results indicate that in SB 19, for chlorophyll *a* content varied significantly but generally increased with increase in percentage concentration of leaf extracts (Fig 3). SB97 variety showed a significant increase in *a*/*b* ratio at T4 when compared to T0, T2 and T3 for *Tithonia diversifolia* fresh leaf segments. This is in line with the study by[15] who reported that aqueous extracts of *T. diversifolia* leaves applied either directly onto cultivated soil containing beans (*Phaseolus vulgaris* L.) or as foliar spray showed increase in the concentrations of chlorophyll and metabolites in the bean plants, such as phenylalanine and tryptophan hence enhanced growth and yield of the beans.

Frequently, researchers have observed a decrease in chlorophyll content in plants treated with allelochemicals. For instance, studies by[7] demonstrated that treating soybean plants with phenolic acids like ferulic, p-coumaric, and vanillic acids significantly reduced biomass and chlorophyll content in leaves which also is in line with the results from the present study. Similar results were observed in other species such as *Parthenium hysterophorus* and *Cucumis sativus*[22]. Allelochemicals can affect chlorophyll accumulation through various mechanisms, including inhibiting chlorophyll synthesis, stimulating chlorophyll degradation, or both. It is believed that certain allelochemicals might interfere with the synthesis of porphyrins, which are precursors of chlorophyll biosynthesis[16]. In this distinct patterns of amount of fresh leaf segments changed chlorophyll contents of SB 19 and SB 97 due to enhanced chlorophyll degradation[15]. The current study did not however, delve into the possible phytochemicals and mechanisms. This is therefore an area of further study.

Conclusion

Lantana camara and *Tithonia diversifolia* extracts inhibited leaf maximum quantum yield at T2 and T3 in SB 97. *Tithonia* significantly increased chlorophyll ratio at T4 in the same variety and greatly altered carotenoid concentration. *Lantana camara* showed stronger allelopathic effects compared to *Tithonia diversifolia.*

Allelochemicals might have led to an increase in non-photochemical quenching first and later decreased thus leading to a varied reduction for leaf maximum quantum yield in SB97. Further the chemicals may interfere with porphyrins precursors during chlorophyll biosynthesis when *Lantana* was applied. Based on the observed allelopathic effects of *Lantana camara* and *Tithonia diversifolia* leaf extracts on chlorophyll fluorescence and photosynthetic pigment concentration, the two plant materials are not recommended to be used by the farmers in areas where the two varieties of soybeans are growing. Further research should focus on investigating the mechanisms of action of the allelochemicals present in these plants.

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