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ORIGINAL ARTICLE

Comparative efficacy of different approaches to managing *Meloidogyne incognita* on green bean

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Urea

Abstract A greenhouse study was conducted to compare the relative efficacy of different approaches to managing *Meloidogyne incognita* on green bean. These approaches included chemical (fumigant, non-fumigant, seed dressing, and seed dip), biological (the egg-parasitic fungus, *Paecilomyces lilacinus* and the mycorrhizal fungus *Glomus* sp.), physical (soil solarization), and cultural (chicken litter and urea) methods. Accordingly, nine different control materials and application methods plus nematode-infected and non-infected controls were compared. Two important parameters were considered: plant response (plant growth and root galling) and nematode reproduction (production of eggs and the reproduction factor Rf). The results showed that the use of chicken litter as an organic fertilizer severely affected the growth and survival of the plants. Therefore, this treatment was removed from the evaluation test. All of the other eight treatments were found to be effective against nematode reproduction, but with different levels of efficacy. The eight treatments decreased (38.9–99.8%) root galling, increased plant growth and suppressed nematode reproduction. Based on three important criteria, namely, gall index (GI), egg mass index (EMI), and nematode reproduction factor (RF), the tested materials and methods were categorized into three groups according to their relative control efficacy under the applied test conditions. The three groups were as follows: (1) the relatively high effective group (GI = 1.0–1.4, Rf = 0.07–0.01), which included the fumigant dazomet, the non-fumigant fenamiphos, soil solarization, and seed dip with fenamiphos; (2) the relatively moderate effective group (GI = 3.4–4.0, Rf = 0.24–0.60), which included seed dressing with fenamiphos and urea; and (3) the relatively less effective group (GI = 5.0, Rf = 32.2–37.2), which included *P. lilacinus* and *Glomus* sp.

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1. Introduction

Green bean (*Phaseolus vulgaris* L.) is an important vegetable crop worldwide. The crop is usually attacked by many plant pathogens, including plant-parasitic nematodes (Hall, 1991). However, root-knot nematodes (*Meloidogyne* spp.) are the

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most frequent damaging plant-parasite nematodes in greenhouses and in vegetable production in general (Koenning et al., 1999).

Meloidogyne spp. cause crop losses of approximately 10% in vegetable crops (Koenning et al., 1999). However, some studies have reported higher percentages (up to 30%) in some local regions, depending on the host cultivar, population density and *Meloidogyne* species involved (Sikora and Fernandez, 2005; Ornat and Sorribas, 2008).

In Saudi Arabia, green bean is grown in open fields and greenhouses mainly for its green pods. The crop is frequently attacked by *Meloidogyne javanica* (Treub) chitwood and *Meloidogyne incognita* (Kofoid & White) chitwood. Although no accurate estimates of crop losses of green bean in the country have been determined, root-knot nematodes generally cause high damage (40–100%) in some local vegetable farms (Al-Hazmi et al., 1983). In a recent study, *M. incognita* was found to be very important and damaging pest on green bean plants (Al-Nadhari, 2014).

Controlling *Meloidogyne* spp. is sometimes difficult because of their extensive host range, short life cycle, high reproductive rate and endoparasitic nature (Manzanilla-lopez et al., 2004). *Meloidogyne* spp. are also difficult to control with a single control method (Barker et al., 1985).

After many years of use, methyl bromide has been completely phased out by January 1st, 2015. Therefore, we must evaluate the application of other available alternatives to methyl bromide to protect our vegetable production, especially in greenhouses.

Different approaches have been used to manage root-knot nematodes in vegetable crops, including the use of fumigant and non-fumigant nematicides, resistant cultivars and biological and physical control measures (Zuckerman and Esnard, 1994; Collange et al., 2011), although, varied in their efficacy due to several factors. Collange et al. (2011) presented an excellent and extensive review of root-knot nematode management in vegetable crop production, including the role of sanitation, soil management, organic and inorganic fertilizers, biological control and heat-based methods.

The aim of this present study was to compare the relative efficacy of different approaches (chemical, biological, physical, and cultural practices) as alternatives to methyl bromide for managing *M. incognita* on green bean under greenhouse conditions in Saudi Arabia.

2. Materials and methods

2.1. Treatments and design

Eight different approaches of *M. incognita* management (Table 1) were comparatively evaluated in a greenhouse pot experiment. *M. incognita*-infected and non-infected control treatments were also included. Thus, 11 treatments with five replicates were arranged in a complete randomized design (CRD) on a greenhouse bench (25 ± 2 °C).

2.2. Test plants

Clean plastic pots (14 cm diam.) were filled with 1500 g/pot of a mixture of equal parts sand and sandy loam soil. The potting mixture was previously steam-sterilized with an autoclave. Pots were then seeded with three green bean seeds (cv. Contender). A week after emergence, the seedlings were thinned to one seedling/pot.

2.3. Nematode inoculum and inoculation

As inoculum, an egg suspension of *M. incognita* (race 2), was prepared (Hussey and Barker, 1973) from a pure greenhouse culture on tomato. Inoculation always took place when seedlings were 3-week-old. Each seedling was inoculated with 10,000 eggs/pot (6.7 eggs/g soil).

2.4. Treatments with nematicides

The soil in each pot to be treated with the fumigant nematicide dazomet was mixed thoroughly in a plastic bag with the recommended dose (50 g/m^2 = 0.76 g/pot). Treated soils were returned to their pots, irrigated to field capacity, and covered with plastic sheets. A week later, the covers were removed, and the soils were aerated for two weeks. Soils were then returned to pots and seeded with bean seeds. Seedlings were thinned and inoculated with *M. incognita* as mentioned before. A similar procedure was followed with the nematicide fenamiphos (9.6 kg/ha = 0.15 g/pot) and the nematode inoculation but without plastic to cover the pots.

For seed dressing (coating), bean seeds were moistened with water and then mixed thoroughly in a plastic bag (seed

Table 1 Control approaches and methods used in the study.

Control approaches	Control method	Tested material	Rate used/remarks
Chemical	Fumigant	Dazomet	50 g/m^2
	Non-fumigant	Fenamiphos	Soil treatment @ 9.6 kg a.i./ha
			Seed dressing @ 2.0% a.i. (w:w)
			Seed-dip @ 2.0% a.i. (w:v)
Biological	Parasitic fungus	*Paecilomyces lilacinus*	0.7% of culture on grains
	Mycorrhiza	*Glomus* sp.	1×10^3 spore/kg soil
Physical	Soil solarization		For 8 weeks (June–July)
Cultural	Organic fertilizer	Chicken litter	2.0% (w:w dry base)
	Inorganic fertilizer	Urea (46-0-0)	600 kg/ha
Check			*M. incognita* (6.7 egg/g soil)
			Non-infected and non-treated seedlings