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Efficacy of *Trichoderma* spp. and Bio-fertiliser in the Management of Root-Knot Nematodes in Tomato in Kenya

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Tomato (*Solanum lycopersicum* L.) is a major fruit vegetable crop, grown mainly by small-scale farmers and consumed in almost all households in Kenya. Root-knot nematodes (RKN) are among the major production constraints of tomato. The RKN are mostly managed using expensive, health-harming, and environmentally unsafe chemicals. The study aimed to evaluate the efficacy of selected *Trichoderma* spp. as biological control fungi and Bio-fertiliser (Plantmate) RKN in tomato. A two-season on-station trial was conducted at Kenya Agricultural and Livestock Research Organization (KALRO), Horticulture Research Institute (HRI). The trial's design was a Randomised Complete Block Design (RCBD), with five treatments replicated four times. The treatments were 20g of (1×10^9 cfu/g) *T. harzianum*, *T. asperellum* (1×10^{10} cfu/ml), a combination of the two *Trichoderma* strains, each in 20 lts of water, Plantmate bio-fertiliser, 100 g, and Control. In the two seasons, the *Trichoderma* strains, singly and in combination, and the plantmate had significantly ($P \leq 0.05$) lower percent galling index compared to the control. The *T. harzianum* had the lowest mean galling index (20%, 20.5%), respectively. The Control had the highest % mean (57%, 62.5%) in the two seasons, respectively. There was a significant difference ($P \leq 0.05$) in tomato yields between treatments in season one. The highest yield (6,588kg/ha; 11,149 kg/ha) was realised from *T. harzianum* treatment, and the least % mean yield (3,955kg/ha; 9,089kg/ha) from the Control in both seasons, respectively. The study concluded that the *Trichoderma* spp. and the bio-fertiliser, Plantmate, are effective in the management of RKN in tomato. They are therefore potential biological agents for use in the integrated pest management (IPM) strategies of tomato Root Knot Nematodes (*Meloidogyne* spp).

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INTRODUCTION

Tomato (*Solanum lycopersicon*) is an important vegetable globally, with an estimated annual production of 159 million tonnes, accounting for 14% of world vegetable production. The fruit or vegetable can be processed, consumed raw, or cooked. It is a source of vitamins, minerals, sugars, amino acids, and dietary fiber (Olaniyan *et al.*, 2007; Noonar *et al.*, 2015; Renna *et al.*, 2018). In Kenya, tomato is a major vegetable crop ranking 3rd after Kale and cabbage. The crop is extensively grown mainly by small-scale farmers and consumed in almost all households (FAO, 2018; Ochilo *et al.*, 2019; Tenesi & Kitonga, 2023). In 2020, among the exotic vegetables, tomato accounted for 38.1% of total production, grown on 28,263 ha with an estimated value of KES 19.9 billion (HCD, 2020).

Tomato production is mainly constrained by biotic factors that include arthropod pests (whiteflies, borers, tomato leafminer *Tuta absoluta* (Meyrick) and diseases (bacterial wilt, Fusarium wilt, early and late blight, viral diseases, and Root-knot nematodes). These pests and diseases affect crop quantity and quality, thus threatening world food security (Seid *et al.*, 2015; Ndegwa *et al.*, 2019). Yield losses due to Root Knot Nematodes in tomato in Kenya are not clearly known, but they are estimated between 30-100%, based on the cropping system (Ngeno, 2019).

According to Nicol *et al.* (2011), the annual damaging effect of plant parasitic nematodes is estimated at US\$ 80 billion. Among the plant-parasitic nematodes, *Meloidogyne* spp., which cause major losses in vegetable crops (Nicol *et al.*, 2011; Landi *et al.*, 2018), are found on tomato. The Root Knot Nematodes (RKN) cause galling in roots, leading to root malfunction, reduced volume, poor soil penetration, and reduced water and nutrient utilization efficiency (Noling, 2019). In Kenya, tomato farmers use costly, unhealthy, and environmentally unsafe chemical pesticides to manage the RKN (Wabere, 2010). This has evoked interest in the use of integrated pest management strategies that are safe for humans and the environment. Such strategies include the use of flooding, crop rotation, resistant varieties, and biological agents, among others. Biological agents (fungi and bacteria) have been used against a myriad of plant pathogens (Prakash & Rao, 2018). Such agents include *Trichoderma* spp. Fungi and bio fertilizer plantmate. The *Trichoderma* spp. infects RKN life stages (eggs, infective juveniles). The soil amendment bio-fertilizer, Plantmate consists of 22 microbes (*Bacillus* sp, Nitrifiers, Actinomycetes, thermophilic fungi, photosynthetic and lactic acid bacteria), (Mitkowski & Abawi, 2003; Sahebani & Hadavi, 2008; Mukhtar, 2018). The bacteria are for decomposition, enzyme production and nutrient transformation, Actinomycetes help in the decomposition of polysaccharides and enzyme

production, *Bacillus* sp. enhance decomposition, and probiotics production, Nitrifiers facilitate nitrogen fixation and nutrient transformation while the Thermophilic fungi aid decomposition, probiotics production and nutrient transformation (Karuku, 2018). The *Trichoderma* spp. is a soil fungus that colonizes root surfaces, root cortical cells, and rhizospheres. The fungi prevent soil-borne diseases and promote plant growth by improving nutrient utilization efficiency and resistance. Several *Trichoderma* spp. including *T. harzianum*, *T. viride*, *T. atroviride*, and *T. asperellum*, have been reported to provide excellent control of RKN in crops (Sharon *et al.*, 2007; Sharon *et al.*, 2009; Yao *et al.*, 2023).

This study aimed at evaluating the effect of *Trichoderma* spp. and Plantmate bio-fertilizer in the management of tomato RKN (*Meloidogyne* spp).

MATERIALS AND METHODS

Study Site

The field experiments were carried out at the Kenya Agricultural and Livestock Research Organization (KALRO), Horticulture Research Institute (HRI), Thika. The Institute is located 5 Kms north of Thika Town in Kiambu County and 43 kms from Nairobi. It lies at latitude 0° 59' S and longitude 37° 04' E at an altitude of 1548m above sea level. The area experiences biannual rainfall of 960 mm with temperatures ranging from 16°C to 24°C. The soils are sandy loam that is shallow to deep. These conditions make the area suitable for tomatoes, which grow in a wide range of conditions. Two-season trials were conducted from June to November 2020. The trials were conducted on naturally nematode-infested soils in the field. The treatments included *Trichoderma harzianum* (Triatum P®), which was acquired from Koppert Biological Systems, *Trichoderma asperellum* (Real Tricho®), from Real IPM LTD, and Plantmate biofertilizer, donated by Wanda Agriculture Group.

Tomato Seedling Establishment

Certified tomato seed variety Kilele F₁ was used in the trial. It was the farmers' preferred variety due to its tolerance to bacterial wilt and market acceptability. The seeds were germinated in tray nurseries (10x20 wells), with a single seed being sown in a well, filled with sterile Peat-moss on 2nd June 2020 and 24th June 2020 for the first and second seasons, respectively. The seedlings were watered regularly until they were ready for transplanting a month later.

Land Preparation

A site known to be infected with Root Knot Nematodes (RKN) was selected. The field was ploughed and harrowed. The trial was then laid out in a Randomized Complete Block Design (RCBD) with five treatments replicated four times. The plots were 3m x 3m separated by a meter path. Holes were made at a spacing of 45cm within and 60cm between the rows, giving a population of 30 plants per plot.

Treatments Application before Transplanting

Two *Trichoderma* strains (*T. harzianum* and *T. asperellum*), singly and in combination, were applied in the respective holes by drenching and left for one month for the fungus to establish before transplanting. The treated holes were watered weekly to keep the fungus alive and multiplying. The treatment doses were applied at 20g (1x10⁹cfu/g) *T. harzianum* (TH), 20ml (1 x 10¹⁰cfu/ml) *T. asperellum* (TA), and a combination of the two strains of the same amounts (TA/TH), in 20lt of water. *Trichoderma* solution (200ml) was applied per hole (Table 1).

Treatments Application for Transplanting

A handful of cattle manure and a tablespoonful of Double Ammonium Phosphate (DAP) were applied in the holes. One-month-old tomato seedlings from the tray nursery were transplanted on 30th June 2020 and 21st July 2020 for seasons one and two, respectively. After transplanting, a second dose of

the *Trichoderma* treatments was applied at the same doses as the first application by drenching. Basal application of Plantmate bio-fertiliser, 100g per hole, was also done. Plain water was used in the

control experiment. Integrated Pest Management (IPM) practices (weeding, watering pests, and disease control) were carried out during the growth of the crop (Table 1).

Table 1: Treatments

No.	Treatment	Code	Dose
1	<i>Trichoderma harzianum</i> (Trianum P®)	TH	20g/20lt water
2	<i>Trichoderma asperellum</i> (Real Tricho®)	TA	20ml/20lt water
3	<i>Trichoderma asperellum</i> plus <i>Trichoderma harzianum</i>	TA/TH	20ml+20g/20lt water
4	Plantmate (organic fertilizer)	M	100g per plant
5	Control	C	Water alone

Data Collection

Nematode Gallling Index

Nematode infection data were collected after the fourth and final harvest (90 days from transplanting). Five tomato plants were randomly selected and gently uprooted to avoid losing any roots. The roots were dipped in water to remove excess soil from the roots for ease of gall scoring. The number of galls indexing was done using 0-10 scale according to Bridge and Page, (1980); Coyne *et al.* (2007) as follows; 0-no knots on roots, 1- few small knots, 2-small knots only but visible, main roots clean, 3-some large knots visible, main roots clean, 4-large knots predominate but main roots clean, 5-50% of roots affected, knotting on some main roots, 6-knotting on main roots, 7-majority of main roots knotted, 8-all main roots including tap root knotted, 9-all main roots severely knotted, the plant usually drying, and 10-all roots severely knotted with no root system.

Tomato Yield Data

Harvesting started two months after transplanting, where all the tomato fruits from each experiment were picked weekly for four weeks when the red colour started setting. Fruit weight was taken per treatment plot and recorded in Kilograms.

Data Analysis

Data on gallling index and yield were subjected to analysis of variance (ANOVA), using SAS Version

8 statistical Software. Means were separated by Fisher's least significant difference (LSD) with 5% Level of significance.

RESULTS

Effects of Treatments on Nematode Gallling Index (seasons 1 and 2)

The results indicated that there was a significant ($P \leq 0.05$) difference between the treatments in season one. The *T. harzianum* had the lowest mean (2.0) nematode gallling index. There was no significant difference between *T. harzianum*, combined treatments (*T. asperellum* + *T. harzianum*) (2.85), and Plantmate (2.9). *Trichoderma. asperellum* was significantly ($P \leq 0.05$) different (3.85) from the other treatments. The control had the highest nematode gallling index mean (5.7) (Table 2).

There was a significant ($P \leq 0.05$) difference between % mean of the gallling index among the treatments in the second season. The control was significantly ($P \leq 0.05$) different from the other treatments, with the highest mean gallling index (6.25). In the increasing order, the mean nematode gallling index was *T. harzianum* (2.05), Plantmate (2.60), and the combination of the two *Trichoderma* strains (2.65), *T. asperellum* (3.20) and the Control 6.25. There was no significance between the Plantmate, *T. harzianum*, and combined *Trichoderma* treatment (Table 2).

Table 2: Effect of the Treatments on Nematodes' percent Galling Index (Seasons 1 and 2)

Treatment	Mean percent nematode severity $\pm$ SE (season 1)	Mean percent nematode severity $\pm$ SE (season 2)
TA	3.85 $\pm$ 0.42b	3.2 $\pm$ 0.37b
TH	2.0 $\pm$ 0.36c	2.05 $\pm$ 0.41c
TATH	2.85 $\pm$ 0.44bc	2.65 $\pm$ 0.36bc
M	2.90 $\pm$ 0.44bc	2.60 $\pm$ 0.41bc
C	5.7 $\pm$ 0.41a	6.25 $\pm$ 0.45a
Cv	53.956	53.157
p-value	<.0001	<.0001
LSD	1.172	1.1179

TA=*T. asperellum*; TH=*T. harzianum*; C=Control; M=Plantmate; TATH; *T. harziunum* + *T. asperellum*; Means within the column followed by the same letter are not significantly different by LSD test at 5 % level

Effect of Treatments on Tomato Yields (Seasons 1 and 2)

There was a significant difference in yields ($P \leq 0.05$) between the *T. harzianum* and the control and the other treatments in season one. The *T. harzianum* treatment gave the highest % mean yields (6,588kg/ha). There was no significant difference ($P > 0.05$) in yield from *T. harzianum* (6,588kg/ha), combined *Trichoderma* 6,158kg/ha),

Plantmate (5,805kg/ha), and *T. asperellum* (5,330kg/ha). The control had the lowest yields (3,955kg/ha) and was significantly ($P \leq 0.05$) different from all treatments apart from *T. harzianum*, combined *Trichoderma*, and Plantmate (Table 3).

There was no significant difference ($P > 0.05$) in mean yield between the treatments in the second season. The *T. harzianum* had the highest mean yields (11,149kg/ha), combined *Trichoderma* (10,938kg/ha), *T. asperellum* (9,570kg/ha), and Plantmate (9,302kg/ha). The least yield was observed in the control (9,089kg) (Table 3).

Table 3: Effect of Treatments on Tomato Yields (Seasons 1 and 2)

Treatment	Mean yield $\pm$ SE(season 1)	Mean yield $\pm$ SE (season2)
TA	5,330.56 $\pm$ 79.91ab	9,570.83 $\pm$ 561.28a
TH	6,588.89 $\pm$ 695.09a	11,149.17 $\pm$ 657.57a
TA/TH	6,158.33 $\pm$ 764.94a	10,938.89 $\pm$ 834.41a
M	5,805.55 $\pm$ 413.82a	9,302.78 $\pm$ 1015.49a
C	3,955.56 $\pm$ 341.36b	9,089.72 $\pm$ 660.87a
Cv	18.75098	15.24642
p-value	0.0259	0.2285
LSD	1573.5	2300.2

TA=*T. asperellum*; TH = *T. harziunum*; C=Control; M=Plantmate; TATH; *T. harziunum* + *T. asperellum*; Means within the column followed by the same letter are not significantly different by LSD test at 5 % level.

DISCUSSION

The study results indicated that the two *Trichoderma* strains and biofertilizer, Plantmate, significantly reduced RKN galling severity in

tomato. Sharon *et al.* (2001) and Sharon *et al.* (2007) reported that *T. harzianum* reduced galling of *M. javanica* on tomato plants. These results also conformed to Shores and Harman (2008), who demonstrated that *Trichoderma* spp. can control

many disease-causing microorganisms. *Harman et al.* (2004) observed a decrease in *M. incognita* in tomato. *Amin et al.* (2010) and *Howell* (2003) reported that *Trichoderma* spp. inhibited the growth of plant-parasitic nematodes. According to *Sahebani & Hadavi* (2008), *Olusola et al.* (2024) and *Contreras-Soto*, (2025), the *Trichoderma* control mechanism of RKN is based on the fungi broad genetic diversity and evolutionary adaptability, which allow them to thrive in various soil conditions and target a wide range of nematodes; production of anti-nematode metabolites that reduce nematode motility, fecundity, and viability; excretion of enzymes that degrade the nematodes cuticle and eggs; directly parasitism on nematode eggs and juveniles that immobilize and hydrolyze the nematodes; plant root colonization promote the presence of favorable microorganisms that out-compete nematodes; promote a defense in plants that deters nematode penetration and feeding, leading to healthy root development.

The study results indicated that *Trichoderma* strains and biofertilizer, Plantmate, significantly gave high yields, where *T. harzianum* gave the highest yields in both seasons. This could be because reduced root galling increases root volume, proper soil penetration, and water and nutrient utilisation efficiency. The results were supported by *Mukhtar* (2018), who observed that the application of *Trichoderma* spp resulted in reduced nematode galling and improved plant weight and yields.

The study revealed that the combination of *T. harzianum* and *T. asperellum* did not show much difference from the individual strains. This could be because there was no synergy between them. This could be attributed to *Trichoderma* species host specificity, where certain species may be more or less effective against pathogens or nematodes. A combination of *Trichoderma* sp. Reported to lead to reduced or similar efficacy, unlike when using single fungal strains. This is attributable to antagonism between strains, reduced niche

competition, hence strain inhibition, strain ineffectiveness, and specificity (*Rahman et al.*, 2018; *Herrera-Rodriguez et al.*, 2026).

CONCLUSIONS

The study concluded that *Trichoderma* spp. and Plantmate bio-fertiliser were effective in the management of Root Knot Nematodes (RKN) in tomato. They are therefore a potential biological agent for use in the integrated pest management strategies of tomato Root Knot Nematodes.

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