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Efficiency of Solarization and Incorporation of Cattle Manure in Management of *Meloidogyne javanica* (Treub.) Chitwood and *Globodera pallida* (Stone) Behrens Associated with Potato

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ABSTRACT

Potato is a strategic crop in Tunisia but is susceptible to many pests and diseases. Nematodes of the genera *Meloidogyne* and *Globodera* are important pests that cause yield losses and depreciation of tuber quality. A trial was carried out in a plot where the soil was naturally infested with *M. javanica* and *G. pallida*. Three soil treatments were tested and compared. Soil solarization (SS) and incorporation of cattle manure (70 T/ha), applied alone or in combination, were assessed for their impact on potato crop. SS alone improved potato growth by 13.56% and yield by 26.53%. Compared to the control, SS combined with cattle manure decreased the multiplication rate of *M. javanica* by 38.14% and enhanced plant height (29.47%), fresh root and shoot weight (47.89 and 59.53%, respectively) and yield (26.40%).

Keywords: organic amendment, plant growth, physical control, root knot and cyst nematodes, *Solanum tuberosum* L., yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the main crops in the cultivated agro-ecological environments of Tunisia (B'Chir and Namouchi-Kachouri 1993). Potato is cultivated in all Tunisian regions to a different extent. The total area planted has already increased to 25,100 ha in 2007 (Anonymous 2008). However, the yields are still lower than those reported in the other potato-producing countries like the United States, China, India, Switzerland and the Netherlands (FAO 2010; NASS 2011). They are also restricted by many diseases and nematodes, among other factors (Wheeler and Riedel 1994).

Endoparasitic nematodes cause severe yield losses in potato crops. Indeed, *Meloidogyne*, the root knot nematode (or RKN), is one of the major constraints in vegetable crops and is considered to be the most damaging plant-parasitic nematode (Sasser and Freckman 1987). Yield losses attributed to these nematodes were estimated to be 5% (Hussey and Janssen 2002). In Tunisia, *M. incognita* (Kofoid and White) Chitw. is responsible of 64.7% of yield losses of potato crops (Hlaoua and Horrigue-Raouani 2007). *Globodera pallida* (Stone) Behrens and *G. rostochiensis* (Woll) Behrens, cyst nematodes, are the most pathogenic and widespread nematodes of potatoes (Greco 1998). Indeed, the damage potential of these nematodes on potato crop in Tunisia is very high and the reported yield losses are of about 45% (B'Chir and Namouchi-Kachouri 1993; Hlaoua 2011). Compared to the untreated control, the use of ethoprophos, a nematicide, has improved production by 251.48% (Ghariani 1995). However, recently, it has become more widely recognized that chemical soil disinfestations are incompatible with sustainable agriculture. Consequently, interest in alternative control has increased. For several decades, soil solarization (SS), based on the use of thermal heat, which is a renewable energy source, has shown evidence of increased demand. This physical control method can constitute an interesting alternative for nematode management and reduction of soil infestation (Horrigue-Raouani and B'Chir 1998; Greco *et al*. 2000). Moreover, the incorporation of large amounts of organic amendments into soil is an alternative for reducing nematode densities and soil-borne pathogens and for improving soil structure and fertility (García-Alvarez *et al.* 2004).

A field experiment was performed in a soil naturally infested with *M. javanica* (RKN) and *G. pallida* (potato cyst nematode: PCN) in the experimental domain of the Higher Agronomic Institute of Chott-Mariem (Centre-East of Tunisia). The objective of the experiment was to assess the effectiveness of SS and cattle manure amendment applied alone or in combination against nematodes (RKN and PCN) multiplication and their impact on potato growth and production.

MATERIALS AND METHODS

Plant material

Soil treatments (SS and/or cattle manure amendment) were evaluated on a potato crop. Before planting, seed tubers (cv. 'Spunta') were placed under environmental conditions favourable for pregermination (20°C, 60-80% relative humidity and natural room light).

Experimental protocol

The trial was conducted in an experimental plot situated at the Higher Agronomic Institute of Chott-Mariem. The soil is naturally infested with *M. javanica* and *G. pallida.* Four treatments were tested in this experiment i.e. control (C), soil solarization (SS) or application of a plastic cover, incorporation of cattle manure (CM) (70 T/ha), and combined application of cattle manure and soil solarisation (CM + SS). The experiment was conducted according to a completely randomized block design with four treatments and 7 replications per elementary treatment. Each block was subdivided into four elementary plots of 8 m × 3 m dimension each. The elementary plots were separated by 1 m wide alley with plastic film inserted to 60 cm depth.

Tillage, irrigation and plantation

Before installing the experimental protocol, the soil has been tilled

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by two successive operations, a large moldboard plowing followed by disc harrowing. Subsequently, the elementary plots of treatments SS and SS + CM were irrigated to field capacity and covered at August 12th until September 20th by a white plastic film (0.135 mm thick). After 33 days, the film was removed. Last tillage operation was done using a plow horse to open furrows for planting (Stapleton 1997). Each elementary plot had four planting lines spaced at 0.75 m. Each row was planted with 25 tubers (0.30 m × 0.70 m). Irrigation was done through a drip irrigation system. The crop was maintained for 118 days and supplemented with additive chemical fertilizers (60 Kg/ha of ammonium nitrate + 60 Kg/ha of potassium nitrate, 8 l/ha phosphoric acid and 25 Kg/ha of magnesium sulphate) for four weeks from the 4th week. Fertilization and other cultural practices were the most commonly used for potato farming in the region. Harvesting was carried out on January 25th.

Sampling and extraction of nematodes

Before applying treatments, composite soil samples were taken from each elementary plot to estimate the initial population of nematodes. At the end of the assay (118 days posy-planting), 10 plants were randomly taken from each elementary plot to assess the nematode population in the soil and roots. Cyst nematodes were extracted using Fenwick after drying and sieving the soil samples (500 g). PCN in roots and *Meloidogyne* (RKN) populations were estimated after extracting nematodes from roots and soil according to the technique used by De Grisse (1969). Nematodes were counted under a stereomicroscope (Leitz, Ernst Leitz Wetzlar). The effects of the treatments tested were assessed based on several growth and production parameters such as plant height, fresh root and shoot weights and yield. The severity of infestation was evaluated based on the galling index estimated according to the scale proposed by Barker (1978) and the multiplication rate (Pf/Pi) of nematodes, respectively.

Statistical analyses

The data were subjected to analyses of variance (ANOVA) using the software program called Statistical Package for the Social Sciences (SPSS) version 11.0 for Windows. The treatment means were compared by Duncan's multiple range test when *F*-tests were statistically significant at $P < 0.05$.

RESULTS

Plant growth

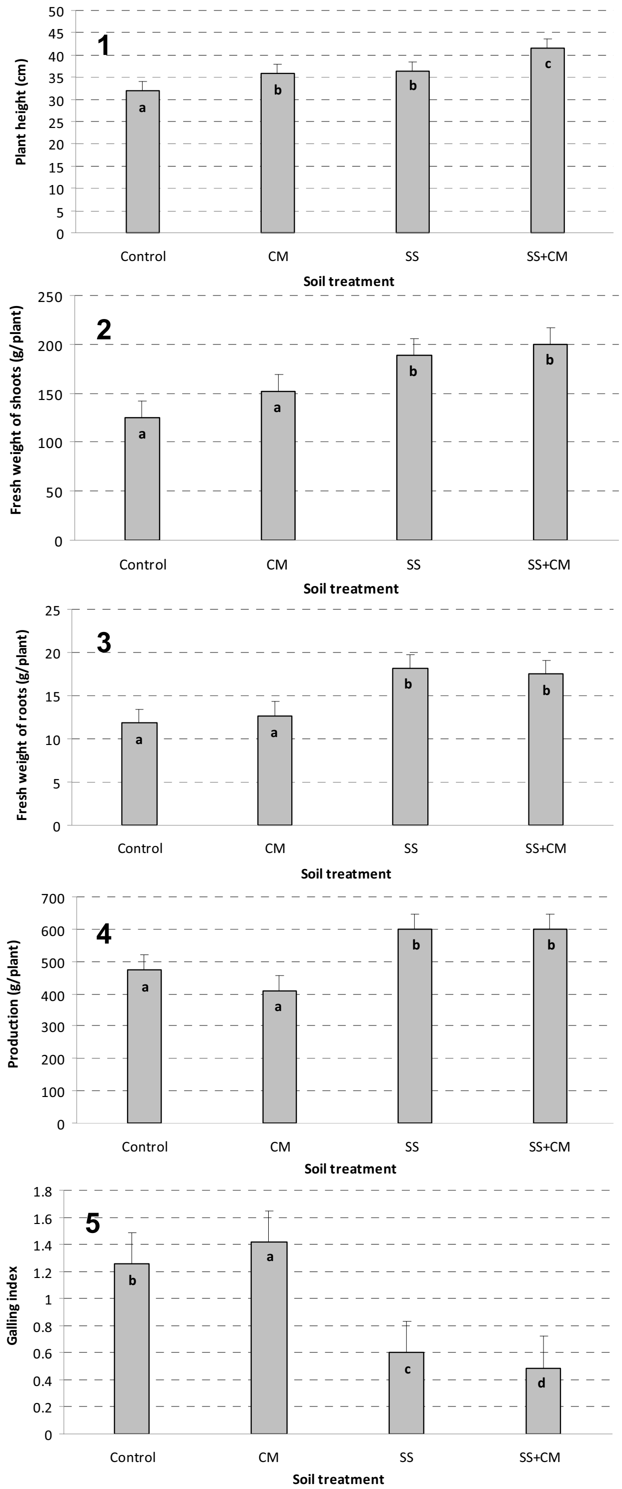
The plant height, fresh weights of shoots and roots (**Figs. 1, 2** and **3**), noted 118 days after planting, showed a significant difference among treatments. SS applied alone significantly ($P < 0.05$) improved plant height by 13.5% and the fresh weights of shoots and roots by 52 and 53.3%, respectively. The combined effect of incorporation of CM and SS was significantly higher ($P < 0.01$) than other treatments tested. Indeed, this treatment improved the aerial part and root growth (fresh weight) by 61.5 and 48.5%, respectively.

Production

The use of CM alone had no effect on potato production recorded after 118 days. However, SS applied alone or combined with CM improved production most efficiently. Compared to the untreated control, yield increased by 26 and 26.5%, respectively, in both these treatments (**Fig. 4**).

Galling index

SS significantly ($P < 0.05$) reduced the galling index by 53.2% recorded 118 days post-planting compared with the untreated plants. The highest reduction (of about 61.4%) in the galling index was obtained with the incorporation of CM in combination with SS (**Fig. 5**).



Potato cv. 'Spunta' plant height (cm) (**Fig. 1**), fresh weight of shoots (**Fig. 2**), fresh weight of roots (**Fig. 3**), average production per plant (**Fig. 4**), and galling index per plant (**Fig. 5**) noted 118 days post-planting depending on the soil treatments tested. Bars with the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$). Each bar represents the mean of 70 plants.

Multiplication rate

The soil used in this trial was infested with *M. javanica* and *G. pallida*. Therefore, the multiplication rate of each nematode was followed separately. In fact, for RKN, the multiplication rate had decreased by 49.5% after incorporation of CM (70 T/ha) into the soil before planting. However, the effect of SS, applied alone or combined with CM, was less efficient in the multiplication of *M. javanica* (**Fig. 6A**). Though, the effect of SS was different. In fact, in the solarized plots, the final population (Pf) of RKN had increased

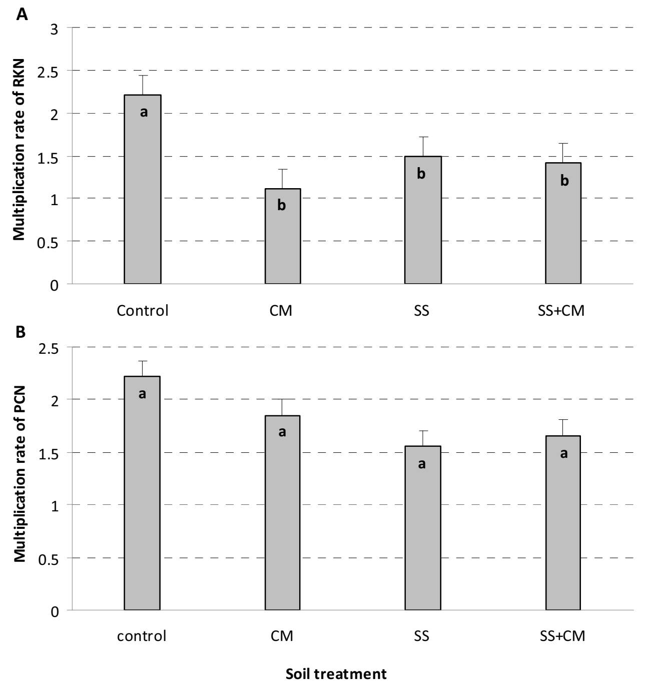


Fig. 6 Multiplication rate (Pf/Pi) of *Meloidogyne javanica* (A) and *Globodera pallida* (B). Bars with the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$).

by 17%. However, only a slight reduction of about 16.8% of PCN Pf/Pi was recorded with the CM treatment (**Fig. 6B**). Multiplication rate of PCN was reduced by 29.9% with SS and by 25.4% with combined application of SS and CM amendment.

DISCUSSION

Root knot nematodes (*Meloidogyne* spp.) are one of the damaging nematodes and can infest several crops (Jepson 1987). In Tunisia, *M. incognita* and *M. javanica* were reported to be associated with potatoes (Hlaoua 2004). PCN are important obligate parasites considered worldwide as traditional potato pests (Ibrahim *et al*. 2000; Manduric *et al.* 2004). In many research reports, the management of each nematode pest was considered separately (Ghariani 1995; Chauvin *et al.* 2008). Some authors signalled that nematicidal plants and animal organic matter may have suppressive effects against some plant parasitic nematodes (Badra *et al*. 1979; Kerkeni *et al*. 2007). According to Akhtar and Malik (2000), organic soil amendments are able to stimulate the activity of microorganisms exhibiting antagonistic effects towards plant-parasitic nematodes. Moreover, some nematicidal compounds may be released in the soil during decomposition. It should be also mentioned that organic matter can control not only nematodes but also soil-borne fungal pathogens. The suppressive effects included the release of fungitoxic compounds, generation of fungistasis (Lockwood 1977), or selective stimulation of antagonistic soil microorganisms (Hoitink and Boehm 1999).

CM and leaf mould decrease populations of *M. incognita* and increase plant growth (Singh *et al*. 1986). Habicht (1975) showed that organic amendments were able to improve yield in addition to their antagonistic effect against *Meloidogyne* and *Globodera*. However, in this work where the soil was infested with both *M. javanica* and *G. pallida*, the use of CM (70 T/ha) alone neither improved plant growth but the multiplication rates of both the root knot and cyst nematodes were reduced as compared to the untreated control soils. This may be attributed to the quantity of CM used as according to Oka *et al*. (2007) results, the nematicidal effect of organic matter had been reached at 100 T/ha or more.

Other control measures such as solarization and biofumigation were largely used against several soil-borne crop pests. SS represents an interesting and environmentally safe alternative for the control of plant parasitic nematodes (Greco *et al*. 2000). Porter and Merriman (1985) suggested that temperature increase during solarizing process was involved in pathogen death. In contrast, others authors have shown that SS acts primarily by increasing soil moisture that enables the resting forms of nematodes (eggs and cysts). In fact, as shown in Horrigue-Raouani and B'Chir (1998) study, SS promotes egg hatching of RKN and exhaustion of soil inoculum and enables the multiplication of antagonistic microorganisms. These authors also showed that this practice may improve the precocity, increase total production, delay the early dying of plants and may significantly reduce the infestation of pepper plants in greenhouses. Stephan *et al*. (1991) reported significant decreases in populations of *M. javanica* and increased cucumber and eggplant yields after SS. When compared to several chemical control methods, solarization was one of the most effective treatments. This technique, applied in this work on a potato crop, improved plant growth and production and could reduce the level of infestation of soil and roots with plant parasitic nematodes especially *M. javanica*. Similar results were obtained by Lepoivre (1999) who attributes the plant growth stimulation to the physical (water retention) and chemical (nitrogen mobilization) effects of solarization. SS improves the growth and yield of grown plants especially in crops installed just after practicing this technique. In fact, Kumar *et al*. (1993) found that SS had reduced the population of plant parasitic nematodes by approximately 90%. However, this practice may present an inconvenient as nematodes may be recovered 70 days post-solarization (McSorley *et al*. 1999). A combination of organic amendment with SS was effective in reducing the severity of various soil-borne plant diseases (Freeman and Katan 1988; Gamliel and Stapleton 1993). Robertson *et al.* (2006) obtained an important result by using pepper wastes as biofumigant in both greenhouse and laboratory experiments. Indeed, according to these authors, this technique is a non-chemical alternative when applied under plastic shelters with fresh sheep and chicken manure to control *M. incognita*. SS combined with CM, used in this work, had improved the growth, production and decreased the multiplication rate of *M. javanica*. However, this technique is less effective in the management of *G. pallida*. Thus, it would be interesting to test other doses and other manure types.

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