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Research Article

Application of Furfural in Sugarcane Nematode Pest Management

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Abstract | Sugarcane, *Saccharum officinarum* is a foremost crop which is widely grown for sugar production. A major impediment to sugarcane cultivation is the infestation by plant parasitic nematodes most notably, the cyst nematode *Heterodera sacchari*. Broadly, synthetic nematicides are utilized in the suppression of soil nematode infestation of sugarcane, with positive outcome in yield. However, emergence of resistant nematode strains and health hazards are associated with the ceaseless use of the synthetics. The efficacy of furfural (2-furanaldehyde) from agricultural biomass waste was examined as a practicable replacement to the regular synthetic nematicide. Agricultural wastes were collected and refluxed with hydrochloric acid to produce furfural. Growth response of sugarcane plants increased significantly (p=0.05) with the highest concentration (75 mg) of furfural. A reduction in nematode population in soil of treated plants was remarked. The results indicated that furfural could be practically applied in the management of nematode pests of sugarcane, while safe guarding the environment from pollution.

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Introduction

The sugarcane plant *Saccharum officinarum,* belongs to the family poaceae, which is an economically predominant grass family. It is a principal crop which accounts for 75% of global sugar production in the Sub-tropical and Tropical regions of the world (Chengarayan and Gallo-Meagher, 2001; Vilela, 2017). Brazil, India and Peru are the largest sugarcane producing countries (Bogden, 2007). The sugarcane plant has the highest bio conversion efficiency among many plants in the same family, the dry matter after harvest can be used for fuel production, while the bagasse is employed in paper making as pulp and it can serve efficiently in solar power fixing (Rainey *et al*., 2006). Nations with high production of sugarcane are dependent on the bagasse for electricity generation. A ton of bagasse is known to produce over 100 kWh of electricity (Ogden, 1990). Similarly, ethanol another by product of sugarcane processing can be deployed to bio fuel and could serve as an alternative to gasoline (Da Rosa, 2005). Plant parasitic nematodes are one of the key pests of diverse crops (Fabiyi *et al*., 2020; Fabiyi, 2021a, b, c). Several plant parasitic nematodes are associated with the sugarcane plant, although planted crops are not as susceptible as the ratoon crops to nematode infestation (Berry *et al*., 2007). All crops grown are vulnerable to attack from one plant parasitic nematode or the other (Bridge and Star, 2007). *Heterodera sacchari,* the cyst nematode is salient to vital crops (Fabiyi *et al*., 2018). High yield losses of about $125 billion is attributed to nematode infestation (Chitwood, 2003). Control of plant parasitic nematodes in commercial cane plant production is by the use of synthetic nematicides (Donga and Eklo, 2018). Some of the consequences of unregulated pesticide use are environmental pollution, human health problems, and pesticide residue contaminants (Fabiyi and

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Olatunji, 2021). The physicochemical characteristics of most nematicides make them mobile in soil and thus contaminate ground water through run off (Pedlowski *et al*., 2012). Many synthetic nematicides are banned due to their toxicity and negative impact in the environment (Haydock *et al*., 2014). Hence, the aim of this research is to produce furfural from agricultural wastes and evaluate the effectiveness on the sugarcane plant nematode *Heterodera sacharri.*

Materials and Methods

Reagents

All reagents used were of analytical grade, these include dichloromethane, acetic acid, hydrochloric acid, ethanol, distilled aniline, and anhydrous magnesium sulphate.

Plant materials

Dry plantain leaves (PLT), sugarcane bagasse (SB) and dry pawpaw stem (PS) were obtained from Ilorin metropolis. The materials were air dried for two weeks and then powdered using a STEEL MAN diesel engine with 7 Horse power capacity; model R175A.

Hydrolysis of plant materials with dilute acids

300 grams each of milled sugarcane bagasse (SB), dry plantain leaves (PLT) and dry pawpaw stem (PS) was packed into 2000 mL quick-fit flask separately in batches, 1500 mL of dilute 8 % hydrochloric acid was added to the flask, the materials were allowed to soak properly into the acid solution to avoid charring, the flask was then connected to a reflux condenser and heated on a sand bath at 200°C for $2^{1/2}$hours (Ali *et al*., 2002; Fabiyi *et al*., 2018). After hydrolysis crude furfural was decanted and filtered. The same process was repeated for each waste material using dilute 8 % hydrochloric acid. The procedure was carefully repeated sequentially until 1kg of each of the agro-waste material was exhausted.

Extraction of furfural

100 mL of the crude furfural solutions from the various hydrolysis was poured into a separating funnel, while 100 mL of dichloromethane (DCM) was added. The organic layer which contains the furfural was separated, dried with anhydrous magnesium sulphate; and filtered. The furfural was obtained by steam distillation (Montane *et al*., 2002; Fabiyi *et al*., 2018). The extracted furfural was collected and stored in sample bottles. This procedure was repeated for all the crude furfural extracted from each of the agro-waste material. Each extracted furfural was coded FFR/PLT, FFR/PS and FFR/SB, that is, furfural from plantain leaves, furfural from pawpaw stem and furfural from sugarcane bagasse respectively.

Screenhouse experiment

Loamy soil was collected and pasteurized at 70°C for three hours. The soil was allowed to cool and then distributed into experimental pots of 30 cm diameter at 25 Kg each and were set aside to stabilize for two weeks. The experiment was a randomised complete block design (RCBD). There were four treatments at four levels and each with three replicates. Cane setts were planted and inoculated three weeks after planting with approximately 500 eggs and juveniles of *Heterodera saccharri* in a hole made at the base of each cane setts (Fabiyi, 2019; Fabiyi *et al*., 2019). Treatments were applied at 25, 50 and 75mg. The untreated plants served as the control, while all treatments were likened to carbofuran as the standard check.

Statistical analysis

Data were collected on heights of each cane plant, number of leaves of each cane plant and nematode population in 200 g soil. parameters were subjected to two-way analysis of variance (ANOVA). Treatment means, where necessary were separated using the new Duncan's multiple range test at 5 % level of probability (Gomez and Gomez, 1984).

Results and Discussion

Results from Table 1 reveals that there was no notable (p=0.05) difference in the numbers of leaves of cane plants treated with different furfural from each of the waste materials. The numbers of leaves were remarkably low in the untreated control plants. The highest (75 mg) dosage of application of furfural produced more leaves. Table 2 represents the response of sugarcane plants treated with furfural. Appreciable (p=0.05) differences were observed in the height of the cane plants. Furfural extracted from sugarcane bagasse was consequentially more effective than furfural produced from other waste materials. Significantly low height was recorded in untreated cane plants. Similarly, nematode population was reduced in cane plants treated with furfural from sugarcane bagasse. Higher nematode population was detected in the untreated control cane sugar plants (Table 3).

Table 1: *Effects of treatment and treatment concentration on the number of leaves of sugarcane plants.*

Treatment	9WAP	10WAP	11WAP	12WAP	13WAP	14WAP	15WAP	16WAP	17WAP	18WAP
CBFN	8ª	8ª	9ª	9ª	10ª	10ª	11ª	12ª	13ª	15ª
FFR/PLT	8ª	8ª	9ª	9ª	11ª	11ª	12ª	12ª	13ª	14ª
FFR/SB	7ª	8ª	9ª	9ª	11ª	11ª	12ª	13ª	13ª	13ᵇ
FFR/PS	7ª	8ª	9ª	9ª	10ª	11ª	12ª	13ª	13ª	12ᵇ
CONTROL	5ᵇ	5ᵇ	6ᵇ	6ᵇ	7ᵇ	8ᵇ	8ᵇ	9ᵇ	10ᵇ	11ᶜ
Dosage/Mg										
One (25 mg)	6	7	7ᵇ	8	8ᵇ	8ᵇ	9ᵇ	9ᵇ	10ᶜ	13ᵇ
Two (50 mg)	6	7	7ᵇ	8	9ᵃᵇ	10ª	10ᵇ	11ª	12ᵇ	12ᶜ
Three (75 mg)	6	8	9ª	9	10ª	11ª	12ª	12ª	14ª	16ª

Treatment with the same letters in the column are not significantly different at p=0.05, using the new Duncan's multiple range test.

Table 2: *Effects of treatment and treatment concentration on the heights of sugarcane plants.*

Treatment	9WAP	10WAP	11WAP	12WAP	13WAP	14WAP	15WAP	16WAP	17WAP	18WAP
CBFN	172.6ª	191.3ª	196.8ª	201.0ª	208.5ª	212.0ª	219.0ª	229.0ª	236.1ª	241.0ª
FFR/PLT	130.1ᶜ	152.7ᶜ	158.1ᶜ	170.1ᶜ	178.2ᶜ	188.5ᶜ	200.1ᵇ	219.7ᵇ	226.4ᵇ	230.8ᵇ
FFR/SB	159.2ᵇ	165.3ᵇ	173.0ᵇ	182.3ᵇ	187.0ᵇ	196.6ᵇ	202.3ᵇ	228.0ª	235.5ª	240.8ª
FFR/PS	131.8ᶜ	150.2ᶜ	162.8ᶜ	169.5ᶜ	178.7ᶜ	187.2ᶜ	190.5bᶜ	197.3ᶜ	204.1ᶜ	209.7ᶜ
CONTROL	115.6ᵈ	126.0ᵈ	137.4ᵈ	145.0ᵈ	149.4ᵈ	153.0ᵈ	159.3ᵈ	167.2ᵈ	176.0ᵈ	185.4ᵈ
Dosage/Mg										
One (25 mg)	120.0ᶜ	130.9ᶜ	137.5c	145.7ᶜ	150.7ᶜ	158.4ᶜ	161.0ᶜ	169.2ᶜ	175.4ᶜ	192.7ᵇ
Two (50 mg)	131.3ᵇ	143.3ᵇ	151.1b	159.3ᵇ	166.8ᵇ	179.3ᵇ	185.5ᵇ	190.8ᵇ	196.8ᵇ	201.6ᵇ
Three (75 mg)	143.6ª	159.0ª	164.0a	170.4ª	184.0ª	190.0ª	206.9ª	211.2ª	217.0ª	221.9ª

Treatment with the same letters in the column are not significantly different at p=0.05, using the new Duncan's multiple range test.

Table 3: *Effects of treatment and treatment concentration on the population of soil nematodes of sugarcane plants.*

Treatments	Soil nematode
CBFN	35ª
FFR/PLT	129ᶜ
FFR/SB	66ᵇ
FFR/PS	143ᵈ
CONTROL	1579ᵉ
Dosage/Mg	
One (25 mg)	155ᶜ
Two (50 mg)	97ᵇ
Three (75 mg)	49ª

Treatment with the same letters in the column are not significantly different at p=0.05, using the new Duncan's multiple range test.

Furfural (2-Furancarboxaldehyde), a naturally occurring compound which is prepared by acid hydrolysis of pentosans is nematicidal (Marcotullio, 2013). The efficacy of furfural at different concentrations on *Meloidogyne javanica* was evaluated by Al-Hamdany *et al.* (1999). They established that furfural at 1000 and 2000 ppm significantly reduce the egg masses and root gall index of cucumber plant. With 4000 ppm of furfural there was no galling. Equivalently, Stephan *et al.* (2001), reported the effectiveness of furfural as a pre-planting nematicide at 4000 ppm for tomato plants, while El-Mougy *et al.* (2008), in green house and field experiments also affirmed that furfural is nematicidal with a sharp decline in *Meloidogyne incognita* population. Commercial furfural was tested by Kokalis-Burelle (2007) on *M. incognita* infecting tomato. Reduced galling and good vegetative growth was spotted. In laboratory experiments, furfural at 0.4 mL/L soil to small pots reduced numbers of *Helicotylenchus dihystera*, *Paratrichodorus* spp., *Pratylenchus zeae*, *Tylenchorhynchus* sp., *Xiphinema elongatum* and *X. mampara* (Spaull, 1997). In the same vein, furfural synthesised from agro-cellulosic materials depicted strong nematicidal activity on *M. incognita* parasitizing groundnut plants (Fabiyi, 2020) All the above corroborated the findings in this research. Considerable reduction in population of *Heterodera saccharri* was exhibited in cane plants treated with the highest concentration of furfural. A striking increase in height of sugarcane plants was recorded in treated plants, which translates to yield increase.

Conclusions and Recommendations

Furfural can be exploited in place of the toxic synthetic nematicides in the curb of cyst nematode parasitizing cane plants. The dissimilarities observed in the results may be due to the existence of impurities in the materials utilized for hydrolysis

Novelty Statement

This is the first report on the application of furfural in the control of *Heterodera saccharri* on sugarcane plants in Nigeria.

Conflict of interest

The authors have declared no conflict of interest.

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