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Efficacy of Furadan (Carbofuran) in Control of Root-knot Nematode (*Meloidogyne incognita* Race 2) in Hybrid Yam Varieties in South-western Nigeria

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Abstract: Furadan (Carbofuran) 3G was applied at the rates of 0, 100, 200 and 300 kg ha^{-1} at the following times of application; T_o: No nematicide or Control; T_1: Rate applied once at planting; T_2: 50% applied at planting + 50% at 3 Months After Planting (MAP). T_3: 50% applied at planting + 50% at 4 MAP, T_4: 50% applied at planting + 50% at 5 MAP, T_5: 50% applied at planting + 50% at 6 MAP respectively to three newly released hybrid yam (TDr 89/02665, TDr 89/02565 and TDr 89/02677) varieties across rainforest and derived savanna ecologies in south western Nigeria. Data were collected on total tuber yield (t ha^{-1}), root-knot nematode incidence, severity rating, root-gall index, reproduction factor and the degree of resistance. Application of Furadan (Carbofuran) resulted in increased in the yield of the three hybrid yam varieties which was significantly higher than the control. Optimum yields were obtained from the application of (100 kg ha^{-1}); 50 kg ha^{-1} at planting plus 50 kg ha^{-1} applied at 3 Months After Planting (MAP) in the three hybrid yam varieties. Additional increase in Furadan (Carbofuran) above this level did not significantly increase tuber yield of the three hybrid yam varieties. The incidence and severity of nematode infection on harvested tubers was influenced by the application of Furadan. Significant reduced incidence of nematode was observed from the application of (100 kg ha^{-1}); 50 kg ha^{-1} at planting plus 50 kg ha^{-1} applied at 3 Months After Planting (MAP) in the three hybrid yam varieties in the two locations. Additional increase in Furadan (Carbofuran) above this level did not significantly reduced incidence of nematode in the three hybrid yam varieties. The severity rating of the hybrid yam tuber varieties showed that reduced galls were obtained from the treated hybrid tubers using the gall index and reproduction factor of Sasser *et al*. [25] for this investigation, the gall index ranged from 1.30-1.40 while the R-factor ranged from 1.75-2.0 hence the three hybrid yam varieties were tolerant to root-knot nematode (*M. incognita* race 2). This result confirms the suppressive effects of Furadan (Carbofuran) application on root-knot nematode *M. incognita* race 2 multiplications on hybrid yam varieties.

Key words: Furadan (Carbofuran) · time of application · root-knot nematode · Meloidogyne incognita race 2 · hybrid yam varieties

INTRODUCTION

Yam (*Dioscorea* spp.) is an important economic crop grown mainly in tropical countries, especially in the yam zone (25°N and 25°S) of West Africa. The bulk of global yam production is concentrated in West Africa, with Nigeria producing the largest proportion followed by Ghana and Cote d'Ivoire [1]. Yam is the second most important root and tuber crop in the World after cassava in terms of production and contributes more than 200 dietary calories per day for 60 million people in the yam zone [2]. Yam production is expanding annually but realized yields are usually considerably lower than potential yields. Increased human population [3] and land pressure [4] result in a shortened fallow with subsequent decrease in soil fertility and increase in pest and disease levels. It is therefore necessary to control the activities of plant-parasitic nematodes in order to increase or at least maintain yields of yam. Plant-parasitic nematodes damage is an important factor in tuber quality reduction and yield loss in yam in the field and in storage. A large number of plant-parasitic nematodes associated with yam cultivation have been reported from various yam producing areas of the world [5-15].

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These are the yam nematode *Scutellonema bradys*, the root-knot nematode *Meloidogyne* spp. and the lesion nematode *Pratylenchus* spp., which are all field and post-harvest pests [10, 11, 13 & 15]. The ultimate objective of plant-parasitic nematode control is the reduction of nematode populations in the soil. A survey report on Nigeria, however, showed that 70% of farmers are aware of nematode symptoms but do not necessarily recognize it as a problem requiring intensive control measure [12]. Some options from amongst the general nematode control strategies available have been found feasible in yam cultivation [16]. A reduction of the nematode population in the field can be effectively achieved by applying nematicides, but the economics of their use needs to be carefully considered, especially in view of the present soaring cost of chemicals. However, Furadan (Carbofuran[R], carbamate insecticide, mfg. Bayer), vydate (240 g a.i. /l: Oxamyl; carbamoyloxime insecticide; mfg. DuPont), Temik (100 g a.i. /kg; mixture of Aldicarb+gamma-HCH; carbamoyloxime insecticide), Miral (100 g a.i. /kg; Isazofas; organophosphorus insecticide/nematicide), Daimidafos (D-D; nematicide) and Demagon (DBCP; nematicide) have been applied in the field to reduce nematodes [17].

The application of D-D at 448 kg ha^{-1} reduced the nematode numbers on infected tubers from 88 to 32% in Puerto Rico [5]. In Nigeria, the use of D-D and DBCP have produced higher yields of clean tubers when applied at rates of 84 to 253 kg ha^{-1} and 28 to 84 kg ha^{-1}, respectively [18]. Carbofuran when applied at 0.15 to 1.5 kg a.i. /ha in planting holes at planting or in rings or bands 15 cm round the yam stands, 10 to 12 weeks after planting, also produced cleaner tubers [19, 20]. When a non fumigant nematicide was used to control root-knot and root-lesion nematodes in yams, tuber yield was increased by 42-49% and storage rot reduced by 14% [9]. Oxamyl, miral or Aldicarb at 2 kg a.i. /ha used as a single side-dressing post-planting treatment, 2 WAP, effectively controlled *S. bradys*, leading to higher yields and clean tubers.

The improvement on world average yield potential may be enhanced if productions in Nigeria especially in areas with low root-knot nematode populations are planted with high yielding hybrid varieties that are adaptable to low populations of root-knot nematodes. This paper seeks to study the yield response of high yielding hybrid yam varieties to different levels of Furadan (Carbofuran) input on root-knot nematodes under field conditions.

MATERIALS AND METHODS

The experiment was conducted for two seasons (2004 and 2005) at the Institute of Agricultural Research and Training experimental Stations at Ibadan (7° 38' N 3° 84' E) and Ilora (7° 48' N 3° 52' E). Ibadan, in which the annual rainfall is 1220 mm and the daily mean temperature is 28°C + 2°C. The soil is classified as Rhodic Harplustalf, Iwo series [21]. Ilora is in a dry sub-humid rainforest area with derived savanna ecology and the soil type is Typic Troposamment. The two experimental plots were naturally infested with *Meloidogyne incognita*. The identity of *M. incognita* was confirmed using perineal patterns, as race 2, as described by Eisenback *et al*. [22]. The pre-crop soil nutrient status of the sites is given in Table 1.

The experiment was a 6×3 factorial with 4 rates of Furadan (Carbofuran) 3G applied at 0, 100, 200 and 300 kg ha^{-1} at the following times of application; T_o: No nematicide or Control; T_1: Rate applied once at planting; T_2: 50% applied at planting + 50% at 3 Months After Planting (MAP). T_3: 50% applied at planting + 50% at 4 MAP, T_4: 50% applied at planting + 50% at 5 MAP, T_5: 50% applied at planting + 50% at 6 MAP and three hybrid yam varieties, TDr 89/02665, TDr 89/02565 and TDr 89/02677 obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. The 18 treatments obtained were arranged in Randomized Complete Block Design and replicated 3 times. Experimental plots consisted of five rows of 5 m length with a planting distance of 1 m within rows. Yam setts (250 g) were planted in mid-October, 2004 at Ibadan and Ilora. The second trial was planted in mid-October, 2005 at the two locations.

200 kg NPK ha^{-1} (N_{40} P_{20} K_{20}) application and staking were done in February at Ibadan and Ilora in 2005 and in February, 2006 in both locations. Weeds were controlled by hand weeding. Harvesting was done from three innermost rows at 12 Months After Planting (MAP) for both trials in the two locations respectively. Soil samples were taken from the experimental plots from both locations before planting and after harvest, in order to determine the initial and final population densities (P_i and P_f). Ten soil core samples were taken from the plots at a depth of 20 cm and thoroughly mixed to form composite samples. Composite samples were taken to the laboratory in sealed bags where they were stored at 10°C for 24 h. The samples were then thoroughly mixed and 250 cm^3 soil sub-samples were processed using the tray extraction method of Whitehead and Hemming [23].

Table 1: Physico-chemical properties of the soil at the two locations before cropping

	Ibadan		Ilora	
	2004	2005	2004	2005
pH (H_2O)	6.10	6.00	6.50	6.20
Organic carbon (g kg^{-1})	8.90	8.30	7.40	7.90
Total N (%)	0.70	0.83	0.63	0.75
Exch. K cmol kg^{-1}	0.68	0.59	0.45	0.39
Available P (mg kg^{-1})	11.65	10.85	7.95	8.32
CEC (cmol kg^{-1})	8.28	7.86	4.89	6.35
% base saturation	97.21	98.90	93.50	96.48
Sand (%)	82.00	84.00	73.50	75.50
Silt (%)	13.00	12.00	12.50	11.50
Clay (%)	5.00	6.00	14.00	13.00

Table 2: Quantitative scheme for assignment of Canto-Saenz's host suitability (Resistance) designation [25]

Plant damage (Gall index)^y	Host efficiency^z (Reproductive factor)	Degree of resistance
<2	<1	Resistance
<2	>1	Tolerant
>2	<1	Hypersusceptible
>2	>1	Susceptible

^{Z}reproductive factor: R = Pf/Pi where Pi = initial population density and Pf = final population density, ^{Y}Gall index: 0 = no gall formation; 5 = heavy gall formation

At harvest, plants were assessed for root-galls in which eggs were extracted from roots and estimated using sodium hypochlorite method of Hussey and Barker [24]. Data obtained were used for host status rating was determined using the rating scheme developed by Sasser *et al*. [25] based on gall index and reproductive factor (R), where $R = P_f/P_i$ (Table 2).

Data were taken on yield per plot, percentage nematode incidence which was calculated as number of tuber infected/total number of tubers harvested. The nematode severity ratings of infected tubers were assessed for galling according to the rating scale of Sasser and Taylor [26] where 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. The data collected were subjected to analysis of variance and means were separated by Duncan's multiple range test [27].

RESULTS AND DISCUSSION

The pre-cropping soil analysis presented in Table 1 indicates that the soils from the two experimental sites were of low acidity (6.0-6.5). Available P was low but exchangeable K was high in both sites. The CEC was moderate in Ibadan but low in Ilora. A comparison of the native nutrients in the soils to the yam nutrient requirements indicated that additional P and N fertilizer compliments were needed in the sites. Since N and K are the critical nutrients in yam [28], all the soils required additional N fertilizer for the hybrid yam varieties to attain their full potential yield. Soil physical structure at Ibadan was gravely with shallow hard pan sub-soil while Ilora was sandy loam and of easily penetrable deep sub-soil. The soils were suitable for yam cultivation in spite of the hard-pan sub-soil at Ibadan which could inhibit tuber penetration of varieties with long tuber shape. The Ilora soil allowed easy tuber size enlargement and elongation.

Effect of root-knot nematode (*Meloidogyne incognita* race 2) on tuber yield was significant in both sites (Table 3). The tuber yield (t ha^{-1}) was influenced by rates of Furadan (Carbofuran) in both sites. In 2004, TDr 89/02565 in Ibadan yielded between 29.12-29.13 t ha^{-1} without any control measure and in 2005 the yield dropped to 18.70 t ha^{-1} due to cessation of rainfall experienced during the planting session. In Ilora, TDr 89/02565 in 2004 yielded between 32.40-32.42 without any control measure and between 33.75-33.81 in 2005 planting session. The same trend was observed for TDr 89/02665 and TDr 89/02677 in both locations.

Application of Furadan (Carbofuran) resulted in increased in the yield of the three hybrid yam varieties which was significantly higher than the control. All treated plants were taller and had more leaves with larger areas than the control plants. This level of vegetative growth implied that the rate of photosynthesis and the accumulation of dry matter were higher for the treated plants than the control plants. This could be attributable to the fact that Furadan (Carbofuran) apart from controlling *M. incognita* race 2 that could otherwise cause stunting also exerted some prophylactic action. The prophylactic effects of Furadan in increasing plant height and vegetative growth of plants have been demonstrated by Johnson and Chalfant [29]; Akinlade and Adesiyan [30] and Adegbite and Adesiyan [31]. The shorter heights recorded for the control plants were probably as a result of the stunting action of *M. incognita* race 2. This type of stunting or reduced heights caused by root-knot nematode has been reported by Thimann [32], Owens and Specht [33], Akinlade and Adesiyan [30], Adegbite and Adesiyan [31] and Adekunle and Fawole [34]. The high yields obtained from the

Table 3: Effect of Furadan (Carbofuran) on the total tuber yield (t ha^{-1}) of three hybrid yam varieties

	Tdr89/02565				Tdr89/02665				Tdr89/02677			
	Ibadan		Ilora		Ibadan		Ilora		Ibadan		Ilora	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
100 kg ha^{-1}												
To Control	29.12d	18.15c	32.10d	33.25d	31.38d	25.35d	27.45d	27.75d	29.36d	27.65d	27.85d	28.35d
T_1 100 kg at planting	29.35c	18.20c	32.35c	33.50c	31.52c	25.98c	27.85c	28.05c	29.98c	28.00c	28.38c	28.68c
T_2 50 kg at planting + 50 kg 3 MAP	32.35a	20.12a	34.56a	36.83a	34.29a	28.98a	30.48a	31.03a	32.97a	31.67a	31.50a	32.45a
T_3 50 kg at plant-ing + 50 kg 4 MAP	29.83b	18.75b	32.60b	33.70b	31.68b	26.05b	28.01b	28.25b	30.01b	28.65b	30.52b	29.83b
T_4 50 kg at plant-ing + 50 kg 5 MAP	29.88b	18.80b	32.63b	33.65b	31.68b	26.06b	28.05b	28.28b	30.05b	28.75b	30.63b	29.85b
T_5 50 kg at plant-ing + 50 kg 6 MAP	29.88b	18.80b	32.63b	33.65b	31.68b	26.06b	28.05b	28.28b	30.05b	28.75b	30.63b	29.85b
200 kg ha^{-1}												
To Control	29.10c	17.70c	30.42c	31.79c	31.00c	25.06c	26.46c	27.45c	28.86c	27.75c	28.10c	28.86c
T_1 200 kg at planting	29.66b	18.75b	32.95b	33.85b	31.55b	26.01b	27.89b	28.10b	30.01b	28.65b	28.43b	29.70b
T_2 100 kg at planting + 100 kg 3 MAP	32.46a	20.23a	34.60a	36.90a	34.39a	29.01a	30.67a	31.08a	33.00a	31.71a	31.65a	32.49a
T_3 100 kg at plant-ing + 100 kg 4 MAP	32.48a	19.95a	33.98a	35.95a	33.91a	29.06a	29.91a	30.15a	33.07a	31.75a	31.68a	32.51a
T_4 100 kg at plant-ing + 100 kg 5 MAP	32.48a	19.95a	33.98a	35.95a	33.91a	29.06a	29.91a	30.15a	33.07a	31.75a	31.68a	32.51a
T_5 50 kg at plant-ing + 50 kg 6 MAP	32.48a	19.95a	33.98a	35.95a	33.91a	29.06a	29.91a	30.15a	33.07a	31.75a	31.68a	32.51a
300 kg ha^{-1}												
To Control	29.12c	17.70c	31.42c	33.01c	31.03c	24.89c	27.00c	27.01c	29.98c	28.00c	28.00c	29.42c
T_1 300 kg at planting	30.00b	18.81b	33.01b	33.88b	31.58b	26.05b	27.93b	28.15b	30.07b	28.71b	28.48b	30.55b
T_2 150 kg at planting + 150 kg 3 MAP	32.50a	20.26a	34.75a	36.98a	34.42a	29.05a	30.72a	31.13a	33.03a	31.76a	31.71a	32.56a
T_3 150 kg at plant-ing + 150 kg 4 MAP	30.52b	18.85b	33.05b	33.93b	31.69b	26.10b	27.95b	28.20b	30.11b	28.77b	28.53b	30.60b
T_4 150 kg at plant-ing + 150 kg 5 MAP	30.52b	18.85b	33.05b	33.93b	31.69b	26.10b	27.95b	28.20b	30.12b	28.77b	28.53b	30.60b
T_5 150 kg at plant-ing + 150 kg 6 MAP	30.52b	18.85b	33.05b	33.93b	31.69b	26.10b	27.95b	28.20b	30.12b	28.77b	28.53b	30.60b

Means followed by same letters in the same column are not significantly different $p < 0.05$ according to Duncan's Multiple Range Test

Table 4: Percentage (%) root-knot (*Meloidogyne incognita* race 2) nematode incidence on three hybrid yam varieties

	Tdr89/02565				Tdr89/02665				Tdr89/02677			
	Ibadan		Ilora		Ibadan		Ilora		Ibadan		Ilora	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
100 kg ha^{-1}												
To Control	40a	40a	40a	42a	40a	41a	45a	46a	40a	42a	40a	45a
T_1 100 kg at planting	35b	35b	35b	37b	35b	37b	40b	40b	35b	37b	40a	40b
T_2 50 kg at planting + 50 kg 3 MAP	30c	30c	30c	32c	30c	28c	30d	30c	30c	30c	30c	30d
T_3 50 kg at plant-ing + 50 kg 4 MAP	33b	35c	35c	37b	35b	36b	35c	36	35b	36b	35b	35c
T_4 50 kg at plant-ing + 50 kg 5 MAP	33b	35c	35c	37b	35b	36b	35c	36	35b	36b	35b	35c
T_5 50 kg at plant-ing + 50 kg 6 MAP	33b	35c	35c	37b	35b	36b	35c	36	35b	35b	35b	35c
200 kg ha^{-1}												
To Control	40a	40a	40a	40a	42a	40a	45a	45a	40a	40a	43a	44a
T_1 200 kg at planting	40a	40a	40a	38b	38b	39a	40b	40b	35b	35b	40a	40b
T_2 100 kg at planting + 100 kg 3 MAP	30c	30c	30c	30c	30c	30c	32c	32c	30c	30c	30c	30d
T_3 100 kg at plant-ing + 100 kg 4 MAP	35b	35b	35b	36b	36b	36b	37b	37b	35b	35b	35b	35c
T_4 100 kg at plant-ing + 100 kg 5 MAP	35b	35b	35b	36b	36b	36b	37b	37b	35b	35b	35b	35c
T_5 50 kg at plant-ing + 50 kg 6 MAP	35b	35b	35b	36b	36b	36b	37b	37b	35b	35b	35b	35c
300 kg ha^{-1}												
To Control	40a	40a	40a	40a	42a	42a	45a	46a	40a	40a	45a	45a
T_1 300 kg at planting	40a	40a	40a	40a	40a	40a	40b	40b	35b	35b	40b	40b
T_2 150 kg at planting + 150 kg 3 MAP	30c	30c	30c	30c	30c	30c	30d	30d	30c	30c	30d	30d
T_3 150 kg at plant-ing + 150 kg 4 MAP	35b	35b	35b	35b	35b	35b	35c	35c	35b	35b	35c	35c
T_4 150 kg at plant-ing + 150 kg 5 MAP	35b	35b	35b	35b	35b	35b	35c	35c	35b	35b	35c	35c
T_5 150 kg at plant-ing + 150 kg 6 MAP	35b	35b	35b	35b	35b	35b	35c	35c	35b	35b	35c	35c

Means followed by same letters in the same column are not significantly different $p < 0.05$ according to Duncan's Multiple Range Test

Table 5: Severity ratings of root knot nematode (Meloidogyne incognita race 2) on three hybrid yam varieties

	Tdr89/02565				Tdr89/02665				Tdr89/02677			
	Ibadan		Ilora		Ibadan		Ilora		Ibadan		Ilora	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
100 kg ha^{-1}												
To Control	2.91a	2.85a	2.75a	2.82a	2.67a	2.71a	2.68a	2.72a	2.83a	2.78a	2.59a	2.61a
T_1 100 kg at planting	2.67b	2.54b	2.42b	2.45b	2.35b	2.38b	2.40b	2.45b	2.45b	2.40b	2.38b	2.36b
T_2 50 kg at planting + 50 kg 3 MAP	1.22d	1.24d	1.31d	1.34d	1.32d	1.38d	1.24d	1.38d	1.38d	1.38d	1.40d	1.39d
T_3 50 kg at plant-ing + 50 kg 4 MAP	1.88c	1.86c	1.98c	1.96c	1.85c	1.79c	1.82c	1.83c	1.83c	1.83c	1.79c	1.80c
T_4 50 kg at plant-ing + 50 kg 5 MAP	1.88c	1.86c	1.98c	1.96c	1.85c	1.79c	1.82c	1.83c	1.83c	1.83c	1.79c	1.80c
T_5 50 kg at plant-ing + 50 kg 6 MAP	1.88c	1.86c	1.98c	1.96c	1.85c	1.79c	1.82c	1.83c	1.83c	1.83c	1.79c	1.80c
200 kg ha^{-1}												
To Control	2.91a	2.85a	2.76a	2.83a	2.68a	2.72a	2.72a	2.72a	2.83a	2.79a	2.60a	2.61a
T_1 200 kg at planting	2.65b	2.52b	2.40b	2.42b	2.34b	2.36b	2.38b	2.39b	2.39b	2.40b	2.36b	2.36b
T_2 100 kg at planting + 100 kg 3 MAP	1.20d	1.20d	1.30d	1.30d	1.30d	1.36d	1.22d	1.23d	1.35d	1.38d	1.38d	1.38d
T_3 100 kg at plant-ing + 100 kg 4 MAP	1.86c	1.86c	1.98c	1.97c	1.84c	1.76c	1.80c	1.84c	1.81c	1.81c	1.79c	1.79c
T_4 100 kg at plant-ing + 100 kg 5 MAP	1.86c	1.86c	1.98c	1.97c	1.84c	1.76c	1.80c	1.84c	1.81c	1.81c	1.79c	1.79c
T_5 50 kg at plant-ing + 50 kg 6 MAP	1.86c	1.86c	1.98c	1.97c	1.84c	1.76c	1.80c	1.84c	1.81c	1.81c	1.79c	1.79c
300 kg ha^{-1}												
To Control	2.91a	2.85a	2.75a	2.82a	2.67a	2.71a	2.68a	2.72a	2.83a	2.78a	2.59a	2.59a
T_1 300 kg at planting	2.65b	2.50b	2.38b	2.38b	2.32b	2.34b	2.38b	2.39b	2.39b	2.40b	2.36b	2.36b
T_2 150 kg at planting + 150 kg 3 MAP	1.18d	1.18d	1.27d	1.27d	1.27d	1.33d	1.18d	1.18d	1.33d	1.35d	1.35d	1.35d
T_3 150 kg at plant-ing + 150 kg 4 MAP	1.83c	1.83c	1.95c	1.95c	1.81c	1.74c	1.78c	1.82c	1.79c	1.79c	1.77c	1.77c
T_4 150 kg at plant-ing + 150 kg 5 MAP	1.83c	1.83c	1.95c	1.95c	1.81c	1.74c	1.78c	1.82c	1.79c	1.79c	1.77c	1.77c
T_5 150 kg at plant-ing + 150 kg 6 MAP	1.83c	1.83c	1.95c	1.95c	1.81c	1.74c	1.78c	1.82c	1.79c	1.79c	1.77c	1.77c

Means followed by same letters in the same column are not significantly different $p<0.05$ according to Duncan's Multiple Range Test

Furadan treated plants could be expected, because the better the growth of the plants, the more the yield to be expected thereof. Similar observations were made by Ayala and Acosta [5], Adesiyan and Badra [35] with the soil application of four granular nematicides (Aldicarb, Oxamyl, Carbofuran and Miral) applied as post planting treatments in yam mounds two weeks after planting at a rate of 2 kg a.i. /ha reduced soil populations of *Scutellonema bradys* to very low levels with remarkable yield increases recorded. Optimum yields were obtained from the application of (100 kg ha^{-1}); 50 kg ha^{-1} at planting plus 50 kg ha^{-1} applied at 3 Months After Planting (MAP) in the three hybrid yam varieties in the two locations. Additional increase in Furadan (Carbofuran) above this level did not significantly increase tuber yield of the three hybrid yam varieties.

Nematode infestation of the hybrid yam tubers is an important factor in tuber quality, yield and storability or shelf life. The incidence of root-knot nematode (*M. incognita* race 2) in harvested tubers was influenced by the application of Furadan (Table 4).

The incidence was lower in Ibadan than in Ilora. Nematode infestation was reported to be preponderant in fields with fallow periods of less than four years [36]. Severity of nematode infection on tubers was influenced by Furadan (Carbofuran). Significant reduced incidence of nematode was observed from the application of (100 kg ha^{-1}); 50 kg ha^{-1} at planting plus 50 kg ha^{-1} applied at 3 Months After Planting (MAP) in the three hybrid yam varieties in the two locations. Additional increase in Furadan (Carbofuran) above this level did not significantly reduced incidence of nematode in the three hybrid yam varieties. Similar observations were made in soybean [37], in okra [30] and in tobacco [38] who all reported a reduced incidence of plant-parasitic nematode with the application of Furadan.

The severity rating of the hybrid yam tuber varieties showed that reduced galls were obtained from the treated hybrid tubers (Table 5). Application of (100 kg ha^{-1}); 50 kg ha^{-1} at planting plus 50 kg ha^{-1} applied at 3 Months After Planting (MAP) in the three hybrid yam varieties in the two locations led to mild infection (1.20-1.40) while in control plants severity ranged between 2.59-2.91. The ovicidal effect of Furadan is more effective in preventing penetration of nematodes into the roots or in reducing nematode activities within the soil. This may suggest that

Table 6: Root galling indices, reproductive factor and degree of resistance of three hybrid yam varieties under field experiment

Variety	Gall index [a]	R-factor [b]	Degree of resistance
Tdr 89/02565	1.32	1.75	Tolerant
TDr 89/02665	1.30	1.75	Tolerant
TDr 89/02677	1.40	2.00	Tolerant

Root knot index: 0 = No gall formation; 5 = Heavy gall formation [After Sasser *et al*. [25]], R = P_f/P_i, where R is the rate of reproduction, P_i = initial population, P_f = final population

Furadan acts directly on the nematodes in the soil thereby preventing or limiting hatching of eggs and the movement of larvae into roots. This is in agreement with the works of Di-sanzo [37], Kabde and Sharma [39], Fadina [40] and Adegbite and Adesiyan [31]. Additional increase in Furadan (Carbofuran) above this level did not significantly reduce severity ratings of the hybrid yam varieties. However, reduced galls on the treated tubers probably indicates that the higher the nematode population, the higher the damage done to the tubers and the higher the level of gall formation which is warty, bumpy and hairy in appearance and which also renders the infested tubers unattractive and reducing their market value.

Using the gall index and reproduction factor of Sasser *et al*. [25] for this investigation, the gall index ranged from 1.30-1.40 while the R-factor ranged from 1.75-2.0 hence the three hybrid yam varieties were tolerant to root-knot nematode (*M. incognita* race 2).

In summary, this result confirms the suppressive effects of Furadan (Carbofuran) application on root-knot nematode *M. incognita* race 2 multiplications on hybrid yam varieties. However, assessment of different rates of Furadan (Carbofuran) on root-knot nematode on hybrid yam varieties would help to determine further which rate of Furadan are most effective against *M. incognita* race 2 and which are most beneficial to improving the nutritional quality of the tubers. Assessment of application rates of Furadan used in current study would help to establish optimum levels for yield improvement and nematode management.

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