American Journal of Agriculture and Forestry
2022; 10(2): 59-63
http://www.sciencepublishinggroup.com/j/ajaf
doi: 10.11648/j.ajaf.20221002.13
ISSN: 2330-8583 (Print); ISSN: 2330-8591 (Online)

Review Article

A Review of Bio-Role Fumigation's in Plant Parasitic Nematode (PPNs) Control

Belay Feyisa

Ethiopian Institute of Agricultural Research (EIAR), Ambo Agricultural Research Centre, Ambo, Ethiopia

Email address:
belay22feyisa@gmail.com

To cite this article:
Belay Feyisa. A Review of Bio-Role Fumigation's in Plant Parasitic Nematode (PPNs) Control. *American Journal of Agriculture and Forestry*. Vol. 10, No. 2, 2022, pp. 59-63. doi: 10.11648/j.ajaf.20221002.13

Received: February 11, 2022; **Accepted**: March 7, 2022; **Published**: March 15, 2022

Abstract: Worldwide there are greater than 4,100 species of PPNs. The most common opponent of agricultural production is PPNs. Plant parasitic nematodes (PPN) cause substantial economic destruction to an extensive range of crops. Nematicide Chemicals are considered the furthermost operative method in reducing nematodes population. Increasing concern over chemical nematicides has increased interest in safe alternative methods to minimize these losses. This review focuses on the role of bio-fumigation against PPNs in sustainable agroecosystems. Bio-fumigation is a long-term approach for controlling diseases, nematodes, insects, and weeds in the soil. It was originally defined as the pest-controlling effect of decomposing Brassica tissues, but it was later broadened to include animal and plant leftovers. Glucosinolates are the principal active molecule responsible for the bio-fumigation process in various plants. Plant age and tissue type influence glucosinolate accumulation and myrosinase activity, which are influenced by environmental factors such as planting density and herbivory. Glucosinolates are sulphur-containing chemicals produced by the secondary metabolism of plants in the order Capparales, which includes the Brassicacea family among others. Natural antimicrobials and anti-carcinogenic agents, glucosinolates are well-known. Therefore, researchers should have to focus on environmentally save methods of plant parasitic nematode management like bio-fumigation. This biofumigation may be replace the fumigant nematicides for future.

Keywords: Anti-carcinogenic, Antimicrobials, Bio-fumigation, Glucosonolate, Myrosinase

1. Introduction

PPNs are the most common hidden enemy to agricultural crop production. Parasitize nearly all plant species and expose the host to secondary infection [25]. Plant parasitic nematodes are one of the most important and dangerous pest groups for many crops, affecting both quantity and quality of crop harvests. Root-knot nematodes (Meloidogyne spp.) are considered, among all PPNs, to be the main agents that damage crops worldwide [35]. In tropical climates, they are even more menacing, as the environmental conditions favor their development and reproduction [18]. They are responsible for a ten percent reduction in annual global crop yields, amounting to an estimated $173 billion in lost revenue per year [8, 12]. However, the total losses caused by PPNs in underdeveloped nations have yet to be calculated. In addition, the roots affected and injured by this pathogen become more prone to secondary Fungi and bacteria infections [26]. Because of their vast host range and fast pace of reproduction (up to a thousand eggs per female), nematodes are difficult to regulate [27]. Chemical nematicides are routinely used to control nematodes, however they are hazardous to plants, pollute the environment, and deplete soil fertility. Furthermore, they are dangerous and can lead to human poisoning, particularly in underdeveloped nations [37]. Moreover, chemical control is expensive, non-affordable and economically viable only for high value crops [41]. These synthetic soil fumigants are highly toxic to pests as well as many beneficial soil organisms [37]. Many of these soil fumigants are harmful to vertebrates, have a high cost, display resistance, and have other negative environmental impacts [6]. Soil ecosystem disruption, resurgent epidemics, and fumigant toxicity to humans and animals have all become major concerns. As a result of all of these negative consequences,

scientists are working to develop sustainable, economically feasible, and non-polluting management approaches. It is critical to take a holistic approach to nematode management, taking into account cultural, biological, and chemical choices as part of an integrated management approach. Bio-fumigation, as well as modified/innovative bio-fumigation, is a long-term solution for controlling diseases, nematodes, insects, and weeds in soil. As a result, plant-based nematicide has become a popular alternative in recent years. Organic amendments were utilized by a large number of researchers and plant protectionists. Concerns over the usage of pesticides have sparked interest in developing alternative pest management measures.

The overall goal of this review is to learn more about the role of bio-fumigation in controlling plant parasitic nematodes, with the following specific goals in mind: review the glucosinolate content of various plant organs and stages, review the difference between glucosinolate and bio-fumigation, and review the factors that affect glucosinolate content in plants.

2. Literature Review

2.1. Glucosinolates

Glucosinolates are the principal active molecule responsible for the bio-fumigation process in various plants. The leftover meal, after oil extraction, comprises a variety of nutritional and anti-nutritional substances (e.g. glucosinolates, sinapine and fiber). Glucosinolates, for example, have anti-carcinogenic qualities in humans, anti-nutritional effects of seed meal in animals, insect pest repellent and fungal disease suppression capabilities [42]. Brassica products, such as oil, meal, and veggies, contain a lot of glucosinolates, which are significant for their nutritional characteristics [1]. Glucosinolates, on the other hand, are necessary for the plant's resistance to pest insects. Myrosinase hydrolyzes glucosinolates to create a variety of poisonous compounds, including isothiocyanates and nitriles, in response to insect feeding or mechanical disruption. Glucosinolates are degraded by myrosinase in response to insect feeding or mechanical disruption, forming a variety of poisonous compounds such as isothiocyanates, nitriles, thiocyanates, and epithio-nitriles, among others [17, 39]. Glucosinolate breakdown products have sparked attention in organic pest management due to their numerous harmful effects.

2.2. Bio-fumigation

Bio-fumigation is a term used to describe the process of volatile pesticidal substances being emitted during the decomposition of plant or animal matter [3, 31]. For the destruction of plant-parasitic as well as other harmful soil microorganisms, bio-fumigation is an environmentally benign management strategy. The capacity of certain plants to suppress nematodes through the nematicidal activity of secondary metabolites has been demonstrated by numerous investigations in the literature [4, 47]. Increasing and combining the bio-fumigant plant enhances soil structure, aids in weed control, lowers soil erosion, and offers organic matter to the organic producer for managing diseases and pests, in addition to giving some disease control [15]. The active compounds' role in the direct suppression of nematodes, as well as the secondary effect in the soil, determine the potential for Brassicaceous amendment as part of an IPM method. The secondary effect is important in enhancing microbial and other microorganism diversity in the soil, and so can be expected to boost competition among soil-borne illnesses in the rhizosphere.

2.3. Type of Plants Known with Bio-fumigation

There are more than 350 genera and 3000 species in the Brassicaceae (brassicas) family, several of which are known to contain GSL. GSLs, on the other hand, aren't just found in brassicas. At least 500 non-brassica dicotyledonous angiosperm plants have been found to contain one or more of the over 120 GSLs [13]. Each GSL has its own chemical property and can be classified into one of three categories: aliphatic, aromatic, or indole [47, 29]. Brassica oleracea, Brassica rapa, Raphanus sativus, Brassica napus, Eruca sativa, Brassica juncea, Brassica campestris, and different mustards are among the plant species that are commonly considered for bio-fumigation [24, 19, 9, 30]. According to Kwerepe and Labuschagne [22], cruciferous residues at a rate of 60 kg/ha resulted in a greater reduction of M. incognita. Crushed cabbage leaves (B. oleracea) incorporated into the soil at 5 g per pot, 10 days before transplanting tomato cv. Youssef and Lashein [46] observed that crushed cabbage leaves (B. oleracea) incorporated into the soil at 5 g per pot, 10 days before transplanting tomato cv. Under greenhouse circumstances, Super Strain B reduces the population of root-knot nematodes.

2.4. Glucosinolate Content in Different Plant Organs

Plant parts and products used as organic nematode amendments, particularly those with high nitrogen/carbon ratios, have been shown to have nematicidal activity, owing to the release of ammonia from plant residue during decomposition in soil or an increase in the population of antagonistic microorganisms [28]. Glucosinolates are found in all parts of the plant, but their amounts vary greatly between organs [14]. Several secondary metabolites, including as terpenoids, alkaloids, and phenolic compounds, have been shown to have nematicidal activity, and nemato-toxic chemicals produced during the decomposition of plant waste have been shown to diminish PPN root infection [40]. Four theories are proposed whether GSLs were responsible for the reduction of summer crops following rapeseed: I GSLs in rapeseed leaves that are generally lost before harvest hinder the growth of the following crop when the leaves decay. (ii) GSLs in empty pod shells, stems, and branches thrown out by combine harvesters, as well as many seeds left in shattered pods, hinder the future crop's growth. (iii) GSLs in rapeseed roots, which all stay in the soil after harvest, have an effect on

later crop growth when the roots decay. (iv) The GSLs in early plant tissues or living plants (volunteer seedlings) that germinated from seeds left behind after harvest and emerged together with.

2.5. Factors that Affect Glucosinolate Content in Plant

When determining plant sensitivity to infestation, changes in the composition of glucosinolate molecules may be crucial [21]. The concentration of glucosinolate changes greatly between different phases of plant development, as well as between different organs [35]. Plant age and tissue type influence glucosinolate accumulation and myrosinase activity, which are influenced by environmental factors like as planting density and herbivory [45]. Genetic and environmental factors, such as plant age, temperature, water stress, and soil type, have been blamed for variations in the amount and pattern of glucosinolates in Brassica plants. The total glucosinolate concentration of rapeseed was significantly affected by reproductive developmental phases (FIS, FBS, and PMS) (Table 1). From flower initiation stage (FIS) to full bloom stage, total glucosinolate content increased (FBS). The amount of glucosinolate in the body decreases as it approaches full maturity (PMS stage) [16]. Previous research on glucosinolate content in Brassica spp. during the life cycle suggests that reproductive organs have higher glucosinolate content than the other vegetative portions [3]. The seed is the ultimate glucosinolate sink, and seeds have the maximum glucosinolate content. The amount of GSL in each plant part, stage of growth, and cultivar varied dramatically. The GSL content of these seedlings' leaves and roots was high [34]. At flowering, the GSL content of rapeseed leaves is substantially lower than that of stems and roots [32]. Rapeseed seedlings had a lot of little roots and a lot of surface area, which could be one of the explanations for the high GSL concentration in their roots [34]. GSL concentrations in root tissue are higher in the early stages of root formation and decrease as the root growth cycle progresses. GSLs of various sorts can be found in the roots and shoots of several plant species [43]. GSL levels are determined by plant genetic characteristics, but they can also change depending on environmental conditions and soil sulphur supplies [8].

2.5.1. Soil Temperature

Green manure incorporation is not suggested at temperatures below 0°C because low soil temperatures impair the enzymatic response during bio-fumigation. Degradation products appear to be immobilized in the presence of organic debris, preventing them from reaching the pests of interest [23].

2.5.2. Moisture

When dried leaf powder was utilized as an organic soil amendment at a greater moisture level, the results were marginally better than when the identical organic soil additives were used at a lower moisture level. Because proper moisture levels aided in the degradation of plant debris and the release of active nematode-inhibiting nematicidal chemicals into the soil [2].

2.5.3. Soil Depth

Roubtsova et al. [33] investigated the direct localized and indirect volatile effects of supplementing M. incognita infested soil with broccoli tissue. M. incognita was reduced by 31 to 71 percent in the altered 10cm layer of the tubes compared to the non-amended layers, most likely due to a nematicidal effect of released broccoli volatiles. These findings show that fumigant nematicidal activity is limited, and that its effectiveness is dependent on a thorough and equal distribution of bio-fumigant material across the soil profile where the target nematodes reside.

Table 1. *Shows the effect of various reproductive developmental stages on glucosinolate content in Rapeseed –Mustard.*

Sl. No.	*Stages*	Year-2004-05 Mean* Glucosinolate Content (µmoles/g plant dry weight)	Year-2004-05 LS Mean* Glucosinolate Content (µmoles/g plant dry weight)	Year-2004-05 LS Mean* Glucosinolate Content (µmoles/g plant dry weight)
1	*FIS*	69.93[c]	70.93[c]	70.46[c]
2	*FBS*	111.88[a]	115.22[a]	114.07[a]
3	*PMS*	90.48[b]	86.38[b]	90.07[b]
CD Values at 5%		0.411	0.96	0.96

Source; Satoko, *et al.,* (2010)

FIS=Flower Initiation Stage; FBS=Full Bloom Stage; and PMS= Pod Maturation Stage

*Means within a column with the same letters are not significantly different at $P < 0.05$.

3. Bio-fumigation and Plant Parasitic Nematodes Control

Bio-fumigation can be employed independently or in combination with other treatments such as sanitation, organic amendments, and solarization [44, 5, 20]. Several Brassicaceae species, such as mustards and cole crops, as well as other species such as marigold, produce nematotoxic GSLs and ITCs [47, 7]. Bio-fumigation has a wide range of effects and does not necessarily harm non-PPNs. Many of these soil fumigants are harmful to vertebrates, have a great charge, display resistance, and have other negative environmental impacts [6]. El-Sherbiny and Awd Allah [11] found that pre-planting with air dried powders of several plants, including cauliflower (a crucifer plant), minimized M. incognita on tomato plants and increased plant growth

parameters. According to Roubtsova et al., [33] bio-fumigants must be distributed uniformly across the soil profile in order to be effective against nematodes.

4. Conclusion and Recommendation

Finally, plant species with large quantities of GLNs have gotten a lot of attention. The appropriate value of employing bio-fumigant crops to farmers should be assessed based on a number of parameters, including pesticide efficacy, crop growth and yield, and production costs. Biofumigation has the ability to efficiently control PPNs and is a long-term solution that uses naturally occurring plant compounds to kill or get Plant Parasitic Nematodes up and running. Bio-fumigant crops and agronomic approaches improve sustainable agricultural productivity by minimizing pesticide loads. It can be concluded that bio-fumigations are a better alternative to nematicides for controlling plant parasitic nematodes and reducing environmental dangers for an ecologically safe environment.

References

[1] Agbemafle, R. Obodai, E. A. Adukpo, G. E. Amprako. N (2012). *Adv. Appl. Sci. Res.*, 3 (5): 2815.

[2] Ahmad F (2009). Studies on the management of root-knot nematode (*Meloidogyne incognita*) with organic soil amendments. Ph.D. Thesis, Aligarh Muslim University, Aligarh. p. 262.

[3] Bello, A., Lopez Perez, J. A., Garcia Alvarez, A., Sanz, R., and Lacasa, A (2004). Biofumigation and nematode control in the Mediterranean region. p. 133-149. Bellostas, N. Sorensen, J. C. Sorensen, H (2004). *Agroindustria*: 3-5.

[4] Chitwood, D. J (2002). Phytochemical based strategies for nematode control. *Annual Review of Phytopathology* 40: 221-249.

[5] Collange B, Navarrete M, Peyre G, Mateille T, Tchamitchian M (2011). Root-knot nematode (Meloidogyne) management in vegetable crop production: The challenge of an agronomic system analysis. Crop Protection, 30, 1251–1262.

[6] Cox, C (2006). Fumigant factsheet: metam sodium. *Journal of Pesticide Reform* 26: 12-16.

[7] Daneel M, Engelbrecht E, Fourie H, Ahuja P (2018). The host status of Brassicaceae to Meloidogyne and their effects as cover and biofumigant crops on root-knot nematode populations associated with potato and tomato under South African field conditions. Crop Protection, 110, 198–206.

[8] De Pascale, S., Maggio, A., Pernice, R., Fogliano, V. and Barbieri, G (2007). Sulphur fertilization may improve the nutritional value of *Brassica rapa* L. subsp. *sylvestris*. *European Journal of Agronomy* 26: 418-424.

[9] Dutta, T. K., Khan, M. R., & Phani, V (2019). Plant-parasitic nematode management via biofumigation using brassica and non-brassica plants: Current status and future prospects. Current Plant Biology, 17, 17–32. doi: 10.1016/j.cpb.2019.02.001.

[10] Edwards, S. and A. Ploeg (2014). Evaluation of 31 Potential biofumigant Brassicaceous plants as hosts for three *Meloiodogyne* species. *Journal of Nematology* 46: 287-295.

[11] El-Sherbiny, A. A., and S. F. A. Awd Allah (2014). Management of the root-knot nematode, *Meloidogyne incognita* on tomato plants by pre-planting soil biofumigation with harvesting residues of some winter crops and waste residues of oyster mushroom cultivation under field condition. *Egyptian Journal of Agronematology*, 13 (1): 189–202.

[12] Elling A. A (2013). Major emerging problems with minor *Meloidoygne s*pecies. *Phytopathol.,* 103: 1092-1102.

[13] Fahey, J. W., Zalcmann, A. T. and Talalay, P (2001). The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry* 56: 5-51.

[14] Font, R. Celestino, M. D. R. Rosa, E. Aires, A. Bailon, A. D. H (2005). *J. Agri. Sci.,* 143, 65.

[15] Griffiths, H. M., Gies, D., Zitter, T. A (2011). Brassicas as biofumigants for controlling soilborne organisms in potato production for upstate New York and northern Pennsylvania. Fact sheet (Online). (http://vegetablemdonline.ppath.cornell.edu/NewsArticles/Brassicas%20Factsheet%20Final%20August%20, 2011.pdf).

[16] Gunjan Bhushan, V. K. Mishra, Mir Asif Iquebal and Singh Y. P (*2013*). Effect of genotypes, reproductive developmental stages, and environments on glucosinolates content in rapeseed mustard. *Asian J. Plant Sci. Res., 3 (1): 75-82.*

[17] Halkier, B. A. Gershenzon, J (2006). *Annu. Rev. Plant Biol.*, 57: 303.

[18] Hussain, M. A.; Mukhtar, T.; Kayani, M. Z.; Aslam, M. N.; Ulhaque, M. I (2012). A survey of okra (*Abelmoschus esculentus*) in the Punjab province of Pakistan for the determination of prevalence, incidence and severity of root-knot disease caused by *Meloidogyne* spp. Pakistan Journal of Botany, v. 44, n. 6, p. 2071- 2075.

[19] Kago, E. K., Kinyua, Z. M., Okemo, P. O., and Maingi, J. M (2013). Efficacy of *Brassica* Tissue and Chalim TM on Control of Plant Parasitic Nematodes. *Journal of Biology* 1: 32-38.

[20] Kruger D H M, Fourie J, Malan A (2013). Cover crops with biofumigation properties for the suppression of plant-parasitic nematodes: A review. South African Journal of Enology and Viticulture, 34, 287–295.

[21] Kusnierczyk, AMidelfart, P. W. H. Armbruster, W. S. Rossiter, J. T. Bones, A. M (2007). *J. Exp. Bot.*, 58: 2537.

[22] Kwerepe, B. C., and Labuschagne, N (2003). Biofumigation and soil solarization as integrated pest management (IPM) components for the control of root-knotnematode, *Meloidogyne incognita* (Kofoid and White) Chitwood on Bambara groundnut [Vigna subterranea (L.) Verdc]. University of Swaziland. *Journal of Agriculture* 11: 56-63.

[23] Lopez Perez, J., Roubtsova, T. and Ploeg, A (2005). Effect of three plant residues and chicken manure used as biofumigants at three temperatures on *Meloidogyne incognita* infestation of tomato in greenhouse experiments. *Journal of Nematology* 37 (4): 489-494.

[24] Lopez Perez, J. A., Roubtsova, T., Garcia, M. D., and Ploeg, A (2010). The Potential of five winter grown crops to reduce root-knot nematode damage and increase yield of tomato. *Journal of Nematology* 42: 120-127.

[25] Moens, M., Perry, R. N., Starr, J. L (2009). *Meloidogyne* species – A diverse group of novel and important plant parasites. In: Perry, R. N., Moens, M., Starr, J. L. (Eds.), Root-knot nematodes. CABI International, Cambrige, MA (USA), pp. 1-17.

[26] Mota, F. C.; Alves, G. C. S.; Giband, M.; Gomes, A. C. M. M.; Sousa, F. R.; Mattos, V. S.; Barbosa, V. H. S.; Barroso, P. A. V.; Nicole, M.; Peixoto, J. R.; Rocha, M. R.; Carneiro, R. M. D. G (2013). New sources of resistance to *Meloidogyne incognita* race 3 in wild cotton accessions and histological characterization of the defense mechanisms. Plant Pathology, v. 62, n. 5, p. 1173-1183. https://doi.org/10.1111/ppa.12022.

[27] Natarajan N, Cork A, Boomathi N, Pandi R, Velavan S, Dhaskshanamoorthy G (2006). Cold aqueous extracts of African marigold, Tagetes erecta for control tomato root-knot nematode, Meloidogyne incognita. Crop Prot. 25: 1210–1213.

[28] Oka Y, Tkachi N, Shuker S, Rosenberg R, Suriano S, Fine P (2006). Laboratory studies on the enhancement of nematicidal activity of ammonia releasing fertilizers by alkaline amendments. Nematology 8: 335-346.

[29] Padilla, G., Cartea, M. E., Velasco, P., De Haro, A. and Ordas, A (2007). Variation of glucosinolates in vegetable crops of *Brassica rapa*. *Phytochemistry* 68: 536-545.

[30] Park W, Kim KS, Jang YS, Lee KB, Kim SJ, Ahn SJ, Hong SW, Lee YH (2017). Variation in glucosinolate contents of cruciferous plants. Rec Nat Prod. 11: 185-192.

[31] Piedra Buena, A., Garcia Alvarez, A., Dies Rojo, M. A., Ros, C., Fernadez, P., Lacasa, A. and Bello, A (2007). Use of pepper crop residues for the control of rootknot nematodes. *Bioresource Technology* 98: 2846- 2851.

[32] Rothe, R., H. Hartung, G. Marks, H. Bergmann, R. Gotz and Scohne F (2004). Glucosinolate contents in vegetative tissues of winter rape cultivars. *J. Appl. Bot.* 78: 41-47.

[33] Roubtsova, T., Lopez Perez, J., Edwards, S. and Ploeg, A (2007). Effect of Broccoli (*Brassica oleracea*) tissue, incorporated at different depths in a soil column, on *Meloidogyne incognita. Journal of Nematology* 39: 111-117.

[34] Satoko Yasumoto, Morio Matsuzaki, Hisako Hirokane and Kensuke Okada (2010). Glucosinolate Content in Rapeseed in Relation to Suppression of Subsequent Crop. *Plant Prod. Sci.* 13 (2): 150-155.

[35] Sarikamiş, G. Yanmaz, R (2011). *J. Med. Plants Res.,* 5: 4388.

[36] Saucet, S. B.; Ghelder, C. V.; Abad, P.; Ducal, H.; Esmenjaud, D (2016). Resistance to root-knot nematodes *Meloidogyne* spp. in woody plants. New Phytologist, v. 211, p. 41-56, https://doi.org/10.1111/nph.13933.

[37] Schreiner, R. P., Ivors, K. L. and Pinkerton, J. N (2001). Soil solarization reduces arbuscular mycorrhizal fungi as a consequence of weed suppression. *Mycorrhiza* 11: 273-277.

[38] Singh KP, Suman A, Singh PN, Srivastava TK (2007). Improving quality of sugarcane growing soils by organic amendments under subtropical climatic conditions of India. Biol Fert Soils. 44: 367–376.

[39] Thanki, N. Joshi, P. Joshi, *Eur.* H (2012). *J. Exp. Biol.*, 2 (5): 1639.

[40] Thoden TC, Hallmann J, Boppré M (2009). Effects of plants containing pyrrolizidine alkaloids on the northern root-knot nematode *Meloidogyne hapla*. Eur. J. Plant. Pathol. 123: 27-36.

[41] Tsay TT, Wu TS, Lin YY (2004). Evaluation of Asteraceae plant for control of Meloidogyne incognita. J Nematol. 36: 36–41.

[42] Tripathi, M. K. Mishra., A. S (2007). *Animal Feed Sci. Techn.*, pp: 1321.

[43] Van Dam, N., Tytgat, T. G., and Kirkegaard, J (2009). Root and shoot glucosinolates: a comparison of their diversity, function and interactions in natural and managed ecosystems. *Phytochemistry Reviews* 8: 171-86.

[44] Wang K H, McSorley R, Kokalis-Burelle N (2006). Effects of cover cropping, solarization, and soil fumigation on nematode communities. Plant and Soil, 286, 229–243.

[45] Wentzell, A. M. Kliebenstein, D. J (2008). *Plant Physiol.*: 147-415.

[46] Youssef, M. M. A., and Lashein, A. M. S (2013). Effect of cabbage (*Brassica oleracea*) leaf residue as a biofumigant on root knot nematode, *Meloidogyne incognita* infecting tomato. *Journal of Plant Protection Research* 53: 271-274.

[47] Zasada, I. A., and H. Ferris (2004). Nematode suppression with brassicaceous amendments: application based upon glucosinolate profiles. *Soil Biology and Biochemistry* 36: 1017 1024.