NUTRIENT STATUS AND PHOTOSYNTHETIC EFFICIENCY OF BANANA (*MUSA* SP.) INFLUENCED BY *MELOIDOGYNE INCOGNITA* INFECTED WITH *PASTEURIA PENETRANS*

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Summary. Investigations were made to study the changes in the leaf nutrient status, total chlorophyll content and photosynthetic efficiency of banana (*Musa* sp.) due to *Meloidogyne incognita* alone and in association with *Pasteuria penetrans*. Significant reduction of *M. incognita* infestation, in terms of gall index, number of egg masses and nematode population in soil, was recorded when more *P. penetrans* spores were added to the soil in which the plants were growing. The infestation of *M. incognita* decreased the nitrogen, phosphorus, potassium and magnesium levels in the leaves of banana and increased the calcium level. The total chlorophyll content and photosynthetic efficiency were reduced by up to 7.2 and 13 percent, respectively, in banana inoculated with *M. incognita* alone. Application of *P. penetrans* induced changes in the opposite direction and the reactions were more pronounced when greater quantities of *P. penetrans* were applied.

Some 34 genera of nematodes are found associated with banana (*Musa* sp.) in India. Among these, the root knot nematode, *Meloidogyne incognita* causes considerable yield loss reaching up to 60% (Jonathan and Rajendran, 1998). Management of this nematode through biological means is receiving considerable current interest due to worries that chemical nematicides lead to environmental pollution. Among the various kinds of organisms utilized in natural control of nematodes, the endospore forming bacterium, *Pasteuria penetrans*, is a potential bioagent for the management of *M. incognita* in banana (Devrajan *et al.*, 2002). Information on changes in the nutrient status and physiology of beans infested with *M. incognita* has been established earlier (Melakeberhan *et al.*, 1987). However, little work has been done on the responses of the host plant to the presence of both *M. incognita* and *P. penetrans*.

An attempt was made to measure changes in leaf nutrient status, total chlorophyll content and photosynthetic efficiency of banana plants in the presence of *M. incognita* alone and in association with the *P. penetrans*.

MATERIALS AND METHODS

Two identical pot experiments were conducted to study the infection behaviour and nutritional and physiological changes in banana (*Musa* sp.) induced by *M. incognita* (Kofoid *et* White) Chitw. alone and in association with *P. penetrans* (Thorne) Sayre *et* Starr. Three different dosages of *P. penetrans, viz.*, 0.25, 0.5 and 0.75 g/kg soil (having 24 x 10^9 spores/g) were applied for the study. The effects of *P. penetrans* on the nematode and thereby plant growth were compared with those of the chemical carbofuran 3G at the rate of 40 g of commercial product/plant. In addition to these treatments, an uninoculated control was also maintained for comparison. The experiments were conducted in a completely randomised block design with four replications at the Department of Nematology, Tamil Nadu Agricultural University, Coimbatore, India.

The bacterium was cultured on tomato plants infested with *M. incognita*. Egg masses of the *M. incognita* were collected and kept in embryo cups with distilled water for hatching. The hatched juveniles (J_2) were added to a suspension of spores of *P. penetrans* and the suspension was agitated by bubbling air through it. After the spores attached to the juveniles, the suspension was pipetted around the roots of tomato plants grown in sterile autoclaved soil (Stirling and Wachtel, 1980). The *P. penetrans* encumbered juveniles were inoculated once per week to build up the spore load. After ten weeks, the roots of the tomato plants were dried, powdered and used as inoculum. A haemocytometer was used to assess the total spore count in one g of the dried powder.

Uniform suckers of banana (cv. Robusta) were collected from a healthy garden of banana, pared to a depth of 1 cm, treated in hot water (50-55 °C) for 10 min. and planted in a sterilized potting mixture (red soil, sand and farm yard manure in equal proportion) in 5 kg capacity clay pots. Thirty days after planting the suckers, the three different dose rates noted above of *P. penetrans* were applied to the rhizosphere of the plants. Freshly hatched juveniles of *M. incognita* were inoculated at a density of 5000/plant by making small holes around the roots seven days after inoculation of the bacterium. Carbofuran was applied three days after nematode inoculation.

The experiments were terminated 120 days after nematode inoculation (DAI). The nematode population in soil was assessed by Cobb's sieving followed by a modi-

Table I. Effect of *Pasteuria penetrans* on *Meloidogyne incognita* infecting banana plants.

Treatment	Gall index	Number of egg masses/ 5 g root	Soil nematode population (J_2/100 ml)	*Pasteuria* infected females (%)
P. penetrans 0.25 g/kg soil	3.7	15.7	331.7	73
P. penetrans 0.50 g/kg soil	2.0	10.9	198.3	82
P. penetrans 0.75 g/kg soil	1.7	8.1	113.7	93
Carbofuran 3 G 40 g/plant	2.7	16.0	262.7	-
Nematode inoculated control	4.7	23.1	362.7	-
Uninoculated control	-	-	-	-
C.D. at 5%	0.3	1.3	28.3	8.5

Table II. Effect of *P. penetrans* on nutrient status, chlorophyll content and photosynthetic efficiency of banana plants infested with *M. incognita*.

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Chlorophyll content (mg/g leaf)	Photosynthetic efficiency (mg CO_2/sec/m^2)
P. penetrans 0.25 g/kg soil	1.91	0.16	3.13	1.24	0.47	7.68	0.195
P. penetrans 0.50 g/kg soil	1.96	0.19	3.29	1.14	0.47	7.69	0.200
P. penetrans 0.75 g/kg soil	2.26	0.22	4.36	1.09	0.57	7.82	0.212
Carbofuran 3 G 40 g/plant	2.21	0.20	4.13	1.10	0.56	7.82	0.211
Nematode inoculated control	1.84	0.16	3.10	1.27	0.47	7.66	0.198
Uninoculated control	2.31	0.23	4.41	1.04	0.63	8.22	0.224
C.D. at 5%	0.20	0.02	0.39	0.12	0.12	0.41	0.014

fied Baermann's funnel technique. Nematode infestation was assessed by recording the root gall index (Heald *et al.*, 1989) and the number of egg masses/5g root. The percentage of bacterium-infected adult females was recorded at the time of termination of the experiment.

Leaf samples were collected from the third leaf from the top of plants from each treatment at 120 DAI and dried and analysed for nutrient contents. Total nitrogen in the leaf was estimated by Micro Kjeldhal method (Humphries, 1956). Phosphorus, potassium, calcium and magnesium contents in the leaf samples were estimated by preparing triple acid extract (Jackson, 1973) and the values were expressed as a percentage of leaf dry matter. Chlorophyll contents of the third leaf of plants at the time of termination were estimated by the method described by Yoshida *et al.* (1971) and expressed in mg/g leaf tissue. Photosynthetic efficiency of leaves was measured with a photosynthetic efficiency meter and the value was expressed in mg CO_2/sec/m^2. The data from the two experiments were pooled and analysed statistically.

RESULTS

The data on the effect of *P. penetrans* on the infestation of *M. incognita* in banana plants are presented in Table I. The bacterium caused significant reductions in nematode infestation compared to that in nematode inoculated control plants. At all dosages, *P. penetrans* reduced gall index significantly compared to the nematode inoculated control. The maximum reduction occurred when *P. penetrans* was added at 0.75 g/kg soil. The bacterium at 0.50 g/kg soil was the next best treatment in reducing the gall index and was not significantly less effective than the 0.75 g/kg soil treatment. The highest gall index (4.7) was found in the nematode inoculated control. The carbofuran treatment resulted in a significantly greater gall index than *P. penetrans* at 0.75 or 0.50 g/kg soil. Similar trends were observed for the numbers of egg masses and soil nematode population. The bacterium at 0.75 g/kg soil resulted in the highest percentage (93) of bacterium-infected females, followed by the 0.50 and 0.25 g/kg soil dosages.

The quantitative estimations of leaf nutrient status, chlorophyll content and photosynthetic efficiency are presented in Table II. Increased calcium and decreased

nitrogen, phosphorus, potassium and magnesium contents were found in plants inoculated with *M. incognita*. The bacterium at 0.75 g/kg soil increased the nitrogen content significantly, by 22.8% over the nematode inoculated control. The nitrogen content in the uninoculated control (2.31% of leaf dry matter) was very similar to the values for *P. penetrans* at the rate of 0.75 g/kg soil (2.26%) and carbofuran treatment (2.21%). *M. incognita* reduced phosphorus and potassium content by 30.4 and 29.7%, respectively, compared to the uninoculated control. *P. penetrans* at the rate of 0.75 g/kg soil increased the phosphorus and potassium contents by 37.5 and 40.6% respectively, compared to the nematode inoculated control, and phosphorus and potassium contents were close to the values for the uninoculated control. The maximum calcium content (1.27%) was observed in the nematode inoculated control, with a value not statistically different from *P. penetrans* at 0.25 g/kg soil. Plants that received the bacterium at 0.75 g/kg soil contained up to 14.1% less calcium than other nematode inoculated treatments and were not statistically different from the uninoculated control plants. Carbofuran treated plants contained 13.3% less calcium than inoculated controls. The lowest content of magnesium (0.47%) was found in the nematode inoculated control treatment and in plants that received *P. penetrans* at 0.25 and 0.5 g/kg soil. A significant increase of 21.3% in magnesium content was detected in the treatment with *P. penetrans* at 0.75 g/kg soil. The lowest chlorophyll content of 7.66 mg/g leaf was found in the nematode inoculated control, which was 7.2% less than in the uninoculated control, and the minimum reduction of 4.9% was found in the *P. penetrans* at 0.75 g/kg soil and carbofuran treatments. The photosynthetic efficiency of leaves was reduced by up to 13.0% in the nematode inoculated control (0.198) over the uninoculated control (0.224). The minimum reduction of 5.8% was found in the treatment with *P. penetrans* at the rate of 0.75 g/kg soil (0.212).

DISCUSSION

The results of the study indicate that the increase in the quantity of *P. penetrans* spores added to the pots decreased the nematode infestation level in banana plants. A similar negative correlation between *P. penetrans* level and the severity of root knot nematode infestation was reported by Somasekar and Gill (1990). The reduced infectivity and reproduction of *M. incognita* in host plants due to *P. penetrans* infection was also reported by Brown *et al.* (1985) and Davies *et al.* (1988). Analysis of nutrient status in the banana leaves revealed that *M. incognita* infection decreased the nitrogen, phosphorus, potassium and magnesium contents and increased the calcium content. Similar decreases in nitrogen, phosphorus (Heffes *et al.*, 1991), potassium (Fatemy and Evans, 1986) and magnesium (Melakeberhan *et al.*, 1987) and increase in calcium (Goswami *et al.*, 1976) contents due to *M. incognita* infestation have been well documented. The changes in nutrient concentration in nematode inoculated plants are associated with a reduction in chlorophyll content, which ultimately leads to reduction of photosynthetic efficiency. The decrease in potassium concentration may affect CO_2 uptake or, by altering osmotic potential, lead to decreased photosynthesis (Ferguson, 1984). Application of *P. penetrans* and carbofuran resulted in an opposite reaction for plants nutrient status and physiological status compared to nematode inoculated control plants. Further, this reaction was increased when *P. penetrans* dosage increased. At higher densities of bacterium inoculation, the plants reacted similarly to uninoculated control plants, which indicates that nematode infestation alone plays a major role in the nutritional and physiological status of banana plants. Hence, these results support the hypothesis that the infection of *M. incognita* by *P. penetrans* reduced the infestation and reproduction of *M. incognita* and nullified the nutritional and physiological stress induced by the nematode. A similar improvement after application of *P. penetrans* to *Heterodera cajani* infecting cowpea plants has been reported by Mohan and Dhawan (2000).

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Accepted for publication on 1 August 2003.