Journal of Advances in Microbiology

7(4): 1-10, 2017; Article no.JAMB.38156
ISSN: 2456-7116

Control of Cowpea (*Vigna unguiculata* L. Walp) Diseases with Intercropping of Maize (*Zea mays* L) and Spray of Plant Extracts

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Authors' contributions

This research work was carried out in collaboration among the four authors MJF, OAE, OAB and MA involved. Author MJF designed the study, wrote the protocol and the first draft of the manuscript. Authors OAE, OAB and AM reviewed the experimental design and all drafts of the manuscript. Author MJF managed and performed the analyses of the study. All the authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMB/2017/38156
Editor(s):
(1) Clara Eleazar, Medical Microbiology, University of Nigeria, Nigeria.
Reviewers:
(1) Hassani Abdelkrim, Ibn khaldoun University, Algeria.
(2) Tariq Mukhtar, Pir Mehr Ali Shah Arid Agriculture University, Pakistan.
Complete Peer review History: http://www.sciencedomain.org/review-history/22702

Original Research Article

Received 14th October 2017
Accepted 16th December 2017
Published 12th January 2018

ABSTRACT

Field experiment was conducted to evaluate the effect foliar spray of aqueous extracts of *Datura stramonium*, *Ricinus communis* and *Jatropha gossypifolia* at three concentrations *(65 50 and 30%)* on cowpea anthracnose disease caused by *Colletotrichum lindemuthianum* in sole cowpea and cowpea / maize intercrop. The total area of the farm was 270m^2 and cowpea population in each cropping system was 324 stands at a spacing of 60x30 cm while the population of maize in the cowpea/maize intercrop was 162 stands at a spacing of 90x60 cm. Spraying of the plant extracts started two weeks after planting (WAP) and continued until 8 WAP. The extract of *D. stramonium* reduced the incidence and severity of the disease most compared to other extracts. Similarly, the disease incidence in cowpea/ maize intercrop was lower than in sole cowpea. The disease incidence at 65, 50 and 30% concentrations on pooled mean for the sole crop were 11, 15 and 21% whereas that of intercrop plants were 9, 12 and 16% respectively. The percentage of normal

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seeds obtained in the study was concentration dependent being highest at 65% in all the extracts and was higher in intercropped (95%) than the sole crop (93%).Similarly, fungal infection on seeds was lower at all concentrations compared to the control. The study therefore shows that extracts of the plants and intercropping of non-host reduced incidence and severity of anthracnose infection with corresponding increase in yield.

Keywords: Colletotrichum lindemuthianum, plant extracts; disease incidence and severity.

1. INTRODUCTION

Cowpea is an important economic crop in many developing regions of the world. The seeds can be boiled and eaten while the young leaves and immature pods are consumed in many African countries [1]. The stems and leaves serve as animal feeds and are often stored for use during the dry season. All parts of the crop are rich in nutrients and fibre. Out of the cowpea total output in Africa, 52% is used as food, 13% as animal feed, 10% for seeds, 9% for others and 16% is wasted [2,3]. Cowpea is able to fix atmospheric nitrogen (N) through its root nodules to increase the soil N content which enables it to survive in poor soils. However, this crop is constantly threatened by socio-environmental and production constraints, such as drought [4], use of low-yielding local cultivars, lack of good planting materials, pest and disease outbreak [5,6].

Cowpea anthracnose is caused by the fungus, *Colletotrichum lindemuthianum.* It is the most important fungal disease of field-grown cowpea capable of 75% yield reduction in Nigeria [7]. The disease affects all stages of the plant but more often in the reproductive stage. Its symptoms include round brownish or purple specks which become darker and enlarge into lesions about 2 cm in diameter [8]. The symptoms are most visible on leaves and ripe fruits but the disease also produces cankers on petioles and stems thereby causing defoliation and rottening of the fruits. Infected fruits have water-soaked and sunken circular spots [9].

Cowpea anthracnose can be controlled effectively by the use of resistant varieties where they exist and culturally by removing the sources of inoculums [10]. The use of synthetic fungicides like Benomyl (Benzimidazole) and Mancozeb (Dithiocarbamate) had proved very effective in time past [11]. However, due to the increased awareness of their side effects attention is now focused on the alternative methods of pathogen control like intercropping and the use of plant extracts. Intercropping cowpea with other crops is a common traditional practice among the rural farmers. The intercropping of compatible crops with cowpea on disease development has produced results which include reduction of the disease incidence and severity. In respect to cowpea production in Nigeria, disease control has relied mostly on the use of chemicals. This study was therefore carried out to determine the effect of plant extracts and intercropping maize with cowpea on incidence and severity of the disease.

2. MATERIALS AND METHODS

2.1 Collection and Preparation of Plant Leaves

Leaves of the three plants namely; jimson weed (*D. stramonium),* physic nut *(J. gossypifolia)* and castoroil seed *(R. communis)* were collected at Ekiti State University. (Latitude 7 7212°N and longitude 5.2575°E) in south western Nigeria and air-dried at 28°C for 6-8 weeks until each plant had a constant weight. The dried leaves were milled using a blender (Okapi®, Mixer-Grinder), packaged into sealable nylon and refrigerated at 4°C for about 2 weeks until they were required for bioassay.

2.1.1 Pictures of the three plants used as extracts in the study

The pictures of the three plants used in the study are shown below.

2.2 Preparation of Plant Extracts

Extracts were prepared by mixing equivalent grams of prepared plant powder (65, 50 and 30) with 100 ml of distilled water at 70°C in 500 ml bottles and kept in hot water bath-shaker for 30 minutes. Thereafter, the liquid extract was separated by vacuum filtration and poured inside standard bottles which were refrigerated at 4°C [12]. These extracts were used as the stock solution from which 65%, 50% and 30% of each extract were prepared.

Plate 1. Castor oil, *Ricinus communis* Linn.

Plate 2. Physic nut, *Jatropha gossypifolia* Linn.

Plate 3. Jimson weed, *Datura stramonium* Linn.

2.3 Isolation and Identification of *C. lindemuthianum*

Cowpea plants showing distinct symptoms of the disease were collected from the cowpea fields at Ekiti State University, Ado Ekiti. The leaves were cut into small pieces of about 1-2 cm^2 and surface sterilized by immersion in 0.2% NaOCl for two minutes and followed by two rinses in sterile distilled water in a laminar flow cabinet. Three leaf cuttings per plate were placed on PDA. The plates were sealed with parafilm and incubated at 28°C for 5-6 days. Single spore of developing colonies was isolated and sub-cultured to obtain pure cultures. Samples from single spore cultures were used for morphological identification on Malt Extract Agar (MEA) at x400 magnification of a compound microscope (OLYMPUS Binocular) [13].

2.4 Field Experiments

The experiment was carried out at the Ekiti State University Teaching and Research Farm (7.7129° N, 5.2523° E) in first week of September, 2012 and repeated in 2013 planting season. Cowpea variety, Ife brown susceptible to anthracnose was intercropped with maize (Variety: SUWAN-ESR). Hot water extracts of *D. stramonium, R. communis* and *J. gossypifolia* were applied separately as foliar spray at three concentrations (65, 50 and 30%). The 2 x 3 x 3 factorial experiment was a split plot design and two cropping systems were used: (a) sole cowpea and (b) cowpea intercrop with maize. The plot size was 2 m x 2 m, separated by boarder row 1 m and the total area of the plot was 270 m^2. The total population of cowpea in each cropping system was 324 and population of Maize in the Cowpea maize intercrop was 162. Cowpea variety Ife brown was planted in the first week of September at 3 seeds $hole^{-1}$ at a spacing of 60 cm x 30 cm and thinned to two per stand while the intercropped maize was planted at a spacing of 60 cm x 90 cm. The seeds of cowpea and maize have been previously sterilized in 0.5% sodium hypochlorite for 30 seconds and rinsed three times in sterile distilled water before sowing.

Two weeks after plant establishment, the sole cowpea and cowpea/ maize intercrop were sprayed with the different concentrations of the extracts and *C. lindemuthianum* conidia suspension containing 10^4 conidia ml^{-1} while the control was sprayed with sterile distil water.

2.5 Disease Assessment

Assessment of the incidence of the disease was determined by using five randomly tagged plants per plot. The number of diseased leaves was counted and expressed as a percentage of the total number of leaves tagged per plant. The assessment commenced at three weeks after planting (WAP) and continued till 8 WAP. The severity of cowpea anthracnose was assessed at 8WAP through the count of lesions number and rating of symptoms expressed with the aid of a visual scale [14]. Five plants per plot were selected from each plant and lesion number was counted. Severity of the disease was assessed through measurement of the size of five randomly selected lesions per plot. Table 1 shows the visual rating for anthracnose disease of cowpea used in this study.

2.6 Seed Health Assessment

Two hundred seeds harvested from each treatment were batched into four replicate samples of 50 seeds each and examined by visual inspection. Under a stereomicroscope for normal and abnormal seeds. Abnormal seeds

Table 1. Disease severity index

Scale	Rating	Symptoms of *Anthracnose* on cowpea
0	No disease	No trace of infection
1	Hypersensitivity	Hypersensitive spot on lower leaves only
2	Trace Infection	Small lesions on lower and upper leaves and stem
3	Slight Infection	Small lesions on lower and upper leaves and stem
4	Moderate infection	Advanced lesions on upper and lower leaves, with or without new infections on stems and petiole
5	Severe infection	Advanced lesions on upper and lower leaves, flowers, buds, stems and petiole and slight infection of pod.
6	Very severe infection	All features of five above with severe infection of pod

Source: Enikuomehin & Peters (2002)

were those with malformed shape, wrinkled seed coat or those bearing fungal propagules and data were analysed using ANOVA and treatment means were separated using Turkey significant honest test.

3. RESULTS

3.1 Effect of Leaf Extracts on Disease Incidence in Cowpea/Maize Intercrop

Table 2 shows the effect of foliar application of leaf extracts of *D. stramonium, R. communis* and *J. gossypifolia* on disease incidence in cowpea and cowpea / maize inter-crop for 2012 and 2013 planting seasons. The disease incidence was significantly lower in 2012 than in 2013 planting seasons for both sole and inter-crop plants. Similarly, incidence of the disease was lower as the concentrations of the extracts increased. At 65% concentration of *D. stramonium,* incidence of the disease for sole and inter-crop plants for 2012 planting season was 11 and 08% respectively. Similarly, incidence of the disease in all the treated plots were significantly ($P \leq 0.05$) lower than the control.

3.2 Effect of Leaf Extracts on Disease Severity in Cowpea/Maize Intercrop

Table 3 shows the effect of foliar spray of leaf extracts of *D. stramonium, R. communis* and *J. gossypifolia* on severity of disease in sole cowpea and maize-cowpea intercrop. All the extracts at the tested concentrations significantly reduced severity of disease compared to the control. At (65%) concentration of the extracts, lesion numbers on leaves were comparable in the sole crop and the intercrop in 2012/2013 planting season. At 50% concentrations of *D. stramonium* and *R. communis* extracts, slight infection were observed on the leaves whereas at 30% concentration, infections were moderate for the sole crop in the two seasons. The level of infections observed on plants that were treated with extracts of *R. communis* and *D. stramonium* were similar (trace and slight) in intercrop plant at 65 and 50% concentration. Severity of infection observed on the control plots were advance lesions on leaves, pods and flowers.

3.3 Effect of Leaf Extracts on Percentage of Normal and Abnormal Seeds in Cowpea/Maize Intercrop

The effects of leaf extracts of *D. stramonium, R. communis* and *J. gossypifolia* on the percentage of normal and abnormal seeds in sole cowpea and cowpea-maize intercrop in 2012 and 2013 seasons are shown in Table 4. Percentage of normal seeds was significantly higher in the 2012 than 2013 season for the sole and intercrop plants and they were concentration dependent. At 65, 50 and 30% concentration *D. stramonium,* the percentage of normal seeds in sole crop for 2012 season were 93.7, 91.4 and 88.7% and the values for the intercrop were 95.3, 93.6 and 90.6% respectively. The percentage of normal seed in intercrop was higher than the sole crop in the two seasons. As the concentrations of the extracts increased, the percentage of normal seeds obtained increased than the abnormal seed. The pooled data of 2012 and 2013 showed that the abnormal seeds recorded in sole crop were higher than the intercrop.

Table 2. Effect of Foliar spray leaf extracts on disease incidence in cowpea/maize intercrop

Plant extracts		Disease incidence					
		Sole-crop		Inter-crop		Pooled mean	
		2012	2013	2012	2013	Sole-crop	Inter-crop
D. stramonium	65	10.7 ^{c}	11.5 ^{c}	08.2 ^{c}	09.5 ^{c}	11.1 ^{c}	08.9 ^{c}
	50	14.0 ^{b}	16.8 ^{b}	11.2 ^{b}	11.8 ^{b}	15.4 ^{b}	11.5 ^{b}
	30	18.5 ^{b}	24.5 ^{b}	14.3 ^{b}	18.2 ^{b}	21.5 ^{b}	16.3 ^{b}
R. communis	65	13.5 ^{c}	15.2 ^{c}	10.1 ^{c}	12.3 ^{c}	14.4 ^{c}	11.2 ^{c}
	50	20.2 ^{b}	26.3 ^{b}	14.4 ^{b}	20.7 ^{b}	23.3 ^{b}	17.6 ^{b}
	30	22.4 ^{b}	27.2 ^{b}	16.8 ^{b}	22.4 ^{b}	24.8 ^{b}	19.6 ^{b}
J. gossypifolia	65	15.2 ^{c}	18.4 ^{c}	11.3 ^{c}	13.2 ^{c}	16.8 ^{c}	12.3 ^{c}
	50	21.8 ^{b}	25.7 ^{b}	16.7 ^{b}	20.8 ^{b}	23.8 ^{b}	18.8 ^{b}
	30	23.6 ^{b}	26.4 ^{b}	19.3 ^{b}	21.2 ^{b}	25.0 ^{b}	20.3 ^{b}
Control		63.5 ^{a}	64.7 ^{a}	60.7 ^{a}	65.2 ^{a}	62.4 ^{a}	64.3 ^{a}

Means with the same letter are not significantly different using Tukeys (HSD)

Table 3. Effect of leaf extracts of *D. stramonium, R. communis* and *J. gossypifolia* on disease severity in cowpea/maize intercrop

Plant extracts	Disease severity						
		Sole-crop		Inter-crop		Pooled mean	
		2012	2013	2012	2013	Sole-crop	Inter-crop
D. stramonium	65	2	2	2	2	2	2
	50	3	3	2	2	3	2
	30	4	4	3	3	4	3
R. communis	65	2	2	2	2	2	2
	50	3	3	2	2	3	2
	30	4	4	3	3	4	3
J. gossypifolia	65	2	2	2	2	2	2
	50	4	4	3	3	4	3
	30	5	5	4	4	5	4
Control		6	6	6	6	6	6

Symptom rating as contained in the text (Table 1)

3.4 Effect of Foliar Spray Leaf Extract on Seed Germination and Fungal Infection in Cowpea Maize Intercrop for 2012/2013 Planting Season

Table 5 shows the effect of three plant extracts at three concentrations (65.50. and 30%) on seed germination and fungal infection in cowpea/maize intercrop for 2012/2013 planting season. All the plant extracts at the tested concentration significantly (P>0.05) had increased seed germination in both the sole and intercrop plant compared to the control. Higher fungal infection were observed on the control seed of the sole and intercrop plant at all the tested concentrations. At 65% concentration, seed germination for sole and intercrop plants were 93.6 and 97.8 respectively while incidence of fungal infections were 6.4 and 4.9% respectively However, for the control plate, seed germination and fungal infection was 67.85 and 67.76% respectively.

3.5 Effect of Intercropping Maize with Cowpea on Yield

Table 6 shows the effect of intercropping maize with cowpea on seed weight. Significant ($P \leq 0.05$) variations in yield were observed at different concentrations of the extracts. Yield of cowpea seed in cowpea maize intercrop was higher than that of sole cowpea at all concentrations of the extracts used in the study. At 65% concentration of *R. communis,* the seed weight of cowpea in cowpea maize intercrop (580 kg/ha) was significantly higher than sole crop (443 kg/ha). Cowpea yield (592 kg/ha) of the intercrop sprayed with extracts of *D. stramonium* at 65% concentration was not significantly different from that sprayed with extracts of *R. communis* (580 kg/ha). Similar trends occurred at 50% concentration. However, at 30% concentration, the yield (293 kg/ha) of cowpea treated with extract *D. stramonium* was significantly higher than that of *R. communis* (273 kg/ha). The yield of cowpea in treated plots at all concentrations was significantly higher than the control.

4. DISCUSSION

Anthracnose disease forms a major biotic factor influencing yield and productivity of cowpea in Nigeria [15]. The extent of yield loss is determined by incidence and severity of infection, among other factors like drought, lack of good seed and attacks by pest such that annual output of 2.1 million MT fell short of domestic demand by 0.52 million metric tonnes [16].

In this study, hot water extracts of the three plants: *D. stramonium, R. communis,* and *J. gossypifolia, were* tested against *C. lindemuthianum* using field bio-efficacy trials. The leaf samples were air dried and powdered to increase the surface area between samples and extraction solvents. This is because air dried plant materials are less fragile and do not deteriorate, an advantage which it has over fresh leaf samples [17]. Bioactive constituents are endogenously synthesized by plants and they are present at varied concentrations in the tissues of different plant species [18,19] as natural protectants against diseases [20] and hot water extraction is capable of preserving the chemistry of constituents. Besides, the method is relatively simple and less costly to use compared to other methods of extraction, and can be recommended for small holder farmers [21].

Table 4. Effect of leaf extract of on incidence of normal and abnormal seeds in cowpea/maize intercrop for 2012/2013 planting season

		2012				2013				Pooled mean			
		Normal and Abnormal seeds (%)											
		Sole crop		Inter crop		Sole crop		Inter crop		Sole crop		Inter crop	
Leaf extract		**NS**	**AB**	**NS**	**AB**	**NS**	**AB**	**NS**	**AB**	**NS**	**AB**	**NS**	**AB**
D. stramonium	65	93.7[a]	06.3[b]	95.3[a]	04.7[b]	91.3[a]	08.7[b]	93.6[a]	06.4[b]	92.5[a]	07.5[b]	94.5[a]	05.5[b]
	50	91.4[a]	08.6[b]	93.6[a]	06.4[b]	89.5[a]	10.5[b]	91.2[a]	08.8[b]	90.5[a]	09.5[b]	92.4[a]	07.6[b]
	30	88.7[a]	11.3[b]	90.7[a]	09.3[b]	87.2[a]	12.8[b]	89.1[a]	10.9[b]	87.9[a]	12.1[b]	89.9[a]	10.1[b]
R. communis	65	90.4[a]	09.6[b]	93.6[a]	06.4[b]	88.5[a]	11.5[b]	91.7[a]	08.3[b]	89.5[a]	10.5[b]	92.6[a]	07.4[b]
	50	89.3[a]	10.7[b]	91.8[a]	08.2[b]	87.4[a]	12.6[b]	90.3[a]	09.7[b]	88.4[a]	11.6[b]	91.1[a]	08.9[b]
	30	87.0[a]	13.0[b]	89.8[a]	10.2[b]	86.3[a]	13.7[b]	87.6[a]	12.4[b]	86.7[a]	13.3[b]	88.7[a]	11.3[b]
J. gossypifolia	65	89.7[a]	10.3[b]	91.6[a]	08.4[b]	89.1[a]	10.9[b]	88.4[a]	11.6[b]	89.4[a]	10.6[b]	90.0[a]	10.0[b]
	50	89.4[a]	10.6[b]	90.6[a]	09.4[b]	87.6[a]	12.4[b]	87.7[a]	12.3[b]	88.5[a]	11.5[b]	89.1[a]	10.9[b]
	30	86,2[a]	13.8[b]	88.7[a]	11.3[b]	85.4[a]	14.6[b]	85.3[a]	14.7[b]	85.8[a]	14.2[b]	87.0[a]	13.0[b]
Control		55.9[b]	44.1[a]	56.3[a]	43.7[a]	54.3[a]	45.7[a]	56.5[a]	43.5[a]	55.1[a]	44.9[a]	56.4[a]	43.6[a]

Means with the same letter are not significantly different using Tukeys (HSD)
S.G = Seed germination, F.I = Fungal infection
600 seeds were plated at 20 seeds /plate each concentrated replicated three times

Table 5. Effect of foliar spray leaf extract of *D. stramonium, R. communis* and *J. curcas* on seed germination and fungal infection in Cowpea Maize intercrop for 2012/2013 planting seasson

Plant extracts	**Conc.**	**Sole-crop**		**Inter-crop**	
		S.G	**F.I**	**S.G**	**F.I**
D. stramonium	65	93.60[a]	6.40[b]	97.80[a]	4.91[b]
	50	92.70[a]	6.31[b]	96.70[a]	4.83[b]
	30	91.80[a]	6.29[b]	95.40[a]	4.77[b]
R. communis	65	92.95[a]	6.51[b]	96.90[a]	4.82[b]
	50	92.57[a]	6.44[b]	95.94[a]	4.87[b]
	30	91.42[a]	6.36[b]	95.40[a]	4.93[b]
J. curcas	65	93.80[a]	6.51[b]	96.20[a]	4.73[b]
	50	92.60[a]	6.56[b]	95.90[a]	4.75[b]
	30	92.30[a]	6.71[b]	95.73[a]	4.92[b]
Control		67.85[b]	26.71[a]	67.76[b]	26.93[a]

Means with the same letter are not significantly different using Tukeys (HSD)

Table 6. Effect of intercropping maize with cowpea on seed weight

Extracts Conc. (%)	Cultural practices	Threshed seed weight (kg ha^{-1})		
		D. stramonium	*R. communis*	*J. gossypifolia*
65	Sole crop	504.67^{a}	443.33^{b}	428.33^{b}
	Cowpea-Maize intercrop	592.33^{a}	580.00^{a}	547.33^{b}
50	Sole crop	417.33^{a}	408.33^{a}	373.33^{a}
	Cowpea-Maize intercrop	519.00^{a}	502.00^{a}	465.00^{b}
30	Sole crop	208.33^{a}	188.33^{a}	213.33^{a}
	Cowpea-Maize intercrop	293.33^{a}	276.67^{a}	275.33^{a}
0	Sole crop	103.33^{a}	103.33^{a}	103.33^{a}
	Cowpea-Maize intercrop	104.67^{a}	104.67^{a}	104.67^{a}

Means with the same letter in each column are not significantly different (P<0.05)
Values are average for two planting season

In this study, incidence of the disease was concentration dependent. At the highest concentrations of the extracts (65%) disease incidence was lower. Severity of infection in plots sprayed with the extracts was characterized by the presence of small lesions only on lower leaves of the cowpea plants while the control plots were characterized by advanced lesions on leaves, pods and petiole. This explain the lower incidence of abnormal seeds recorded on the treated plots than the control. This is important if the seed will be used for planting in subsequent years since it will improve their germination percentage. [22] reported that the incidence of *Cercospora* Species and *Fusarium* Specie was significantly $p \leq 0.05$ reduced on seeds sprayed with the extracts of *Chromolaena odorata* and *Tithonia diversifolia*, in addition lower number of abnormal seeds were recorded in treated plots than in the control which is in agreement with the current study.

In this study, the plant extracts were effective in the control of *C. lindemuthianum* on the field *D. stramonium* was the best plant extract in terms of the ability to suppress anthracnose disease on the field. [23] reported that extracts of some indigenous plants were effective in-vitro but failed to control the spread of the pathogen on the field, which contrasts the results of the current study. In the field, abiotic interactions such as temperature and solar radiation may negatively interfere with the performance of active constituents in botanical extracts. The stability of bioactive substances to temperature and ultraviolet radiation may vary with their chemical structure and this may be responsible for the failure reported by [23]. However, the results of this study are similar to the report of [24] where the fungus, *Pythium aphanidermatum,* the causative organism of chilli disease of pepper, was controlled in-vitro and on the field with extracts of twenty-three medicinal plants. The result showed that *A. sativum, A. cepa* and *T. procumbens* extracts effectively controlled the disease. Similarly, [25] reported that alcohol and water extracts of *Piper betle, Ocimum sanctum* and *Citrus limon* significantly suppressed the mycelial growth of *C. lindemuthianum* in vitro and reduced the spread of the disease in the field.

The effect of intercropping maize with cowpea in both 2012 and 2013 showed that the incidence and severity of anthracnose disease were less in the intercrop than in sole cowpea. Apart from this, the incidence of abnormal seeds was significantly lower in extracts sprayed plots than the control. The chances of normal seeds obtained from the intercropped plots treated with plant extracts was also higher than those obtained from the sole cropping. The maize plant used in this study is not affected by anthracnose which possibly reduced the rate of disease spread in the intercropped plants.

In this study, the yield in the intercropped cowpea was higher than the sole crop. Intercropping has been reported to alter the response of host plants and pathogens to changes in the environment [26] and this, to a large extent, generates diverse alterations in the ecosystem which may be responsible for reduced incidence and severity of infection. Apart from this, intercropping tends to reduce the speed of wind (velocity) which would invariably reduce air circulation and hence reduction in the rate of inoculum transfer [27]. The result obtained in this study agree with the work of [28] who reported that the incidence and severity of foliar diseases of sesame (*Sesanum indicum*) was reduced when intercropped with maize at different population densities.

5. CONCLUSION

This research work therefore provide alternative method for the management of cowpea diseases without necessarily relying on the use of synthetic fungicides and can be easily recommended to small scale farmers in Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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