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Original Research Article

Improving the efficacy of *Tithonia diversifolia* extract in management of foliar diseases of sesame intercropped with maize under tropical conditions

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Abstract

Cercospora leaf spot (CLS) and Alternaria leaf blight (ALB) diseases are major constraints to sesame production. Although disease management through intercropping of sesame with maize and foliar-spray with extracts of *Tithonia diversifolia* have been found to be effective, the frequency of application of the extracts required to achieve optimal disease control have not been determined. Therefore, a study was carried out to determine the effect of frequency of application of *T. diversifolia* extract on CLS and ALB diseases of sesame intercropped with maize during the early (June–September) and late (August–November) cropping seasons of 2011. Field experiments laid out in a Randomised Complete Block design and in a split plot arrangement with three replications were conducted in Ejigbo, Nigeria. Treatments consisted of aqueous *Tithonia diversifolia* leaf extract applied at 7.0, 7.5 or 8.0% (w/v) in one-, two- or three-spray regimes at 2-week intervals from three weeks after planting (WAP) to plots of sesame intercropped with maize; Unsprayed sesame/maize intercrop; sesame/maize intercrop sprayed with Carbendazim (50%)WP and unsprayed sole sesame plots. Results revealed that CLS and ALB incidence, severity and defoliation were significantly ($p < 0.05$) reduced by three-spray regime of 7.5% (w/v) *T. diversifolia* extract. The efficacy of 7.5% (w/v) *T. diversifolia* extract was comparable to that of 8.0% (w/v) *T. diversifolia* extract or synthetic fungicide (Carbendazim 50%WP). This study showed that the three-spray regime of 7.5% w/v *T. diversifolia* leaf extract is sufficient to control foliar diseases of sesame intercropped with maize.

Keywords: Alternaria leaf blight; Cercospora leaf spot; plant extract, *Sesamum indicum*, *Tithonia diversifolia*, intercropping; spray regimes.

INTRODUCTION

Sesame (*Sesamum indicum* L.) is an important oil seed crop across the world because of the wide range of domestic and industrial uses (Kamlesh et al., 2017; Abadi, 2018; Noureldin and Andrey, 2019). The crop is grown mainly for its seed which contains 50–60% oil and 19–25% protein with antioxdant ligans such as sesamolin and sesamin, which prevent rancidity and give sesame oil long shelf life (Nagendra Prasad et al., 2012). Nigeria is the seventh leading producer in the world with its 573,000 MT ha^{-1} accounting for 9.52% of the world production (FAOSTAT, 2020). Sesame is Nigeria's largest agricultural export product from which USD109.46M was earned as foreign exchange in the first quarter of 2019 (Olowe, 2019). Despite the huge production potentials of sesame in the world and the demand for organic sesame, the area under organic sesame production relative to the total area of cultivation was about 0.50% as in 2017 (FAOSTAT, 2018). However, one of the constraints to sesame production in the tropics is the adverse effect of foliar diseases, namely, Cercospora leaf spot and Alternaria leaf blight which account for 20–55% of yield losses (Olowe, 2019). These diseases also caused significant reduction in sesame seed quality (Enikuomehin et al., 2002; Jimoh et al., 2016). Nevertheless, the huge production potential of sesame in the tropics had earlier been confirmed under sole cropping (Olowe 2004; Olowe and Adeniregun, 2010) and intercropping systems (Olowe and Adeyemo, 2009; Adekunle et al., 2014).

Disease management options available in subsistent farming systems in the tropics include intercropping and foliar spray with plant extracts. Intercropping has the advantage of giving farmers multiple harvests from component crops (Nagesh, 2015) as well as reduction of disease incidence and severity (Finisa, 1996; Enikuomehin et al., 2006) with attendant improvement in crop yield (Olasantan et al., 2007). An earlier study (Enikuomehin et al., 2010) reported that intercropping sesame with maize in alternate row (1:1) arrangement reduced CLS and ALB incidence and severity as well as enhanced production of good quality seeds. Furthermore, foliar spray of leaf extract of *T. diversifolia* or *Chromolaena odorata* on sesame intercropped with maize induced significant reductions in disease incidence and severity, with attendant improvement in crop yield and seed health (Jimoh et al., 2016). Unfortunately, integrated approach that includes intercropping and foliar application of plant extracts is yet to be adopted for disease control in sesame in the tropics.

Tithonia diversifolia (Hemsl) A. Gray also known as Mexican sunflower or Tree Marigold is an annual flowering plant that is usually between 1.2–3 m in height with 5–17 × 3.5–12 cm-sized leaves (Ajao and Moteetee, 2017). It is an invasive weed that has become a problem for farmers because of its allelopathic properties and ability to suppress native species (Omokhua et al., 2017). However, *T. diversifolia* has been used as organic fertiliser (Ajao and Moteetee, 2017) as well as remedy for numerous human ailments (Madurera et al., 2002; Njoroge and Bossmann; 2006; Ajao and Moteetee, 2017). Extracts of *T. diversifolia* have also been used in the control of insect pests of different crops (Dougoud et al., 2019). We hypothesised that reduction of foliar diseases of sesame intercropped with maize can be achieved through multiple sprays of *T. diversifolia* leaf extract. Therefore this study was undertaken to determine the number of times that the foliar spray is required to achieve optimal disease management and crop yield in a sesame/maize intercrop. This will further make simpler and adoptable, the prescription of foliar spray of T. diversifolia leaf extract in a sesame/maize intercrop as a sesame disease management option.

MATERIALS AND METHODS

Location and description of experimental site

Field experiments were conducted during the early (June–September) and late (August–November) cropping seasons of 2011 at the Teaching and Research Farm of Osun State University, College of Agriculture, Ejigbo, Nigeria (71′5N and3′25E), a forest-savannah agro-ecology in southwest Nigeria. The rainfall pattern is bimodal, with peak in July and September. Average annual rainfall was 1269.1 mm. Mean monthly minimum and maximum temperatures ranged between 21.8°C–23.7°C and 27.1°C–36.7°C, respectively. Digital weather station was located 200 m away from the experimental site.

Experimental design and treatment

Treatments were arranged in a Randomised Complete Block Design and in a split plot arrangement with three replications. Spray regimes were allocated to main plot and extract concentrations to sub plot.

Experimental materials

Sesame seeds of Var. E8 (an early maturing variety known for tolerance to both Cercospora leaf spot and Alternaria leaf blight diseases of sesame) was sourced from Research and Development Centre, Federal University of Agriculture, Abeokuta, while the maize seeds (Var. TZSR-Y) were obtained from the Institute of Agricultural Research and Training, Ibadan, Oyo State, Nigeria. Earlier reports have identified *Cercospora sesami* Zim and *Alternaria sesami* (Kawamura) Mohanty and Behera as pathogens of Cercospora leaf spot and Alternaria leaf blight diseases, respectively (Enikuomehin et al., 2010; Oduwaye and Enikuomehin, 2013). The plant extract used in the study was obtained from fresh leaves of *T. diversifolia* (Hemsi) A. Gray. Sesame seeds were sown by mixing 10 g of seeds thoroughly with one kg sandy soil. This method was employed in order to achieve uniform distribution.

Crop husbandry

Sesame seeds were sown by dibbling along the row in intercrop with maize in single alternate row (1:1) arrangement (Enikuomehin et al., 2010). Maize population in the intercrop was 53,000 plants per hectare with row spacing of 75 × 25 cm. Sesame population was 133,333 plants per hectare at 75 × 10 cm intra-row spacing. Plot size was 5.0 × 3.75 m (18.78 m^2). Manual weeding was done twice at 3 and 6 WAP.

Preparation of plant extracts

Fresh leaves of the plant were obtained and soaked in 2% solution of sodium hypochlorite for 1 min, washed in several changes of tap water and air dried at room temperature (28 ± 2 °C) for 6 days. Air-dried plant parts were then blended into powder using Sayona blender® (model No: SY-86) from where 80, 75 and 70 g of each plant were weighed with sensitive weighing balance. Weighed test plants were mixed with 100 ml sterile distilled water, then sieved through 1-mm cheese cloth and suspension of each was made up to 1 L. The suspension was applied at the rate of 1 L per plot (18.75 m^2) using a 2 L Volpi hand sprayer.

Application of plant extracts

Plant extracts in three concentrations of 8.0, 7.5 and 7.0% (w/v) were sprayed on sesame at 2-week intervals on different plots of sesame intercropped with maize in a single alternate row (1:1) arrangement from 3 WAP. Spray regimes consisted of:
1-spray regime (sprayed once at 2WAP)
2-spray regime (sprayed twice at 2WAP and 4WAP)
3-spray regime (sprayed thrice at 2, 4 and 6 WAP)
Control plots which were left unsprayed were the sole and sesame/maize plots. Synthetic fungicide Carbendazin 50% WP was applied at 3WAP at the rate of 35 g/L

Disease assessment

Assessment of disease incidence (DI) commenced at 3 WAP and continued weekly until 12WAP to determine the number of plants and leaves diseased (Enikuomehin et al., 2010). Assessment of the number of plants diseased was done on two permanent quadrats (50 × 100 cm) placed randomly per plot. The total number of plants and the number of diseased plants per quadrat were counted and expressed as percentages. Number of leaves diseased was obtained from five randomly tagged plants per plot. The number of leaves diseased was expressed as a percentage of the total number of leaves per tagged plant. Defoliation was also assessed weekly by counting the number of nodes and missing leaves on each main stem of tagged plants per plot (Jimoh et al., 2017)

Disease severity for CLS was assessed at 13WAP through the count of lesion number on five plants per plot were selected, and on each plant, the number of lesions on a quarter ($^1/_4$) of the area of one leaf at the second node was counted (Enikuomehin et al., 2002; Jimoh et al., 2016). Severity of ALB disease was assessed through measurements of size of five randomly selected ALB lesions per plot. This was done by measuring the area (length × breadth) of each lesion with the aid of a metre rule (Enikuomehin et al., 2002; Enikuomehin et al., 2010).

Yield assessment

Five sesame plants per plot were randomly selected and tagged for grain yield attribute analysis (number of capsules per plant, seed weight per plant and grain yield) after harvest.

Data Analysis

All data collected were subjected to analysis of variance using GENSTAT Discovery (Edition 4) package and means of significant treatments were compared using Tukey's Studentised Range Test at 5% probability level.

RESULTS

The incidence of CLS as influenced by the frequency of application of *T. diversifolia* extract in sesame/maize intercrop is shown in Table 1. Generally, increased number of spraying regimes significantly ($p \leq 0.05$) reduced CLS incidence in the intercrop. In particular the three-spray regime of *T. diversifolia* extract at 8.0% (w/v) induced the highest reduction in CLS incidence. On pooled mean basis, three-spray regime of *T. diversifolia* extract at 8.0% (w/v) significantly ($p \leq 0.05$) reduced CLS incidence to 40.04% (leaf infected) and 67.48% (plant infected) relative to 67.61% and 88.46% respectively in the unsprayed intercrop. The efficacy of *T. diversifolia* extract at 8.0% (w/v) was however comparable to the effect of 7.5% (w/v) (three-spray regime of *T. diversifolia*) or the synthetic fungicide (Carbendazim) (Table 1).

Against the Alternaria Leaf Blight (ALB) disease (Table 2), the three-spray regime of *T. diversifolia* extract at 7.5% (w/v) enhanced the lowest incidence. However, the effect was not significantly ($p \leq 0.05$) superior to that of 8.0% (w/v) *T. diversifolia* or the synthetic fungicide (Carbendazim).

Table 3 shows that increased frequency of application of *T. diversifolia* extract induced reductions in leaf defoliation. The three-spray regime of *T. diversifolia* extract at 7.5% (w/v) induced the lowest per cent defoliation (8.84% on pooled mean basis), a value that was comparable to most other treatments except the sole crop (26.7%).

The effect of frequency of the application of *T. diversifolia* extract on CLS and ALB severity is shown in Tables 4 and 5. Severity of CLS and ALB in the intercrop was significantly ($p \leq 0.05$) reduced by the three-spray regime of *T. diversifolia* at 7.5% (w/v) or 8.0% (w/v). This effect was comparable to that of the synthetic fungicide (Carbendazim). CLS lesion number or ALB lesion size in plots sprayed with 7.5% (w/v), 8.0% (w/v) of *T. diversifolia* extract or the synthetic fungicide were not significantly ($p \leq 0.05$) different from each other (Tables 4 and 5).

Table 6 shows that on pooled mean basis, yield values in plots sprayed with the three-spray regime of 7.5% (w/v) of *T. diversifolia* extract were significantly ($p \leq 0.05$) higher than yield values in the unsprayed intercrop. Capsule number plant, seed weight/plant and grain yield from plots sprayed with *T. diversifolia* extract at 7.5% (w/v), 8.0% (w/v) or synthetic fungicide (Carbendazim) were comparable ($p \leq 0.05$) and significantly ($p \leq 0.05$) higher than yield values from the sole crop (Table 6).

Table 1. Effect of frequency of application of *Tithonia diversifolia* leaf extract on incidence of Cercospora leaf spot disease of sesame in sesame/maize intercrop during early and late cropping seasons in Ejigbo, Nigeria.

Treatment (Frequency of Application of Plant extract)	Conc (%) (w/v)	Disease Incidence (%)					
		M_r-CLS		M_p-CLS		Pooled mean (x)	
		Early Season	Late Season	Early Season	Late Season	M_r-CLS	M_p-CLS
One-spray regime	7.0	72.59b	67.44b	91.53b	90.17b	70.02b	90.85bc
	7.5	56.87cd	60.71b	91.57b	91.81b	55.89bcde	91.69bc
	8.0	60.95bcd	55.70b	90.37b	89.13b	55.83bcde	89.75bc
Two-spray regime	7.0	70.31bc	64.50b	88.26b	84.52b	67.41bc	86.49bc
	7.5	48.63de	57.35b	79.58c	86.75b	52.99cdef	81.37c
	8.0	57.21cd	57.70b	85.41bc	84.25b	57.55bcdef	83.79bc
Three-spray regime	7.0	65.23bc	61.97b	89.36b	87.71b	63.60bcd	88.53bc
	7.5	36.45e	43.82b	67.46d	67.23c	40.13ef	67.34d
	8.0	39.82e	40.26b	69.90d	65.07c	40.04ef	67.48d
Carbendazim (50%WP)		36.60e	49.28b	68.23d	68.19c	39.77ef	68.22d
Sesame/Maize		65.22bc	70.00b	87.95b	88.97b	67.61bc	88.46bc
Sole Sesame		96.71a	98.33a	100.00a	100.00a	96.0a	100.00a

Means with the same letter along the column are not significantly different at $p \leq 0.05$ according to Tukey's Studentised Range Test.
Early Season: June–September, 2011; Late Season: August–November, 2011.
M_r-CLS: Maximum incidence of leaf infected (%) by Cercospora leaf spot at 12WAP
M_p-CLS: Maximum incidence of plant infected (%) by Cercospora leaf spot at 12WAP

Table 2. Effect of frequency of application of *Tithonia diversifolia* leaf extract on incidence of Alternaria leaf blight of sesame in sesame/maize intercrop during early and late cropping seasons in Ejigbo, Nigeria

Treatment (Frequency of Application of Plant extract)	Conc. % (w/v)	Disease Incidence (%)					
		M_r-ALB		M_p-ALB		Pooled mean (x)	
		Early Season	Late Season	Early Season	Late Season	M_r-ALB	M_p-ALB
One-spray regime	7.0	15.08b	13.19b	79.90b	88.60ab	14.14b	84.25b
	7.5	14.24b	7.57cd	79.38b	85.17ab	10.90bcde	82.27b
	8.0	13.15b	6.63cd	81.36b	87.42ab	9.89bcde	82.85b
Two-spray regime	7.0	15.87b	9.57bc	86.26b	79.45bc	12.72bcd	81.39b
	7.5	12.16bc	5.2cd	79.16b	83.62b	10.43bcde	82.57b
	8.0	11.12bc	3.33cd	82.99b	83.33b	7.22bcde	81.57b
Three-spray regime	7.0	10.69bc	7.02cd	80.76b	85.38b	8.86bcde	81.91b
	7.5	5.09d	2.78d	62.49c	63.09d	3.94e	62.64d
	8.0	6.21cd	3.32cd	68.36c	69.97cd	4.77de	68.77d
Carbendazim (50%WP)		6.36cd	7.33bcd	63.11c	65.43d	6.60cde	64.27d
Sesame/Maize		13.14b	9.37bcd	82.78b	86.35b	12.20bcd	84.56b
Sole Sesame		35.43a	21.10a	100.00a	100.00a	31.27a	100.00a

Means with the same letter along the column are not significantly different at $p \leq 0.05$ according to Tukey's Studentised Range Test.
Early Season: June–September, 2011; Late Season: August–November, 2011.
M_r-ALB: Maximum incidence of leaf infected (%) by Alternaria leaf blight at 12WAP
M_p-CLS: Maximum incidence of plant infected (%) by Alternaria leaf blight at 12WAP.

Table 3. Effect of frequency of application of *Tithonia diversifolia* leaf extract on defoliation of sesame in sesame/maize intercrop during early and late cropping seasons in Ejigbo, Nigeria

Treatment (Frequency of Application of Plant extract)	Conc. % (w/v)	Leaf defoliation (%)		
		*M_d		
		Early Season	Late Season	Pooled mean (x)
One-spray regime	7.0	14.33bcd	14.67b	14.5b
	7.5	13.00bcde	13.66bc	13.3bc
	8.0	16.00b	13.00bcde	14.5b
Two-spray regime	7.0	15.33bc	13.67bc	14.5b
	7.5	14.00bcde	10.66cdef	12.3bc
	8.0	10.00cde	10.33def	10.2bc
Three-spray regime	7.0	14.00bcde	12.67bcde	13.3bc
	7.5	9.67de	8.00f	8.84c
	8.0	11.67bcde	9.33f	10.5bc
Carbendazim (50 %WP)		8.67e	10.00ef	9.3c
Sesame/Maize		12.33bcde	13.33bcd	12.8bc
Sole Sesame		27.67a	25.67a	26.7a

Means with the same letter along the column are not significantly different at $p \leq 0.05$ according to Tukey's Studentised Range Test.
Early Season: June–September, 2011; Late Season: August–November, 2011.
*Md: Maximum leaf defoliation at 12WAP

Table 4. Effect of frequency of application *Tithonia diversifolia* leaf extract on the severity of Cercospora leaf spot disease of sesame intercropped with maize during early and late cropping seasons in Ejigbo, Nigeria

Treatment (Frequency of Application of Plant extract)	Conc. % (w/v)	Severity Index*		
		Lesion number / $^1/_4$ leaf area		
		Early Season	Late Season	Pooled mean (x)
One-spray regime	7.0	19.31abc	16.30b	17.81abc
	7.5	15.17cd	9.59bc	12.46bcde
	8.0	16.87bcd	11.36bc	14.12bcd
Two-spray regime	7.0	20.66ab	15.05b	17.85abc
	7.5	15.86bcd	11.01bc	13.43bcde
	8.0	11.65de	10.11bc	10.88cde
Three-spray regime	7.0	16.21bcd	13.30bc	14.88cdef
	7.5	6.9e	7.50c	7.21ef
	8.0	8.04e	7.75c	7.87ef
Carbendazim (50 %WP)		6.60e	7.30c	6.95f
Sesame/Maize		17.82bc	13.53bc	15.89bc
Sole Sesame		26.21a	23.61a	24.91a

Means with the same letter along the column are not significantly different at $p \leq 0.05$ according to Tukey's Studentised Range Test.
Early Season: June–September, 2011; Late Season: August–November, 2011
*Severity index obtained at 13WAP as number of lesions per $^1/_4$ leaf area at the second node (see text)

Table 5. Effect of frequency of application *Tithonia diversifolia* leaf extract on severity of Alternaria leaf blight of sesame intercropped with maize during early and late cropping seasons in Ejigbo, Nigeria

Treatment (Frequency of Application of Plant extract)	Conc % (w/v)	Severity Index* Lesion size (mm^2)		
		Early Season	Late Season	Pooled mean (x)
One spray regime	7.0	25.67b	5.07b	15.4b
	7.5	23.33b	4.93b	14.1b
	8.0	30.33b	4.37b	17.3b
Two spray regime	7.0	31.33b	5.06b	18.2b
	7.5	14.87b	5.20b	10.0b
	8.0	29.13b	3.03b	16.1b
Three spray regime	7.0	24.33b	5.60b	14.9b
	7.5	6.00c	2.50b	4.2c
	8.0	9.67c	2.73b	6.2c
Carbendazim (50%WP)		5.07c	2.43b	4.0c
Sesame/Maize		28.00b	2.60b	16.3b
Sole Sesame		169.33a	22.67a	96.0a

Means with the same letter along the column are not significantly different at $p \leq 0.05$ according to Tukey's Studentised Range Test. Early Season: June–September, 2011; Late Season: August–November, 2011.
*Lesion size obtained at 13WAP (see text).

Table 6. Effect of frequency of application *Tithonia diversifolia* leaf extract on the yield indices of sesame in a sesame/maize intercrop during early and late cropping seasons in Ejigbo, Nigeria

Treatment (Frequency of Application of plant extract)	Conc. % (w/v)	Yield Indices: No. of Capsules /plant			Seed weight/plant (g)			Grain yield (kg/ha)		
		Early Season	Late Season	Mean (x)	Early Season	Late Season	Mean (x)	Early Season	Late Season	Mean (x)
One-spray regime	7.0	27.0c	46.0ab	36.5c	3.2b	6.4ab	4.8c	225.2de	348.4abc	286.9cd
	7.5	26.7v	66.7ab	46.7bc	3.0b	9.3ab	6.2bc	229.8a-e	380.3ab	340.0abc
	8.0	62.3abc	69.3ab	65.8abc	6.9ab	9.7ab	8.3abc	258.9b-e	347.2abc	303.3bcd
Two-spray regime	7.0	62.7abc	46.7ab	54.7bc	6.6ab	6.5ab	6.6abc	344.6a-d	326.2bc	335.4abc
	7.5	63.3abc	54.0ab	58.7bc	6.3ab	7.6ab	7.0bc	360.0a-d	401.3a	380.9ab
	8.0	67.9abc	72.7ab	69.8abc	7.8ab	10.2ab	9.0abc	372.4a-c	402.4a	387.4a
Three-spray regime	7.0	61.7abc	53.3ab	57.0bc	6.2ab	7.3ab	6.8bc	247.7c-e	345.3abc	296.5cd
	7.5	93.0a	113.3a	103.2a	10.9a	15.9a	13.4a	407.6a	401.6a	404.6a
	8.0	94.0a	105.ab	99.7a	10.6a	14.8ab	12.7a	392.4ab	404.8a	398.6a
Carbendazim (50%WP)		81.7ab	88.7ab	85.2ab	10.6a	12.4ab	11.5ab	405.6a	407.9a	406.6a
Sesame/Maize		51.7bc	49.7ab	50.7bc	6.2ab	6.9ab	46.6bc	303.4a-e	397.2a	350.3a
Sole Maize		43.7bc	34.0b	38.8c	4.6b	4.8b	4.7c	193.2e	278.5e	235.9d

Means with the same letter along the column are not significantly different at $p \leq 0.05$ according to Tukey's Studentised Range Test. Early Season: June–September, 2011; Late Season: August–November, 2011.

DISCUSSION

The availability of cheap and easily adoptable options in plant disease management is an incentive for rural farmers in developing economies around the world. This study confirms earlier reports that intercropping (Enikuomehin et al., 2010) or foliar application of extracts (Enikuomehin and Peters, 2002) reduce the incidence and severity of CLS and ALB diseases of sesame as well as enhance sesame seed quality. Both methods are environment-friendly and easily adoptable by subsistent farmers in rural communities. The report of Jimoh et al. (2016) that the combination of sesame/maize intercropping and foliar spray with *T. diversifolia* extract reduced the intensity of foliar diseases of sesame was also validated by the findings of this study. However, an additional input by this study into sesame disease management is the finding that the multiple application of *T. diversifolia* leaf extract to sesame intercropped with maize further reduced CLS and ALB diseases of sesame. Specifically, lower disease incidence and severity was achieved by a 3-spray regime of 7.5% (w/v) *T. diversifolia* leaf extract relative to the one-spray regime.

Some of the reasons why diseases are reduced in an intercrop include alteration of wind and rain flow, vector movement, modification of microclimate within the canopy, changes in host morphology and physiology as a result of competition for air and light as well as obstruction of inoculum transfer and the cumulative effect of these factors on pathogen development (Enikuomehin et al., 2010; Boudreau, 2013). For plant extracts, interference with pathogen expression is through the activity of the antifungal constituents (Gurjar et al., 2012). Hence, the adverse effect of the combination of intercropping and plant extracts on disease development may be due to the combined impact of these factors on the pathogen and the host-pathogen relationship. For example, the multiple spray of *T. diversifolia* extract exposed the pathogens to the fungitoxic constituents for a longer period of time while the shading effect of the maize (which is taller) would have interfered with the activity of *Cercospora sesami,* the CLS pathogen. According to Daub and Ehrenshaf (2000), Cercosporin a light sensitive toxin is the basis of the pathogenicity of *C. sesami*. Similarly, it is likely that the higher the concentration of the extract, the more the volume of antifungal constituents to which the pathogen is exposed. This may explain why higher concentrations (7.5 and 8.0%w/v) of *T. diversifolia* leaf extract applied thrice induced higher reductions in disease than similar concentrations of the same extract sprayed once.

Intercropping sesame with maize is a popular subsistence farming practice among resource-constrained farmers in small landholdings in the tropics (RMRDC, 2004; Boudreau, 2013). For this category of farmers, the use of synthetic fungicide is unattractive, mainly due to the prohibitive cost of chemicals and problems associated with mammalian toxicity, environmental degradation, adulteration issues as well as dosage management problems. Conversely, the use of plant extracts is a viable alternative that does not have the aforementioned challenges. The plant materials are found around the farmers living environment and are easy to prepare. Therefore, the complimentary effect of a sesame/maize intercrop and 3-spray regime of *T. diversifolia* leaf extract is a farmer-friendly option that has great prospects in sesame disease management in tropical environments.

Tithonia diversifolia is a plant that has attained the status of a noxious weed in tropics (GISD, 2016; Olabode et al., 2017), because of the wild proliferation potential and wind dispersal mechanism. According to Ajao and Moteetee (2017), alkaloids, flavonoids, phenols, saponins, tanins and terpenoids are phytochemicals found in *T. diversifolia* leaf. Of these phytochemicals, Terpenoids are most predominant in the form of sesquiterpenes (Ajao and Moteetee, 2017). Sut et al. (2018) had reported the pharmacological activities of Tagitinin C (a form of sesquiterpene) isolated from *T. diversifolia*. Tagitinin C has also been reported to be an antimalarial agent by Goffin et al. (2002). Therefore, the use of *T. diversifolia* leaf extract as a foliar spray in the control of sesame diseases does not potent any health of environmental risk to the end users. The extract is being used in the treatment of malaria in rural communities in the tropics (Goffin et al., 2002; Afolayan et al., 2016). With this study, the potential to convert this plant for valuable use in plant disease management is a positive development for agricultural development in the tropics. *Tithonia diversifolia* may also dispose similar controlling effect on other pests and diseases.

On average, sesame seed yield ranged between 286.9 and 406.6 kg/ha but were markedly lower than African (1,137.3 kg/ha) and world (1,943.20 kg/ha) average values as reported by FAOSTAT (2020). This may be due to the high level of the diseases on sesame varieties used in the study. In conclusion, the outcome of the study highlights the potentials of the combination of plant extracts and intercropping as a viable option in the management of foliar disease of sesame in tropical environments.

CONCLUSION AND RECOMMENDATION

Results of this study demonstrated the benefits of intercropping and foliar application of *T. diversifolia* extract in the management of foliar disease of sesame. Our study further showed that 3-spray regime of 7.5% w/v *T. diversifolia* leaf extract is sufficient to control foliar diseases of sesame intercropped with maize. This is therefore recommended for farmers as an environment-friendly and low-cost disease management option in sesame production.

CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to research, authorship and publication of this article.

ETHICAL COMPLIANCE

The authors have followed the ethical standards in conducting the research and preparing the manuscript.

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