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Effect of mixed cropping and plant extracts on the growth, yield and pest control of jute (*Corchorus olitorius* L.)

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ABSTRACT

This study investigated the effect of plant extracts (*Azadirachta indica* and *Piper guineense*) on the growth and yield of jute (*Corchorus olitorius* L.) (Cor) under sole and mixed cropping with *Amaranthus hybridus* (Ama) and *Celosia argentea* (Cel). The highest percentage increase in plant height, number of leaves, number of branches and stem girth (130.6, 865.0, 220.4 and 114.0%, respectively) was found in untreated Cor + Cel, cypermethrin treated Cor + Ama, cypermethrin treated Cor and *A. indica* extract treated Cor + Ama, respectively. The highest percentage increase in shoot weight (71.0%), marketable yield (53.9%) and total biomass (51.5%) was in *A. indica* treated *C. olitorius*. Extract treatment had no effect on the number of branches at four, five and seven weeks after planting (WAP) in Cor + Ama + Cel; four, five and six WAP in Cor + Cel; four and six WAP in Cor + Ama; as well as four and five WAP in Cor. The highest percentage increase in leaf fresh weight was obtained in cypermethrin treated Cor (53.3%) and Cor + Ama + Cel (52.2%), while the smallest increase was in *P. guineense* treated Cor (1.1%) and Cor + Ama (2.5%). The activity of *A. indica* was independent of time of application while *P. guineense* was not. Among the extract treated groups, the highest percentage increase in shoot weight (71.0%), marketable yield (53.9%) and total biomass (51.5%) was in *A. indica* treated Cor. The activity of the extracts against insect pests of sole cropped Cor increased significantly ($p < 0.05$) with increasing extract concentration. The highest efficiency with the use of *P. guineense* was 250 g dm^{-3} at four, five and six WAP (94.0, 92.7 and 90.3%, respectively) and 200 mg dm^{-3} at seven WAP (81.7%). In the case of *A. indica* extract, the highest efficiency was found with the use of 200 g dm^{-3} at four, six and seven WAP (92.7, 85.3 and 100%, respectively). *A. indica* extract (250 g dm^{-3}) treatment gave the highest efficiency at five WAP (100%).

Key words: insect pests, leafy vegetable, pest management, synthetic insecticides, sustainable agriculture

INTRODUCTION

The diets of many people in developing countries are dominated by starchy staple foods and are low in animal protein, leading to a high prevalence of malnutrition and stunted growth (Ijarotimi et al. 2003). The situation is worsened by the increase in population, level of poverty and decreasing soil productivity with long-term cropping. These observations underscore the need for appropriate integrated and sustainable management strategies in addressing the situation. Recent developmental efforts have resulted in the spread of information on the value of fresh vegetables in the human diet

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(Oniango 2001). Soft edible structures developed from plant parts other than the seed are usually regarded as vegetables. They are mostly eaten as accompaniments to starchy staples in a raw or cooked form, alone, with meat or fish, in stews, soups or various preparations in which groundnut, melon seed, and palm oil are also commonly added (Ogbalu et al. 2005).

Vegetables like *Amaranthus hybridus* L., *Celosia argentea* L., and *Corchorus olitorius* L. are commonly grown for their edible leaves (leaf vegetables) (Ojeifo et al. 2006). Green leafy vegetables are widely used for food in many countries of the world; they are rich sources of beta carotene, ascorbic acid, minerals and dietary fibre (Negi and Roy 2001, Oboh and Akindahunsi 2004). In Nigeria, crops and cropping systems are diverse owing to large agro-ecological and cultural diversity, which in turn leads to variable cropping patterns. In the traditional Nigerian agricultural system, vegetables are grown in mixtures with cereals, grain legumes and tubers (Ikeorgu 1989, Olasantan 1999, 2005). Although local farmers are favourably disposed to advancements in agricultural practices, the high adaptive index of some of these emerging technologies, coupled with low yield, pesticide toxicity and the changing nature of social-environmental interactions raise a series of unresolved questions on improved productivity (Porter et al. 2003). There has been considerable interest in sustainable production systems for agronomic crops where plant height, stem strength and the number of leaves were major considerations (Eltun et al. 2002, Dapaah et al. 2003, Ngouajio et al. 2003, Jagadamma et al. 2008). Research by various authors show that intercropping increases the size and stability of yields compared to sole cropping (Thangataa and Alavalapatib 2003, Hauggaard-Nielsen et al. 2006, Jahansooz et al. 2007).

Insect pests are also a major factor affecting the productivity of vegetables. The Food and Agriculture Organisation (FAO 1997) reported that the estimated annual losses due to insect pests alone stands at about 15%-20% during production and 18%-20% during storage. The Federal Department of Agriculture (Nigeria) estimated that about 60% of the total food and fibre produced are lost to insect pests (Mohammed 2002). These massive losses underscore the need for a sustainable and environmentally friendly approach for addressing the situation. Synthetic chemical insecticides have proved very effective in the control of insect pests. However, problems associated with chemical insecticides, such as depletion of the ozone layer, health hazards, insect resistance, irregular supplies and cost have led to increased demand for alternatively safer, cheaper and more ecologically friendly methods in the control of these insects. Medicinal plants have received considerable attention as potential sources of alternative materials for use as insecticides and antifeedants. They contain a wide range of bioactive chemicals that are potentially suitable for use in integrated pest management (Pavela 2004, Akendengue et al. 2005, Han et al. 2006, Jovanovic et al. 2007, Georges et al. 2008, Montes-Molina et al. 2008, Javed et al. 2008).

The use of natural plant products as insecticides is particularly important in a country like Nigeria where synthetic insecticides are expensive and not readily available. In addition, farmers are poorly equipped to handle them. Extracts of *Azadirachta indica* (neem) and *Piper guineense* have components capable of influencing the physiology and behaviour of a wide range of insects, mites and nematodes (Dhar et al. 1998, Schaaf et al. 2000, Ngono Ngane et al. 2003). The bark, leaf and seed oil are particularly useful parts of the neem tree (Han et al. 2006). Major biologically active components reported in *A. indica* and *P. guineense* include: azadirachtin, triterpenoids, piperolein acids, guineensine, essential oils, sterols and amides, among others (Martins et al. 1998, Schaaf et al. 2000, Siddiqui et al. 2000, Muse et al. 2003, Ngono Ngane et al. 2003, Gopal et al. 2007). Most reports on the use of plant extracts are in relation to stored cereals and legumes, with scant information on vegetables. There is little information on the management of *C. olitorius* using an integrated approach involving mixed cropping and use of *A. indica* and *P. guineense* extracts despite their excellent pharmacological, insecticidal and antifeedant properties. The objective of this research was to study the effects of mixed cropping (with *A. hybridus* and *C. argentea*) and plant extracts on the growth and yield performance of *C. olitorius.*

MATERIAL AND METHODS

Raw material collection and preparation

The cypermethrin, *C. olitorius*, *A. hybridus* and *C. argentea* used in this study were obtained from the Ondo State Agricultural Development Programme, Akure, Nigeria. Fresh bark samples of *A. indica* were obtained from disease-free trees in a local farm in Akure, Nigeria. Sundried *P. guineense* was obtained from the Oja-Oba market in Akure. The plant parts were authenticated in the Department of Crop Soil and Pest Management of the Federal University of Technology, Akure, Nigeria before use. The vegetable seeds were subjected to hot water treatment to break seed dormancy before sowing.

Preparation of plant extracts

Fresh bark samples of *A. indica* and sundried *P. guineense* were separately peeled and ground to crumbs in a mortar. Thereafter 100, 150, 200 and 250 g of each were measured and separately soaked in 1 dm^3 of water, giving four concentrations: 100 g dm^{-3}, 150 g dm^{-3}, 200 g dm^{-3} and 250 g dm^{-3}, respectively. After 24 hours, the extract solutions were sieved with cheesecloth to obtain clear extract solutions. Cypermethrin (synthetic pesticide) was prepared according to the manufacturer's specifications (0.2% v/v).

Site preparation, preparation of seedbed and cultivation of seeds

The field experiments were conducted on a previously cultivated site during the early season of 2005 and replicated in 2006 at the Teaching and Research Farm of the Federal University of Technology, Akure (327 m above sea level; 7°16' N, 5°12' E) located in the rainforest zone of south-western Nigeria. The experimental site has luxuriant vegetation, well-drained fertile soils free from iron concentrates and annual rainfall between 1150-2000 mm. The fallow vegetation on the land was manually cleared and the debris packed to the borders to obtain clean seedbeds for sowing the crops. Seedbeds (three per treatment group represent a plot) measuring 2 m by 2 m were constructed with a space of 1 m between the blocks. The vegetable seeds were sown in rows 30 cm apart and thinned to 20 stands per row with an average spacing of 10 cm within rows (60 stands m^{-2}) two weeks later. Weeds were manually removed in the plots at two and five weeks after planting. A composite sample of the soil in the experimental area was collected for routine laboratory analysis. Ten stands were randomly selected per plot and tagged for data collection.

Mixed cropping and treatment with plant extracts

The crops were planted as follows: plot 1, sole *C. olitorius;* plot 2, 1:1 rows of *C. olitorius* and *C. argentea*; plot 3, 1:1 rows of *C. olitorius* and *A. hybridus* and plot 4, 1:1:1 rows of *C. olitorius, C. argentea* and *A. hybridus.* The seeds were sown and thinned as described above. Data were collected weekly from four to seven WAP for growth parameters (plant height, number of leaves, stem girth and number of branches per plant). At seven WAP, tagged vegetables in each plot were harvested, washed and the following yield parameters were measured: leaf, shoot and root weights, total biomass and leaf area. Established seedlings in each plot were sprayed weekly (using a Harry brand hand sprayer) with the extracts obtained from *A. indica* and *P. guineense* at 250 g dm^{-3} from four to seven WAP. Growth parameters, namely: plant height, number of leaves, number of branches, stem girth, were determined weekly from four to seven WAP. The cypermethrin treated group served as a positive control. Yield parameters, including leaf fresh weight, leaf area, shoot weight, root weight, marketable yield and total biomass, were determined at seven WAP.

Prevalence of insect pests

Sampling of the pest population on established crop stands from different plots was done four times early in the morning at weekly intervals. At each sampling, the numbers of insects on the plants on each bed were recorded using the direct counting method. Insects responsible for damage found on the plant were collected in sample bottles containing formalin and taken to the laboratory for identification. The insect density on each plot was counted a day before and a day after spraying. Percentage efficiency was determined using the Henderson – Tilton formula (Püntener 1981):

$$\textit{Efficiency}\ (\%) = \frac{\text{N in Co before treatment} \times \text{N in T after treatment}}{\text{N in Co after treatment} \times \text{N in T before treatment}} \times 100$$

where N – insect population, T – treated, Co – control.

Data analysis

The design of each experiment was a randomised complete block (RCBD) with three replications. Means of triplicate readings were subjected to analysis of variance (ANOVA) while means were separated using Duncan's Multiple Range Test. Relevant data were subjected to correlation and regression analyses. All analyses were carried out using the Statistical Package for Social Scientists (version 10).

RESULTS

Physical and chemical properties of soil at site of experiment

Soil pH and organic matter remained fairly constant after cropping (Tab. 1). Decreases were recorded in

Table 1. Physical and chemical properties of soil at site of experiment

Time of analysis	Particle size (%)			pH	Organic matter %	Exchangeable cation					
	sand	silt	clay			N (%)	P (mg kg^{-1})	K	Ca (cmol kg^{-1})	Mg	Na
Before planting	54	18	30	6.63	2.41	0.70	26.61 b	0.76 b	2.40	1.00	0.87
After planting	54	18	30	6.33	2.20	0.64	10.83 a	0.51 a	2.00	1.50	0.64

Means followed by different letters in the same column are significantly different at p = 0.05

Table 2. Growth of *C. olitorius* intercropped with *A. hybridus* (Ama) and *C. argentea* (Cel) before application of plant extracts at 1-3 WAP

Intercropping design	WAP	Cor	Cor + Ama	Cor + Cel	Cor + Ama + Cel
No of leaves	1	20.1 b ± 1.16	20.3 b ± 1.50	20.1 b ± 3.05	17.2 a ± 1.33
	2	27.3 b ± 0.87	25.3 a ± 2.27	27.1 b ± 3.97	24.0 a ± 2.21
	3	48.2 b ± 3.94	45.9 a ± 2.46	48.8 b ± 7.14	45.7 a ± 2.44
No of branches	2	5.0 ± 1.38	5.4 ± 0.59	5.4 ± 1.37	4.8 ± 0.44
	3	8.2 ± 0.48	8.6 ± 0.61	8.6 ± 0.32	7.3 ± 0.38
Stem girth	1	2.4 ± 0.01	2.1 ± 0.19	2.1 ± 0.18	2.2 ± 0.19
	2	2.5 ± 0.24	2.3 ± 0.09	2.4 ± 0.16	2.3 ± 0.10
	3	3.5 ± 0.26	3.6 ± 0.33	3.5 ± 0.43	3.3 ± 0.14

Means followed by different letters in the same row are significantly different at p = 0.05

the sodium, potassium and phosphorus contents of the soil. This observation suggests that cultivation of *C. olitorius* is accompanied by depletion in phosphorus and potassium contents. Table 2 showed the growth parameters of sole and mixed cropped *C. olitorius* (Cor) at one to three WAP before application of plant extracts. Tables 3 and 4 show the effect of mixed cropping and plant extract and its interaction effects on the growth of *C. olitorius* at four to seven WAP. The highest percentage increase in plant height, number of leaves, number of branches and stem girth (130.6, 865.0, 220.4 and 114.0%, respectively) were observed in untreated *C. olitorius* + *C. argentea* (Cel), cypermethrin treated *C. olitorius* + *A. hybridus* (Ama), sole cropped cypermethrin treated *C. olitorius* and *A. indica* extract treated *C. olitorius* + Ama, respectively (Figs 1-4).

Growth parameters

Gradual increases in plant height were recorded in all of the treatment groups. Within the mixed cropped group treated with plant extract, *A. indica* extract treated groups had significantly higher values. The interaction effect was significant in the height of sole and mixed cropped *C. olitorius*. The plant height of *C. olitorius* when intercropped with Ama (Cor + Ama), Cel (Cor + Cel) and Ama + Cel (Cor + Ama + Cel) was significantly higher ($p < 0.05$) in *A. indica* extract treated groups at four to six WAP. The values obtained for both *P. guineense* and *A. indica* treated mixed cropped *C. olitorius* were significantly higher than the untreated group. However, plant heights were generally higher in sole cropped *C. olitorius* (Tab. 3). Among the untreated groups, the number of leaves was significantly higher when intercropped with Ama (Cor + Ama); the value obtained, 109.1, represent a 75.1% increase from four to seven WAP. When intercropped with Cel (Cor + Cel), the number of leaves was 84% at seven WAP (representing a 73.4 percent increase). No significant difference ($p > 0.05$) was observed in the number of leaves of *A. indica* and *P. guineense* treated sole *C. olitorius*, Cor + Cel, Cor + Ama + Cel at four WAP. This trend changed at five to seven WAP for sole *C. olitorius,* while the Cor + Cel with *A. indica* extract treated group had significantly higher values. The highest increase in the number of leaves was in *A. indica* extract treated sole cropped *C. olitorius* (77.8%; Fig. 2). A similar range was observed when intercropped with celosia and treated with *A. indica* and *P. guineense* extract (71.8 and 73.9%, respectively). Cypermethrin treated sole cropped *C. olitorius* and Cor + Ama had significantly higher percentage increase values (79.2 and 86.6%, respectively, (Fig. 4). However, they had the least per cent increase when intercropped with Cel (68.2%) and Ama + Cel (48.7%). There were significant increases with intercropping in the number of

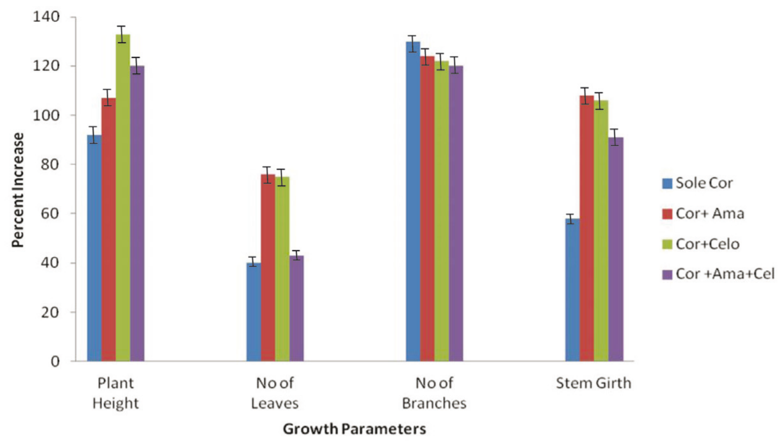

Figure 1. Effect of no spray on the growth of sole and mixed cropped *C. olitorius*

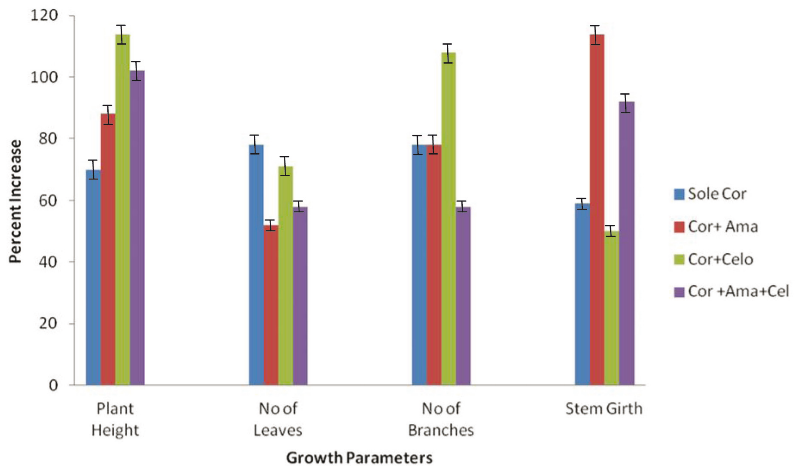

Figure 2. Effect of plant extract (*A. indica*) 250 g dm^{-3} on the growth of *C. olitorius*

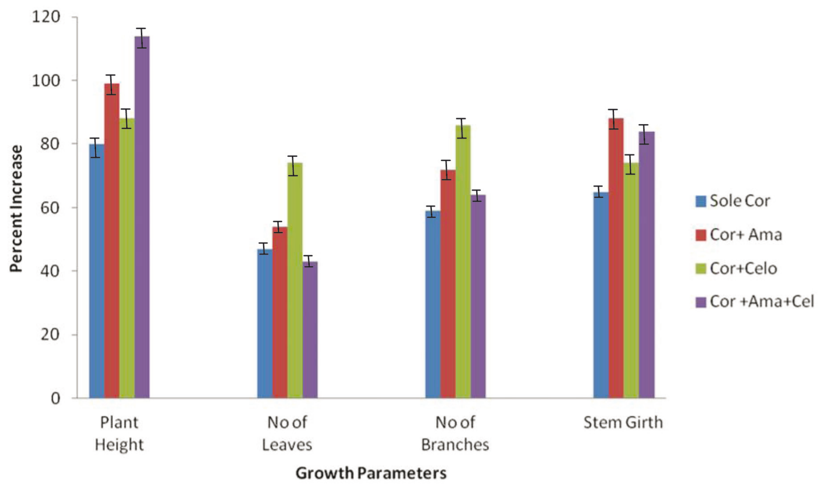

Figure 3. Effect of *P. guineense* (250 g dm^{-3}) on the growth of sole and mixed cropped *C. olitorius*

branches of *C. olitorius* over the entire planting period. Sole cropped *C. olitorius* had the smallest values throughout the period, while Cor + Ama had the highest values at four, five, and seven WAP.

Extract treatment had no effect on the number of branches at four, five, and seven WAP after planting in *C. olitorius* mixed cropped with Ama + Cel (Cor + Ama + Cel); four, five, and six WAP in *C. olitorius* mixed cropped with Cel (Cor + Cel); four and six WAP in *C. olitorius* intercropped with Ama (Cor + Ama); and four and five WAP in sole cropped *C. olitorius*. The highest increase was observed

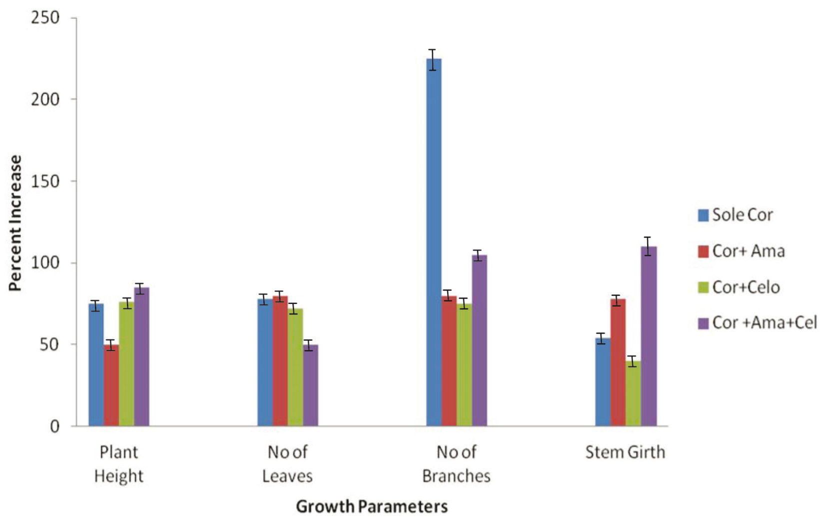

Figure 4. Effect of cypermethrin (0.2% v/v) on the growth of sole and mixed cropped *C. olitorius*

Table 3. Effect of mixed cropping and plant extract on plant height and number of leaves of *C. olitorius* at 4-7 WAP

Parameter	Intercropping model	Biocide	Week 4	Week 5	Week 6	Week 7
Plant height (cm)	*C. olitorius*	Untreated	63.4 c	90.9 c	97.1 b	120.4 d
		A. indica	80.4 f	100.7 d	120.5 f	136.6 f
		P. guineense	75.1 e	96.3 cd	117.3 f	135.0 f
		Cypermethrin	83.1 f	111.3 e	121.4 f	143.5 g
	C. olitorius + *A. hybridus*	Untreated	53.5 b	74.8 ab	90.4 b	109.0 c
		A. indica	65.0 cd	93.4 c	109.4 cd	122.5 de
		P. guineense	60.5 bc	81.7 b	100.2 bc	119.8 d
		Cypermethrin	81.9 f	100.7 d	112.0 de	122.5 de
	C. olitorius + *C. argentea*	Untreated	46.4 a	80.0 b	90.1 b	106.9 b
		A. indica	59.9 bc	102.4 d	109.7 de	128.2 e
		P. guineense	59.1 bc	100.1 d	102.6 cd	109.8 c
		Cypermethrin	75.3 e	103.2 d	116.3 e	129.5 e
	C. olitorius + *A. hybridus* + *C. argentea*	Untreated	42.73 a	69.3 a	76.7 a	92.7 a
		A. indica	66.9 cd	100.0 d	113.6 e	135.0 f
		P. guineense	59.0 bc	91.4 c	104.0 cd	126.5 e
		Cypermethrin	70.9 e	100.5 d	122.6 f	135.7 f
No of leaves	*C. olitorius*	Untreated	58.6 b	69.7 a	94.7 a	80.9 a
		A. indica	70.8 e	100.3 d	99.1 ab	125.9 e
		P. guineense	69.5 de	79.4 b	95.1 a	101.6 b
		Cypermethrin	73.3 e	106.2 e	112.1 de	131.3 f
	C. olitorius + *A. hybridus*	Untreated	62.3 c	79.4 b	99.3 ab	109.1 c
		A. indica	80.8 f	93.5 c	109.6 cd	123.7 e
		P. guineense	74.8 e	86.4 c	101.4 bc	116.3 c
		Cypermethrin	83.5 f	95.1 cd	109.5 cd	155.7 g
	C. olitorius + *C. argentea*	Untreated	48.5 a	86.7 c	104.8 cd	84.0 a
		A. indica	65.0 cd	116.5 f	116.6 e	111.7 c
		P. guineense	62.3 c	93.2 c	106.3 cd	108.3 c
		Cypermethrin	79.8 f	165.6 h	167.7 h	133.7 f
	C. olitorius + *A. hybridus* + *C. argentea*	Untreated	55.9 b	91.9 c	94.1 a	80.1 a
		A. indica	76.5 ef	97.9 d	123.1 f	120.1 de
		P. guineense	72.0 e	99.1 d	116.3 e	103.0 bc
		Cypermethrin	81.1 f	138.2 g	145.1 g	120.6 de

Means followed by different letters in each column for a given trait are significantly different at p = 0.05

Table 4. Effect of mixed cropping and plant extract on number of branches and stem girth of *C. olitorius* at 4-7 WAP

Parameter	Intercropping model	Biocide	Week 4	Week 5	Week 6	Week 7
No of branches	*C. olitorius*	Untreated	7.3 a	12.0 b	15.0 b	16.5 a
		A. indica	12.9 de	16.0 e	21.1 f	23.0 f
		P. guineense	12.0 d	15.3 c	16.8 c	19.1 d
		Cypermethrin	13.4 e	21.6 f	25.7 g	42.9 i
	C. olitorius + *A. hybridus*	Untreated	9.5 c	14.0 c	16.6 c	20.6 e
		A. indica	13.4 e	16.3 e	18.1 d	23.9 f
		P. guineense	12.1 d	14.5 c	18.1 d	20.8 e
		Cypermethrin	15.3 f	16.3 e	18.4 d	27.8 g
	C. olitorius + *C. argentea*	Untreated	8.3 b	12.8 b	16.9 c	17.7 b
		A. indica	10.3 c	17.1 e	18.4 d	21.4 e
		P. guineense	9.9 c	15.4 d	18.2 d	18.2 c
		Cypermethrin	13.2 e	17.3 e	19.4 e	22.9 f
	C. olitorius + *A. hybridus* + *C. argentea*	Untreated	8.3 b	11.5 a	12.4 a	17.5 b
		A. indica	13.4 e	16.5 e	20.7 f	21.0 e
		P. guineense	12.7 d	15.1 c	12.4 a	20.7 e
		Cypermethrin	14.5 f	20.5 f	24.2 g	29.5 h
Stem girth (mm)	*C. olitorius*	Untreated	4.5 d	4.9 a	5.5 b	6.9 b
		A. indica	4.8 d	6.2 ef	7.0 de	7.7 d
		P. guineense	4.5 d	5.3 c	6.7 d	7.5 c
		Cypermethrin	5.4 e	6.4 f	7.1 e	8.2 e
	C. olitorius + *A. hybridus*	Untreated	3.9 ab	4.7 a	5.9 bc	7.4 c
		A. indica	4.3 cd	5.3 c	7.1 e	9.2 ef
		P. guineense	4.2 bc	4.9 ab	6.1 c	7.8 d
		Cypermethrin	5.7 e	5.9 de	7.1 de	10.1 f
	C. olitorius + *C. argentea*	Untreated	3.8 ab	5.1 bc	6.6 d	7.2 c
		A. indica	4.7 d	5.4 c	6.8 d	7.2 c
		P. guineense	4.1 bc	5.2 c	6.7 d	7.1 bc
		Cypermethrin	5.3 e	6.9 g	6.9 de	7.3 c
	C. olitorius + *A. hybridus* + *C. argentea*	Untreated	3.2 a	4.5 a	4.9 a	5.6 a
		A. indica	4.6 d	6.0 e	7.6 f	8.9 e
		P. guineense	4.2 cd	5.5 cd	7.1 de	7.8 d
		Cypermethrin	4.9 d	6.8 g	8.1 g	10.2 f

Means followed by different letters in each column for a given trait are significantly different at $p = 0.05$

in untreated sole cropped *C. olitorius* (125.5%), while the other untreated mixed cropped groups had percentage increases between 111.3-116.2%. Among the extract treated groups (Figs 2 and 3), *A. indica* treated sole *C. olitorius*, Cor + Ama and Cor + Cel had the highest percentage increase (78.3, 78.1 and 107.2%, respectively).

The lowest percentage increase was observed in sole cropped *P. guineense* treated *C. olitorius* (59.5%, Fig. 3) and *A. indica* treated Cor + Ama + Cel (56.7%, Fig. 2). The number of branches was highest in cypermethrin treated Cor + Ama (27.80; 81.3% increase), Cor + Ama + Cel (29; 104.1% increase) and sole cropped Cor (42.9; 220.4%). Stem girth was lower in untreated mixed cropped *C. olitorius*. However, this trend was reversed in the plant extract treated groups. The highest percentage increases were observed in *P. guineense* (sole Cor, 65:6; Cor + Cel, 74.4%), and *A. indica* treated Cor + Ama + Cel. The cypermethrin treated group had significantly higher stem girth than the others (Tab. 4). Table 5 shows the yield of sole and mixed cropped *C. olitorius* treated with plant extracts. Leaf fresh weight (23.9 g), leaf area (168.9 mm^2), shoot weight (54.6 g), marketable yield (87.4 g m^{-2}) and total biomass (64.4 g) were significantly higher in untreated Cor + Ama. The lowest shoot weight (39.4 g), root weight (5.97 g), marketable yield (63.8 g m^{-2}) and total biomass (56.8 g m^{-2}) were obtained in untreated Cor + Ama + Cel. Cypermethrin treated sole and mixed cropped *C. olitorius* had the highest values of all of

Table 5. Effect of mixed cropping and plant extract on yield of *C. olitorius* at 7 WAP

Intercropping design	Biocide	Leaf fresh weight	Leaf area	Shoot weight	Root weight	Marketable yield	Total biomass
C. olitorius	Untreated	18.9 ab	128.1 c	49.5 b	8.7 c	77.8 b	58.9 ab
	A. indica	23.5 d	170.9 f	84.7 f	10.7 e	119.8 g	89.2 g
	P. guineense	19.1 b	162.1 e	59.4 d	9.4 d	87.2 c	70.4 d
	Cypermethrin	29.0 g	216.7 h	85.3 f	11.6 f	125.0 h	96.2 h
C. olitorius + *A. hybridus*	Untreated	23.9 d	168.9 e	54.7 c	8.4 c	87.5 c	64.4 bc
	A. indica	30.5 g	182.1 g	60.8 d	9.4 d	99.4 de	69.0 cd
	P. guineense	24.5 d	167.0 e	59.5 d	9.0 cd	93.6 d	67.9 cd
	Cypermethrin	30.0 g	212.6 lh	64.0 e	11.6 f	105.6 f	77.1 e
C. olitorius + *C. argentea*	Untreated	21.7 c	99.9 a	47.7 b	6.7 ab	76.3 b	57.6 a
	A. indica	26.5 e	190.7 g	67.1 e	10.8 ef	102.8 ef	72.3 d
	P. guineense	24.0 d	141.8 d	52.3 c	6.0 b	87.1 c	63.1 b
	Cypermethrin	29.0 fg	206.9 h	70.1 e	10.9 ef	107.9 f	83.9 f
C. olitorius + *A. hybridus* + *C. argentea*	Untreated	18.4 a	113.1 b	39.4 a	6.0 a	63.8 a	56.8 a
	A. indica	24.3 d	147.7 d	64.1 e	9.7 d	99.6 de	71.7 d
	P. guineense	26.3 e	120.5 b	63.7 e	9.6 d	98.0 d	68.9 cd
	Cypermethrin	28.0 f	171.5 f	82.2 f	13.9 g	124.1 h	111.7 i

Means followed by different letters in each column are significantly different at p = 0.05

Table 6. Efficiency (%) of plant extract concentration in the control of insect pests infesting *C. olitorius*

	Biocide (mg dm^{-3})	Weeks after planting (WAP)			
		4	5	6	7
P. guineense	250	94.0 b ± 6.00	92.7 d ± 7.33	90.3 bc ± 4.91	78.0 bc ± 1.53
	200	86.0 b ± 7.02	78.7 bc ± 12.13	85.0 ab ± 2.08	81.7 bc ± 4.41
	150	51.3 a ± 5.24	23.0 a ± 14.57	42.3 a ± 16.91	58.7 ab ± 9.35
	100	60.7 a ± 7.86	48.0 abc ± 13.65	55.7 ab ± 3.18	47.7 a ± 8.67
A. indica	250	90.7 bc ± 4.70	100.0 d	63.3 ab ± 31.80	94.7 c ± 5.33
	200	92.7 bc ± 7.33	83.0 cd ± 8.50	85.3 ab ± 7.36	100.0 c
	150	70.3 a ± 4.91	45.7 abc ± 15.72	73.0 ab ± 3.46	64.7 ab ± 10.09
	100	72.0 ab ± 14.05	37.0 ab ± 21.50	67.0 ab ± 1.73	59.0 ab ± 9.50
	Synthetic biocide	100.0 c	100.0 d	100.00 c	100.0 c

Means followed by different letters in each column are significantly different at p = 0.05

the evaluated yields. *A. indica* treated sole cropped *C. olitorius*, Cor + Ama and Cor + Cel had significantly higher leaf fresh weight than *P. guineense* treated groups. Amongst the *A. indica* treated groups, mixed cropped Cor had higher values for all of the evaluated yields. The highest percentage increase in leaf fresh weight was obtained in cypermethrin treated sole cropped *C. olitorius* (53.3%) and Cor + Ama + Cel (52.2%), while the lowest increase was observed in *P. guineense* treated sole cropped Cor (1.06%) and Cor + Ama (2.5%). Among the extract treated groups, the highest percentage increase in shoot weight (71%), marketable yield (53.9%) and total biomass (51.5%) was observed in *A. indica* treated sole cropped *C. olitorius*. Tables 6-8 showed the efficiency of *A. indica* and *P. guineense* extracts and mixed cropping in the control of *C. olitorius* insect pests. During both seasons, cropping combinations influenced the infestation and severity of the three leafy vegetable pests. There was reduced pest infestation in the Cor + Ama + Cel mixed crop compared with Cor + Cel and Cor + Ama. Infestation was higher in the sole cropped *C. olitorius*. *Podagrica* sp., *Sylepta* sp. *Dsysdercus* sp., and *Zonocerus* sp. were the most abundant pests in the cropping systems studied. The activity of the extracts against pests infesting sole cropped Cor increased significantly ($p < 0.05$) with increasing extract concentration. The highest efficiency with the use of *P. guineense* was 250 mg dm^{-3} at four, five and six WAP (94, 92.7 and 90.3%, respectively) and 200 mg dm^{-3} at seven WAP (81.6%). With *A. indica* extract, the highest efficiency was

Table 7. Impact of plant extracts and mixed cropping on insect pest abundance of *C. olitorius* depending on the year and time (weeks) after planting (WAP)

	Parameters	2005				2006			
		4	5	6	7	4	5	6	7
Plant extract	Untreated	4.4 c	3.9 c	3.4 c	3.2 c	10.3 c	8.9 d	9.5 c	6.2 c
	A. azadirachta	3.8 bc	2.5 b	1.8 b	1.4 b	5.1 b	2.3 b	1.0 a	0.8 a
	P. guineense	3.1 b	2.4 b	2.1 b	1.7 b	5.9 b	4.7 c	2.2 b	1.4 b
	Cypermethrin	2.3 a	1.3 a	1.1 a	0.8 a	3.9 a	1.3 a	0.8 a	0.8 a
Crop mixtures	Cor.	18.0 c	13.0 c	8.5 b	6.7 c	25.3 d	18.3 c	14.9 c	10.9 d
	Cor + Ama	10.9 a	8.7 b	7.0 ab	6.3 c	17.0 b	12.0 b	10.7 b	7.6 c
	Cor + Cel	12.3 b	7.7 a	6.3 a	5.7 b	19.7 c	12.3 b	9.2 b	5.0 b
	Cor + Cel + Ama	9.9 a	8.8 b	6.6 a	4.2 a	10.9 a	8.3 a	6.9 a	3.3 a

Means followed by different letters in each column for a given trait are significantly different at p = 0.05
Ama – *A. hybridus*, Cel – *C. argentea,* Cor – *C. olitorius*

Table 8. Pearson correlation matrix showing the relationship between extract efficiencies at 4-7 WAP and *Piper guineense* or *Azadirachta indica* extract concentration

	Extract (mg dm^{-3})	Time	Extract concentration (mg dm^{-3})			
			250	200	150	100
P. guineense	250	0.89	1.00			
	200	0.26	-0.22	1.00		
	150	-0.35	0.60	-0.58	1.00	
	100	0.64	-0.59	-0.90	-0.27	1.00
A. indica	250	0.19	1.00			
	200	-0.41	-0.28	1.00		
	150	-0.11	0.70	-0.39	1.00	
	100	0.08	0.56	-0.42	-0.97	1.00

observed with the use of 200 mg dm^{-3} at four, six and seven WAP (92.7, 85 and 100%, respectively). 250 mg dm^{-3} *A. indica* extract treatment gave the highest efficiency at five WAP (100%). Results in Table 8 show that the activity of *P. guineense* at 100 and 250 mg dm^{-3} is time-dependent (WAP) with r (Pearson correlation coefficient) values 0.64 and 0.89, respectively. Results obtained with *A. indica* extracts suggest that the activity of *A. indica* extract is independent of time of application (whether four, five, six, or seven WAP) with the use of 100, 150 and 250 mg dm^{-3} (r = 0.08, 0.11 and 0.19, respectively). Low r values indicate little or no relationship between the parameters studied. A strong positive relationship was observed between percent efficiency and application times (WAP) in *P. guineense* treated Cor.

DISCUSSION

Growth, development and yield of Corchorus olitorius under sole and mixed cropping

The significantly higher plant height of *C. olitorius* in sole cropping compared to mixed may be due to reduced competition for sunlight; hence, enough photosynthetic surfaces would be available to promote an increase in height (Adebayo and Akoun 2002). The number of leaves/plant in the mixed samples were significantly higher than in the sole because *C. olitorius* had higher height amongst the mixtures and tall plants have a faster rate of growth because they are less affected by the shading effect of neighbouring plants. These plants were thus able to trap the active radiation portion of the solar spectrum for photosynthesis more effectively. The height advantage further ensured the competitiveness of *C. olitorius* and subsequently its yield. The enhanced edible yield (leaves only) obtained in the mixed compared to sole cropping suggests that *C. olitorius* was able to compete with the neighbouring plants for available water, nutrients and light and able to utilize it effectively. In addition, the increased number of leaves is synonymous with an increased photosynthetic area and thus greater photosynthetic production, which translates into higher yield (Ibrahim 2002). Chowdury (1988) showed that the net returns from mixed crops of okra/ginger were higher than their monocrops. Ojeifo and Lucas (1987) reported that *C. olitorius* could be conveniently intercropped with another crop without adverse competition for incoming light. The impressive results obtained with mixed cropped *C. olitorius* are consistent with recent reports that mix cropping increases the size and stability of yields compared to sole cropping (Hauggard-Nielsen et al. 2006). Yield advantage of crops in mixtures often accrues from the capacity of the component species to increase the capture and use of biophysical resources relative to that achievable by growing the crops separately (Jahansooz et al. 2007). Yield increases with intercropping are associated with complimentary effects, better resource use efficiency and the buffering effects of the mixtures against diseases and weeds (Anil et al. 1998, Dapaah et al. 2003).

Growth, development and yield of Corchorus olitorius as affected by plant extract

There were improvements in the growth of *C. olitorius* treated with aqueous plant extracts. This may be due to a reduction in insect pests or the percentage infestation by the pests or both. The vegetables treated with plant extracts grew taller and had more leaves compared with the untreated control plants. The number of leaves/plant in the *A. indica* and *P. guineense* treated plants were higher than in the control. The results were comparable to those obtained for cypermethrin treated plants. This may be due to better protection from the various vegetable insect pests by the plant extracts. *A. indica* treated mixed cropped *C. olitorius* had higher values for edible yield and leaf area, which suggests that yield was influenced primarily by the level of competition with the neighbouring plants for available water, nutrients and light, which corroborate the findings of Montes-Molina (2008) in which mean yield was significantly higher in *A. indica* treated maize. The results from this research agreed with the findings of various authors on the efficacy of aqueous *A. indica* extract in reducing insect and pest damage in field crops (Mojumder et al. 2002, Javed et al. 2008).

Growth and development of Corchorus olitorius as affected by mixed cropping and plant extracts

The interaction effect of mixed cropping and plant extract treatment showed a strong positive relationship with the growth and yield parameters of *C. olitorius*. The strong performance with the treatment combination suggests that benefits associated with the use of the plant extracts and mixed cropping are complementary. While mixed cropping may enhance more efficient nutrient utilisation, plant extract treatment might have created an environment not suitable for insect growth and proliferation. The cropping system impacts soil properties, and by extension, their ability to support a good crop yield (Liebig et al. 2004, Hauggaard-Nielsen et al. 2006, Jagadamma et al. 2008). A combination of other factors, namely tillage, crop sequence and cropping intensity, influence soil quality indicators and yield parameters (Liebig et al. 2004). Better resource use efficiency and the buffering effects of the plant extracts against diseases and weeds may have accounted for the increased yield in mixed cropped field crops (Anil et al. 1998). The use of these plant extracts thus has potential for use for improving the growth and yield performance of *C. olitorius*.

Insect pest abundance under sole and mixed cropping

Findings from this study support the general view that cropping systems have a reducing influence on insect pest infestations and associated crop damage. Mixed cropping of Cor + Ama + Cel reduced pest infestation in comparison to Cor + Cel, Cor + Ama or Ama + Cel. On the other hand, sole cropping increased the pest density on the vegetables. The most abundant insect pests associated with the crops studied were *Podagrica* sp., *Sylepta* sp., *Dsysdercus* sp., and *Zonocerus* sp. The incidences of these insect pests were significantly reduced in mixedcropped *C. olitorius.* This is consistent with previous studies by Ogbalu et al. (2005) and Akinlosotu (1983). Ogenga-Latigo et al. (1992) demonstrated that intercropping beans with closely spaced maize reduced the incidence of *A. fabae* on beans. Similarly¸ Sinthanantham et al. (1990) observed a lower incidence of bean aphid on beans intercropped with maize than on sole cropped beans. Also, Edema et al. (1997) reported that aphid infestation was lower on intercropped than sole cropped cowpea.

Insect pest abundance as affected by plant extracts

The results of this study confirmed the insect control characteristics of the plants screened. The insect infestation rate was lower in sole and mixed cropped *C. olitorius* sprayed with aqueous plant extracts. *A. indica* and *P. guineense* extracts were effective in protecting the crops from the various insect pests, with values comparable to the synthetic insecticide (Cymbush^{R}) used as a positive control. The presence of components capable of influencing the physiology and behaviour of a wide range of insects, mites and nematodes in *A. indica* and *P. guineense extracts* (Dhar et al. 1998, Schaaf et al. 2000, Ngono Ngane et al. 2003) may explain their efficacy in the control of insect pests infesting the vegetables studied. The major biologically active components reported in *A. indica* and *P. guineense* include: azadirachtin, triterpenoids, piperolein acids, salanine, nimbidin, guineensine, essential oils, sterols and amides, amongst others (Martins et al. 1998, Schaaf et al. 2000, Siddiqui et al. 2000, Muse et al. 2003, Ngono Ngane et al. 2003, Gopal et al. 2007). These components suppress some of the insects' desire for food and destroy eggs and immature insects.

CONCLUSIONS

1. Mixed-cropped *C. olitorius* had better growth and yield parameters than its sole-cropped counterpart.
2. Mixed cropping and plant extract sprays interacted positively to control insect pests and enhance yield.
3. The use of an aqueous extract of *A. indica* bark and *P. guineense* seed at concentrations ≥ 200 g dm^{-3} may give effective protection against insect pests infesting these vegetables and enhanced growth and yield comparable with the use of synthetic insecticides.

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