Research Article

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Effect of phyto-extracts of neem (*Azadirachta indica*) and garlic (*Allium sativum*) on leaf spot disease of groundnut (*Arachis hypogaea* L.)

<https://doi.org/10.1515/opag-2020-0035>

received December 12, 2019; accepted May 12, 2020

Abstract: A field experiment was conducted to investigate the effect of aqueous and ethanolic extracts of neem (*Azadirachta indica* A. JUSS) and garlic (*Allium sativum* L.) against *Cercospora* leaf spot (CLS) disease of groundnut (*Arachis hypogaea* L.). A split plot design using two exotic (“fleur” 11 var., 65-13 var.) and one local (village var.) variety of groundnut as the main factor and ten treatments comprising one negative control (sterile distilled water), one positive control (fungicide: spavozeb) and eight phyto-extracts replicated three times was applied. Treatments were applied to plots at 45, 60, 75 and 90 days after planting (DAP). Results showed that CLS disease incidence ranged between 66.67% and 88.89% at 65 DAP for 10% ethanolic extract of garlic and 20% aqueous extract of garlic, respectively. Disease severity was lowest for 20% ethanolic extracts of neem seeds (14.74%) and garlic bulb (14.99%) at 65 DAP. Yield obtained from treatments of ethanolic extracts of garlic (3.62 t ha⁻¹) was significantly higher ($p < 0.05$) than the control (2.40 t ha⁻¹) but comparable to the spavozeb treatment (3.09 t ha⁻¹). Exotic varieties were more productive (3.13 and 3.43 t ha⁻¹) than the more resistant local variety (2.67 t ha⁻¹).

Keywords: *Arachis hypogaea* L., garlic, neem, incidence, leaf spot disease, severity, yield

1 Introduction

Groundnut (*Arachis hypogaea* L.) is an annual leguminous crop, fourth largest source of edible oil, third largest source of vegetable protein and the sixth most important oilseed crop worldwide (Ambang et al. 2011; Adjou and Soumanou 2013; Kantwa et al. 2014). In developing countries, it is widely used in crop rotation schemes to improve soil fertility and yield per unit area due to its ability to biologically fix atmospheric nitrogen (Hamasselbé 2008; Ambang et al. 2011). Groundnut contains approximately 48.32% oil, 22–25% protein, 20% carbohydrate, 5% fiber and ash and vitamins B and E (Kumar et al. 2017). Between 2013 and 2014, the world production was 39.34 million tons with India as the world’s leading producer (Ramesh and Zacharia 2017). It has been estimated that about 90% of the world production of groundnut is in Asia and Africa (FAOSTAT 2014). The United States and China produce more than 3 t ha⁻¹ while Africa produces about 1 t ha⁻¹.

Groundnut production in Africa is low and unstable, contributing to about 26% of the world production due to unreliable rains, non-irrigated cultivation and small-scale producers with little or no mechanization options, pests and diseases (Ambang et al. 2011). In Cameroon, groundnut is produced in all regions with an average yield of about 0.85 t ha⁻¹ (Ambang et al. 2011) compared to a global average of 1.5 t ha⁻¹ (FAOSTAT 2014). Low yields in Cameroon may be attributed to low availability of improved varieties to local farmers, poor agronomic practices as well as pests and diseases (Fontem et al. 1996; Ambang et al. 2008; Ambang et al. 2010; Ambang et al. 2011; Koita et al. 2017). Among diseases, early and late leaf spots caused by *Cercospora arachidicola* Hori and *Cercospora personatum* (Berk and Curt), respectively, are the most important foliar diseases of peanut in the world (Fontem et al. 1996; Ogwulumba et al. 2008; Ambang et al. 2011). Disease-induced damages include the loss of photosynthetic tissue that leads to premature defoliation, reducing pod yield and seed quality and increased production costs (Kokalis-Burelle et al. 1991; Brennemen and

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Culbreath 2000). Losses attributed to *Cercospora* leaf spot (CLS) disease are estimated to be between 40 and 50% (Ambang et al. 2011; Hossain and Hossain 2013).

To alleviate this production drop due to these leaf spot diseases, resistant varieties and synthetic phytosanitary products have been used in most countries. Varietal resistance is an effective and practical method for managing crop diseases but the unavailability and high cost of such seeds limits its application (Lucas et al. 1992). Chemical control using fungicides and/or in combination with phyto-extracts results in harmful consequences on the environment (Srinivas et al. 1997; Ambang et al. 2008; Koita et al. 2017). Moreover, synthetic products are very expensive and inaccessible to small-scale producers. However, there has been extensive and continuous research in the quest to obtain low-cost alternatives that will control these diseases and improve production with minimal environmental consequences.

Studies have been carried out to examine the antimycotic potential of phyto-extracts of medicinal and aromatic plants (Srinivas et al. 1997; Kishore et al. 2001; Ambang et al. 2008; Ambang et al. 2011; Kantwa et al. 2014; Dooh et al. 2015; Ahmad et al. 2016; Toan et al. 2018; Awasthi et al. 2018). Kumar et al. (2017) showed that spraying a suspension of *Trichoderma harzianum* and *Pseudomonas fluorescens* reduced the incidence of *C. arachidicola* and *C. personatum* by 20.1% and 22.19%, respectively. Ambang et al. (2011) reported the potential of methanolic extracts of *Thevetia peruviana* seeds against the incidence and severity of the leaf spot disease of groundnut. Also, Ngegbe et al. (2017) reported the fungicidal and fungitoxic ability of phyto-extracts of the leaves of *Tithonia diversifolia* (Hemsley) A. Gray (Mexican sunflower), *Chromolaena odorata* Linn and *Tridax procubens* Linn (Coat button) and their potential use as biocides against the leaf spot disease of groundnut.

Based on the antimycotic potential of botanical extracts, this study was carried out to (i) evaluate the effects of aqueous and ethanolic phyto-extracts of neem seeds (*Azadirachta indica* A. Juss.) and garlic (*Allium sativum* L.) on the incidence and severity of early and light blight diseases of three varieties of groundnut and (ii) evaluate the agronomic performance and yield of these groundnut varieties following the phyto-extract treatments.

2 Materials and methods

2.1 Study site

The experiment was conducted at the research and application farm of the Faculty of Agronomy and Agricultural

Sciences at the University of Dschang, West region of Cameroon. The farm is situated at latitude 5.5° North and longitude 10.05° East at an altitude of 1,410 m (Djeugap et al. 2015). The vegetation of the exploited site is dominated by the following species: *Tithonia diversifolia*, *Mimosa pudica*, *Ageratum conyzoides*, *Ageratum houstonianum*, *Cyperus esculentus*, *Bidens pilosa* and *Pennisetum purpureum*.

The farm is located in the western highlands, which is agro-ecological zone III characterized by a rainy season that runs from mid-March to mid-November and a dry season that runs from mid-November to mid-March. The average annual rainfall varies between 1,800 and 2,000 mm, and the average annual temperature is around 20.03°C with the maximum temperature ranging between 25 and 28°C in April and the minimum temperature oscillating around 14 and 16°C in December (Akongo 2010; IRAD-Dschang 2010).

The soil in the study site is ferralitic with a gentle slope. According to Mboba (2012), the soils of the surrounding site are moderately acidic (pH-H₂O = 6.71). The organic carbon content is high (>2.5%), and the organic matter content varies between 4.2 and 6%. The soil is of very poor quality with a C/N ratio of >20 that reflects low total nitrogen content (Bernaert and Bitondo 1992).

2.2 Planting material

Seeds of three groundnut varieties that produced 2 or 3 grains pod⁻¹, obtained from the local markets of Ndjombe and Dschang, were used in this experiment (Table 1). These varieties included two exotic varieties with growth cycles that last for 90 days (“fleur” 11 var. and 65-13 var.) and one local variety of a longer growth cycle that lasts for 120 days (“village” var.) (Table 1).

2.3 Land preparation and experimental design

Plant debris of the forecrop (tomato) was cleaned off the surface of the soil at the experimental site. The soil was tilled manually (0–10 cm), and the experimental plot was delineated. The experimental setup was a split plot design with varieties as the main factor and the phyto-extract treatments as the secondary factor. Three varieties, ten treatments comprising one negative control (sterile distilled water), one positive control (fungicide: spavozeb) and eight phyto-extracts (aqueous and ethanolic) replicated three times were used in the experiment. Phyto-extract treatments

Table 1: Agronomic characteristics of the varieties used (IRAD-Dschang 2010)

Variety	Type	Growth cycle (days)	No. grain gousse ⁻¹	Growth habit
“Fleur” 11 var.	Fastigiata	90	2	Erect
65-13 var.	Spanish	90	3	Erect
Village var.	Virginia	120	2	Climbing

comprised 10 and 20% aqueous and ethanolic extracts of neem (*Azadirachta indica* A. JUSS) seeds and garlic bulbs (*Allium sativum* L.). The varieties and phyto-extract treatments were randomly applied to the main plots and the subplots, respectively.

2.4 Preparation of aqueous and ethanolic extracts

Aqueous and ethanolic extracts of neem (*A. indica* A. Juss.) seeds and garlic (*A. sativum* L.) bulbs were prepared at the laboratory prior to application. Neem seeds from Chad and garlic bulbs bought at the local market in Dschang were used. Crude extracts were obtained by sterilizing the plant organs in a solution of 10% sodium hypochlorite (NaOCl) for 1 min, rinsed five times in distilled water and then dried (Akinbode and Ikotun 2008). Dried seeds or bulbs were ground using a mortar and pestle and sieved through a 40 mm sieve. The grounded powder (100 g) was weighed into a conical flask and 100 mL of the solvent was added (distilled water or ethanol) to obtain a ratio of 1:1 w/v (weight/volume). This was then corked with a rubber lid and shaken for 20 min to mix and allowed overnight at room temperature (25°C before filtering the content). To obtain a concentration of 10 and 20% for field application, the filtered content was diluted accordingly; to obtain a concentration of 10%, 100 mL of the filtered plant extract suspension was added to 900 mL of distilled water to make up to 1 l (Tunwari and Nahunnaro 2014).

2.5 Planting and field management

Two seeds were sown to the depth of about 5 cm and a spacing of 40 cm × 30 cm on flat beds measuring 1.5 m × 0.8 m (1.2 m²) giving a planting density of 82,500 plants ha⁻¹ (Bangata et al. 2013). The seeds were sown after clearing and minimum tillage of the soil, and the seedlings were thinned to one plant per hole 20 days after planting (DAP). The varieties and phyto-extract treatments were randomly applied to the main plots and the subplots, respectively.

The rate of germination of the three groundnut varieties was evaluated at the level of the field as follows:

Rate of germination (%)

$$= (\text{Number of seeds germinated} / \text{Number of seeds sown}) \times 100.$$

NPK complex (12–24–12) and 150 kg ha⁻¹ of KCl were used to fertilize the plants through topdressing 15 DAP. Throughout the study, four manual weeding operations were carried out. The first weeding operation was carried out 15 DAP and the other three operations were carried out before 60 DAP to avoid the damage of the gynophore.

2.6 Application of treatments

Phyto-extracts and other treatments were first applied at the onset of CLS disease (50 DAP) as indicated by disease symptoms observed. Foliar applications were carried out at 50 DAP, 60 DAP, 70 DAP and at 80 DAP. Applications were performed using a pressurized hand sprayer. Spraying was done in the evening to prevent solar heat from denaturing plant extracts. Precautions were also taken to avoid drift effects. Spavozeb (fungicide with active ingredient: 80% mancozeb) was applied at the recommended rate (2 kg ha⁻¹).

2.7 Disease incidence and severity

Disease incidence and severity were observed throughout the experiment. Disease incidence of CLS, expressed as a percentage (%), was determined by applying the formula of Subrahmanya et al. (1995):

Disease incidence (%)

$$= (\text{Number of infected plants} / \text{Total number of plants}) \times 100.$$

Disease severity was evaluated on four randomly selected and tagged plants per experimental unit at 65 and 85 DAP using the International Crops Research

Institute for the Semi-Arid Tropics (ICRISAT) scale that ranges from 1 to 9 (Subrahmanya et al. 1995). Disease assessment at the level of the plot was carried out using the formula coined by Chaube and Pundhir (2005).

2.8 Growth and yield

Vegetative growth and production parameters in this study were as follows: germination rate (%), plant height (cm) measured with a graduated ruler, number of nodules obtained by uprooting and counting (six plants per subplot) and yield estimated using the average weight (fresh and dry) of seeds per plant and the planting density (Doikh 2001).

2.9 Data analysis

Data collected on the growth, disease and yield parameters were arranged in a spreadsheet using Microsoft excel 2013. The spreadsheet was imported into SPSS version 20 (statistical package for social sciences), and analysis of variance was carried out with mean values separated using the Tukey test at a probability threshold of 5%.

3 Results and discussion

3.1 Rate of germination and nodulation

The variety 65-13 showed the highest germination rate (90% and 96%) and the variety “fleur” 11 the least (55% and 73%) at the field and laboratory levels, respectively (Table 2). The high germination rate of 65-13 var. is similar to results obtained by Bourou et al. (2015), with

Table 2: Germination and nodulation rates of cultivated varieties

Variety	Germination rate (%)		Nodulation rate (%)
	Field	Laboratory	
“Fleur” 11 var.	55	73	39.62
65-13 var.	90	96	40.57
Village var.	78	88	43.34

the ICG 1471 variety having a germination rate of 91.33%. The varieties village and “fleur” 11 had a germination rate below 85% (Table 2), considered low by International Seed Testing Association. This low germination rate may be due to poor storage conditions of the seeds that were bought from the local market and the shelf life of the two varieties.

At the level of the field, the nodulation rate for the three varieties was relatively high (39–43%) compared to standard data (between 10 and 20%) (Nigam et al. 1983). However, these results are similar to those obtained by Halidou (2012), who obtained a useful nodulation between 30 and 60% on three peanut varieties (Meredji, Latiya and Kampala) in Dschang (Table 2). The high nodulation rate obtained is probably due to the presence of compatible and efficient nitrogen-fixing bacteria of the genus *Rhizobium* in the soil at the study site.

3.2 Plant growth before the application of phyto-extracts

Plant height, number of branches and the number of leaflets of the studied varieties are presented in Table 3 and Table 4. The village variety had the highest height (8.75 cm) than the “fleur” 11 (6.83 cm) and 65-13 (7.33 cm) varieties at 45 DAP. A similar trend was observed for the number of branches possibly because the village variety was the most adapted in the study site. However, there was no significant difference observed among the varieties in terms of height, the number of leaflets and the number

Table 3: Plant height and number of branches before phyto-extract applications

Variety	Height (cm)			Number of branches plant ⁻¹	
	15 DAP	30 DAP	45 DAP	30 DAP	45 DAP
“Fleur” 11 var.	4.3 ± 0.5 ^a	4.8 ± 0.14 ^a	6.8 ± 1.1 ^a	3.7 ± 0.4 ^a	4.9 ± 1.2 ^a
65-13 var.	5.0 ± 0.7 ^a	6.7 ± 0.94 ^a	7.3 ± 1.6 ^a	3.3 ± 0.6 ^a	4.5 ± 0.7 ^a
Village var.	5.0 ± 0.3 ^a	5.7 ± 0.87 ^a	8.8 ± 1.1 ^a	3.5 ± 0.4 ^a	5.3 ± 0.5 ^a

Mean values with the same letter within column are not significantly different at $p < 0.05$; $\pm$: standard error; DAP: days after planting.

Table 4: Number of leaflets before phyto-extract applications

Varieties	Number of leaflets plant ⁻¹		
	15 DAP	30 DAP	45 DAP
“Fleur” 11 var.	18.33 ± 1.15 ^a	49.33 ± 5.13 ^a	81.67 ± 06.80 ^a
65-13 var.	17.00 ± 1.00 ^a	43.23 ± 4.14 ^a	85.33 ± 14.51 ^a
Village var.	18.00 ± 2.08 ^a	49.67 ± 4.04 ^a	98.33 ± 10.01 ^a

Mean values with the same letter within column are not significantly different at $p < 0.05$; $\pm$: standard error; DAP: days after planting.

of branches before the application of phyto-extracts (Tables 3 and 4).

3.3 Effects of phyto-extract treatments on growth parameters

Table 5 shows that phyto-extract treatments had no significant effect on the growth (plant height and number of branches) of the studied groundnut varieties. However, the three varieties demonstrated different growth habits. In terms of plant height, 65-13 var. grew significantly ($p < 0.05$) taller (33.81 and 44.73) than the “fleur” 11 (25.69 and 33.65) and the village variety (25.45 and 36.96) following

phyto-extract treatments at 65 DAP and 85 DAP, respectively (Table 5). However, 65-13 var. produced significantly lower number of branches than the “fleur” 11 and village varieties at 65 and 85 DAP (Table 5). This confirms that the village variety is more branching than “fleur” 11, which is also more branching than the 65-13 var. (Table 5) in conformity of their growth habit (Table 1).

3.4 CLS disease incidence and severity

3.4.1 Disease incidence

At 65 DAP, plants treated with phyto-extracts showed no significant difference in the incidence of CLS disease (Table 6). Generally, the disease incidence was lower in plants treated with aqueous and ethanolic extracts compared to the control. This is similar to previous work by Ambang et al. (2010).

Disease incidence among all treatments ranged between 66.67% (lowest) and 88.89% (highest) at 65 DAP for 10% ethanolic extract of garlic and 20% aqueous extract of garlic, respectively (Table 6). This shows that 10% ethanolic extract offered the best control measure and reduced CLS incidence by 11.11%. This corroborates the results obtained by Kantwa et al. (2014), who

Table 5: Effect of phyto-extract application on the growth and development of groundnut

Treatments	Height (cm)		Number of branches plant ⁻¹	
	65 DAP	85 DAP	65 DAP	85 DAP
Control	28.3 ± 4.0 ^a	37.3 ± 10.2 ^a	9.8 ± 4.7 ^a	7.9 ± 2.6 ^a
Spavozeb	25.7 ± 7.2 ^a	37.3 ± 10.2 ^a	7.9 ± 2.6 ^a	7.9 ± 2.6 ^a
Aqueous extract of neem seeds 10%	28.6 ± 4.6 ^a	39.6 ± 5.9 ^a	8.7 ± 2.7 ^a	8.7 ± 2.7 ^a
Aqueous extract of neem seeds 20%	28.9 ± 4.8 ^a	36.9 ± 5.7 ^a	9.0 ± 3.1 ^a	9.0 ± 3.0 ^a
Ethanolic extract of neem seeds 10%	29.2 ± 4.1 ^a	39.9 ± 7.1 ^a	8.5 ± 3.7 ^a	8.5 ± 3.7 ^a
Ethanolic extract of neem seeds 20%	28.7 ± 5.5 ^a	40.2 ± 7.3 ^a	9.3 ± 2.8 ^a	9.3 ± 2.8 ^a
Aqueous extract of garlic 10%	28.7 ± 5.1 ^a	38.0 ± 6.4 ^a	8.3 ± 3.1 ^a	8.3 ± 3.0 ^a
Aqueous extract of garlic 20%	27.8 ± 7.1 ^a	38.6 ± 6.0 ^a	8.4 ± 2.2 ^a	8.4 ± 2.2 ^a
Ethanolic extract of garlic 10%	28.0 ± 5.9 ^a	37.0 ± 6.8 ^a	9.1 ± 3.4 ^a	9.1 ± 3.4 ^a
Ethanolic extract of garlic 20%	29.2 ± 4.2 ^a	38.4 ± 7.1 ^a	8.8 ± 2.8 ^a	8.6 ± 2.8 ^a
Varieties				
“Fleur” 11 var.	25.7 ± 3.8 ^b	33.6 ± 6.4 ^b	8.1 ± 1.4 ^b	7.9 ± 1.4 ^b
65-13 var.	33.8 ± 2.8 ^a	44.7 ± 4.5 ^a	6.4 ± 1.3 ^c	6.5 ± 1.4 ^c
Village var.	25.5 ± 3.6 ^b	37.0 ± 5.0 ^b	11.8 ± 3.0 ^a	11.4 ± 2.6 ^a
Interactions				
Treatments × varieties	NS	NS	NS	NS

Mean values with the same letter within column are not significantly different at $p < 0.05$; $\pm$: standard error; NS: not significant; DAP: days after planting.

Table 6: Incidence and severity of CLS disease

Treatments	Disease incidence (%)		Disease severity (%)	
	65 DAP	85 DAP	65 DAP	85 DAP
Control	77.78 ± 26.35 ^a	100.00 ± 0 ^a	19.14 ± 1.68 ^a	22.58 ± 3.49 ^{ab}
Spavozeb	80.56 ± 32.54 ^a	100.00 ± 0 ^a	16.00 ± 1.22 ^{bc}	19.83 ± 2.58 ^{ab}
Aqueous extract of neem seeds 10%	80.56 ± 20.83 ^a	100.00 ± 0 ^a	17.19 ± 2.38 ^b	20.99 ± 4.35 ^{ab}
Aqueous extract of neem seeds 20%	72.22 ± 34.10 ^a	100.00 ± 0 ^a	17.21 ± 2.09 ^b	21.09 ± 3.24 ^{ab}
Ethanollic extract of neem seeds 10%	77.78 ± 29.16 ^a	100.00 ± 0 ^a	16.74 ± 1.97 ^b	21.20 ± 2.86 ^{ab}
Ethanollic extract of neem seeds 20%	72.22 ± 31.73 ^a	100.00 ± 0 ^a	14.74 ± 0.26 ^c	18.47 ± 1.97 ^b
Aqueous extract of garlic 10%	83.33 ± 21.65 ^a	100.00 ± 0 ^a	16.73 ± 1.77 ^b	18.69 ± 2.34 ^{ab}
Aqueous extract of garlic 20%	88.89 ± 25.34 ^a	100.00 ± 0 ^a	17.15 ± 2.22 ^b	22.99 ± 5.99 ^a
Ethanollic extract of garlic 10%	66.67 ± 35.35 ^a	100.00 ± 0 ^a	16.93 ± 2.45 ^b	18.69 ± 2.91 ^{ab}
Ethanollic extract of garlic 20%	86.11 ± 28.26 ^a	100.00 ± 0 ^a	14.87 ± 0.47 ^c	18.62 ± 2.20 ^{ab}
Varieties				
“Fleur” 11 var.	87.50 ± 18.27 ^a	100.00 ± 0 ^a	17.42 ± 1.99 ^a	21.35 ± 3.07 ^a
65-13 var.	93.33 ± 17.28 ^a	100.00 ± 0 ^a	17.60 ± 2.11 ^a	21.54 ± 2.83 ^a
Village var.	55.00 ± 30.37 ^b	100.00 ± 0 ^a	14.99 ± 0.81 ^b	18.06 ± 3.80 ^b
Interaction				
Treatments × varieties	NS	—	Significant	NS

Mean values with the same letter within column are not significantly different at $p < 0.05$; $\pm$: standard error; NS: not significant; DAP: days after planting.

observed that phyto-extracts of garlic and neem were effective in inhibiting the mycelial growth and sporulation of a pathogenic fungus *Alternaria alternata* (Fr.) Keissler isolated from the infected leaves of groundnut. However, at 85 DAP, the disease incidence was 100% for all the phyto-extract treatments irrespective of the variety (Table 6) suggesting that the frequency of application was low.

3.4.2 Disease severity

Disease severity of CLS was significantly ($p < 0.05$) different among phyto-extract treatments (Table 6). At 65 DAP, plants treated with phyto-extracts showed disease severity comparable to the chemical treatment (16% for spavozeb) but significantly lower than the negative control (19%; Table 6). In other words, at 65 DAP, neem seeds and garlic bulb extracts significantly reduced the severity of CLS disease compared to the negative control. The lowest disease severity was observed on plants following the application of 20% ethanolic extracts of neem (14.74%) seeds and garlic (14.99%) bulb at 65 DAP (Table 6). This result is similar to that obtained from previous studies confirming 20% extracts as the most effective in food poison technique (Ahmad et al. 2016).

At 85 DAP, 20% ethanolic extract of neem seeds showed the least disease severity that was significantly different from

Table 7: Effects of phyto-extract treatments and varieties on the yield of groundnut

Treatments	Yield (t ha ⁻¹)	
	Fresh pods	Dry pods
Control	4.18 ± 0.91 ^b	2.40 ± 0.46 ^b
Spavozeb	4.93 ± 0.87 ^{ab}	3.09 ± 0.62 ^{ab}
Aqueous extract of neem seeds 10%	4.02 ± 0.45 ^b	3.03 ± 0.32 ^{ab}
Aqueous extract of neem seeds 20%	3.65 ± 0.93 ^b	2.92 ± 0.77 ^{ab}
Ethanollic extract of neem seeds 10%	4.00 ± 1.02 ^b	2.88 ± 0.57 ^{ab}
Ethanollic extract of neem seeds 20%	6.10 ± 0.53 ^a	3.19 ± 0.61 ^{ab}
Aqueous extract of garlic 10%	4.17 ± 0.89 ^b	2.91 ± 0.76 ^{ab}
Aqueous extract of garlic 20%	3.97 ± 0.92 ^b	3.10 ± 0.80 ^{ab}
Ethanollic extract of garlic 10%	4.59 ± 1.01 ^b	3.62 ± 0.84 ^a
Ethanollic extract of garlic 20%	6.03 ± 0.75 ^a	3.62 ± 0.71 ^a
Varieties		
“Fleur” 11 var.	4.60 ± 1.17 ^{ab}	3.13 ± 0.64 ^a
65-13 var.	4.93 ± 1.05 ^a	3.43 ± 0.69 ^a
Village var.	4.16 ± 1.14 ^b	2.67 ± 0.61 ^b
Interaction		
Treatments × varieties	NS	NS

Mean values with the same letter within column are not significantly different at $p < 0.05$; $\pm$: standard error; NS: not significant.

Figure 1: Resistance or susceptibility level of (a) “fleur” 11 var., (b) 65-13 var. and (c) village var. against leaf spot disease.

the other treatments (Table 6). This demonstrates that the extracts of garlic bulbs and neem seeds were effective in controlling the leaf spot disease of groundnut with extracts of garlic bulbs reacting faster than extracts of neem seeds. Similar results were obtained by Kantwa et al. (2014) when they observed *in vitro* phyto-extract (garlic and neem) inhibition of mycelial growth of the fungus *Alternaria alternata* causing leaf blight in groundnut. The local variety (village var.) showed the least severity (18%) compared to the varieties (65-13 var. and “fleur” 11 var.) indicating that the aforementioned variety was more resistant than others (Table 6 and Figure 1). This confirms previous suggestion by Ambang et al. (2008) that host resistance combined with phyto-extract treatment application considerably inhibits the progress of CLS of groundnuts and that the two methods could be used in an integrated management scheme to improve groundnut production.

3.5 Effects of treatments and varieties on yield

In terms of dry weight basis, yield obtained from the phyto-extract treated plots was higher than that of the control plots (Table 7). Yield obtained from plots treated with ethanolic extracts of garlic (3.62 t ha^{-1}) was significantly higher ($p < 0.05$) than that of the control (2.40 t ha^{-1}) but comparable to that obtained from spavozeb treatment (3.09 t ha^{-1}). This indicates the anti-fungal properties of the ethanolic phyto-extracts of garlic and its possible use to increase the yield of groundnut by reducing disease incidence and severity (Fontem et al. 1996; Srinivas et al. 1997; Ambang et al. 2011; Kantwa et al. 2014; Ahmad et al. 2016; Ngegba et al. 2017). However, the varieties (“fleur” 11 var. and 65-13 var.) are

more productive than the local variety (village var.). Thus, the phyto-extract treatments could be used to reduce the impact of CLS on the yield of both and local groundnut varieties.

4 Conclusion

Pests and diseases are among the factors that contribute to low and unstable production of groundnut in Africa. CLS is one of the most important diseases causing enormous losses in terms of yield in small-scale producers. Scientific efforts have been employed to find readily available, cheap and eco-friendly strategies to substitute synthetic phytosanitary products and limit yield-oriented impacts of CLS on groundnut. In this study, an attempt to manage CLS of three groundnut varieties using aqueous and ethanolic phyto-extracts was made. Results showed that the combination of varietal resistance and phyto-extracts applied appropriately can be used in integrated pest management programs that will yield both economic and environmental benefits.

Conflict of interest: The authors declare no conflict of interest.

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