# *Original Research Article*

**Integrated management of Root-Knot Nematode (*Meloidogyne* Spp) using Fresh Organic Manure and *Crotalaria brevidens* intercrop for improved growth and yield of Tomato**


**ABSTRACT**

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables worldwide. Tomato productivity is limited by among other factors, biotic constraints including root-knot nematodes (*Meloidogyne* species), which lower both quality and quantity of the crop. Two trials were conducted at the Horticulture Research and Teaching Field, Egerton University, Kenya, to evaluate effects of fresh organic manure and slender leaf (*Crotalaria brevidens* var. *brevidens* Benth.) intercrop on management of root-knot nematode during tomato production as well as establish their effect on tomato growth and yield. Variables measured were nematode infestation, plant height, stem collar diameter, number of internodes and branches, number of fruits and fresh fruit weight. Use of fresh organic manure and slender leaf intercrop showed suppressive effect on nematode population resulting in a 27.8% to 53.5% reduction in nematode population and significantly improved tomato growth, fruit numbers by 22.2% to 49.7% and fresh fruit weight by 24.5% to 80.4% when used alone and in combinations compared to the control treatment. The combination of fresh goat dung and slender leaf intercrop resulted in the highest reduction in nematode population of 53.5% and highest increase in total number of fruits of 49.7% and fresh fruit weight of 80.4%.


**Keywords**: *Solanum lycopersicum,* galls, goat manure, cow manure, slender leaf


## 1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables worldwide. Tomato productivity is limited by among other factors, biotic constraints including root-knot nematodes (*Meloidogyne spp*), which reduce both the quality and quantity of tomato. Root-knot nematodes can cause up to 80% yield losses especially in heavily infested tomato growing fields [1]. The short life cycle of six to eight weeks enables root-knot nematode populations to survive well in the presence of a suitable host and their populations build up to a maximum usually as crops reach maturity [2,3]. Control of root-knot nematodes is difficult since the pathogen is soil-borne with a wide host range and usually attacks the underground parts of the plant [4].

Currently, the primary control measures employed against root-knot nematodes are crop rotation and chemical nematicides as a pre-plant fumigation of soil. Although crop rotation can be an effective method of managing root-knot nematode, it is not feasible among smallholder crop production systems due to limited land resource. Chemical nematicides on the other hand are effective and fast-acting but are currently being reappraised with respect to their effects on the environment and human health as well as the high cost of purchase [5]. There is therefore need for development of alternative sustainable management strategies for the pest that are ecofriendly and relatively affordable to smallholder tomato growers.

Alternative strategies for management of root-knot nematodes such as heat treatment, soil solarization, crop rotation with non host plants, intercropping and application of organic soil amendments of crop and/or animal origin [6] that do not pollute the environment have been emphasized to researchers, farmers and scientists [7]. Studies have shown that host plants can be protected against root-knot nematode infection through intercropping practices especially with plants with nematicidal or nematostatic properties [3]. *Crotalaria* has been documented as a poor host to many plant-parasitic nematodes including *Meloidogyne* species. *Crotalaria* increases bacterivorous nematode population densities and nematode-trapping fungal propagules, thus enhancing microbial activities against *Meloidogyne* species [8]. Besides pest suppression or control, other associated benefits of intercropping other crops with *Crotalaria* are greater yield stability, greater land-use efficiency, increased competitive ability toward weeds and improvement of soil fertility [9].

Use of organic manure reduces negative effects of root-knot nematode on host crop with a resultant increase in growth and yield of the crop [10]. An organic manure amendment improves activities of non-pathogenic organisms and directly suppresses soil borne pathogens during decomposition [11]. Predatory nematodes tend to be higher in organic amended soil thus suppressing parasitic nematodes in the soil [12]. Well-decomposed composts are stable and mineralize slowly releasing low concentrations of toxic nematicidal compounds [13]. [14] proposed that raw organic manures may be more effective than composted manures as toxic compounds could quickly build up to reach toxicity threshold level for nematodes and other soil-borne pathogens.

Integrated Crop Management (ICM) strategies have world-wide been developed for many crops that have resulted in reduced pesticide use, higher crop yields and economic value, as well as reduced economic risks for farm management owing to lower variation in the severity of pest problems [15]. Further improvement of such programs will promote their wide-spread applicability and improve on performance of crop production systems. This study sought to investigate the effects of integrating fresh organic manure (cow and goat dung) and slender leaf (*Crotalaria brevidens* var. *brevidens* Benth.) intercrop as an alternative management strategy for suppressing root-knot nematode during tomato production, as well as establish the effect of the strategy on growth and fruit yield of the crop.

## 2. MATERIALS AND METHODS

Two trials (July to October 2019 and January to April 2020) were conducted at the Horticulture Research and Teaching Field of Egerton University, Njoro, Kenya. The field lies at a latitude of 0°23′ S and longitude 35°35′ E in the Lower Highland III Agro Ecological Zone (LH3), at an altitude of ≈2238 m above sea level. The soils are predominantly vitric mollic andosols with a pH of 6.0 to 6.5 [16]. The site monthly mean temperature and monthly rainfall during the study period is presented in Figure 1.

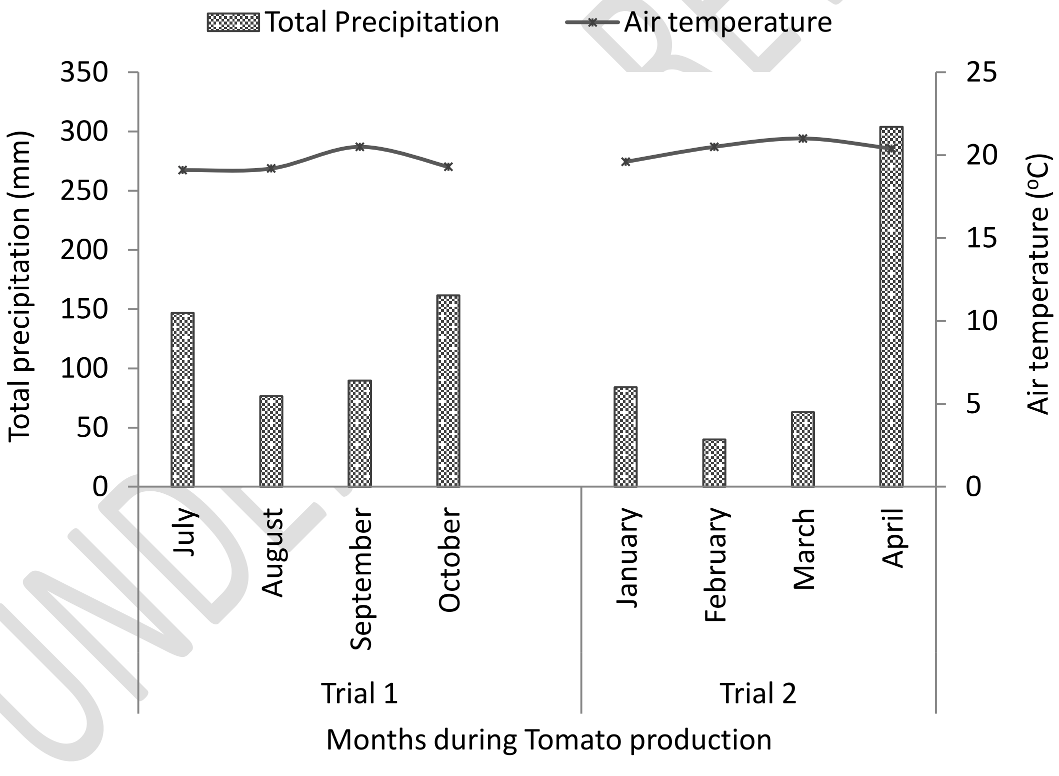


Fig. 1. Average monthly air temperature ($^{o}C$) and precipitation (mm) during Tomato production over the two trials (July to October 2019 and January to April 2020). Source: Egerton University Engineering Department (2020).

Tomato cultivar Rio Grande and Slender leaf seeds were obtained from Kenya Seed Company in Nakuru - Kenya. 'Rio Grande' is a determinate tomato cultivar with a high yielding potential and one of the most popular among open field tomato growers in Kenya. Slender leaf is an annual or short-lived perennial herb in the family Fabaceae. The genus is common in the tropics and subtropics, with the greatest number of species occurring in Africa.

The experiment was a 2 x 3 factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications. The two factors under study were cropping regime at two levels (tomato intercropped with slender leaf and monocrop tomato) and fresh organic manure at three levels (cow dung, goat dung and no organic manure) giving a total of six treatment combinations; (i) fresh cow dung with no slender leaf; (ii) fresh goat dung with no slender leaf; (iii) fresh cow dung and slender leaf; (iv) fresh goat dung and slender leaf; (v) slender leaf with no organic manure; (vi) control (monocrop tomato with no organic manure). Each experimental unit comprised of 5 troughs each 2 m long, 0.4 m wide and 0.2 m high in a 2 × 2 m plot separated from each other by 1 m path. Each block comprised of 6 such arrangements to accommodate the six treatment combinations. Individual blocks were 17 m long separated from each other by 1.5 m path. Soil for filling the troughs was sterilized by covering with airtight clear polyethylene sheets for a period of eight weeks. Troughs filled with sterilized soil were placed on a clear polyethylene sheet to prevent contaminating the field with nematodes.

Tomato seed were sown in rows spaced 20 cm apart in a raised nursery bed and transplanted into troughs filled with soil in the field when the seedlings were 5 weeks old. Diammonium phosphate (DAP) fertilizer was applied at the rate of 240 $kg{\cdot}ha^{-1}$ [17] and thoroughly mixed with the soil prior to transplanting. Tomato seedlings were transplanted spaced 60 cm apart within the trough giving a population of 4 plants/trough and a total of 20 plants per experimental unit. In intercropped plots, slender leaf seedling rows were made across the trough at a distance of 60 cm between adjacent rows of slender leaf and 30cm from individual tomato rows giving a total of three rows of slender leaf per trough. Slender leaf seeds were drilled at the same time with the sowing of tomato seeds in the nursery so as to have them well established by the time of transplanting tomato seedlings. Thinning of the slender leaf seedlings was done when the plants were about 10 cm tall to a spacing of 10 cm between plants giving a total of four plants per row and twelve plants per trough. Tomato plants were top dressed with Calcium Ammonium Nitrate at the rate of 240 Kg $ha^{-1}$ [17] applied in two splits; first split at three weeks after transplanting and the second split three weeks later.

Two weeks after tomato transplanting, second instar juvenile stage of *Meloidogyne* species inoculum suspension of approximately 250 juveniles per plant was sprinkled on each experimental unit. Thereafter, fresh organic manure at a rate of 15 ton $ha^{-1}$ was also applied in furrows made adjacent to tomato plants in individual troughs as per the designated treatments. Fresh cow and goat dung were obtained from the Tatton Agriculture Park (TAP) of Egerton University.

Nematode infestation was determined by evaluating nematode population in the soil and gall assessment on tomato roots at the end of the experiment. To determine the nematode populations in the soil, second stage juveniles (J2) were extracted from 100 $cm^3$ soil from each experimental unit, using the method described by [18]. The soil samples were placed in sieves lined with double layered tissue paper. The sieves were half immersed in plastic beakers containing 250 ml of distilled water for 24 hours to allow nematode migration into the water underneath. Quantification of juveniles was done under a light microscope with gridded petri dishes. Three 1 ml replicate samples were drawn from the well mixed suspension to establish the average number of juveniles per millimeter and later determine the number of nematodes per 100 $cm^3$ soil of each experimental unit, and subsequently the average number of nematodes per treatment combination. For gall assessment, plants were gently uprooted and their roots washed under tap water to remove the adhering soil. Galling was determined by counting the number of galls and data obtained recorded as number of galls per plant (no./plant).

Four plants from the inner rows of each experimental unit were randomly selected and tagged for collection of data on plant height, stem collar diameter, number of internodes, number of branches and yield. Plant growth data were collected on a two weeks interval beginning at the second week after application of treatments to first harvest. Plant height of the tagged plants was measured in centimeters (cm) from the ground level to the point of growth using a meter ruler and the number of internodes and branches were counted and recorded as number of internodes or branches per plant (no. /plant). At the same time, stem collar diameter of the four tagged tomato plants was measured at ≈ 2 cm from the ground level using a digital vernier caliper (Model 599-577-1/USA) and the data obtained was used to compute the average stem collar diameter of plants for the different treatments in millimeters (mm).

Tomato fruits from each experimental unit were harvested twice every week at breaker stage. At each harvest, tomato fruits from each tagged plant were physically counted and weighed in kilograms (kg/plant) using a weighing balance (ATZ; Shangai Precision and Scientific

Instrument Co., Shangai, China). Data obtained were later used to compute the average number of fruits per plant (no./plant) and weight of fruits per plant (kg/plant) for the different treatments.

The Proc univariate procedure of SAS (ver. 9.1; SAS Institute, Cary, NC) was used to determine normality and equal variances assumptions of analysis of variance of the data before analysis. Where assumptions were not met appropriate transformation was done. Data were subjected to ANOVA using the GLM procedure of SAS at $p \leq 0.05$. Means for significant treatments, at the F test, were separated using Tukey's honestly significant difference test at $p \leq 0.05$.

## 3. RESULTS

### 3.1 Effects of Slender Leaf Intercrop and Fresh Organic Manure on Nematode Infestation on Tomato

Use of fresh organic manure and slender leaf intercrop either alone or in combination reduced nematode population in the soil by between 27.8 –53.5% in comparison with the control treatment (Table 1). Plots with fresh goat dung and slender leaf intercrop recorded the lowest juvenile root-knot nematode population in the soil and had the highest reduction of 53.5% of juvenile root-knot nematode population in the soil compared to the control treatment. Plots where tomato was intercropped with slender leaf with no fresh manure applied had higher numbers of juvenile root-knot nematodes in the soil among intercropped and fresh manure treated plots but had lower numbers of juvenile root-knot nematodes in the soil with a 27.8% reduction in the population of juvenile root-knot nematodes in the soil compared to the control treatment. Among the other treatments, plots applied with fresh cow dung and slender leaf intercrop had slightly lower soil nematode population followed by those applied with fresh goat dung and fresh cow dung in that order. Comparing the main effects of growing tomato with slender leaf intercrop and without slender leaf, intercropping tomato with slender leaf significantly reduced the number of juvenile root-knot nematode populations by 24.4% compared to when tomato was grown as a monocrop (Table 2). Similarly, growing tomato with fresh cow and goat dung significantly reduced juvenile root-knot nematode population by 32.9% and 37.7%, respectively compared to when no fresh organic manure was applied (Table 2).

Similar to the trends observed for juvenile root-knot nematode population in the soil, the number of galls on tomato roots was consistently lower on tomato plants grown with fresh organic manure and slender leaf intercrop. The use of fresh organic manure and slender leaf intercrop reduced number of galls in the tomato roots by between 58.4–65.4% in comparison with the control treatment. Overall, the lowest number of root gall was recorded in plots with fresh goat dung and slender leaf intercrop while the highest number was under control treatment (Table 1). Intermediate number of root galls was obtained for the other treatments but the differences in the number of galls among all intercrop and fresh manure treatments were not statistically significant. A comparison of the two cropping regime showed that, intercropping tomato with slender leaf reduced the number of root-knot nematode galls by 36.8% compared to when tomato was grown as a monocrop (Table 2) with the reduction being statistically significant. Similarly, growing tomato with fresh organic manure significantly reduced the number of root-knot nematode galls on tomato roots by 44.8% and 48.7% for fresh cow and fresh goat manure, respectively compared to when no fresh organic manure was applied (Table 2).

Table 1. Effects of slender leaf intercrop and fresh organic manure on root-knot nematode (juveniles) population in the soil and galls of tomato plant

| Treatments | | Nematode Infestation | | | |
|---|---|---|---|---|---|
| | | Number of juveniles/100 g soil | | Number of galls/plant | |
| Slender leaf intercrop | Fresh organic manure | Average (no.) | Reduction (%) | Average (no.) | Reduction (%) |
| Slender leaf | Cow | 31.50b* | 48.72** | 120.11b | 62.93 |
| | Goat | 28.58b | 53.47 | 112.00b | 65.43 |
| | No manure | 44.33ab | 27.82 | 134.94b | 58.35 |
| No slender leaf | Cow | 39.42b | 35.82 | 133.39b | 58.83 |
| | Goat | 37.33b | 39.22 | 123.28b | 61.95 |
| | No manure | 61.42a | | 324.00a | |

*Means followed by the same letter within a column and a parameter are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$.

**Reduction computed in reference to nematode (juvenile) population or galls in the control treatment (No slender leaf, No manure)

Table 2. Main effects of slender leaf intercrop and fresh organic manure on root-knot nematode (juveniles) population in the soil and root galls of tomato plant

| | Nematode Infestation | | | |
|---|---|---|---|---|
| | Number of juveniles/100 g soil | | Number of galls/plant | |
| *Intercrop* | Average (no.) | Reduction (%) | Average (no.) | Reduction (%) |
| Slender leaf | 34.81b* | 24.42** | 122.35b | 36.79 |
| No slender leaf | 46.06a | | 193.56a | |
| *Organic manure* | | | | |
| Cow dung | 35.46b | 32.94 | 126.75b | 44.76 |
| Goat dung | 32.96b | 37.67 | 117.64b | 48.73 |
| No manure | 52.88a | | 229.47a | |

*Means in a column followed by the same letter within a main treatment and a variable are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$.

**Reduction computed in reference to nematode (juvenile) population or galls in the control treatment (No slender leaf, No manure).

**3.2 Effects of Slender Leaf Intercrop and Fresh Organic Manure on Tomato Plant Growth**

Growing tomato under combined application of fresh organic manures and slender leaf intercrop did not significantly influence tomato plant height but resulted in relatively better growth than when the two technologies were used in isolation or not used at all (Table 3). In most sampling dates, tomato plants tended to be tallest in plots with fresh goat dung treatment and shortest under the control treatment. Plant height was also tended to be higher in plots with slender leaf intercrop and fresh organic manure (fresh goat or cow dung) compared to plots with either slender leaf intercrop or cow dung alone during most sampling dates. By the final sampling date (at 70 DAT), tomato plants were tallest in plots applied with goat dung and shortest in the control treatment. Among the other treatments, tomato plants grown with fresh cow dung and slender leaf intercrop tended to be taller followed by those in plots with goat dung and slender leaf intercrop, then those grown with fresh cow dung, with the shortest plants being those grown with slender leaf intercrop with no fresh organic manure. Comparing the two cropping regime, plots with tomato intercropped with slender leaf had taller plants compared to monocrop, although the difference in height of tomato plants grown under the two cropping regimes was not statistically significant (Figure 2A). Similarly, tomato plants grown with fresh organic manure were significantly taller than those grown without application of fresh organic manure during all sampling dates except at 28 DAT when the difference was not statistically significant (Figure 2A).

Tomato collar diameter was also significantly affected by the use of fresh organic manure and slender leaf intercrop during production (Table 3). The lowest collar diameter amongst all the treatments was observed in the control plants. Growing tomato plants under combined use of fresh goat or cow manure and slender leaf intercrop resulted in plants with thicker stems compared to those of plants from other treatments in most sampling dates. Tomato plants intercropped with slender leaf had slightly thicker stems compared to tomato plants grown as a monocrop (Figure 2B). Likewise, growing tomato with fresh organic manure generally resulted in significantly thicker plants compared to when no fresh organic manure was applied in all sampling dates (Figure 2B).

The number of tomato stem internode was also influenced by the use of fresh organic manure and slender leaf intercrop during production (Table 3). Using the two technologies in combination resulted in higher number of internodes than where they were not used at all. Internode numbers also tended to be slightly higher for monocrop tomato grown with fresh cow or goat dung compared to the internode numbers recorded for control plants. Comparing the main effects, tomato plants intercropped with slender leaf had slightly higher number of internodes compared to tomato plants grown as a monocrop (Figure 2C). Tomato grown with fresh organic manure also had higher number of internodes compared to when no fresh organic manure was applied (Figure 2C).

Similarly, the use of fresh organic manure and slender leaf intercrop significantly improved plant branching ability (Table 3). The number of branches per plant was higher for plants grown with fresh organic manure and slender leaf intercrop compared to plants grown where the two technologies were each used in isolation or were not used at all in most sampling dates. In most sampling dates, plants grown with cow dung and slender leaf intercrop had the highest number of branches while the least number of branches per plant was recorded on control treatment plants. Comparing the two cropping regime, tomato intercropped with slender leaf had more branches compared to tomato grown as a monocrop, although the difference was not statistically significant except during the final data collection date at 70DAT (Figure 2D). Similarly, tomato grown with fresh organic manure had significantly more branches compared to those grown without fresh organic manure at all data collection dates (Figure 2D).

Table 3. Effects of slender leaf intercrop and fresh organic manure on plant growth during Tomato production

| Treatment | | Days after Transplanting | | | |
|---|---|---|---|---|---|
| Slender leaf intercrop | Fresh organic manure | 28 | 42 | 56 | 70 |
| | | Plant height (cm) | | | |
| Slender leaf | Cow | 31.02* | 47.36 | 64.33 | 73.53 |
| | Goat | 32.15 | 45.50 | 61.03 | 72.52 |
| | No manure | 32.41 | 44.63 | 57.70 | 66.84 |
| No slender leaf | Cow | 29.23 | 46.05 | 63.63 | 71.52 |
| | Goat | 31.93 | 47.93 | 64.33 | 74.71 |
| | No manure | 30.54 | 41.69 | 55.49 | 64.55 |
| | | Collar diameter (mm) | | | |
| Slender leaf | Cow | 6.78ab** | 9.11ab | 11.30a | 12.45ab |
| | Goat | 7.50a | 9.47a | 11.23a | 12.71a |
| | No manure | 6.53b | 9.04ab | 10.22ab | 11.50ab |
| No slender leaf | Cow | 6.43b | 9.46a | 10.97ab | 12.28ab |
| | Goat | 6.64b | 9.20ab | 10.99ab | 12.35ab |
| | No manure | 6.17b | 7.73b | 9.26b | 10.61b |

| | | | | | |
|---|---|---|---|---|---|
| Number of internodes (no./plant) | | | | | |
| Slender leaf | Cow | 8.04 | 11.01 | 12.90a | 13.72 |
| | Goat | 8.29 | 10.92 | 12.29ab | 13.54 |
| | No manure | 8.04 | 10.63 | 12.21ab | 13.71 |
| No slender leaf | Cow | 8.04 | 10.38 | 12.58a | 13.39 |
| | Goat | 7.96 | 10.67 | 12.54a | 13.50 |
| | No manure | 7.88 | 9.75 | 11.21b | 12.46 |
| Number of branches (no./plant) | | | | | |
| Slender leaf | Cow | 3.45b | 6.26 | 7.29a | 9.63a |
| | Goat | 4.71a | 6.00 | 7.29a | 9.58a |
| | No manure | 3.13b | 5.13 | 6.33ab | 8.71ab |
| No slender leaf | Cow | 4.00ab | 6.25 | 7.21a | 9.44a |
| | Goat | 3.54b | 6.00 | 6.83ab | 8.92ab |
| | No manure | 3.21b | 4.67 | 5.88b | 7.92b |

*Means in a column not followed by a letter within a variable are not significantly different according to F-test at $p \leq 0.05$.

**Means in a column followed by the same letter within a variable are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$.

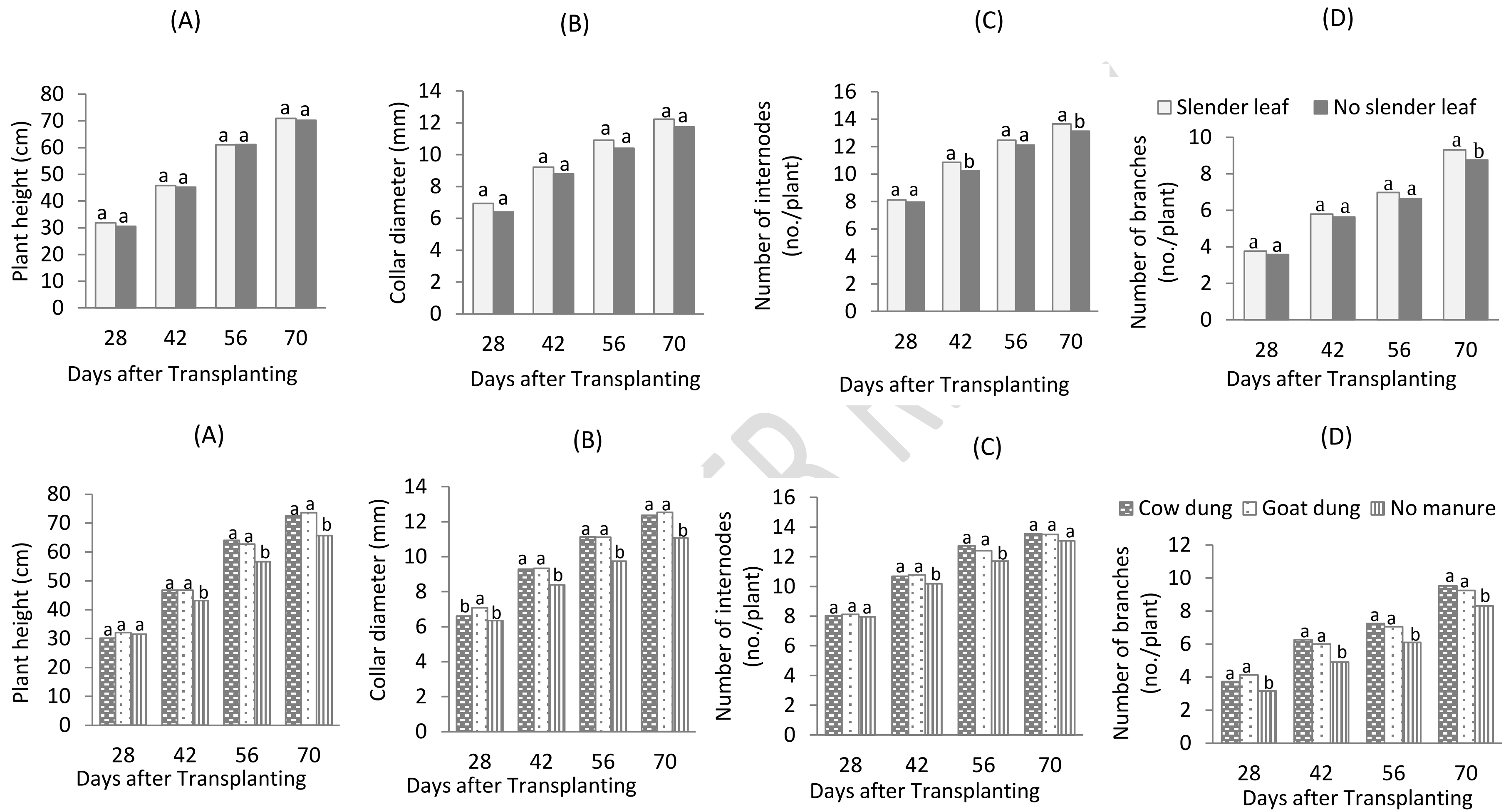


Fig. 2. Main effects of slender leaf intercrop and fresh organic manure on growth variables; (A) Plant height, (B) Collar diameter, (C) Number of internodes and (D) Number of branches during tomato production. Means followed by the same letter within a variable are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$.

### 3.3 Effects of Slender Leaf Intercrop and Fresh Organic Manure on Tomato Yield

Tomato plants grown with fresh organic manure and slender leaf intercrop had significantly higher fruit yield in terms of number of fruits per plant and fresh fruit weight per plant compared to yields obtained from the control treatment (Table 4). Growing tomato plants using fresh organic manure and slender leaf intercrop increased the number of tomato fruits per plant and fresh fruit weight per plant by between 22.2 – 49.7% and 24.5 – 80.4%, respectively in comparison with the control treatment. Generally, the highest fruit number and total fruit weight per plant was obtained on plants grown with fresh goat dung and slender leaf intercrop while the lowest yields were obtained under the control treatment. In terms of fruit numbers among the other treatments, plants grown with fresh goat dung gave higher fruits than those grown with fresh cow dung and slender leaf intercrop, followed by those grown with fresh cow dung with the least number of fruits per plant obtained on plants grown with a slender leaf intercrop alone. On the other hand, fresh fruit weight per plant was higher on plants grown with fresh cow dung and slender leaf intercrop followed by those grown with fresh goat dung, then those grown with fresh cow dung with the lowest fresh weight obtained from plants grown without fresh manure.

Comparing the two cropping regimes, tomato intercropped with slender leaf had more fruits (5.9%) and higher fruit weight per plant (17.0%) compared to tomato grown as a monocrop (Table 5). Similarly, growing tomato with fresh organic manure significantly enhanced tomato fruit yield in terms of fruit number (fresh cow dung 22.1% and fresh goat dung 32.4%) and fresh fruit weight per plant (fresh cow dung 33.9% and goat dung 47.8%) compared to when the plants were grown without application of fresh organic manure (Table 5).



Table 4. Effects of slender leaf intercrop and fresh organic manure on yield of Tomato during Tomato production

| Treatments | | Tomato Yield | | | |
|---|---|---|---|---|---|
| Slender leaf intercrop | Fresh organic manure | Fruit number (no./plant) | Increase (%) | Fruit weight (kg/plant) | Increase (%) |
| Slender leaf | Cow | 32.46ab* | 33.14** | 1.62ab | 58.82 |
| | Goat | 36.50a | 49.71 | 1.84a | 80.39 |
| | No manure | 29.79ab | 22.19 | 1.27ab | 24.51 |
| No slender leaf | Cow | 33.67ab | 38.11 | 1.46ab | 43.14 |
| | Goat | 35.21ab | 44.42 | 1.56ab | 52.94 |

| | No manure | 24.38b | 1.02b |
|---|---|---|---|

*Means followed by the same letter within a column and a parameter are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$.

**Percent increased calculated in reference to yield of the control treatment (No slender leaf, no fresh manure).

Table 5. Main effects of slender leaf intercrop and fresh organic manure on fruit yield during tomato production

| | Tomato Yield | | | |
|---|---|---|---|---|
| | Fruit numbers | Increase | Fruit weight | Increase |
| *Intercrop* | (no./plant) | (%) | (kg/plant) | (%) |
| Slender leaf | 32.92a* | 5.92** | 1.58a | 17.04 |
| No slender leaf | 31.08a | | 1.35a | |
| *Organic manure* | | | | |
| Cow dung | 33.06a | 22.08 | 1.54a | 33.91 |
| Goat dung | 35.85a | 32.39 | 1.70a | 47.83 |
| No manure | 27.08b | | 1.15b | |

*Means in a column followed by the same letter within a main treatment and a parameter are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$.

**Percent increased calculated in reference to yield of the control treatment (No slender leaf, no fresh manure).

**4. DISCUSSION**

In the current study, use of fresh organic manure and slender leaf intercrop proved of potential benefit in tomato production. Root-knot nematodes both in the soil and on the roots of tomato plant were lower under fresh organic manure and slender leaf intercrop treatments than in the control treatment. Compositing of amendments in soil enhances microbial activities and increases number of antagonists [19]. According to [20], organic manure such as livestock waste stimulates the generation of predators and parasites of plant parasitic nematode. Suppression of *Meloidogyne* species populations by fresh organic manure in the current study could thus have been as a result of toxic effects during decomposition and increased microbial activities in the soil leading to a poor host environment for the root-knot nematodes thus inhibiting their penetration into the roots. Suppression of *Meloidogyne* species by fresh organic manure could also have been due to increased number of root-knot nematode antagonists generated during decomposition of fresh organic manure in the soil. According to [14] fresh organic manures can be more effective to control root-knot nematodes compared to composted manures since toxic compounds can quickly reach threshold level required to control nematodes with rapid increase in number of beneficial microorganisms and microbial activities. Similar to the findings of our study, studies by [10] reported a significant reduction in the soil population of root-knot nematode and root gall index by organic manure amendment compared with the control treatment.

Similar to the effects of fresh organic manure on the population of juvenile root-knot nematodes in the soil and root galls on tomato roots, intercropping tomato with slender leaf reduced juvenile root-knot nematode populations and number of nematode root-knot galls compared to when tomato was grown as a monocrop. These findings corroborate findings by [3] who reported significantly lower number of juvenile nematodes in the soil and root galls in tomato plants when *Crotalaria* plants were used as intercrop. According to [8], *Crotalaria* intercrop suppresses plant-parasitic nematodes by enhancing microbial activities against *Meloidogyne* species. Some compounds of microbial origin exuded by Crotalaria roots disrupt biological activities of root-knot nematodes that are essential for the successful plant-nematode interaction [21].

From the results of the current study, combined use of fresh organic manure and slender leaf intercrop registered higher reduction in root-knot nematode (juvenile) population in the soil and the number of galls on the roots of tomato plants. According to [22], combination of treatments is more effective than individual treatment in management of root-knot nematodes. The combined diverse mechanisms could reduce egg hatching factors, enhancing plant growth, inducing systemic resistance in the plant, alter root exudates and inhibit penetration of nematodes into the roots as well as reduced galling [23]. In the current study, higher suppression of root-knot nematode achieved with combined use of fresh goat dung and slender leaf intercrop could possibly be as a result of production of more root-knot nematode predatory microorganism and other competing beneficial organisms by the fresh goat dung manure and slender leaf intercrop as well as increased plant tolerance or resistance to nematode infection through enhanced plant growth. As noted in the results, treatments with lower number of juvenile root-knot nematode populations registered fewer number of root galls in the current study. This implies that root-not nematodes stimulate formation of root galls. Studies by [24] reported a strong positive correlation of nematode juveniles and root galling, where the root galling on plant root increase with increase in nematode population in the rhizosphere of the plant.

Growing tomato plants with application of fresh organic manure and slender leaf intercrop resulted in significantly taller and thicker stems and plants with more internodes and branches. Better plant growth observed on tomato grown under these treatments in the current study could be as a result of lower number of root-knot nematodes and root galls registered under these treatments leading to the better crop performance. On the other hand, the reduced plant growth under the control treatment could partly have been as a result of high number of root galls which could have hindered plant water and nutrients supply by the roots. Root galls caused by root-knot nematode leads to vascular damage which disturbs water and mineral uptake resulting in severe reduction in plant growth [25]. Besides, improved plant growth in fresh manure and slender leaf intercrop treatments could also be associated with increased supply of plant nutrients following application of fresh organic manure [26] and use of *Crotalaria* plants [8]. Apart from improving soil fertility, *Crotalaria* plants competes with weeds without becoming a weed and grows vigorously to provide good ground coverage [8] which may have contributed to better performance of tomato plants intercropped with slender leaf.

Increased tomato yield recorded under fresh organic manure and slender leaf intercrop in the current study could be associated with the reduced root-knot nematode and enhanced tomato growth recorded under these treatments. Increased tomato yield following application of fresh organic manure in the current study could be attributed to better nutrient availability and growth promoting substances leading to higher fruit set percent. According to [27], application of organic nutrient sources increases activities of beneficial microorganisms due to increased organic pool in the soil, resulting in production of growth promoting substances and improved nutrient availability. Good ground coverage by slender leaf plant could also have led to reduced evapotranspiration rate resulting to improved soil moisture status as well as enhanced uptake of nutrients resulting to higher photosynthesis. Increased photosynthesis increases the assimilation rates leading to more food being manufactured and translocated to active sinks thus promoting vigorous growth and production of more fruits [28].

## 5. CONCLUSIONS

Based on the results, we conclude that combined use of fresh organic manure and slender leaf intercrop as a potential strategy for use in suppressing root-knot nematode populations with a resultant increase in growth and yield of tomato. The present study forms a basis for advocating for the use of fresh organic manure and slender leaf as an effective method to control root-knot nematodes in field grown tomato. Among the treatments tested, combined use of fresh goat dung and slender leaf intercrop in tomato production stands to benefit tomato growers more in terms of higher suppression of root-knot nematode and higher tomato fruit yield. Based on the findings of our study, we recommend use of fresh goat dung and slender leaf intercrop in management of root-knot nematode during tomato production with in regions with similar climatic conditions to those of our study site. In addition, further studies on the use of these technologies using different tomato varieties and in different tomato growing climatic conditions to those of the current study are recommended to further validate the results.

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