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Pesticide Alternatives for Controlling Root rot and Root knot of Cucumber under Plastic House Conditions

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Abstract- Fusariumsolani and Meloidogyneincognita rank high among serious soilborne pathogens affecting cucumber plants and cause root-rot and root-knot diseases, respectively. Furfural (10mL/L) and different rates of urea fertilization (25, 50, and 100 g/m^2) individually or in combination were evaluated against root-rot incidence and root-gall formation on cucumber grown under plastic house conditions. The treatments were applied before cucumber transplanting as soil drench under natural infestation with these root pathogens.Reduction in either root rot or root knot infections were observed with varying degrees in the tested treatments. The combination between furfural and urea showed superior effect relative to each of them alone. Treatments resulted in significant ($P \leq 0.05$) control of both diseases and increased the harvested yield. Based on the production figures and prices of cucumber, urea, and Furfural; the net profit resulting from the application of Furfural (10mL/L) + Urea 100 g/m^2 over that of the fungicide and nematicide application equaled 3375 LE/plastic house. Therefore, these methods are recommended for wider applications since they introduced efficient disease control and increased yield of cucumber.

***Index Terms*-Cucumber, root rot, root knot, Fusraiumsolni, Meloidogyne incognita, furfural, urea.**

I. INTRODUCTION

Cucumber (*Cucumissativus* L.) is grown all over the world as a good source of vitamins, minerals, fiber and roughages. This vegetable crop is attacked by several fungi, bacteria, viruses and nematodes. The root-rot fungus (*Fusariumsolani*) and root-knot nematodes (*Meloidogyne*spp.) rank high among all pathogens attacking cucumber as they cause tremendous yield losses. For example, based on 2011-2012 total Egyptian production figures and prices on wholesaling basis; not retail [1], estimated annual yield losses in cucumber due to damage by plant-parasitic nematodes in Egypt at 15% resulting in 103696.24-metric-ton loss which equaled L.E. 155.54 (= US $19.5) million. These figures are subject to increase annually with the continuous expansion in cucumber-cultivated areas. Also, the increase in commodity prices since 2011 may inflate this estimate further. Concerns over the potential impact of disease management practices including the use of synthetic fungicides and nematicides on the environment or on consumer health have prompted producers to examine alternative methods to combat fungal and nematode diseases. There is a growing need to develop alternative approaches for controlling plant diseases. Root and stem rot diseases caused by pathogens which survive in soil are responsible for serious losses in vegetable crop yield. Also [2] recorded that Fusarium stem and root rot of cucumber at four commercial greenhouses in Leamington, Ontario, Canada causing losses of 25-35%. Compared to other worldwide survey [3], *Meloidogyne* spp. are still first in terms of their importance as nematode pests in Egypt [1] and elsewhere [4] in spite of difference in regions, climate, and prevailing crops. The disease caused by these insidious nematodes is often the only, or one of the few, nematode diseases of crops known to farmers owing to its subterranean activities but severe symptoms [5,6]. These nematodes are worldwide in distribution, attacking a wide range of agricultural crops [3]. The overall losses of vegetables caused by root-knot nematodes have been estimated to be considerably high [7]. An alternative to chemical pesticide application is that it may be possible to utilize a scheme of inducible plant defenses which may provide protection against a broad spectrum of disease-causing pathogenic microorganisms. Furfural [2-Furancarboxaldehyde] is a naturally occurring compound, present in some essential oils and in foods such as bread, baked products, and coffee. It is prepared industrially by treatment with hot sulphuric acid of pentosans contained in agricultural residues, such as cereal straw, brains, and sugarcane bagasse. Furfural is a new pesticide active ingredient intended for the use as a fumigant to control plant parasitic nematodes and fungi infesting plant roots. The technical formulation (Furfural Technical) contains 99.7% furfural and is used in formulating products and applied to growing media and/or soils in greenhouses and fields [8,9]. Also, [10] reported that most of drip irrigation treatments reduced populations of *Pythiumultimum* and *F. oxysporum* and increased stem height compared to the non-treated controls. Metham sodium, furfural + metham sodium, sodium azide, and chloropicrin significantly reduced the incidence of Lateris stem rot caused by *Sclerotiniasclerotiorum*. On the other hand, it was reported that mixtures of blackstrap molasses and urea could control root knot nematodes in Alabama [11]. They found that urea alone worked as nematicidal compound when applied at a rate of 0.4 g/kg of soil, though this rate can be phytotoxic to plants. When soil was amended with urea and carbon-rich blackstrap molasses, however, phytotoxicity was abolished; nematode populations decreased, and plant weight and height increased. This work indicated that superior results are obtained when nitrogen was added in urea form. Moreover, [12] found that soil amended with carbon rich hemicellulosic waste had more nematicidal efficacy when urea was also added to the soil. Also, [13] found that the addition of soil amendments and microbial antagonists increased nematode control when applied to the soil. The success or failure of soil amendments are in fact linked to the C: N ratio with 15 to 20 being ideal [14]. The present research focuses on finding compounds that are safe to human and environment. The objective of the present work was to evaluate the suppression activity of some pesticide alternatives applied as soil drench before transplanting against root knot and root rot diseases of cucumber under commercial plastic houses conditions.

II. MATERIALS AND METHODS

Evaluating the efficacy of furfural and/or urea fertilization treatments against root rot and root knot incidence of cucumber was performed under plastic house conditions located at The Researches and Experimental Station, National Research Centre (NRC), Noubaria region, Behiera Governorate. Different concentrations of either furfural and /or urea fertilization was applied as soil drench in the following treatments:

1- Furfural (10ml/L).
2- Furfural (10ml/L) + Urea 25 g/m^2
3- Furfural (10ml/L) + Urea 50 g/m^2
4- Furfural (10ml/L) + Urea 100 g/m^2
5- Urea 25 g/m^2
6- Urea 50 g/m^2
7- Urea 100 g/m^2
8- Control (received only the recommended chemical fungicide Rizolex-T 50% as transplanting dipping at the rate of 2g/L) and the chemical nematicideFuradan (Carbofuran) as soil drench at the rate of 1.0 g/m^2.

The experimental plastic house consists of 8 rows, each (0.75 x 60m, width x long). Each row divided into 3 parts 20m long each and every part considered as one replicate. Three replicates were used for each treatment in a complete randomized block design. The proposed treatments were prepared at the laboratory of Plant Pathology Dept., NRC and just before application. The prepared furfural solution was incorporated into the cultivated row site at the rate of 20L/row (distributed for the three replicates) 5 days before transplanting cucumber, then mulched with black mulching polyethylene sheets. Meanwhile, urea granules were incorporated into the cultivated row site at the afore-mentioned rates. Cucumber *c.v*. Hesham seedlings were transplanted on the middle of September and received recommended agriculture practices, *i.e*. irrigation and foliar NPK fertilization. The harvest began after 60 days of transplanting and continued to the end of January. Monitoring and scouting of root rot and root knot incidence were recorded up to 45 days from transplanting. Percentage of disease incidence was recorded as the number of diseased plants in relative to the number of planted seedlings; the average of disease incidence in each treatment was calculated. The root rotted cucumber plants were isolated in order to identify the causal fungal agent with the aid of morphological and microscopic characters as described by [15]. For root-knot nematode records, the tops of the plants were cut off and the roots gently washed free of soil. Roots were stained in hot acid fuchsin-lactophenol, cleared with lactophenol and nematode galls and egg masses were counted (Taylor and Sasser, 1978). The centrifugal-flotation technique [16] was used to extract nematode juveniles from soil (200 g soil/plant). Perineal patterns of isolated *Meloidogyne* females were prepared for identification to the species level [17].

Statistical Analysis

Two-way ANOVA was used to analyze differences between applied treatments [18]. Averages of treatments were compared using Duncan's New Multiple Range Test [19].

III. RESULTS AND DISCUSSION

It is necessary to consider the occurrence with which most serious diseases of plants appear in an area year after year, the rapid spread of most plant diseases, and the reasonable approaches of curing a disease after it has begun to develop. With these considerations in mind, it is easy to understand why almost all management measures are aimed at protecting plants from becoming diseased rather than at curing them after they have become diseased. As a matter of fact, few infectious plant diseases can be satisfactory controlled in the field by therapeutic chemical means without side effects on the environment and/or human beings. Controlling soilborne pathogens of plants is particularly complex. This is because these pathogens occur in a dynamic environment at the interface of root and soil. Hence, it was our intention to apply pesticide alternatives such as furfural or urea fertilization as protective measures against harmful fungus *F. solani* and *Meloidogyne incognita*. Therefore, the present work aimed mainly at reducing the populations of such plant pathogens using environmentally friendly rational compounds againstroot-rot and root-knot diseases which cause considerable losses to cucumber plants under protected cultivation system. We tried to use such compounds as protective alternative treatments and compare them with chemical treatments. Visual scouting and monitoring throughout the period of this study revealed that the applied treatments could reduce root-rot disease incidence. Data in Table (1) and Figure (1) showed that the recorded percentage of cucumber root-rot incidence was 5.7% in furfural treatment compared to 13.7% in chemical application with Rizolex. Meanwhile, urea fertilization at concentrations of 25, 50 and 100 g/m^2 showed gradual reduction in the disease incidence being 8.6, 6.3 and 4.2%, respectively. Further reduction to 3.3, 1.8 and 1.3% in root rot incidence was observed on combining furfural (10mL/L) with urea application at concentrations of 25, 50 and 100 g/m^2. A similar effect was also reported for tomato wilt caused by *F. oxysporum* [20]and stem rot of liatris, dotted gayfeather (*Liatrispunctata*) caused by *Sclerotiniasclerotiorum*[10]. Moreover, botanical aromatics, furfural, citral and

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benzaldehyde showed potential for control of both fungal pathogens and phytoparasitic nematodes [21]. There are a few cited reports explaining the furfural mode of action against soil micro-flora. In this regard, the pesticide market has some products containing 90% furfural in a liquid formulation registered as commercial products, e.g. Crop Guard, Multiguard Protect, and Protect [8,9].

Table. 1. Percentage of root-rot incidence of cucumber in response to application of furfural and/or urea concentrations under plastic house conditions

Treatment	Root rot incidence %
Furfural (10mL/L)	5.7 d
Urea 25 g/m^2	8.6 b
Urea 50 g/m^2	6.3 c
Urea 100 g/m^2	4.2 e
Furfural (10mL/L)+ Urea 25 g/m^2	3.3 f
Furfural (10mL/L) + Urea 50 g/m^2	1.8 g
Furfural (10mL/L) + Urea 100 g/m^2	1.3 g
Control (Rizolex , Furadan)	13.7 a

Figures with the same letter are not significantly ($P \leq 0.05$) differentaccording to Duncan's New Multiple Range Test.

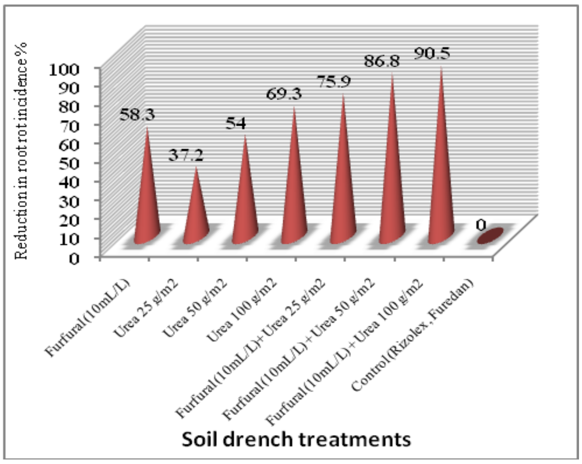

Fig. 1. Reduction in root rot incidence of cucumber in response to application of furfural and/or urea concentrations under plastic house conditions

Moreover, such an effect varied depending on the host plant and rate of application, and may reflect its effects on other soil microorganisms. In fact, many researchers conducted laboratory and field trails concerning the efficacy of furfural against soil microorganisms [23,24,25,26,27]. They recorded that furfural is a natural bactericide, herbicide, fungicide, insecticide and nematicide. Furfural interacts with the cuticle of the nematode, effectively stripping the protective layers which results in the cuticle swelling and disintegrating. Movement of the nematode is impeded and it subsequently dies through dehydration or attack by parasitic organisms. Due to its contact mode of action, correct positioning of furfural is imperative for effective control. Residue analyses showed no levels of furfural above natural background levels found within the plant or fruit even after multiple applications during the growing season [25,28]. Results in Table (2) and Figure (2) showed that the applied treatments reduced the number of soil-J_2 of the nematode identified as *Meloidogyne incognita*, number of galls and egg-masses in roots of cucumber plants, compared to untreated control (chemical pesticides). Besides the nitrogenous fertilizers, urea is well known to control Phytonematode populations in soil in Egypt [29,30] and elsewhere [31]. Combined treatments with furfural and urea showed significant superior effect against nematode relative to treatment with a single compound or the untreated check (chemical pesticides). The furfural treatment reduced averages of *M. incognita*-J_2 number in soil from 197 to 97, number of root galls from 92 to 47, and number of egg-masses from 16 to 12. Meanwhile, urea treatments as 25, 50 and 100 g/m^2 reduced J_2 in soil, root gall number and number of egg-masses by (51.7, 60.9, 65.4%), (47.8, 62.1, 72.8%) and (33.3, 42.8, 52.3%); respectively. Also, combined application of Furfural (10mL/L) + Urea 100 g/m^2 demonstrated the highest reduction in number of J_2 in soil, root gall number and number of egg-masses by 81.7, 86.9 and 80.9%, respectively (Figure 2). Such an effect in a descending order was also observed concerning combined treatments of Furfural (10mL/L) + Urea 50 g/m^2 and of Furfural (10mL/L) + Urea 100 g/m^2. They recorded reduction as75.8, 83.6, 71.4% and 73.0, 80.4, 61.9%, in respect to the numbers of J_2 in soil, root galls and egg-masses, respectively. In the United States [32], furfural is being investigated for the control of nematodes in turf, peanuts, vegetable crops, ornamentals and fruit and vine crops. Due to furfural's low phytotoxicity, applications can be made post-plant as well as pre-plant of the crops. This property allows for in-season applications to provide season long nematode control. Furfural is a contact nematicide and must be mechanically incorporated or moved into the soil profile with irrigation. The product currently being tested is Multiguard Protect which contains 1.04 kg a.s./l of furfural. Rates ranging from 53.5 kg a.s./ha to 155.5 kg a.s./ha are currently being tested and activity has been demonstrated on *Belonolaimus*spp. (sting), *Hoplolaimusgaleatus*(lance), *Criconemellaxenoplax*(ring), *Meloidogyne*spp. (root-knot) and *Paratrichodorus minor* (stubby root) nematodes. Pre-plant applications up to 448 kg a.s./ha have been tested and shown to be safe on strawberries, tomatoes and peppers. Although furfural can be injected into soil, field and microplot studies have demonstrated that delivery by drenching results in the greatest pesticidal activity [32]. Also, [24] studied the efficacy of furfural at different concentrations for control of the root-knot nematode *Meloidogynejavanica*on cucumber and eggplant. The results indicated that using 1000 and 2000 ppm of furfural significantly reduced the root galling index in cucumber while, no galls were observed on the roots when 4000 ppm of furfural was used. Similar results were also obtained with eggplant except that 5000 ppm was needed to completely inhibit root galling.

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Table. 2. Effect of furfural and urea treatments on the number of Meloidogyne incognita juveniles in soil, galls and egg masses on roots of cucumber under plastic house conditions

Treatments	No. J_2 in Soil (200 g)	No. galls in roots (5g)	No. egg-masses in roots (5g)
Furfural (10mL/L)	97 b	47 b	12 b
Urea 25 g/m^2	95 b	48 b	10 c
Urea 50 g/m^2	77 c	36 c	8 d
Urea 100 g/m^2	68 d	25 d	6 e
Furfural (10mL/L)+ rea 25 g/m^2	53 e	18 e	4 f
Furfural (10mL/L)+ Urea 50 g/m^2	48 f	15 f	3 g
Furfural (10mL/L)+ Urea 100 g/m^2	36 g	12 g	2 h
Control (Rizolex , Furadan)	197 a	92 a	16 a

In a column, figures with the same letter are not significantly ($P \leq 0.05$) differentaccording to Duncan's New Multiple Range Test.

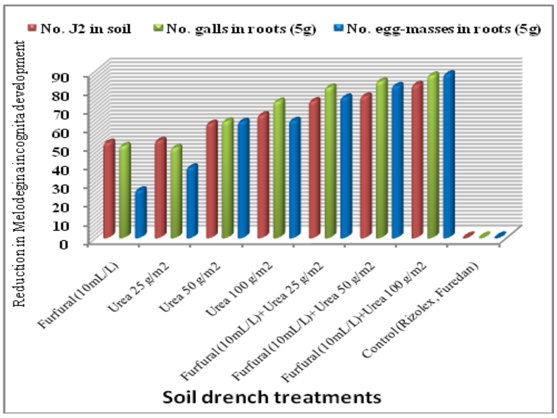

Fig. 2. Reduction in the number of juveniles in soil, galls and egg masses on roots of *Meloidogyne incognita* of cucumber under plastic house conditions in response to furfural and urea treatments

In the present study, it seems that the applied urea when used as soil amendments not only increased fertility of soil, but also caused considerable stress on the root knot nematode, *Meloidogyneinognita*. In this regard, the exact mechanism of action of organic amendments may be due to the secondary products from their decomposition which are directly toxic to nematodes [33], or they have beneficial ingredients for plant growth and increasing natural enemies [34]. Yet, it seems likely that nematode toxicity resulting from the production of ammonia released from the decomposition of urea could probably contribute to the suppression of *M. incognita* population levels [29,31,35]. Similarly, [36,37] reported that with the liberal supply of water, oil seed cakes decomposed and released many compounds including ammonia, phenols and aldehydes and these substances have a nematicidal nature. Also, there was no sign of phytotoxicity due to the tested amendments. Besides, in plants grown in soil amended with organic additives, the roots undergo physiological changes with make them unsuitable for nematode penetration and feeding and thus inducing certain degree of resistance against nematode invasion [38,39].

The harvested cucumber yield in all treatments was significantly higher than that in the control treatment. Data in Table (3) and Figure (3) revealed that the combined treatments of furfural and Urea showed higher yield production than that from plots where each compound was applied singly as well as the fungicide and nematicide control treatment.

Table. 3. Effect of different applications of furfural and/or urea concentrations on produced yield of cucumber grown under plastic house conditions

Treatment	Produced yield	
	Average Yield Kg/row	Yield Ton/plastic house
Furfural (10mL/L)	222.4 e	1,779
Urea 25 g/m^2	208.6 g	1,668
Urea 50 g/m^2	212.4 f	1,699
Urea 100 g/m^2	216.4 f	1,731
Furfural (10mL/L) + Urea 25 g/m^2	234.6 d	1,876
Furfural (10mL/L) + Urea 50 g/m^2	248.2 c	1,985
Furfural (10mL/L) + Urea 100 g/m^2	252.6 b	2,020
Control (Rizolex, Furadan)	152.2 a	1,217

Figures with the same letter are not significantly ($P \leq 0.05$) differentaccording to Duncan's New Multiple Range Test.

Highest effective treatments which reflected in the obtained cucumber yield increase were urea fertilization at the rate of 100 g/m^2 combined with furfuralwhich recorded yield of 252.6 Kg/row with an increase of 65.9% over the control treatment, followed by urea fertilization at the rate of 50 and 25 g/m^2 combined with furfuraltreatments which recorded yield increase as 63.0 and 54.1%; respectively. Meanwhile, single treatments of furfuraland Urea fertilization with 100, 50, 25g/m^2 recorded yield as 222.4, 216.4, 212.4, and 208.6 Kg/row with increase of 46.1, 42.1, 39.2 and 37.0%.

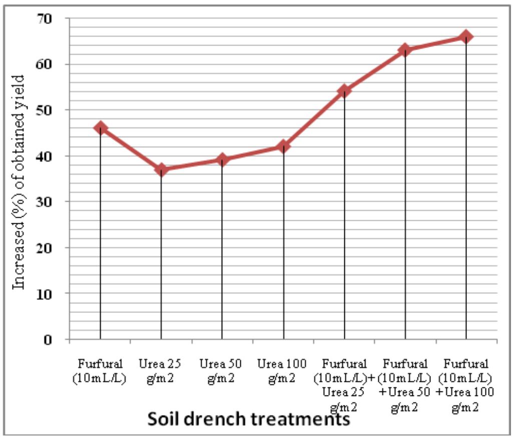

Fig. 3. Yield increase (%) of cucumber grown under plastic house conditions in response to soil application with furfural and/or urea concentrations

It is clear that more reduction in cucumber root-knot and root-rot incidence occurred when the furfural was combined with urea fertilization. In this regards, the use of fertilizers in the control of soil borne root-rot diseases of crop plants is a common practice. Nitrogen present in the fertilizer is absorbed by the plant and function in protein synthesis and seed production whereas potassium is involved in many cellular functions including photosynthesis, phosphorylation, water maintenance, reduction of nitrates and reproduction. Urea inhibited soilborne fungi-infected roots on mung bean [40]. Also, [41] stated that control of fungi infecting roots with the use of mineral fertilizers could presumably be due to the increase in tolerance with the development of thicker cuticle and cell wall or more sclerenchyma tissue with different nutrient regimes which was correlated with the difficulty in penetration of a pathogen. Complete suppression of *Macrophomina phaseolina* was obtained when urea and DAP were used in combination with *Acaryochloris marina* leaves powder on okra [42]. Similarly, [40] reported that urea showed significant reduction in *M. phaseolina*infecting mung bean. Furthemore, [43] reported that root rot diseases in mung bean caused by *Fusarium*spp., *M. phaseolina* and *R. solani*were reduced by the addition of urea and potash. Furthermore, root rot diseases caused by *F. oxysporum* and *R. solani* were reduced by the addition of mineral fertilizers [44]. In general, the greatest benefit to the plant is provided when full nutrient sufficiency is provided; however, the response to a particular nutrient may be different when going from deficiency to sufficiency than from sufficiency to excess [45]. Since each nutrient functions as part of a delicately balanced interdependent system with the plant genetics and the environment, it is important to establish a nutrient balance for optimum crop response. Through an understanding of the disease interactions with each specific nutrient, the effects on the plant, pathogen, and environment can be effectively modified to improve disease control, enhance production efficiency, and increase crop quality. Knowledge of the relationship between plant nutrition and disease provides a basis for reducing disease severity as well as enhance integrated crop production systems. Through an understanding of the disease interactions with each specific nutrient, the effects on the plant, pathogen, and environment can be effectively modified to improve disease control, enhance production efficiency, and increase crop quality [45]. These methods introduced efficient disease control and increasing yield of many crops [46,47]. Therefore, such approaches may be applied on large scale.

IV. CONCLUSION

The importance of the present work is based on the proposed pesticide alternatives as protective compounds which might be able to inhibit important cucumber pathogens and prevent them from causing damage. The obtained results showed that furfural combined with urea fertilization can have a considerable fungicidal and nematicidal activity in the soil. A reduction in *Meloidogyne incognita* galling and egg-masses following the application of such treatments suggested that these products can protect plants from pathogen invasion tocontinue its life cycle inside roots. Apparently, the compounds applied herein could maintain soil conditions favorable for root development and deliver protection against pathogens. Based on the production figures (Table 3) and prices of cucumber (5 LE/ Kg), urea (5 LE/ Kg), and Furfural (250 LE/liter); the net profit resulting from the application of Furfural (10mL/L) + Urea 100 g/m2 over that of the fungicide and nematicide application equaled 3375 LE/plastic house. Therefore, these methods are recommended for wider applications since they introduced efficient disease control and increased yield of cucumber.

V. ACKNOWLEGMENTS

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