Field Evaluation of Using the Nematophagus Fungus *Dactylaria brochopaga* for the Management of Root-Knot Nematode, *Meloidogyne incognita* Infecting Soybean, *Glycine max*

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Abstract

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A field experiment was carried out during 2020 growing season in a soybean field naturally infested with the root-knot nematode *Meloidogyne incognita* for evaluating the use of the nematophagus fungus, *Dacylaria brochopaga,* against nematode infection, compared with the chemical nematicide Furadan (Carbofuran). The fungus was prepared in two forms, as liquid (DBL) and granules (DBG) biocide. DBG and Furadan treatments were applied once at planting date, whereas DBL was applied once after seed germination. Results obtained indicated that DBG and Furadan treatments significantly reduced nematode final population (P_f) in soil by 32.4 and 36.5%, respectively, when soybean cv. Giza-22 was used, and by 47.1 and 48.2% when cv. Giza-111 was used, compared to the control treatment. DBL had no significant effect on P_f for both soybean cultivars. The root-gall index (RGI) at mid-season was not significantly influenced by DBG and DBL treatments, whereas Furadan treatment reduced RGI by 30.6% for cv. Giza 111 and 22.5% for cv. Giza-22. At harvest, RGI was significantly reduced with DBG and Furadan treatments by 31.6% and 33.3%, respectively, in case of cv. Giza-22 and by 39.3 and 42.9% in case of cv. Giza-111, respectively, compared to the control treatment. Whereas, no significant effect on RGI was obtained by the DBL treatment for both soybean cultivars, either at mid-season or at harvest, compared to the control. Soybean seed yield of cv. Giza 22 was significantly increased by DBG treatment (10.9%), and 12.3% in case of cv. Giza -111, compared to the control. DBL and Furadan treatments had no significant effect on seed yield of both cultivars.

Keywords: Soybean, root-knot nematodes, predacious fungi, formulation, biological control.

Introduction

Soybean, *Glycine max* L. Merr. is considered one of the most important oilseed crops worldwide. Its seeds contain about 30% oil and 40% protein **(**El-Abady *et al*., 2008). So it is extensively used in the manufacture of animal and human feed-staff and other purposes such as plastics, lubricants, candles, varnishes, soap, biodiesel and lecithin (Fontana, 2011).

The root-knot nematodes (*Meloidogyne* spp.) are economically important plant pathogens, distributed worldwide, infecting nearly every species of higher plants (Karssen & Moens, 2006; Moens *et al*., 2009). About 70% of the damage caused by phytonematodes is attributed to the root-knot nematodes, as loss in the yield is estimated by 80% in heavily infested fields with average yield loss ranging from 28 to 68% (Chaudhary *et al*., 2011).

Soybean plants were reported to be infected with the root-knot nematodes in many soybean-growing areas of the world (Koenning, 2015). Three species of root-knot nematodes (*Meloidogyne incognita*, *M. javanica* and *M. arenaria*) are widely distributed and prevalent in the regions of warmer climate and account for the most of reported damage in these regions with long growing soybean (Sikora *et al*., 2018). Considerable losses in soybean yield due to the root-knot nematodes were also reported by many investigators worldwide (Fourie *et al*., 2015; Korayem & Mohamed, 2018; Lima *et al*., 2017; Sikora *et al*., 2010; Wrather & Koenning, 2009).

Control of the southern root-knot nematodes, *Meloidogyne incognita* is extremely difficult because it is a obligate and sedentary endo-parasite, and has more than one generation per year, that are overlapped with each other.
Sustainable management of pathogenic nematodes is a strategy which aims at reducing and maintaining the nematode population below economic threshold levels by using different ecofriendly methods without use of toxic nematicides. Biological control of phytonematodes by fungal antagonists has been most extensively studied and appeared to be most important in regulating nematode population in soil (Chen & Dickson, 2004), it is ecofriendly and offers a sustainable and cost-effective alternative to harmful nematicides (Shamalie *et al*., 2011). Predacious fungi have received most attention for biological control of nematodes due to their specific ability to capture and kill nematode (Yang & Zhang, 2014). More than 700 species of nematophagous fungi have been described as biological control agents against phytonematodes based on their infection mechanism. Of them 380 species were described as predacious fungi (Zhang *et al*., 2011). The predacious fungus, *Dactylaria brochopaga* was isolated from soil samples collected from the rhizosphere of soybean grown in different locations of Egypt (Korayem *et al*., 2021). Suppressive effect of *D. brochopaga* against the root-knot nematode *M.incognita* infecting snap bean and eggplant

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under field condition has been reported (Noweer & Aboul-Eid, 2016; Noweer & El-Kelany, 2019). The objective of the present study was to evaluate the suppressive effect of predacious fungus *D. brochopaga* formulated in liquid and granules as commercial products against *M. incognita* infecting soybean plants in the field.

Materials and Methods

Plant materials

Seeds of two certified soybean cultivars, Giza-22 and Giza-111 were obtained from the Field Crop Research Institute, Ministry of Agriculture, Egypt.

Origin of the fungus

Native *Dactylaria brochopaga* fungus was isolated from rhizosphere of soybean infected with root-knot nematodes by using nematode water agar (NWA) medium (Korayem *et al*., 2021), propagated and maintained on potato dextrose Agar (PDA) medium (Harwig *et al*., 1979).

Preparation of *D. brochopaga* in liquid and granule formulations

As to liquid formulation (DBL), spores of the fungus were mixed with yeast, molasses and water, and as to granular formulation (DBG), spores were mixed with Vermiculite, yeast and molasses. Formation of the bio-products, their contents, dose and date of application are presented in Table (1). One liter from the liquid formulation was dissolved in 50 L of water before treatment, then each hill received 25 ml.

Field experiment

The experiment was carried out during 2020 season in a sandy soil field naturally infested with the root-knot nematode, *Meloidogyne incognita,* at Abdel-Samad Village, Imbaba, Giza, Egypt. The experimental area (around 320 m^2) was prepared before planting in rows of 60 cm wide and 10 m long. Calcium superphosphate (15% P_2O_5) and potassium sulphate (48.5%) fertilizers were added to the soil at the recommended rate during seedbed preparation. Ammonium nitrate (33.5%N) at the rate of 50g/m^2 was added in two equal portions, one and two months after seed germination. The experimental area was then divided into two equal parts, 160 m^2 each, with each part divided into four plots each of 40 m^2, and each of these plots was divided into four microplots (replicates) of 10m^2 each. On May 25, 2020, seeds of two soybean cvs. (Giza-22 and Giza-111) were separately planted in hills at the rate of 4-5 seeds per hill, and each cultivar was planted in an area of 160 m^2 (sixteen microplots). Before planting, composed soil samples were taken from each microplot to determine the nematode initial population density (Pi). Four treatments, DBG, DBL, Furadan and control were applied following a randomized block design with four replicates per each treatment. Root samples were taken from each replicate at both mid-season (25-7-2020) and at harvest (20-9-2020) for assaying root galling. In addition, 250 ml soil samples were collected from each replicate at harvest for assaying the nematode final population density (Pf).

Nematode assay in soil and roots

Nematode second stage juveniles (j2) were extracted from 250 g soil samples according to the sieving method (Christie & Perry, 1951). While the nematode root-gall index (GI) of each plant root was estimated using the following 0-6 scale: 1= no galls, 2= 1-20% root galling, 3= 21-40%, 4= 41-60%, 5= 61-80%, 6= 81-100% root galling (Barker, 1985).

Reduction of j2 in soil (% efficiency of treatment) was determined at harvest according to Handerson & Tilton (Püntener, 1981) formula:

$$\text{Efficiency \%} = 1 - \frac{\text{no. j2 after treatment} \times \text{no. j2 in control before treatment}}{\text{no. j2 before treatment} \times \text{no. j2 in control after treatment}} \times 100$$

Whereas reduction (%) in the root gall index (GI) was calculated according to the following formula:

$$\text{Reduction \%} = \frac{\text{average of GI in control-average of GI in treatment}}{\text{average of GI in control}} \times 100$$

Estimation of soybean yield

At harvest, seeds were collected from each replicate (40 plants per treatment), and soybean seed yield (g/plant) was determined.

Statistical analysis

Data were subjected to analysis of variance using SPSS statistical software, and comparison between averages was done using Duncan's multiple range test at P= 0.05.

Table 1. Formulation of the tested bio-products and pesticide Furadan used in this study, their contents, dose and date of application.

Treatments	Formulation	Dose and date of application
D. brochopaga granules (DBG)	Grandular compound, spores of the fungus were mixed with 1kg Vermiculite + 10g yeast +20 ml molasses, the number of spores was adjusted to 25 × 10^2 spores/1g of the mixture	25g/m^2 mixed once with soil at planting
D. brochopaga Liquid (DBL)	Liquid compound, fungal spores were mixed with 10 g yeast and 20 ml molasses dissolved in one L of water. Number of spores in the liquid was adjusted to 25 × 10^2 spores per 1 ml	25 ml per hill, once as soil drench after germination
Furadan (Carbofuran)	Chemical nematicide: 2,3-dihydro-2,2-dimethyl-7-benzo-furanyl methyl carbamate.	6g/m^2 once at planting
Control (untreated)	-	-

Results

Effects of the nematophagus fungus *Dactylaria brochopaga* in liquid formulation (DBL) and granular formulation (DBG), and the chemical nematicide Furadan on the root-knot nematode infection and yield of soybean cv. Giza-22 are presented in Table 2. Data indicated that the final nematode population (Pf) was significantly (P=0.05) reduced by DBG and Furadan treatments with 32.4% and 36.5%, respectively, whereas DBL treatment did not affect the nematodes compared with the control treatment. As to the root-gall indices at mid-season, only Furadan treatment had a significant effect with 30.6% reduction in root galling, compared with the control, whereas both biocide treatments (liquid and granules) did not affect root-galling compared with the control treatment. Whereas at harvest, significant reduction in root galling was obtained by DBG and Furadan treatments with 31.6% and 33.3% reduction, respectively, compared with the control treatment. The seed yield significantly increased by 12.3% over the control with the DBG treatment, whereas no significant effect was obtained by DBL and Furadan treatments.

Data presented in Table (2) showed the effect of biocides and Furadan treatments on the nematode infecting soybean cv. Giza-111. The same trend was obtained with both DBG and Furadan treatments which significantly reduced the nematode final population (Pf) by 47.1% and 48.2%, respectively, compared to the control, whereas the DBL treatment had no significant effect. Root gall index was significantly reduced by 22.5% at mid-season by Furadan treatment, whereas at harvest both DBG and Furadan treatments significantly reduced root-gall indices by 39.3 and 42.9%, respectively, compared with the control treatment, and no significant effect was obtained by the DBL treatment. As to seed yield no significant effect was obtained by Furadan and DBL treatments, whereas it significantly increased by 10.9% over the control by the DBG treatment.

Discussion

Effect of the nematophagus fungus *D. brochopaga* commercial liquid and granules biocides on soybean infected with the root-knot nematode *Meloidogyne incognita* was evaluated under field conditions. Results obtained indicated that granular biocide (DBG) and Furadan treatments significantly reduced nematode the number of j_2 in soil (Pf) and root galling at harvest time. No significant reduction in nematode infection occurred by using the DBL liquid formulation compared with the control treatment, which could be attributed to the date of application, since DBL was applied after seed germination. In this case, many nematode juveniles (j_2) may already have penetrated soybean roots before the application of the biocide. It was also observed that no significant effect of the DBG biocide treatment on nematode root galling was observed at mid-season, whereas significant effect was observed at harvest, which could be explained by the fact that the nematophagus fungus needs more time to show its effectiveness. In addition, soybean seed yield was significantly increased following the DBG treatment compared with other treatments, which could be attributed to the combined effect of the fungus and its carrier (vermiculite) which contains magnesium silicate, a mineral nutrient required for plant growth.

The biological control of phytonematodes by nematophagus fungi has been documented earlier by many investigators (Al-Ani, 2022; Askary, 2015; Devi, 2018; Hallmann *et al.,* 2009; Moosavi & Zare, 2012; Yang & Zhang, 2014). A commercial product of the nematophagus fungus *D. brochopaga* was recently applied to control the root-knot nematodes *Meloidogyne incognita* infecting different hosts by suppressing the nematode population under field conditions (Aboul-Eid *et al*., 2016; Noweer & Aboul-Eid, 2016; Noweer & El-Kelany, 2019). Using environment-friendly control methods of plant-parasitic nematodes instead of toxic chemical nematicides is badly needed to promote sustainable agriculture (Doran & Zeiss, 2000; Sharma *et al*., 2020; Singh *et al*., 2021).

Table 2. Effect of microbial compounds and Furadan® on *Meloidogyne incognita* infecting soybean.

	No. J_2 in 250 g soil			Root gall index per plant*				
Treatment	Pi	Pf	Efficiency (%)	At mid-season	Reduction (%)	At harvest	Reduction (%)	Seed yield (g/plant)
Giza-111								
DBL	500	1850 a	15.4	3.2 a	11.1	5.2 a	8.8	80.0 b
DBG	490	1450 b	32.4	3.1 a	13.9	3.9 b	31.6	88.8 a
Furadan	450	1250 b	36.5	2.5 b	30.6	3.8 b	33.3	81.5 b
Control	480	2100 a	-	3.6 a	-	5.7 a	-	79.0 b
Giza-22								
DBL	300	1950a	13.4	3.9 a	2.5	5.1 a	8.9	77.5 b
DBG	290	1150b	47.1	3.8 a	5.0	3.4 b	39.3	86.5 a
Furadan	270	1050b	48.2	3.1 b	22.5	3.2 b	42.9	81.5 b
Control	280	2100a	-	4.0 a	-	5.6 a	-	78.0 b

DBL = *D. brochopaga*, liquid compound, DBG = *D. brochopaga*, granular compound, Pi= initial nematode population, Pf = final nematode population. % efficiency was calculated according to Handerson and Tilton Formula. * = average of 20 plants.
Values followed by the same letters in the same column are not significantly different according to Duncan's new multiple range test at P=0.05.

Inundative biological control systems (introduction of a bioagent into soil once with high population density) is a promising method for nematode management and should be encouraged. Success or failure of a bioagent to reduce nematode population in the soil depends on its adaptability to the rhizosphere environment, host specificity, and its ability to persist in the soil for a long period of time. Under complicated biotic and abiotic factors in the rhizosphere, persistence and activity of inserted bioagent may be suppressed and in some cases, and subsequently disappear within a short period of time. Thus, rational scientific management of native microbial communities inhabiting the soil, improving plant health and suppressing nematode pathogens could be a good strategy for sustainable nematode management.

الملخص

كريم، أ.م.، إ.م.أ. نوير وم.م.م. محمد. 2026. التقييم الحقلي لاستخدام الفطر المفترس للنيماتودا *Dactylaria brochopaga* في إدارة نيماتودا تعقّد الجذور (*Meloidogyne incognita*) التي تصيب فول الصويا (*Glycine max*). مجلة وقاية النبات العربية، 44(3):396−401.
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أُجريت تجربة حقلية خلال موسم النمو لعام 2020 في حقل فول صويا مُصاب طبيعياً بنيماتودا تعقّد الجذور (*Meloidogyne incognita*)، وذلك لتقييم كفاءة الفطر المفترس للنيماتودا *Dactylaria brochopaga* في مكافحة الإصابة النيماتودية، مقارنةً بالمبيد النيماتودي الكيميائي فورادان (كربوفوران). جرى تحضير الفطر بطريقتين: مستحضر سائل (DBL) ومستحضر حبيبي(DBG) . طُبِّق كلٌّ من DBG وفورادان مرة واحدة عند ميعاد الزراعة، في حين طُبِّق DBL مرة واحدة بعد إنبات البذور. أظهرت النتائج أن معاملتي DBG وفورادان خفّضتا معنوياً الكثافة النهائية للنيماتودا في التربة بنسبة 32.4 و 36.5%، على التوالي، عند استخدام صنف فول الصويا جيزة−22، وبنسبة 47.1 و 48.2%، على التوالي، عند استخدام الصنف جيزة−111، مقارنةً بمعاملة الشاهد. ولم يكن لمعاملة DBL تأثير معنوي في الكثافة النهائية للنيماتودا للصنفين كليهما. لم يتأثر دليل تعقّد الجذور (RGI) في منتصف الموسم معنوياً بمعاملتي DBG و DBL، في حين خفّضت معاملة فورادان قيمة دليل تعقد الجذور بنسبة 30.6% للصنف جيزة−111 و22.5% للصنف جيزة−22. وعند الحصاد، انخفض RGI معنوياً في معاملتي DBG وفورادان بنسبة 31.6 و 33.3%، على التوالي، في حالة الصنف جيزة−22، و39.3 و42.9% في حالة الصنف جيزة−111، مقارنةً بمعاملة الشاهد. وفي المقابل، لم تُسجَّل تأثيرات معنوية لمعاملة DBLفي دليل تعقد الجذور للصنفين كليهما سواءً في منتصف الموسم أو عند الحصاد مقارنةً بالشاهد. كما ازداد محصول بذور فول الصويا للصنف جيزة−22 معنوياً نتيجة المعاملة DBG بنسبة 10.9%، وقابلها 12.3% للصنف جيزة−111، مقارنةً بالشاهد، في حين لم تُظهر معاملتا DBL وفورادان تأثيراً معنوياً في محصول البذور لكلا الصنفين.

كلمات مفتاحية: فول الصويا، نيماتودا تعقّد الجذور، الفطور المفترسة، الصياغات، المكافحة الحيوية.

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References

Aboul-Eid, H.Z., E.M.A. Noweer and E.A.S. Mona. 2016. Efficacy of some biocontrol compounds on root-knot nematode, Meloidogyne incognita, infesting potato under field conditions. Egyptian Journal of Biological Pest Control, 26(2):217-222.

Al-Ani, L.K.T., F.E.D.F. Soares, A. Sharma, S. de los Santos-Villalobos, A.V. Valdivia-Padilla and L. Aguilar-Marcelino. 2022. Strategy of nematophagous fungi in determining the activity of plant parasitic nematodes and their prospective role in sustainable agriculture. Frontiers in Fungal Biology, 3:863198. https://doi.org/10.3389/ffunb.2022.863198

Askary, T.H. 2015. Nematophagous fungi as biological agents of phytonematodes. Pp. 81-125. *In*: Biocontrol Agents of Phytonematodes. T.H. Askary and P.R.P. Martinelli (eds.). CABI, Wallingford, UK.

Barker, K.R. 1985. Nematode extraction and bioassays. Pp. 19-35. *In*: An Advanced Treatise on Meloidogyne. Volume 2: Methodology. K.R. Barker, C.C. Carter and J.N. Sasser (eds.). North Carolina State University and United States Agency for International Development, Raleigh, NC, USA.

Chaudhary, K.K., D. Brhane, H. Okube, T. Zaid and E. Dagnew. 2011. Distribution, frequency of occurrence and population density of root-knot nematodes in Hamelmalo, Eritrea. African Journal of Microbiology Research, 5(31):5656-5661. https://doi.org/10.5897/AJMR11.1004

Chen, S.Y. and D.W. Dickson. 2004. Biological control of nematodes by fungal antagonists. Pp. 979-1025. *In*: Nematology: Advances and Perspectives. Volume 2: Nematode Management and Utilization. Z.X. Chen,

S.Y. Chen and D.W. Dickson (eds.). CABI Publishing, Wallingford, UK.

Christie, J.R. and V.G. Perry. 1951. Removing nematodes from soil. Proceedings of the Helminthological Society of Washington, 18(2):106-108.

Devi, G. 2018. Utilization of nematode-destroying fungi for management of plant-parasitic nematodes: A review. Biosciences Biotechnology Research Asia, 15(2):377-396. https://doi.org/10.13005/bbra/2640

Doran, J.W. and M.R. Zeiss. 2000. Soil health and sustainability: Managing the biotic component of soil quality. Applied Soil Ecology, 15(1):3-11. https://doi.org/10.1016/S0929-1393(00)00067-6

El-Abady, M.I., S.E. Seadh, A.M. Attia and A.E.A. El-Saidy. 2008. Impact of foliar fertilization and its time of application on yield and seed quality of soybean. Pp. 299-313. *In*: Proceedings of the Second Field Crops Conference. Giza, Egypt.

Fontana, J.D. 2011. Biodiesel: Para Leitores de 9 a 90 Anos. 1st ed. Universidade Federal do Paraná (UFPR), Curitiba, Brazil. 253 pp.

Fourie, H., D. De Waele, A.H. McDonald, C. Mienie, M. Marais and A. De Beer. 2015. Nematode pests threatening soybean production in South Africa, with reference to Meloidogyne. South African Journal of Science, 111(9-10):1-9. https://doi.org/10.17159/sajs.2015/20140377

Hallmann, J., K.G. Davies and R. Zare. 2009. Biological control using microbial pathogens, endophytes and antagonists. Pp. 380-411. *In*: Root-Knot Nematodes. R.N. Perry, M. Moens and J.L. Starr (eds.). CAB International, Wallingford, UK.

Harwig, J., P.M. Scott, D.R. Stoltz and B.J. Blanchfield. 1979. Toxins of molds from decaying tomato fruit. Applied and Environmental Microbiology, 38(2):267-274. https://doi.org/10.1128/AEM.38.2.267-274.1979

Karssen, G. and M. Moens. 2006. Root-knot nematodes. Pp. 59-90. *In*: Plant Nematology. R.N. Perry and M. Moens (eds.). CABI Publishing, Wallingford, UK.

Koenning, S.R. 2015. Root-knot nematode. Pp. 98-100. *In*: Compendium of Soybean Diseases and Pests. G.L. Hartman, J.C. Rupe, E.J. Sikora, L.L. Domier, J.A. Davis and K.L. Steffey (eds.). APS Press, St. Paul, MN, USA.

Korayem, A.M. and M.M.M. Mohamed. 2018. Potential loss in soybean yield due to root-knot nematode, Meloidogyne arenaria, in sandy soil. Egyptian Journal of Agronematology, 17(1):43-50.

Korayem, A.M., M.M.M. Mohamed, E.M.A. Noweer, M.M.A. Youssef, M.M.A. Hammam and U.S. El-Kelany. 2021. Survey and identification of phytonematodes and their fungal antagonists associated with soybean in different ecological locations of Egypt. Journal of Innovations in Pharmaceutical and Biological Sciences, 8(4):14-21.

Lima, F.O.S., V.R. Corrêa, S.R. Nogueira and P.R.R. Santos. 2017. Nematodes affecting soybean and sustainable practices for their management. Pp. 95-110. *In*: Soybean: The Basis of Yield, Biomass and Productivity. M. Kasai (ed.). Hirosaki University Press, Japan.

Moens, M., R.N. Perry and J.L. Starr. 2009. Meloidogyne species – a diverse group of novel and important plant parasites. Pp. 1-17. *In*: Root-Knot Nematodes. R.N. Perry, M. Moens and J.L. Starr (eds.). CABI, Wallingford, UK.

Moosavi, M.R. and R. Zare. 2012. Fungi as biological control agents of plant-parasitic nematodes. Pp. 67-107. *In*: Plant Defence: Biological Control. J.M. Mérillon and K.G. Ramawat (eds.). Springer, Dordrecht, the Netherlands. https://doi.org/10.1007/978-94-007-1933-0

Noweer, E.M.A. and H.Z. Aboul-Eid. 2016. Evaluation of the nematode-trapping fungus, Dactylaria brochopaga, on the root-knot nematode Meloidogyne incognita infecting snap bean (*Phaseolus vulgaris*) cv. Ogzera under field conditions. Egyptian Journal of Biological Pest Control, 26(2):223-227.

Noweer, E.M.A. and U.S. El-Kelany. 2019. Biological control of root-knot nematode Meloidogyne incognita infesting eggplant by the nematode-trapping fungus *Dactylaria brochopaga* and the egg-parasitic fungus *Verticillium chlamydosporium* under field conditions. Journal of Innovations in Pharmaceutical and Biological Sciences, 6(4):1-6.

Püntener, W. 1981. Manual for Field Trials in Plant Protection. Ciba-Geigy Ltd., Basel, Switzerland. 250 pp.

Shamalie, B.V.T., R.M. Fonseka and R.G.A.S. Rajapaksha. 2011. Effect of Trichoderma viride and Carbofuran (Curator®) on management of root-knot nematodes and growth parameters of gotukola (*Centella asiatica* L.). Tropical Agricultural Research, 23(1):61-69.

Sharma, V., R. Salwan and L.K.T. Al-Ani. 2020. Molecular Aspects of Plant Beneficial Microbes in Agriculture. Elsevier, Cambridge, MA, USA. 454 pp.

Sikora, E.J., K.S. Lawrence and J. Murphy. 2010. Survey of plant-parasitic nematodes in soybean fields in Alabama. Research Report Series. Alabama Agricultural Experiment Station, Auburn University, Auburn, AL, USA.

Sikora, R.A., B. Claudius-Cole and E.J. Sikora. 2018. Nematode parasites of food legumes. Pp. 290-345. *In*: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. 3rd ed. R.A. Sikora, D. Coyne, J. Hallmann and P. Timper (eds.). CABI, Wallingford, UK.

Singh, S., V. Kumar, D.S. Dhanjal, S. Bhardwaj, V. Dakha, S. Thotapalli, J. Singh, L.K.T. Al-Ani and L. Aguilar-Marcelino. 2021. Rhizosphere biology: A key to agricultural sustainability. Pp. 161-182. *In*: Current Trends in Microbial Biotechnology for Sustainable Agriculture. A.N. Yadav, J. Singh, C. Singh and N. Yadav (eds.). Springer Nature, Singapore. https://doi.org/10.1007/978-981-15-4439-2

Wrather, J.A. and S.R. Koenning. 2009. Effects of diseases on soybean yields in the United States, 1996-2007. Plant Health Progress, 10(1):1-7. https://doi.org/10.1094/PHP-2009-0401-01-RS

Yang, J. and K.Q. Zhang. 2014. Biological control of plant-parasitic nematodes by nematophagous fungi. Pp. 231-262. *In*: Nematode-Trapping Fungi. K.Q. Zhang and K.D. Hyde (eds.). Fungal Diversity Research Series, Volume 23. Springer, Dordrecht, the Netherlands. https://doi.org/10.1007/978-94-017-8730-7

Zhang, Y., G.H. Li and K.Q. Zhang. 2011. A review on the research of nematophagous fungal species. Mycosystema, 30(6):836-845.

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