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Field Efficacy of Neem Seed Oil and Diazinon in the Management of Sweetpotato Weevil, *Cylas puncticollis* (Boh.) in South-eastern Nigeria

Collins N. Ehisianya[1], Donald A. Ukeh[2], Musa D. Isah[2], Ndowa E. S. Lale[3] & Ododika C. Umeozor[4]

[1] Sweetpotato Research Programme, National Root Crops Research Institute, Umuahia, Abia State, Nigeria

[2] Department of Crop Science, University of Calabar, Calabar, Nigeria

[3] Department of Crop and Soil Science, University of Port-Harcourt, Rivers State, Nigeria

[4] Department of Environmental and Animal Biology, University of Port-Harcourt, Rivers State, Nigeria

Correspondence: Donald A. Ukeh, Department of Crop Science, University of Calabar, Calabar, Nigeria. Tel: 234-80-510-721-20. E-mail: donald.ukeh@yahoo.co.uk

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Abstract

The efficacy of the pre- and post-planting application of neem seed oil (NSO) or/and diazinon and time of harvest for the control of sweetpotato weevil, *Cylas puncticollis* (Boh.) was evaluated during the 2009 and 2010 cropping seasons. Forty-eight plots of 3 x 4 m^2 each were demarcated and 240 sweetpotato (var. TIS2532.op.1.13) vine cuttings were dipped into 0, 30 and 50 mls NSO and 30 mls of diazinon (60 EC) mixed in 2 and 10 litre soapy water, respectively and kept for 30 mins before planting. Similar treatment was also basally applied post-planting at 1MAP. In 2009, results showed that treatments (NSO or diazinon or their combinations) did not significantly influence percentage plant stand at harvest in both years, but lower percentage plant stands were obtained at 6 MAP (47.72%) than at 5MAP (56.87%). Significantly higher mean total weights of 34.44 t/ha was obtained in 2009 and 8.99 t/ha in 2010 respectively. Similarly, yield ranged from as high as 53.69 t/ha at 5MAP in 2009 to as low as 5.51t/ha at 6MAP in 2010. Significantly lower attributes of *C. puncticollis* as a pest were obtained in 2009 than in 2010. Treatments significantly suppressed root damage from 68.59% (Pr0Pt0) to 44.38% (Pr3Pt3) at 5 to 6MAP. Time of application was significant as 50 mls of NSO applied pre- and post-planting gave highest (35.30%) control of the pest at harvest.

Keywords: infestation, *Cylas puncticollis,* diazinon, neem seed oil, severity score, sweetpotato

1. Introduction

Sweetpotato, *Ipomoea batatas* L. (Lamarck) is a low labour, low cost and low risk crop (Kennedy, 2002), with the potential for yield improvement and year-round availability (Edison et al., 2009). It can be eaten boiled, fried or roasted and converted to canned or pureed form to enhance the shelf life. Its vines and leaves are used for human and animal consumption (Kimber, 1972). Recently, the crop has come to be appreciated as high fibre food and as green vegetable because of high levels of vitamin A, vitamin C, iron and potassium (Loebensein, 2009). The clamour for orange-fleshed sweetpotato (OFSP) is due mainly to the nutritional and health advantages in its high vitamin A content.

Despite the importance of sweetpotato to the subsistence economy, growth in output in the last three decades was accounted for by increase in land area (Ojiako, 2008) than by increase in yield. This could be attributed to a major biotic constraint to its production and utilization worldwide identified by farmers as *Cylas* species of which *Cylas puncticollis* (Boh.) (Coleoptera: Brentidae) and *C. brunneus* (Fab.) are confined to Africa (Chalfant et al., 1990; Lenne, 1991; Wolfe, 1991). Studies by Nwana (1979) and Ehisianya et al. (2011) have shown that they are a major production constraint in Nigeria, with losses due to sweetpotato weevil damage range from 1-100%. Thematic survey of sweetpotato production, utilization and marketing in the South Eastern Nigeria shows that farmers grow the crop twice a year and practice the so-called in-ground storage and piece-meal harvesting (Ehisianya et al., 2011). This enables the presence of the crop in the field throughout the year, thereby providing a suitable environment for the weevil population growth. The pests infest all plant parts; roots, stems,

foliage, and flowers seeds (Edison et al., 2009). Larval feeding in the stems at times can be substantial; the role of this feeding in yield reduction has produced contradictory results (Lema& Hahn, 1987; AVRDC, 1991), but extensive damage to root (Stathers et al., 2003) can lead to a complete loss.

Progress in breeding weevil resistant cultivars has been slow because the heritability of the trait (Kreuze et al., 2009) is extremely low. Consequently, varieties with immunity or a high level of resistance are not yet available (Collins et al., 1991) despite the progress in finding weevil resistant components in some varieties (Stevenson et al., 2009).

Reports show that chemical control in the field can reduce weevil populations (Muruyanda et al., 1986: Edmunds et al., 2008), although chemical insecticides may not adequately control weevils because of the cryptic nature of immature developing within vines and roots. Several other factors such as their limited flying activity which implies that the insect is carried from place to place via movement of plant materials; their host specificity of the genus *Ipomoea*, weevil preference for oviposition in the absence of root, in older vines and their characteristic mode of entry and damage to plant, make sweetpotato weevils vulnerable to effective control by integration of simple cultural practices such as clean cultivation, the use of tender vine cuttings for planting a new crop and timely planting and prompt harvesting to avoid dry period. According to Smit (1997), the practice of piecemeal harvesting has a positive effect on the control of weevil infestation.

Diazinon (Diazol 60 EC) is one of the world widely used insecticide for agricultural pest control (U.S.G.S, 2001) and it is classified as moderately toxic, depending on the formulation (Extension Toxicology Network, 1996). Neem-based pesticides are easy to prepare, cheap and highly effective, providing a long term protection (Emosairue & Ukeh, 1996; Umoetok et al., 2009) to plants against pest and constitute an important source of pesticide (Brahmachari, 2004) for economically poor third world country farmers.

Only in the last decade has the crop been the focus of an intense, coordinated, global effort to realize its full potential as a source of food, feed, processed products, and income for millions of small farmers and low-income consumers in Africa, Asia, and Latin America. The objectives of this study were to determine the efficacy of integrating neem seed oil and Diazinon, and time of application in the management of *C. puncticollis*.

2. Materials and Methods

Field trial was conducted to determine the efficacy of diazinon and neem seed oil for the control of *C. puncticollis* at the research farm of National Root Crops Research Institute (NRCRI), Umudike (Latitude 05° 29°N, Longitude 07° 33°E and Altitude 122m above sea level and altitude 1231.6m above sea level) during the 2009 and 2010 cropping seasons. The trial was laid out in a randomized complete block design with sweetpotato cv. TIS2532.op.1.13, neen seed oil (0, 30 and 50 mls), and diazinon (30 mls). Treatments were mixed in 2 and 10 litres of soapy water, respectively and replicated three times. Preparation of soap emulsifier was done by weighing and dissolving 20g of toilet soap (Ajayi et al., 1999) in 5 litres of water. Ten vines were planted on a ridge of 3 m with two ridges in a plot at a space of 0.3m between plants, 2 m between plots and 2 m between blocks. Weeding was done manually at 4WAP and rouging at 8 and 10 WAP after which Fertilizer (NPK, 15:15:15) was applied at the rate of 400 kg/ha. Banded application method was used for post-treatments because Chalfant et al. (1987) reported that it provide a better control.

At harvest, five and six months after planting MAP, roots were sorted and graded. The numbers and weights of total and marketable (≥100g) (Levett, 1993) roots (yield) at harvest were determined (ha^{-1}). Count data such as *C. puncticollis* adults, immature and total progeny numbers were transformed to square root values, whereas data in percentages were transformed to arcsine values. This was done to improve the normality of variable (variance stability) after which data obtained were subjected to analysis of variance using SAS GLM procedure. Treatment means were separated using Sudentized Newman Keul's (SNK) test (P=0.05).

Mean number of roots/hectare = (X_2 divided by X_1) multiplied 33333,333

Mean weight of roots/hectare (tonnes) = [(W_1 divided by X1) multiplied 33333, 333] divided by 1000

Where, 0.3x1m = 33333,333 plant per hectare, X_1 = number of plant per plot at harvest, X_2 = number of roots per plot at harvest and W_1 = weight of root per plot at harvest.

Percentage infestation = (number of infested roots per plot divided by the number of total roots harvested per plot multiplied by 100), while percentage damage = (weight of infested roots per plot divided by weight of total roots harvested per plot multiplied by 100).

Severity of root (n=5) damage per plot was assessed using a five-point score, where 1 = 0%; 2 = 1-25%; 3 = 26-50%; 4 = 51-75%; 5 = ≥75% (Stathers et al. 2003).

Percentage control = Percentage damage of check (Pr0Pt0) minus percentage damage of treatment divided by percentage damage of control) multiplied by 100

Treatments were:

Pr0 =Pre- Planting Application of Control

Pr1 = Pre- Planting Application of Diazinon EC (30 mls)

Pr2 = Pre-Planting Application of Neem Seed oil EC (30 mls)

Pr3= Pre-Planting Application of Neem Seed oil EC (50 mls)

Pt0 = Post-Planting Application of Control

Pt1= Post-Planting Application of Diazinon EC (30 mls)

Pt2 = Post-Planting Application of Neem Seed oil (30 mls)

Pt3= Post-planting application of Neem Seed oil EC (50 mls)

3. Results

Meteorological data obtained during the field trial is presented in Table 1 and showed that monthly rainfall in Umudike had a characteristic bi-modal rainfall distribution with peaks in major and minor farming seasons: May and October in 2009, June and August in 2010. The mean monthly temperature ranged from 26.0-29.0ºC in 2009 and 26.15-29.40ºC in 2010.

Table 1. Mean rainfall (mm), temperature (ºC) and relative humidity (%) of Umudike, Abia State during the field trial

	2009			2010		
Months	Rain(mm)	Temp.ºC	R.H (%)	Rain(mm)	Temp.ºC	R.H (%)
January	62.8	28	61.5	0	28.6	60.75
February	62.8	29	67	78.2	29.4	62.55
March	47.8	29	67	34.1	29.25	65.2
April	100.5	28	67	129	29.3	69.45
May	416.2	28	75	213.3	28.45	76.9
June	237.6	27	77.5	427	26.75	82.3
July	306.3	26	82.5	310.2	26.3	81.6
August	287.4	26	83	376.2	26.25	82.75
September	205.5	26	79	303.3	26.15	82
October	311.1	27	77	34.9	26.8	82.15
November	237	27	66	77.8	27.15	79.25
December	0	28.5	62.5	0	27.25	62.1

Source: Meteorological unit, NRCRI, Umudike, 2010.

The result indicated that there were no significant treatments ($P > 0.05$) differences among the treatment combination in the mean percentage plant stand at 6 MAP in 2009, 5 MAP and 6 MAP in 2010. But in 2009, there was a significant difference ($P < 0.05$) among treatments at 5 MAP in (Table 2). Analyses of variance showed no significant difference among treated roots with respect to percentage infestation at 5MAP in both years. Values ranged from 5.59 (Pr3Pt3) to 30.96 (Pr0Pt0) in 2009 and 56.40 (Pr3Pt1) to 69.49 (Pr1Pt3) in 5MAP of 2009 and 2010 respectively. At 6MAP in 2009 however, control (Pr0pt0) was significant higher than Pr3Pt3, but not with others. The trend for percentage damage was similar to that of infestation. As significant differences among treatments were only observed at 6MAP in 2009. High percentage damage to sweetpotato roots recorded in roots treated with Pr0Pt0 (75.28), Pr0Pt1 (72.57), Pr1Pt0 (66.19) and Pr1Pt2 (61.85). Moderate damage were recorded on the other roots and they differ significantly from Pr3Pt3 (12.29) (Table 3). Analysis of variance showed no significant ($P \leq 0.05$) treatment differences in the mean *C. puncticollis* severity score of roots at 5MAP in both years. At 6MAP, high score values were obtained from Pr0Pt0, Pr0Pt1, Pr0Pt3, Pr2Pt3,

although not significantly different from Pr1Pt0, Pr2Pt1, Pr2Pt2, Pr1Pt1, Pr1Pt3 and Pr2Pt0, but significantly ($P < 0.05$) different from Pr0Pt2, Pr3Pt2, Pr3Pt1 and Pr2Pt3 (1.67). However, there were no significant ($P > 0.5$) differences in treated root scores in 2010 (Table 4). In all treated sweetpotato plots, there were no significant differences in number of *C. puncticollis* total progeny in roots harvested 5 and 6MAP in both years, excerpt in 6MAP of 2009. The control (Pr0Pt0) gave significantly ($P < 0.05$) higher number of total progeny than others, excerpt for Pr3Pt0, Pr3Pt2, Pr3Pt1 and Pr3Pt3 (Table 4). Table 5 presents the mean number of immature and adult *C. puncticollis* in treated roots harvested 5 and 6 MAP in 2009 and 2010. Roots harvested at 5MAP in both years showed no significant differences ($P > 0.05$) in the number of weevils. However at 6MAP in 2009, significant treatment differences ($P < 0.05$) were observed in the numbers of immature and adults in dissected roots. The control plots (Pr0Pt0) did not significantly differ from the others, but was significantly lower than plots treated pre-planting with 50 mls of NSO. The results based on combined data of two years showed significant differences ($P < 0.05$) in the percentage of root and damaged by *C. puncticollis*. Sweetpotato roots treated with Pr0Pt0 had 68.59%, followed by Pr1Pt0 (59.56%), while Pr3Pt3 (44.38%) was the least damaged, respectively. The trend in percentage control by treatments was similar to damage as Pr3Pt3 gave highest control of 35.30%, but was not significantly different from other, excerpt the Pr0Pt0 (0.00%) (Table 6). Data also indicated that there were significantly ($P \leq 0.05$) higher numbers and weights of total (34.44 and 8.99t/ha) and marketable (33.66 and 8.74t/ha) sweetpotato roots harvested in 2009 than in 2010 (Table 7). In 2010, *C. puncticollis* attributes namely: damage (76.10 and 30.45) and severity score (3.75 and 2.55) values were significantly ($P \leq 0.05$) higher than 2009, except total progeny numbers (137 to 86.2). The time of harvest showed no significant ($P > 0.05$) treatment differences in the mean number of total and marketable sweetpotato roots harvested at 5 MAP (47726.00 and 39208.00) and at 6MAP (46676.00 and 38722.00), whereas, significantly lower weights of total and marketable sweetpotato roots were harvested at 6MAP (18.60 and 18.08t/ha) than at 5MAP (24.84 and 24.32t/ha). Sweetpotato roots harvested 5MAP was significantly lower when compared with roots harvested 6MAP in respect of root percentage infestation, severity score, adult and immature numbers respectively.

Table 2. Effect of treatment combinations and time of harvest on mean percentage of sweetpotato (var. TIS2532.op.1.13) plant stand at harvest in 2009 and 2010

Treatment combinations	2009		2010	
	5MAP	6MAP	5MAP	6MAP
Pr0Pt0	56.36[ab]	46.00[a]	70.08[a]	51.84[a]
Pr0Pt1	73.40[a]	62.29[a]	76.26[a]	45.85[a]
Pr0Pt2	49.33[ab]	45.00[a]	56.71[a]	45.00[a]
Pr0Pt3	53.73[ab]	45.00[a]	56.25[a]	40.96[a]
Pr1Pt0	51.84[ab]	46.98[a]	59.33[a]	43.08[a]
Pr1Pt1	62.91[ab]	54.83[a]	66.84[a]	50.77[a]
Pr1Pt2	58.36ab	42.91[a]	52.80[a]	43.85[a]
Pr1Pt3	67.91[ab]	54.33[a]	53.85[a]	50.62[a]
Pr2Pt0	59.00[ab]	44.52[a]	61.22[a]	49.05[a]
Pr2Pt1	56.15[ab]	45.96[a]	54.82[a]	48.90[a]
Pr2Pt2	55.81[ab]	46.98[a]	57.72[a]	54.78[a]
Pr2Pt3	59.06[ab]	41.63[a]	47.91[a]	42.09[a]
Pr3Pt0	40.08[ab]	44.01[a]	65.62[a]	52.60[a]
Pr3Pt1	47.60[ab]	44.83[a]	56.15[a]	45.96[a]
Pr3Pt2	50.00[ab]	49.92[a]	53.93[a]	54.36[a]
Pr3Pt3	32.09[ab]	47.09[a]	57.62[a]	45.06[a]

Means within a column followed by the same letter do not differ significantly from each other ($P > 0.05$; SAS, PROC GLM, SNK).

Table 3. Effect of treatment combinations and time of harvest on mean percentage *Cylas puncticollis* infestation and damage to sweetpotato (var. TIS2532.op.1.13) roots in 2009 and 2010

Treatment combination	Infestation (%)				Damage (%)			
	2009		2010		2009		2010	
	5MAP	6MAP	5MAP	6MAP	5MAP	6MAP	5MAP	6MAP
Pr0Pt0	30.96[a]	76.51[a]	59.39[a]	90.00[a]	39.52[a]	75.28[a]	69.55[a]	90.00[a]
Pr0Pt1	11.15[a]	62.05[ab]	59.27[a]	83.51[a]	14.94[a]	72.57[a]	64.03[a]	86.71[a]
Pr0Pt2	14.90[a]	46.69[ab]	58.79[a]	90.00[a]	17.18[a]	50.27[ab]	67.94[a]	90.00[a]
Pr0Pt3	13.89[a]	48.21[ab]	58.73[a]	90.00[a]	15.79[a]	45.53[ab]	65.71[a]	77.85[a]
Pr1Pt0	14.13[a]	59.90[ab]	58.95[a]	77.01[a]	15.94[a]	66.19[a]	61.74[a]	85.07[a]
Pr1Pt1	9.92[a]	48.39[ab]	62.98[a]	85.17[a]	16.70[a]	52.28[ab]	68.71[a]	87.26[a]
Pr1Pt2	13.55[a]	63.70[ab]	62.62[a]	90.00[a]	16.02[a]	61.85[a]	68.93[a]	90.00[a]
Pr1Pt3	15.16[a]	45.68[ab]	69.49[a]	90.00[a]	15.96[a]	40.60[ab]	72.63[a]	87.73[a]
Pr2Pt0	10.91[a]	47.29[ab]	59.73[a]	90.00[a]	9.02[a]	42.21[ab]	61.39[a]	90.00[a]
Pr2Pt1	16.42[a]	50.55[ab]	62.27[a]	82.86[a]	17.33[a]	53.72[ab]	64.89[a]	87.57[a]
Pr2Pt2	8.52[a]	57.41[ab]	57.64[a]	75.00[a]	8.90[a]	57.64[ab]	56.44[a]	82.62[a]
Pr2Pt3	6.62[a]	40.90[ab]	58.29[a]	83.10[a]	3.52[a]	28.39[ab]	65.44[a]	87.59[a]
Pr3Pt0	11.62[a]	29.24[ab]	58.69[a]	75.00[a]	13.73[a]	30.76[ab]	70.89[a]	81.14[a]
Pr3Pt1	15.88[a]	27.89[ab]	56.40[a]	76.75[a]	11.12[a]	29.29[ab]	60.01[a]	84.91[a]
Pr3Pt2	8.86[a]	26.74[ab]	58.48[a]	84.15[a]	7.00[a]	25.40[ab]	63.87[a]	86.80[a]
Pr3Pt3	5.59[a]	14.72[b]	60.00[a]	90.00[a]	7.60[a]	12.29[b]	67.65[a]	90.00[a]

Means within a column followed by the same letter do not differ significantly from each other ($P > 0.05$; SAS, PROC GLM, SNK).

Data were transformed to arc sine √x prior to analysis.

Table 4. Effect of treatment combinations and time of harvest on mean *Cylas puncticollis* severity score (1-5) and total progeny in sweetpotato (var. TIS2532.op.1.13) roots in 2009 and 2010

Treatment combination	Severity score				Total progeny			
	2009		2010		2009		2010	
	5MAP	6MAP	5MAP	6MAP	5MAP	6MAP	5MAP	6MAP
Pr0Pt0	3.00[a]	5.00[a]	3.67[a]	5.00[a]	9.02[a]	24.51[a]	12.54[a]	9.01[a]
Pr0Pt1	2.67[a]	4.33[ab]	2.67[a]	4.67[a]	6.38[a]	22.57[ab]	12.96[a]	7.34[a]
Pr0Pt2	2.00[a]	3.00[bc]	3.00[a]	4.33[a]	3.82[a]	15.55[abc]	7.85[a]	7.80[a]
Pr0Pt3	2.00[a]	3.67[abc]	3.00[a]	4.67[a]	4.44[a]	16.27[abc]	7.87[a]	6.98[a]
Pr1Pt0	2.33[a]	3.33[abc]	3.00[a]	4.33[a]	5.48[a]	18.28[abc]	8.02[a]	7.66[a]
Pr1Pt1	2.00[a]	3.00[bc]	3.33[a]	4.33[a]	3.65[a]	15.23[abc]	9.36[a]	6.20[a]
Pr1Pt2	2.67[a]	3.00[bc]	3.00[a]	4.00[a]	5.11[a]	16.05[abc]	8.35[a]	7.73[a]
Pr1Pt3	2.33[a]	2.67[bc]	3.00[a]	4.67[a]	5.03[a]	15.55[abc]	9.90[a]	7.59[a]
Pr2Pt0	2.00[a]	2.67[bc]	3.00[a]	4.67[a]	4.52[a]	13.42[abc]	12.31[a]	7.92[a]
Pr2Pt1	2.00[a]	3.33[abc]	2.67[a]	4.67[a]	3.50[a]	15.57[abc]	10.67[a]	8.27[a]
Pr2Pt2	1.67[a]	3.33[abc]	2.67[a]	4.00[a]	3.50[a]	14.29[abc]	10.54[a]	9.88[a]
Pr2Pt3	1.67[a]	3.67[abc]	3.67[a]	4.33[a]	2.31[a]	11.35[abc]	10.45[a]	7.69[a]
Pr3Pt0	1.67[a]	2.00[c]	3.00[a]	4.67[a]	3.61[a]	9.46b[c]	10.04[a]	5.39[a]
Pr3Pt1	1.67[a]	2.00[c]	2.67[a]	4.67[a]	2.08[a]	7.26[c]	11.15[a]	7.48[a]
Pr3Pt2	1.67[a]	2.33[c]	2.67[a]	4.67[a]	3.51[a]	8.71b[c]	7.21[a]	10.18[a]
Pr3Pt3	1.33[a]	1.67[c]	3.00[a]	4.33[a]	1.11[a]	4.41[c]	10.31[a]	8.65[a]

Data (Progeny) were transformed to square root (x+c) **0.5 prior to analysis.

Table 5. Effect of treatment combinations and time of harvest on mean number of immature and adult *Cylas puncticollis* in sweetpotato (var. TIS2532.op.1.13) roots in 2009 and 2010

Treatment combination	Immature				Adult			
	2009		2010		2009		2010	
	5MAP	6MAP	5MAP	6MAP	5MAP	6MAP	5MAP	6MAP
Pr0Pt0	8.31[a]	22.12[a]	11.13[a]	6.16[a]	3.47[a]	10.43[a]	5.74[a]	6.51[a]
Pr0Pt1	5.82[a]	20.40[ab]	11.20[a]	4.44[a]	2.58[a]	9.60[ab]	6.45[a]	5.84[a]
Pr0Pt2	3.46[a]	14.04[abc]	7.12[a]	6.01[a]	1.58[a]	6.64[abcd]	3.24[a]	4.97[a]
Pr0Pt3	4.18[a]	14.45[abc]	7.23[a]	4.96[a]	1.49[a]	7.37[abcd]	3.09[a]	4.54[a]
Pr1Pt0	5.12[a]	16.62[abc]	7.13[a]	5.45[a]	1.80a	7.53[abc]	3.67[a]	5.23[a]
Pr1Pt1	3.50[a]	13.91[abc]	8.30[a]	4.33[a]	0.82[a]	6.10[abcd]	4.21[a]	4.36[a]
Pr1Pt2	4.37[a]	14.66[abc]	7.31[a]	5.74[a]	2.43[a]	6.52[abcd]	3.90[a]	5.15[a]
Pr1Pt3	4.92[a]	14.28[abc]	8.89[a]	5.62[a]	0.80[a]	6.08[abcd]	4.31[a]	5.08[a]
Pr2Pt0	4.14[a]	12.49[abc]	11.41[a]	5.15[a]	1.79[a]	4.84[bcd]	4.60[a]	5.98[a]
Pr2Pt1	3.50[a]	14.01[abc]	9.59[a]	6.08[a]	0.00[a]	6.67[abcd]	4.65[a]	5.52[a]
Pr2Pt2	3.33[a]	13.11[abc]	9.41[a]	7.09[a]	1.05[a]	5.66[abcd]	4.74[a]	6.84[a]
Pr2Pt3	2.00[a]	10.65[abc]	9.57[a]	6.19[a]	1.15[a]	3.81[cd]	4.16[a]	4.55[a]
Pr3Pt0	3.54[a]	8.96[bc]	9.38[a]	3.60[a]	0.47[a]	3.00[cd]	3.56[a]	3.98[a]
Pr3Pt1	2.08[a]	6.69[c]	10.03[a]	4.78[a]	0.00[a]	2.78[cd]	4.81[a]	5.72[a]
Pr3Pt2	3.27[a]	8.14[bc]	6.55[a]	7.75[a]	1.20[a]	3.08[cd]	2.97[a]	6.60[a]
Pr3Pt3	1.11[a]	4.10[c]	9.55[a]	7.11[a]	0.00[a]	1.63[d]	3.57[a]	4.86[a]

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

Data were transformed to arc sine √x prior to analysis.

Table 6. Effect of treatment combinations and time of harvest on mean percentage damage to sweetpotato (var. TIS2532.op.1.13) roots by *Cylas puncticollis* and control based on combined data from two years

Treatment combination	Damage (%)			Control (%)		
	5MAP	6MAP	Mean	5MAP	6MAP	Mean
Pr0Pt0	54.54	82.64	68.59[a]	0	0	0.00
Pr0Pt1	39.48	79.64	59.56[ab]	27.61	3.63	13.17
Pr0Pt2	42.56	70.13	56.35[ab]	21.97	15.14	17.85
Pr0Pt3	40.75	61.69	51.22[b]	25.28	25.35	25.32
Pr1Pt0	38.84	75.63	57.24[ab]	28.79	8.48	16.55
Pr1Pt1	42.7	69.77	56.24[ab]	21.71	15.57	18.01
Pr1Pt2	42.47	75.93	59.20[ab]	22.13	8.12	13.69
Pr1Pt3	44.3	64.16	54.23[ab]	18.78	22.36	20.94
Pr2Pt0	35.21	66.1	50.66[b]	35.4	20.01	26.14
Pr2Pt1	41.11	70.64	55.88[ab]	24.62	14.52	18.53
Pr2Pt2	32.67	70.13	51.40[b]	40.1	15.14	25.06
Pr2Pt3	34.48	57.99	46.24[b]	36.78	29.83	32.59
Pr3Pt0	42.31	55.95	49.13[b]	22.42	32.3	28.37
Pr3Pt1	35.56	57.1	46.33[b]	34.8	30.91	32.45
Pr3Pt2	35.44	56.1	45.77[b]	35.02	32.12	33.27
Pr3Pt3	37.62	51.14	44.38[b]	31.02	38.12	35.30

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

Data (Damage) were transformed to square root (x+c) **0.5 prior to analysis.

Table 7. Effect of year and time of harvest on yield and *Cylas puncticollis* attributes of treated sweetpotato (var. TIS2532.op.1.13) roots based on combined data from two years

Attribute	Year			Time of harvest		
	2009	2010	LSD	5MAP	6MAP	LSD
Root yield						
Total root number (ha^{-1})	61567	32835	4993.2	47726	46676	7061.5
Total root weight (t/ha)	34.44	8.99	2.88	24.84	18.6	2.88
Marketable root number (ha^{-1})	50369	27562	4107.1	39208	38722	4107.1
Marketable root weight (t/ha)	33.66	8.74	2.88	24.32	18.08	2.88
Cylas puncticollis (Boh.)						
[1]Percentage root infestation	29.9(29.81)	85.5(62.88)	3.83	41.2(33.58)	74.2(65.58)	3.83
[1]Percentage root damage	30.45(31.20)	76.10(90.00)	3.32	45.9(40.00)	75.3(66.55)	3.32
Severity score	2.55	3.75	0.2	2.52	3.78	0.2
[2]Total progeny	137.3(9.24)	86.2(8.92)	0.98	68.2(7.08)	155.5(11.07)	0.98
[2]Adult number	22.6(3.51)	25.5(4.79)	0.46	12.2(2.76)	35.9(5.55)	0.46
[2]Immature number	114.7(8.48)	60.7(7.32)	0.9	56.0(6.45)	119.5(9.35)	0.9

Mean percentage infestation and damage are arcsine values, whereas mean *C. puncticollis* (Boh.) total progeny, adult and immature stages are square root values.

4. Discussion

The results indicated that the year of planting, neem seed oil and diazinon applied as pre and post planting or their combinations had no significant impact on percentage plant stands at harvest of sweetpotato roots from a delayed (or minor) cropping season in Umudike, in 2009 and 2010. This is an indication that NSO and Diazinon or their combinations are not phyto-toxic at these dosages. However, sweetpotato yields (root number and weight) from treated roots were significantly higher in 2009 than in 2010. Lowe and Wilson (1974) reported that wide variability in sweetpotato root yield among individual plants of the same cultivar has been attributed to propagation material, environmental and soil factors and not the treatments. Yields ranged from 34.44t/ha to 8.99t/ha in 2009 and 2010 and 24.84t/ha to 18.60t/ha at 5 and 6MAP respectively. This result is in agreement with Akoroda (2009) who reported that sweetpotato yield ranged from 1-40t/ha in 3-7 months after planting. This may be attributed to rainfall, temperature and soil condition of the experimental sites in both years. Earlier study carried out by Gruneberg et al. (2005) showed that the highest mean root yields were obtained at a location with 600 mm rainfall in the growing season. On the other hand, lowest root yields were obtained at locations with very high rainfall and very low rainfall in the growing season. Consequently, *Cylas puncticollis* attributes (infestation and damage) of roots also increased significantly in 2010 when compared with 2009. This could be attributed to the residual effect of azadirachtin and may have been hastened by climatic factors (Jacobson, 1986). Earlier study by Isman et al. (1990) concluded that the bioactivity of neem oil was dependent on its azadirachtin content. Furthermore, the high incidence of the weevil at various stages of development on the control plot indicated the high susceptibility of the sweetpotato variety (TIS2532.op.1.13) to weevil attack as reported by Anioke and Ogbalu (2003). However, the application of NSO and Diazinon treatments had a significant reduction in the sweetpotao weevil infestation and damage of roots. The precise effect of plant oils (Don-Pedro 1989) on gravid female beetles is still unclear. Nevertheless, oils (Singh et al., 1978; Credland, 1992) have been reported to cause the death of developing embryo through asphyxiation. However, the significantly lower number of the immature stages, adults (total progenies) despite the higher scores in 2010 could be attributed to exit of the weevil following it emergence from the roots.

Harvesting of the treated sweetpotato roots at 5MAP significantly increased yield when compared with 6MAP. This agrees with Onunka (2009) report that elite variety (TIS87/0087) matures at 5MAP when compared with the land races. Furthermore, the reduction in yield at 6MAP may be attributed to root dehydration caused by increased weevil tunneling, soil cracking, higher temperature and lower rainfall. Delayed harvesting to 6MAP also increased infestation especially as the weevils were more abundant and injurious during the drier growing season.

Fifty mls of NSO applied pre- and post-planting gave highest control (35.30%) of the pest at harvest, this corroborates the findings that neem products (Ogunwolu & Oddunlami, 1996; Lale & Mustapha, 2000; Ukeh et

al., 2007) performed equally or sometimes better than some synthetics. It appears that neem seed oil could be a potential source of natural and low-cost insecticide to control sweetpotato pests.

5. Conclusion

The study revealed that the integration of neem seed oil and diazinon, applied singly or in combination was not phytotoxic to the crop and it significantly lowered *C. puncticollis* infestation and damage of sweetpotato roots in delayed production and thus, provided adequate protection of roots. Under minor rain-fed sweetpotato cropping, harvesting should be done at 5MAP to minimize damage by *C. puncticollis* in field. Furthermore, sequential harvesting may have reduced roots fresh weight, but may not reduce the root dry matter which is of major important to processors.

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References

Ajayi, F. A, Lale, N. E. S., & Joshua, S. D. (1999). Evaluation of neem (*Azadirachta indica* Juss) seed oil for control of tomato fruitworm *Heliothis armigera* (Hubner) in Maiduguri, Nigeria. *Appl. Trop. Agric., 4*, 93-99.

Akoroda, M. O. (2009). Sweetpotato in West Africa. In The Sweetpotato (Loebenstein, G., & Thottappilly, G. eds.). (pp. 441-468). Springer Science and Business Media B. V. http://dx.doi.org/10.1007/978-1-4020-9475-0_19

Anioke, S. C., & Ogbalu, O. K. (2003). Field Evaluation of Four Sweet Potato Cultivars for Yields and Sweet Potato Weevil (*Cylas puncticollis* Boh.) damage during the early cropping season in Southeastern Nigeria. *Nig. Agric. J., 34*, 82-86.

AVRDC. (1991). *Annual review 1990*. Asian Vegetable Research and Development Center, Tainan, Taiwan.

Brahmachari, G. (2004). Neem-An omnipotent plant: A retrospection. *Chem. Biochem., 5*, 408-421. http://dx.doi.org/10.1002/cbic.200300749

Chalfant, R. B., Hall, M., & Seal, D. R. (1987). Insecticidal control of soil insects of sweetpotato in the Georgia coastal plain. *Appl. Agric. Res., 2*, 152-157

Chalfant, R. B., Jansson, R. K., Seal, D. R., & Schalk, J. M. (1990). Ecology and management of sweet potato insects. *Ann. Rev. Entomol., 35*, 157-180. http://dx.doi.org/10.1146/annurev.en.35.010190.001105

Collins, W. W., Jones, A., Mullen, M. A., Talekar, N. S., &Martin, F. W. (1991). Breeding sweetpotato for insect resistance.A global overview. In: Sweetpotato Pest Management. A global perspective (Janssen, R. K., & Raman, K. V., Eds.). (pp. 379-398). West-view Press, Boulder Co, USA.

Credland, P. F. (1992). The structure of Bruchid eggs may explain the ovicidal effect of oils. *J. Stored Prod. Res., 28*, 1-9. http://dx.doi.org/10.1016/0022-474X(92)90025-L

Don-Pedro, K. N. (1989). Mechanisms of action of some vegetable oils against *Sitophilus zeamais* (Motsch) (Coleoptera: Curculionidae) on wheat. *J. Stored Prod. Res., 25*, 217-223. http://dx.doi.org/10.1016/0022-474X(89)90015-5

Edison, S., Vinayaka, H. T., Makeshkumar, T., Srinivas, G. S., & Padmaja, G. (2009). Sweetpotato in the Indian Sub-Continent. In The sweetpotato (Loebenstein, G., & Thottappillyeds, G.). (pp. 391-414). Springer Science and Business Media B. V.

Edmunds, B. A., Boyyette, M., Clark, C. A., Ferrin, D., Smith, T. P., & Holmes, G. (2008). Postharvest Handling of sweetpotatoes. *North Carolina Cooperative Extension Services*, Raleigh, NC.

Ehisianya, C. N, Lale, N. E. S., Umeozor, C. O., Amadi, C. O., & Zakka U. (2011). Evaluation of the effectiveness of variety, tillage method and time of harvest on sweetpotato yield and the population of sweetpotato weevil, *Cylas puncticollis* (Boheman) (Coleoptera: Brentidae). *Int. J. Advanced Sci. Tech. Res., 1*(2), 165-183.

Emosairue, S. O., & Ukeh, D. A. (1996). Field trial of neem products for the control of Okra flea beetle (*Podagrica* spp) in south eastern Nigeria. *Afr. J. Plant. Prot., 6*, 22-26.

Extension Toxicology Network. (1996). EXTOXNET Pesticide Information Profiles: Diazinon, Retrieved June 15, 2010, from http://ace.orst.edu/cgi-bin/mfs/01/pips/diazinon.htm?8#mfs

Gruneberg, W. J. K., Manrique, K., Zhang, D., & Hermann, M. (2005). Genotype x Environment Interaction for a diverse set of sweetpotato clones evaluation across varying eco-geographic conditions in Peru. *Crop Sci. 45*, 2160-2171. http://dx.doi.org/10.2135/cropsci2003.0533

Isman, M. B., Koul, O., Lowrey, D. T., Arnason, J. T., Gagnon, D., Stewart, J. G., & Salloum, G. S. (1990). Development of a neem-based insecticide in Canada. (pp. 32-30). In: Proceedings of a workshop on Neem's Potential in Pest Management Programs (J. C. Locke, & R. H. Lawson, Eds.). USDA-ARS, Beltsville, MD. ARS-86.

Jacobson, M. (1986). The Neem Tree: Natural Resistance par excellence. In: M. B. Green, & P. A. Hedin (eds.). Insecticides of the Plant Origin. Natural resistance of plants to pests. *Am.Chem. Soc., 296*, 220-232.

Kennedy, G. (2002). Food Security in the context of urban sun-Saharan Africa Food Africa Internet Forum 31 March-11, April Internet Paper for Food Security Theme. Retrieved from http://foodafrica,nri.org

Kimber, A. J. (1972). The sweetpotato in subsistence agriculture. *Papua New Guinea Agric. J., 23*(3-4), 80-102.

Kreuze, J. K., Valkonen, J. P. T., & Ghislain, M. (2009). Genetic engineering. (pp. 41-63). In: The sweetpotato. (G. Loebenstein, & G. Thottappilly eds.). Springer Science and Business Media B. V. http://dx.doi.org/10.1007/978-1-4020-9475-0_5

Lale, N. E. S., & Mustapha, A. (2000). Efficacy and acceptability of neem *Azadirachta indica* A. Juss) seed, oil and Primiphos-methyl applied on three storage devices for control of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Zeitschrift Fuer Pflanzenkrankheitan Pflanzenschutz, 107*, 399-405.

Lema, K. M., & Hahn, S. K. (1987). *Integrated management of the sweetpotato weevils in Africa: An example of low input package.* In Proceeding of 11th International Congress of Plant Protection, October 5-9, 1987, Manila, Philippines.

Lenne, J. M. (1991). Diseases and pest of sweetpotato: South-east Asia, the pacific and East Africa. *Natural Resources Institute Bull., 46*, 116.

Levett, M. P. (1993). The effects of methods of plants cuttings of sweetpotato (*Ipomoea batatas* (L.) Lam) on yield. *Trop. Agric. Trin., 70*(2), 110-115.

Loebenstein, G. (2009). Origin, Distribution and Economic Importance. In: The sweetpotato (G. Loebenstein, & G. Thottappillyeds.). (pp. 9-12). Springer Science and Business Media B. V.

Lowe, S. B., & Wilson, L. A. (1974). Comparative analysis of tuber development in six sweetpotato Cultivars. 1, Tuber initiation, tuber growth and partitioning of assimilate. *Ann. Bot., 38*, 307-17.

Muruyanda, D. A., Beardsley, J. W., & Mitchell, W. C. (1986). Insecticidal control of sweetpotato weevils *Cylas formicarius elegantulus* (Coleoptera: CurcuIionidae) in Hawaii, USA. *Trop. Agric., 63*(1), 55-57.

Nwana, I. E. (1979). The Biology of *Cylas puncticollis* Boheman (Coleoptera: Apionidae) on sweetpotato (*Ipomoea batatas (L). Lam*). *Nig. J. Entomol., 3*, 185-190.

Ogunwolu, E. O., & Oddulami, A. T. (1996). Suppression of *Callosobruchus maculatus* (F.) on cowpea with *Zanthroxylumzaninoxyloides* (Lam.) Waterm (Rutaceae) compared to neem seed powder and Primiphos-methyl. *Crop Prot., 15*, 603-607. http://dx.doi.org/10.1016/0261-2194(95)00088-7

Ojiako, I. A. (2008). Analysis of acceleration, deceleration and stagnation in output, Land area, and yield of sweetpotato (*Ipomoea batatas* L. Lam.) in Nigeria, 1961-2007. (pp. 94-101). In: Sweetpotato in Nigeria (M. O. Akoroda, & I. Egeonueds). Proceedings of First National Sweetpotato Conference, Sweetpotato Promotion Group.Held 16-18 September, 2008. Faculty of Agriculture and Forestry, University of Ibadan, Nigeria.

Onunka, N. A. (2009). Determination of optimum period of maturity of sweetpotato landraces under improved management in northern Nigeria.Proceedings of the 43rd Annual Conference of the Agricultural Society of Nigeria, Abuja.Held from 20th-23rd Oct. pp. 68-71.

Singh, S. R, Luse, R. A., Leuschner, K., & Nangju, D. (1978). Groundnut oil treatment for the control of *Callosobruchus maculatus* (F.) during cowpea storage. *J. Stored Prod. Res., 14*, 77-80. http://dx.doi.org/10.1016/0022-474X(78)90001-2

Smit, N. E. J. M. (1997). The effect of the indenous cultural practices of in-ground storage and piecemeal harvesting of sweetpotato on yield and quality losses caused by sweetpotato weevil in Uganda. *Agric. Ecosys. Environ., 64*, 191-200. http://dx.doi.org/10.1016/S0167-8809(97)00022-4

Stathers, T. E., Rees, D., Kabi, S., Mbiliny, I. L., Smit, N., Kiozya, S., … Jeffries, D. (2003). Sweetpotato infestation by *Cylas* spp. in East Africa: 1. Cultivar differences in field infestation and the role of plant factors. *Int. J. Pest Manage., 49*(2), 131-140. http://dx.doi.org/10.1080/0967087021000043085

Stevenson, P. C., Muyinza, H., Hall, D. R., Porter, E. A., Farman, D., Talwana, H., & Mwanga, R. O. M. (2009). Chemical basis for resistance in sweetpotato *Ipomoea batatas* to the sweetpotato weevil, *Cylas puncticollis* (Boh.). *Pure Appl. Chem., 81*(1), 141-151. http://dx.doi.org/10.1351/PAC-CON-08-02-10

Ukeh, D. A., Emosairie, S. O., Udo, I. A., & Ofem, U. A. (2007). Field evaluation of neem (*Azadirachta indica* A. Juss) products for the management of lepidopterousstemborers of maize (*Zea mays* L.) in Calabar, Nigeria. *Res. J. Appl. Sci., 2*, 15-19.

Umoetok, S. B. A., Osuagwu, A. N., Udo, I. A., Idiongette, M. I., & Ukeh, D. A. (2009). Effects of *Azadirachta indica* products on the management of *Ootheca mutabilis* on *Telfairia occidentalis* in Calabar, Southeast Nigeria. *Crop Prot., 28*, 583-587. http://dx.doi.org/10.1016/j.cropro.2009.03.002

USGS, (2001). Does Diazinon pose a threat to a neighbourhood stream in Tallahassee, Florida: United States Geological Survey fact sheet FS-143-00, p. 4.

Wolfe, G. W. (1991). The origin and dispersal of the pest species of *Cylas* with a key to the pest species groups of the world. In Jansson, R. K., & Raman, K. V. (Eds.). (pp. 13-44). Sweepotato Pest Management.A Global Perspective. Westview Press. Boulder Co. USA.