Comparative Profitability of Managing *Meloidogyne incognita* on Cowpea (*Vigna unguiculata*) using Carbofuran and Pulverized *Aloe keayi* Leaves

A.A. Tanimola[*1], B. Fawole[2] & A.O. Claudius-Cole[2]

Keywords: *Vigna unguiculata*- Gross margin- Root-knot nematodes- Yield- Nigeria

Summary

The cost-benefit of managing Meloidogyne incognita *on cowpea (*Vigna unguiculata*) using leaves of* Aloe keayi *and carbofuran was evaluated in two field experiments at the University of Ibadan in Southwest Nigeria with the aim of selecting the more profitable management option. The experiments were laid out in a randomized complete block design and the treatments were:* A. keayi *at 80 kg/ha, carbofuran at 2 kg a.i./ha, untreated-infected control and uninfected control. Two-week old Ife Brown cowpea seedlings were inoculated with 10,000 eggs of* M. incognita *(except uninfected control). Air-dried milled leaves of* A. keayi *and carbofuran were applied one week after inoculation (WAI). Data collected at 10 WAI were: growth, yield, gall index (root damage), and* Meloidogyne *numbers. The costs and benefits of treatments were calculated. Treatment of* M. incognita*-infected cowpea with* A. keayi *and carbofuran improved vegetative growth by 201.6% and 183.5%, respectively compared to untreated-infected cowpea. Root damage was reduced by 62.5% and 68.8% by* A. keayi *and carbofuran, respectively.* A. keayi *compared effectively with carbofuran in reduction of nematode population. Treated cowpea with* A. keayi *improved grain yield by 219.9% that translated to a gross margin (GM) of US$ 798.1 per hectare; whereas carbofuran gave a yield increase of 200.5% that translated into a GM of US$ 692.3 per hectare. Cost:benefit (CB) analysis showed positive return per hectare when cowpea was treated with* A. keayi *and carbofuran. Management of* M. incognita *on cowpea with* A. keayi *(CB=0.61) is more profitable than carbofuran (CB=0.74).*

Résumé

Rentabilité comparative de la gestion de *Meloidogyne incognita* sur le niébé (*Vigna unguiculata*) en utilisant le carbofuran et la poudre de feuilles d'*Aloe keayi*

Le rapport coût-bénéfice de la lutte contre Meloidogyne incognita *sur le niébé (*Vigna unguiculata*), en utilisant la poudre des feuilles d'*Aloe keayi *et le carbofuran, a été évalué dans une expérience en champ à l'Université d'Ibadan dans le sud-ouest du Nigeria en vue de choisir le meilleur traitement. L'expérience a été menée selon un dispositif en blocs complétement randomisés. Les traitements étaient l'utilisation de la poudre des feuilles d'*A. keayi *avec 80 kg/ha, l'utilisation du carbofuran avec 2 kg m.a./ha, un témoin non traité-contaminé et un témoin non contaminé. Des plantules de la variété de niébé Ife Brown âgées de deux semaines ont été inoculées avec 10.000 œufs de* M. incognita *(sauf pour les témoins). La poudre des feuilles de* A. keayi *et le carbofuran ont été appliqués sur les plantes une semaine après inoculation (SAI) des œufs de* M. incognita*. Les mesures des données ont été faites 10 semaines après inoculation. Ces données concernaient la croissance, le rendement, l'indice de galles et la population de nématodes. Les coûts et les bénéfices des différents traitements ont été calculés. Les traitements du niébé infecté par* M. incognita *ont amélioré la croissance végétative de 201,6% et de 1835%, respectivement pour* A. keayi *et pour le carbofuran, par rapport au témoin infecté non traité. Les dommages aux racines ont été réduits de 62,5% et de 68,8% respectivement pour* A. keayi *et le carbofuran. L'utilisation des poudres de feuilles de* A. keayi *a réduit la population de nématodes avec des résultats similaires à ceux obtenus avec le carbofuran. Le niébé traité avec* A. keayi *a amélioré le rendement en grains de niébé de 219,9% équivalant à une marge brute de 798,1 $ US par hectare; alors*

[1]University of Port Harcourt, Faculty of Agriculture, Department of Crop and Soil Science, Ibadan, Nigeria.
[2]University of Ibadan, Faculty of Agriculture and Forestry, Department of Crop Protection and Environmental Biology, Ibadan, Nigeria.
[*]Corresponding author: Email: tanimoladebo@yahoo.com

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que le carbofuran a montré une augmentation de rendement de 200,5% équivalant à une marge brute de 692,3 $US par hectare. L'analyse du rapport coût/bénéfice par hectare est positif quand le niébé est traité avec A. keayi *et le carbofuran. La lutte de* M. incognita *en utilisant* A. keayi *est plus rentable (rapport coût-bénéfice=0,61) par rapport à l'utilisation du carbofuran (rapport coût-bénéfice=0,74)*

Introduction

Cowpea, *Vigna unguiculata* (L.) Walp is a key staple food for the poor sector of many developing countries and is believed to be native to Africa (18). Cowpea represents a source of income for the farmers of West and Central Africa, where it is the most economically important indigenous African legume crop (16). Nigeria is the largest cowpea producer in the world, but its production has been associated with low yields (9, 24). Plant-parasitic nematodes contribute to yield losses in cowpea in Nigeria and worldwide with root-knot nematodes (*Meloidogyne*) being implicated as major species found on cowpea resulting in estimated yield loss of 20-90% in cowpea production (24). *Meloidogyne incognita*, a notable species of the root-knot nematodes has been identified as a major reason for yield reduction in cowpea (6, 24). Synthetic nematicides are effective in nematode management (10, 25). However, the hazards they pose as environment pollutants, cost of purchase and the need for skill in their application necessitate the need for alternative options (1, 7, 25). These alternatives should be cost effective, more sustainable, environment-friendly and should curtail the menace that plant-parasitic nematodes cause in crop production.

Management strategies for soil-borne plant pathogens are currently shifting toward increased dependence on use of resistance, botanicals, biological and cultural methods that might eventually reduce the use of synthetic pesticides (8, 25, 27). The use of botanicals is being encouraged for the control of plant-parasitic nematodes since it has been reported to be effective (8, 10). Plant species are known to contain natural pesticidal materials, but many of them have not been extracted profitably (8, 20). Information on the screening of diverse plants for pest management is still not sufficient, especially in their contribution to cost of production (30). Besides, a clear understanding of costs and benefits of nematode management tactics is essential, but such knowledge is usually lacking for many management measures proposed (14, 35). There is growing literature on the use of botanicals to manage pests and diseases of crops (5, 10). However, additional information on the profitability of using botanicals in managing pests and diseases is necessary to facilitate the adoption of this management measure by the farmers.

The discovery of plants that have nematicidal properties, are environment-friendly and can be produced and applied at low cost is a key factor contributing to increased crop productivity (2, 20). Gwary and Asala (12) reported the profitability of some fungicides, but similar reports on synthetic nematicides and other management measures being advocated for plant-parasitic nematodes are scarce. *Aloe* species, including *Aloe keayi* have been reported to show nematicidal potential in the management of *Meloidogyne* species (17, 26, 32). This research was carried out to compare profitability of managing *M. incognita* on cowpea with dried *A. keayi* leaves in comparison to carbofuran to select the more cost-effective measure.

Materials and methods

Field studies were conducted to compare the economics of managing root-knot disease on cowpea caused by *M. incognita* using air-dried milled *A. keayi* leaves and a synthetic nematicide (carbofuran). These studies were carried out in two trials during the rainy seasons of April to June (2011) and August to October (2011) at the Crop Garden of Department of Crop Protection and Environmental Biology, University of Ibadan in Southwest Nigeria (latitude N 07° 27.029' and longitude E 03° 53.827' with an elevation of 218 metres above sea level). The fresh leaves of *A. keayi* were laid on laboratory benches and air-dried for eight weeks in the laboratory at ambient tropical conditions. The air-dried leaves were later milled into fine powder using Kenwood electric blender.

The trials were laid out in a randomized complete block design on a land area of 262.8 m^2 (43.8 m x 6 m) which was divided into four blocks of 9.7 m x 4 m each. The soil type of the experimental site was sandy loam. Each block was divided into plots of 1.8 m x 4 m, with an alley of 0.5 m between plots and 1 m between blocks. Each plot was sown with cowpea *cv.* Ife Brown [a susceptible variety to *M. incognita* (24)] at two seeds per hole with a spacing of 50 cm by 60 cm, and later thinned to one. Each treatment within a block had three rows with eight plants per row to produce a plant population of 24 cowpea stands/treatment within a block.

The treatments within each block were randomly assigned. The treatments comprised of air-dried milled *A. keayi* leaves at a rate of 80 kg/ha, carbofuran (5G) at the rate of 2 kg a.i./ha, infected-untreated and uninfected cowpea. The *M. incognita* uninfected cowpea were grown on an uninfested plot that was denematized by application of carbofuran at 3 kg a.i./ha three weeks before sowing. Eggs of *M. incognita* race 2 were extracted from roots of infected *Celosia argentea* using the hypochlorite method (13). Each cowpea plant was inoculated with 10,000 eggs of *M. incognita* at two weeks after sowing (WAS) except for plants in control (denematized) plots. Treatments were applied by carefully removing rhizosphere soil around each cowpea seedling to a band of 5 cm and applying dried powder of *A. keayi* leaves at 80 kg/ha (0.8 g/plant) and carbofuran at 2 kg a.i./ha (0.1 g/plant) after which the area was immediately covered with soil. The experiment ran for three months. At harvest, plant height (cm) and number of leaves were determined. The pods were harvested and yield (kg/ha) determined. The grain yield of cowpea (kg/ha) was determined from the grain yield of each treatment net plot using the equation I:

Grain yield (kg/ha) = Grain yield plot^{-1} (kg/ha) X 10,000 m^2 /Net plot size (m^2) (I)

The roots of eighteen randomly selected cowpea stands per treatment within a block were carefully dug out and assessed for root damage using gall index with the scale of Taylor and Sasser (33);

0= No galls or egg masses;
1= 1 – 2 galls or egg masses;
2= 3 – 10 galls or egg masses,
3= 11 – 30 galls or egg masses;
4= 31 – 100 galls or egg masses and
5= more than 100 galls or egg masses.

This procedure was repeated for the other three blocks and also repeated in similar manner in the second trial.

Eggs of *M. incognita* were extracted from infected roots using the method of Hussey and Barker (13). Soil nematode population was determined by extraction soil using the pie-pan method (34) and later estimated using a stereomicroscope at X40 magnification.

Reproductive factor was calculated using $R_f=P_f/P_i$, where P_f is final nematode population and P_i is initial nematode population.

The cost of producing cowpea using treatments was assessed separately and the yield was used to determine benefits.

Economic assessment was carried out using the partial budget techniques involving analysis of variable costs and benefits of the treatments (21).

Determination of variable costs

Various items and activities necessary in cowpea production, such as, land preparation, cowpea seeds, planting, cost of carbofuran, cost of *Aloe*, milling of *Aloe*, application of carbofuran and *A. keayi*, and cultural operations, were quantified and given cost estimates per hectare.

Benefit assessment of treatments

Benefit was determined from the yield obtained from treatments assigned to the plots.

Yield of cowpea was determined by weighing the seeds from the plots and calculating the equivalent per hectare (kg/ha).

- *Total revenue= Total yield per treatment plots (kg/ha) x current gross field price*
- *Total variable cost (₦/ha) for each treatment= is sum of cost for each action taken during production of cow pea*
- *Gross margin (₦/ha) for each treatment was determined= Total revenue – total variable cost*
- *Marginal rate of return (%)* for each treatment was calculatedin equation (II):

$$\frac{\textit{Gross margin/treatment x 100}}{\textit{Total variable cost of treatment}} \quad \textbf{(II)}$$

- *Cost:Benefit* (CB) ratio was determined by dividing total cost of treatment application by gross margin per treatment per hectare.

Data analysis

Nematode counts were transformed using logarithm transformation where necessary prior to analysis. Data obtained from the two trials were combined prior to analysis because they were similar. Data were analyzed using analysis of variance with SAS (29) statistical package for all the treatments tested and means separated using Fisher's Least Significant Difference (LSD) at 5% level of probability. The values presented in the tables as results are the average of both trials.

Results

Effects of milled *A. keayi* leaves and carbofuran on growth of *M. incognita*-infected cowpea

Plant height of cowpea treated with milled *A. keayi* leaves was significantly higher (25.7 cm) than other treatments at harvest (Table 1). The shortest plants were from the infected-untreated cowpea (15.7 cm) and these were significantly shorter (p≤0.05) than the plants of the other treatments. The highest (p≤0.05) number of leaves was recorded in cowpea treated with *A. keayi* (154.9) whereas the fewest leaves were recorded in the *M. incognita* inoculated and untreated plants (73.5) (Table 1).

The highest fresh shoot weight (FSW) was recorded in *A. keayi*-treated cowpea (116.7 g) followed by carbofuran- treated plants (109.7 g). Both differed significantly from the infected-untreated cowpea (38.7 g) (Table 1). *M. incognita* infected-untreated plants had the highest fresh root weight (12.9 g), however it was not significantly higher than that of carbofuran-treated plants (11.2 g). The lowest mean fresh root weight was obtained from the uninfected plants (8.8 g) although it was not significantly lower than the fresh root weights of *A. keayi* and carbofuran-treated cowpea.

A. keayi-treated cowpea had the highest dry shoot weight (DSW) (47.3 g) which did not differ significantly from carbofuran-treated plants (43.3 g) but did differ significantly from infected-untreated plants (18.6 g) (Table 1).

Effects of air-dried milled *A. keayi* leaves and carbofuran on gall index (GI), egg population and second-stage juvenile population

The highest root damage (*GI*=4.8) was recorded in *M. incognita* infected-untreated cowpea. The root damage based on gall index in *A. keayi*-treated cowpea was not significantly higher (1.8) than that of carbofuran-treated plants (1.5) (Table 2).

The highest *M. incognita* egg population was obtained from the roots of infected-untreated cowpea (157,800) and this was significantly higher than mean egg populations from other treatments.

There was no significant difference between the egg populations of *M. incognita* from *A. keayi*-treated and carbofuran-treated cowpea. The trend observed in the second-stage juveniles' population was similar to that of egg population. Infested-untreated plots had the highest mean second-stage juvenile (J_2) population (2487.5) and this was significantly higher than the mean J_2 population when compared with the other treatments. The J_2 population of carbofuran-treated plot was not significantly lower than J_2 populations found in *A. keayi* plots (Table 2).

Table 1

Effects of milled *A. keayi* leaves and carbofuran on growth of cowpea at 10 weeks after inoculation (10 WAI).

Treatments	Plant height(cm)	Number of leaves	Fresh shoot w eight (g)	Fresh root w eight (g)	Dry shoot w eight (g)
Inoculated+untreated control	15.7c	73.5d	38.7b	12.9a	18.6b
Aloe keayi 80 kg/ha	25.7a	154.9a	116.7a	9.6b	47.3a
Carbofuran 2 kg a.i/ha	24.2b	125.8b	109.7a	11.2ab	43.3a
Uninoculated control	24.5b	95.6c	76.5ab	8.8b	37.1a
LSD (P≤0.05)	0.8	9.6	43.1	3.2	10.2

Table 2

Effects of milled *A. keayi* leaves and carbofuran on gall index (root damage) and nematode numbers at 10 WAI

Treatments	Gall index	Egg /root system	J_2 in soil
Inoculated + untreated control	4.8a	157800.0a	2487.5a
Aloe keayi 80 kg/ha	1.8b	15175.0b	475.0b
Carbofuran 2 kg a.i/ha	1.5b	15000.0b	350.0b
Uninoculated control	0c	0c	0c
LSD (P≤0.05)	0.3	7530.6	268.9

Rating scale for gall index: 0= no galls or egg masses; 1=1-2 galls or egg masses; 2= 3-10 galls or egg masses; 3=11-30 galls or egg masses; 4= 31-100 galls or egg masses; 5= more than 100 galls or egg masses.

Effects of milled *A. keayi* leaves and carbofuran on yield (kg/ha) of *M. incognita*-infected cowpea

The effects of treatments on yield of cowpea infected with *M. incognita* and treated with milled leaves of *A. keayi* and carbofuran is presented on Table 3. At harvest, *A. keayi*-treated plants produced the highest yield (662.5 kg/ha) which was significantly higher than the yields produced from both uninfected (624.6 kg/ha) and carbofuran-treated plants (622.4 kg/ha). The lowest yield was produced from infected-untreated plants (207.1 kg/ha).

Cost:Benefit (CB) analysis of the management of M. incognita on cowpea using dried- milled A. keayi leaves and carbofuran

The economics of the management of *M. incognita* on cowpea using air-dried milled leaves of *A. keayi* and carbofuran are presented in Table 4.

Benefits obtained from each trial were presented as yield (kg/ha) prior to conversion to monetary values. In terms of costs of production, a higher cost of production vis-à-vis application of treatments was incurred with the application of carbofuran (₦79, 190; US$ 501.2); whereas, ₦74, 950 that translated to US$ 474.4 cost was incurred when *A. keayi* was applied (Table 4). Cost of production for uninfected cowpea in the trial was N60, 060 that translated to US$ 380.1, whereas a total cost of ₦58, 520 (US$ 370.4) was incurred for infected-untreated plants.

Table 3

Comparative effects of treatments on yield of cowpea infected with root-knot nematode in cost benefit trial on the field.

Treatments	Yield (kg/ha)
Infected-untreated	207.1c
Aloe keayi 80kg/ha	662.5a
Carbofuran@2 kg. a.i/ha	622.4b
(Uninfected)	624.6b
LSD (P≤0.05)	7.9

Table 4

Comparative Cost:Benefit (*CB*) analyses of application of carbofuran and milled *Aloe keayi* leaves in managing *Meloidogyne incognita*-infected cowpea.

Activities/Items	Carbofuran @ 2 kg a.i./ha	*Aloe keayi* @ 80 kg/ha	Infected untreated	Uninfected
Clearing (₦ ha^{-1})	12,5	12,5	12,5	12,5
Planting (₦ ha^{-1})	12,5	12,5	12,5	12,5
Weeding (₦ ha^{-1})	25	25	25	25
Cost of Carbofuran (40 kg) (₦ ha^{-1})	14	-	-	-
Cost of milled *Aloe* (80 kg) (₦ ha^{-1})	-	8	-	-
Carbofuran application (₦ ha^{-1})	5			
Cost of insecticide (2L) (₦ ha^{-1})	2,4	2,4	2,4	2,4
Insecticide application (₦ ha^{-1})	2,4	2,4	2,4	2,4
Aloe application (₦ ha^{-1})	-	5	-	-
Aloe milling cost (₦ ha^{-1})	-	1,6	-	-
Harvesting (₦ ha^{-1})	2,49	2,65	830	2,5
Cow pea seeds (2 kg) (₦ ha^{-1})	300	300	300	300
Total cost (₦ ha^{-1})	79,19	74,95	58,52	60,06
Yield (kg/ha)	622.4	662.5	207.1	624.6
Gross Revenue (₦ ha^{-1})	186,72	198,75	62,139	187,38
Gross Margin (₦ ha^{-1})	107,53	123,8	3,619	127,32
MRR (%)	136,00%	165,00%	6.2%	212,00%
C:B ratio	0.74	0.61	16.2	0.4

Note: Gross revenue was determined based on sale price of 1 kg weight of cowpea= ₦300. Milling cost for 25 kg air-dried leaves of *Aloe keayi* = ₦500. MRR= marginal rate of returns on application of treatment. C:B ratio= Cost:Benefit; Exchange rate as at 2011-US$ 1= ₦158

Gross margins from the treatment of *M. incognita*-infected cowpea with carbofuran and milled *A. keayi* leaves.

There were positive returns per hectare from the application of treatments especially from carbofuran, *A. keayi* and uninfected plants as observed by percentage returns, cost-benefit ratio and gross margin (*GM*) (Table 4). Application of carbofuran gave 136% of return on control and *GM* of N107, 530 that translated to US$ 680.6 per hectare (Table 4). Based on *CB* ratio, *A. keayi*-treated plants had a lower ratio of 0.61 compared with that of carbofuran (0.74) (Table 4). However, uninfected cowpea plants gave the lowest *CB* ratio of 0.47 per hectare among all the treatment plots (Table 4). The highest *CB* ratio was from the infected-untreated cowpea with ratio of 16.1.

Discussions

Meloidogyne incognita-infected cowpea treated with A*. keayi* at 80 kg/ha, carbofuran at 2 kg a.i/ha and uninfected plants showed better growth than infected-untreated cowpea. *Aloe keayi*-treated and uninfected control cowpea compared favourably with carbofuran-treated plants in growth. The good growth recorded in *A. keayi* and carbofuran treated cowpea might be linked to the nematicidal abilities based on the active principles within them. In addition to this, *A. keayi* might have been a source of nutrients after decomposition and also increased soil biological activity and soil conditions leading to good growth (28) while carbofuran has been reported as an effective nematicide thereby ensuring improved growth over untreated plants (15). The improvement in growth in cowpea treated with either carbofuran or *A. keayi* showed that treated plants were able to perform basic physiological processes promoting good growth because nematode populations were appreciably reduced in treated plots, resulting in reduced infection and damage. Root-knot infection has been linked to reduction in the photosynthetic rates and total chlorophyll in crops leading to poor growth and ultimately losses in yield in some crops (11, 31). A reason might be the reduction in the efficiency of some vital organs such as roots and alterations in the physiological process leading to poor growth and some cases to crop failure or death (3).

The infected-untreated plants had the highest fresh root weight which was an indicator of the significant extent of root damage recognized by the presence of heavy galls on the roots. The gall index which is a measure of root damage showed that infected-untreated plants had highly damaged roots with respect to their very high gall index in this experiment. *A. keayi* at 80 kg/ha compared favourably with carbofuran at 2 kg a.i/ha in the reduction of the root damage caused by *M. incognita* which confirms nematicidal efficacy of *A. keayi*. Whether the effect was nematicidal or nematotoxic as not determined but it clearly reduced the ability of *Meloidogyne* to reproduce effectively. The highest numbers of eggs and second-stage juveniles were also recorded in infected–untreated cowpea because there was no measure applied to either kill or reduce the nematode activity on these plants. Carbofuran at 2 kg a.i/ha and *A. keayi* at 80 kg/ha reduced population of *M. incognita* in the treated plants due to their nematicidal abilities. The reproductive factor recorded for carbofuran and *A. keayi*–treated plants were not significantly different indicating that *A. keayi* 80 kg a.i/ha compared favourably with carbofuran at 2 kg a.i/ha in the reduction of *M. incognita* reproduction in cowpea. This outcome confirmed that A. *keayi* and carbofuran both possessed nematicidal properties. Application of *A. keayi* and carbofuran improved cowpea yield compared with *M. incognita* infected-untreated cowpea. The higher yield recorded from the *A. keayi* treatment is probably due to the dual effect of nematicidal properties exhibited on the nematode; as well as a source of nutrients and increased microbial activity that enhanced plant growth more than in the carbofuran-treated plants resulting in higher yields. Yield in infected-untreated plants was significantly lower than yield in the other 3 treatments. The activities of *M. incognita* in infected-untreated cowpea caused havoc on growth, development and ultimately resulted in very low yield. It highlights that if *M. incognita* is left unattended on cowpea, significant yield losses in quantity and quality will be inevitable (3, 23).

The higher costs of production recorded in the application of carbofuran than in *A. keayi* in both trials are explained by the higher costs of carbofuran and its application. It is a known fact that application of most synthetic nematicides is responsible for an increase in the production cost in many crops, though synthetic nematicides do effectively manage plant-parasitic nematodes (3, 8, 25). The lower total cost of production incurred in *A. keayi* treatment than in carbofuran treatment might be due to easy availability of the *Aloe* species with little or no cost attached in Nigeria. Most Aloe species are being cultivated as pot herbs in many home gardens in Nigeria and West Africa because of its medicinal and cosmetic values thereby making them widely available. In the recent, there has been plan towards the cultivation of beneficial *Aloe* species as plantation crops in Nigeria to satisfy its huge demand by industries. Also, the processing cost incurred in the production of milled *A. keayi* leaves was lower when compared with carbofuran for special skills were not required both in processing and application. This view was supported by Ghazalbash and Abdollahi (11) who posited that plant extracts may be easily and cheaply produced by farmers and small scale industries as chopped leaf and powders while their application is inexpensive.

The low cost of production in both uninfected and *M. incognita* infected-untreated cowpea was because no treatments were applied in the management of the nematodes, except the general costs incurred in the common activities in cowpea production.

There was a higher marginal rate of return (*MRR*) on treatment application using *A. keayi* at 80 kg/ha than in carbofuran at 2 kg a.i/ha which was explained by a lower input costs and higher yield. However, the uninfected plants gave the highest MRR because no nematodes were presented and thus no nematode control was necessary to safeguard the plants and thereby recording good yield with no additional cost incurred in the management of *M. incognita*. The low MRR of infected-untreated cowpea showed that *M. incognita* infection if unattended in cowpea will give poor return from the production.

In terms of cost:benefit ratio (*CB*), *A. keayi* treatment had a lower *CB* ratio than the carbofuran treatment while uninfected cowpea had the lowest *CB* ratios per hectare in the trial while the *CB* ration of infested cowpea as much higher than 1. These results confirm that treatment with with dried–milled leaves of *A. keayi* at 80 kg/ha or carbofuran at 2 kg a.i/ ha in infested cowpea is worth employing in the management of *M. incognita* since their *CB* ratios in the trials were still lower than 1 (4) while no nematode treatment will results in a serious loss if it is taken into account that the *CB* ratio of this treatment was 16.2. Of course cowpea production is most profitable if the field is not infested with nematodes however, this condition is rare, since most farmlands are infested by *Meloidogyne* species due to its ubiquitous nature and high rate of reproduction (22). The results in this trial further showed that yield obtained from cowpea whether treated or uninfected is still low when compared to the potential yield of 2-3 tonnes per hectare in Nigeria (23). Various reasons might be adduced for this, ranging from environmental factors, poor soil fertility, impact of other pests and diseases, amongst other (19, 22). However, application of air-dried milled leaves of *A. keayi* in the management of *M. incognita* on cowpea ensured improvement in cowpea grain yield thereby making the production more profitable.

Conclusion

The application of *A. keayi* at 80 kg/ha improved growth, yield and nematode management of *M. incognita*-infected cowpea. The best nematode management in terms of suppression of *M. incognita* reproduction and population was in carbofuran-treated plants, but *A. keayi* compared favourably with carbofuran and performed significantly better than infected-untreated cowpea. Cost benefit analysis showed that *A. keayi* treatment is less expensive as management option than carbofuran vis-à-vis costs of production and benefits. The results in the study showed that it is more profitable to use air-dried milled leaves of *A. keayi* at 80 kg/ha than carbofuran in the management of *M. incognita* on cowpea.

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Literature

1. Adekunle O.K. & Fawole B., 2003, Chemical and non chemical control of Meloidogyne incognita infecting cowpea under field conditions, *Moor J. Agric. Res.*, **4**, 1, 94–99.
2. Adekunle O.K. & Akinlua A., 2007, Nematicidal effects of *Leucaena leucocephala* and *Gliricidia sepium* extracts on *Meloidogyne incognita* infecting okra*, J. Agric. Sci.*, **52**, 1, 53-63
3. Adesiyan S.O., Caveness F. E., Adeniji M.O. & Fawole B., 1990, *Nematode pests of Tropical Crops Heinemann Educational Books* (Nigeria) Ltd. 114 pp.
4. Aiyeloja A.A., 2007, *Potentials of small scale forest-based enterprises in poverty reduction in South-west Nigeria.* A Ph.D thesis submitted to the Department of Forest Resources Management, Faculty of Agriculture and Forestry, University of Ibadan, 252 pp.
5. Akpheokhai L.I., Claudius-Cole A.O. & Fawole B., 2012, Evaluation of some plant extracts for the management of *Meloidogyne incognita* on Soybean (Glycine max), *World J. Agric. Sci*., **8**, 4, 429-435
6. Babatola J.O. & Omotade M.A., 1991, Chemical control of the nematode pests of cowpea, *Vigna unguiculata* (L.) Walp. *Crop Prot*., **10**, 121-124
7. Bell C. A., 2000, *Fumigation in the 21st century. Crop. Prot*., 19, 563-569.
8. Chitwood D. J., 2002, Phytochemical based strategies for nematode control, *Annu. Rev. Phytopathol*., **40**, 221-249.
9. FAOSTAT., 2013*, Cowpea production statistic for year 2011*. Retrieved November 7, 2013, from http://www.faostat.fao.org/site/567 (November 7, 2013)
10. Fawole B., 2009, *Phytonematology: small animals, big impac*t (An inaugural lecture 2008 presented at the University of Ibadan). Ibadan University Press, Ibadan, Nigeria. 31 pp.
11. Ghazalbash N., & Abdollahi M., 2013, Effect of medicinal plant extracts on physiological changes in tomato inoculated with *Meloidogyne javanica* and *Fusarium oxysporum*, *Pak. J. Nematol.*, **31**, 1, 21-37
12. Gwary D.M. & Asala S.W., 2006, Cost-benefit of fungicidal control of Anthracnose on sorghum in Northern Nigeria, *Int. J. Agric. Biol*. **8**, 3, 306-308.
13. Hussey R.S. & Barker K.R., 1973, A comparison of methods of collecting inocula for *Meloidogyne* species including a new technique, *Plant Dis. Report,* **57**, 1025 – 1028.
14. Ivan, J.T. & Edward P.C., 1987, *Principles of nematode control,* pp 87-130. In: *Principles and practice of nematode control* (Eds. R.H. Brown, B.R. Keroy). Academic Press Inc. (London) Ltd.
15. Khan R.A., Khan M.R., Sahreen S., Jan S., Bokhari J. & Rashid U., 2011, Phytotoxic characterization of various fractions of *Launaea procumbens, Afr. J. Biotechnol.*, **10**, 5377-5380.
16. Langyintuo A.S., Lowenberg-DeBoer J., Faye M., Lambert D., Ibro G., Moussa B., Kergna A., Kushwaha S., Musa S. & Ntoukam G., 2003, Cowpea supply and demand in West and Central Africa, *Field Crops Res*., **82**, 215–231.
17. Mahmood I., Saxena S.K. & Zakinaddin R., 1979, Effects of some plant extracts in the mortality of *M. incognita* and Ro*tylenchus reniformis*, *Acta Bot. Indica*, **7**, 2, 121-132.
18. Mangala R. & Mauria S., 2006, *Handbook of Agriculture. Facts and figures for teachers, students and all interested farmers.* Indian Council of Agricultural Research, New Delhi 110012.M/S Chandu Press, Delhi 1346pp
19. Mortimore M.J., Singh B.B., Harris F. & Blade S.F., 1997, *Cowpea in Traditional Cropping Systems.* In: Singh B.B.; Mohan-Raj D.R., Dashiell K.E., Jackai L.E.N (Eds.) *Advances in Cowpea Research.* Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS) IITA, Ibadan, Nigeria. pp. 99-113.
20. Ofuya T.I., 2009, *Formulation of medicinal plants for crop protection in Nigeria*. In: *Formulation of medicinal plant in plant and Animal production in Nigeria*. Proceedings of the 5th Annual Conference, School of Agriculture and Agricultural Technology (Akure- Humbolt Kellog) (S.O. Agele, F.O. Osundahunsi, V.A.J Adekunle, I.B. Osho & M.O. Olufayo eds). Federal University of Technology, Akure, Nigeria. 20th-23rd April, 2009, pp 1-6.
21. Okoruwa V.O., Obadaki F.O. & Ibrahim, G., 2005, Profitability of beef cattle fattening in the cosmopolitan city of Ibadan, Oyo State, *Moor, J. Agric. Res.* **6**, 1, 45-51
22. Olowe T., 2004, Occurrence and distribution of root-knot nematodes, *Meloidogyne* spp. in cowpea growing areas of Nigeria, *Nematol.*, **6**, 811–817.
23. Olowe T., 2007. Reaction of cowpea genotypes to the root-knot nematode *Meloidogyne incognita*, *Nematol. Medit*. **35**,177-182.
24. Olowe T., 2010, Variation in virulence of *Meloidogyne incognita* races 1, 2, 3, and 4 on cowpea genotypes, *Eur. J. Sci. Res.*, **43**, 3, 340-350
25. Osei K., Fening J.O., Gowen S.R. & Jama, A., 2010, The potential of four non-traditional legumes in suppressing the population of nematodes in two Ghanaian soils, *J. Soil Sci. Environ. Manage*, **1**, 4, 63-68.
26. Pandey R. & Hasseb A., 1988, Studies on the toxicity of certain medicinal plants to root-knot nematode, *M. incognita*. *Indian J. Plant Pathol.*, **6**, 2, 184-186
27. Pattison A.B., Versteeg C., Akiew S. & Kirkegaard J., 2006, Resistance of *Brassicaceae* plants to root-knot nematode (*Meloidogyne* spp.) in northern Australia, I*nt. J. Pest Manage.***,** **52**, 1, 53-62
28. Radwan M.A., El-Maadaway E.K. & Elamayem A., 2007, Comparison of the nematicidal potentials of dried leaves of five plant species against *Meloidogyne incognita* infecting tomato, *Nematol. Medit.*, **35**, 81-84.
29. SAS Institute., 2009. SAS User's Guide: Statistics, SAS Institute, Cary. NC. USA.
30. Satish S., Mohana D.C., Ranhavendra M.P. & Raveesha K.A., 2007, Antifungal activity of some plant extracts against important seed borne pathogens of *Aspergillus* sp*., J. Agric. Technol.*, **3**, 1, 109-119.

31. Swain B. & Prasad J.S., 1988. Chlorophyll content in rice as influenced by the root-knot nematode, *Meloidogyne graminicola* infection, *Current Science*, **5**7, 895-896
32. Tanimola A.A. & Fawole B., 2012, In vitro *nematicidal activity of some* Aloe *species on eggs and second-stage juveniles of* Meloidogyne incognita. Inaugural Conference of the Nigerian Society of Nematologists on 16th-17th October, 2012 at Conference Centre, University of Ibadan, 31 pp.
33. Taylor A. L. & Sasser J. N., (1978), *Biology, identification and control of root-knot nematodes* (*Meloidogyne* species) a cooperation publication of North-Carolina State University and WAIP. 11p.
34. Whitehead A.G. & Hemming J.R., 1965, A comparison of some quantitative methods of extracting small vermiform nematodes from soil, *Ann. Appl. Bio.*, **55**, 25 – 38.
35. Whitehead A.G., 1998*, Plant nematode control.* CAB International, Wallingford UK, 384 pp.

A.A. Tanimola, Nigerian, PhD, Lecturer, University of Port Harcourt, Faculty of Agriculture, Department of Crop and Soil Science, Rivers State, Nigeria.

B. Fawole, Nigerian, PhD, Professor, University of Ibadan, Faculty of Agriculture, Department of Crop Protection and Environmental Biology, Oyo State, Nigeria.

A.O. Claudius-Cole, Nigerian, PhD, Senior Lecturer, University of Ibadan, Faculty of Agriculture, Department of Crop Protection and Environmental Biology, Oyo State, Nigeria.