EFFICACY OF NEEM, TITHONIA AND TEPHROSIA LEAF EXTRACTS IN MANAGEMENT OF ROOT-KNOT NEMATODES IN FRENCH BEANS (*Phaseolus vulgaris* L.)

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Abstract
Root-knot nematodes (*Meloidogyne* spp.) are a major problem in Frenchbean production within the smallholder farming systems. Control of root-knot using synthetic nematicides is not viable due to environmental concerns relating to their toxic residues. There is need to develop alternative control options that will promote soil health and reduce parasitic nematode densities. A study was conducted at Chuka University Horticultural Demonstration Farm to determine the efficacy of Neem (*Azadirachta indica* A. Juss), Tithonia (*Tithonia diversifolia* and Tephrosia (*Tephrosia purpurea)* leaf extracts in management of root-knot. Controlled lath house and field trials were conducted where the treatments were extracts from Neem, Tithonia and Tephrosia at different concentration levels of 25 ml/L, 50 ml/L and 100 ml/L). Vydate (Oxamyl 10%) a synthetic nematicide served as a standard positive control while treatments with no extracts application and no nematode application served as negative controls. The treatments in the lath house were arranged in completely randomized design while the field trials were arranged in randomized complete block design. Fench beans were planted on nematode infested soils and data on root galling indices and yield components was collected. Data collected was subjected to analysis of variance and significantly different means separated using Tukey's Studentized Range Test at *P*=0.05. The extracts evaluated reduced root galling with their efficacy being similar to that of Vydate® (Oxamyl 10%) which was used as a positive control. Neem extracts treatments had the lowest mean galling index of followed by Tithonia. Root-knot nematode galling indices were highest in the untreated control at 10 both in trial I and trial II. Treatment trials from Neem and Tithonia at concentration levels of 100 ml/L resulted to highest yield of French beans while yield from the untreated plants were the lowest. The results indicate extracts can be adopted to suppress root-knot nematodes.

Keywords: Neem, Tithonia, Tephrosia, Phytochemicals, French-beans, Nematodes, Phytotoxicity

Introduction

Root-knot nematodes (*Meloidogyne* spp.) are a major constraint to successful vegetable production all over the world, causing severe damage that leads to dramatic yield losses (Irene *et al*., 2017). Existing control measures involving applications of chemical nematicides are not viable in the medium to long term due to environmental concerns relating to toxic residues (Muhammad *et al*., 2017). There is therefore a need to develop alternative control options for integrated parasitic nematode management that will promote soil health and reduce parasitic nematode densities (Emmanuel *et al*., 2017). *Meloidogyne* spp. is a major problem in French beans productions in many French bean production systems in Kenya.

Root-knot nematodes are small unsegmented worms and are mostly microscopic and they cause significant damage in almost all crops **(**Perry *et al*., 2009). The *Meloidogyne* spp. attacks over 140 species of more than 115 plant genera in 46 families (Patil *et al.,* 2017). Nematicides are recommended for the

management of nematodes but they are highly toxic compounds that have very low LD 50 values (Odeyemi *et al*., 2013). In many parts of the world most of the nematicides are banned because of their harmful effect on human and environment.

Therefore, it has become an important issue to find alternative control strategies that can lead to effective nematode control and also assure the safety of the consumers of horticultural products. Many plants are known to have nematicidal properties which may be utilized as organic amendments or bio-pesticides. Use of plant extracts on eggs and larvae to reduce the nematode population is promising in the crop protection against root-knot nematodes Plant extracts having the nematicidal properties may also enhance the plant growth.

Patil *et al*. (2017) tested the extracts of neem for their effects on larval mortality of nematode and the extracts exhibited significant mortality. Oyinlola et *al*. (2017) reported that aqueous extracts from tithonia and tephrosia reduced nematode populations in the soil with corresponding increases in plant height, plant leaf and fruit yield. This study aimed at evaluating the efficacy of neem, tithonia and tephrosia extracts which are readily available in management of root-knot nematodes in French beans.

Material and Methods

Study site

The experiments were conducted at Chuka University. The area is situated approximately 186 km from Nairobi along the Nairobi-Meru highway and lies at an approximately 0°19.9896′ South latitude, 37°38.7522′ East longitude and 1452 m elevation above the sea level. The climate is warm temperate and experiences a bimodal rainfall of about 1000-1599 mm.The average annual temperature is 19.5 °C. The long rainy season occur in March to July and the short rains occur from October to December. The soils at the University farm are nitisol.

Acquisition of Test Plants Material

Fresh shoot leaves of Tithonia and Tephrosia were collected from open fields around Chuka University. Commercial Neem leaf formulation (Nimbecidine) for comparison with extracted Neem was purchased from a local Agro-chemical shop. Neem leaves were sourced from the coastal region where Neem trees grow extensively. The plant species were taxonomically identified and authenticated by using the available colour pictures followed by description and identification characters. The plants were identified and authenticated by a taxonomist and voucher specimen of the plant deposited at Chuka University Chemistry laboratory with voucher No. MSC/HORT5/11/2017.

Extraction and Storage of Crude Extracts

Extracts were prepared as described by Oloruntola *et al.* (2017). The fresh leaves were air-dried in shade for 2 weeks then coarsely powdered with a mechanical grinder separately. Two hundred grams of dried powder of each plant species were weighed and dissolved in 500 ml of 95% absolute ethanol in an Erlenmeyer flask for elucidation. After 24 hours of soaking the solutions were filtered through two layers of cheese-cloth gauze and Whitman's No. 2 - filter paper before the filtrates were subjected to evaporation using a rotary flash evaporator under reduced pressure at 60 °C for 60 minutes to concentrate the extract and remove the ethanol. Extracts were stored in airtight container in refrigerator at 10 ºC. Concentrations were prepared following Muhammad *et al*. (2017) procedure. Concentration of 2.5% (25 ml/L) 5% (50 ml/L) and 10% (100 ml/L) were prepared separately by adding 2.5 ml ,5 ml and 10 ml of the extract residuals with 5 ml of acetone to enhance dissolution and made up to 100 ml by adding tap water.

Preparation of Root-knot Nematode Inoculum

For extraction of juveniles the roots were gently washed to remove adhering soil particles. The washed roots were cut into small bits of 2.5 cm longitudinally then placed over tissue paper spread on a wire

gauge and kept in a Petri plate filled with water. The level of water was maintained in Petri plate and left undisturbed for 48 hrs. Later, the suspension in the Petri plate was collected and observed for nematodes using a light-binocular microscope.

Experimental Design and treatment application

The treatments were tithonia, neem and tephrosia leaf extracts each at a concentration of 2.5% (25 ml/L), 5% (50 ml/L) and 10% (100 ml/L), Vydate (Oxamyl 10%) and Commercial Neem leaf formulation (Nimbecidine) served as a standard positive control. Distilled water was used as a standard negative control. In all these treatments 50 ml of the extracts was used as an inoculant. Lath house experiment was laid out in completely randomized design with 3 replications while the field trials were laid out in randomized complete block design with three replications

The first trial was conducted from September 2017 to January 2018. The experiment was repeated as trial two from February to August 2018. There were a total of 225 pots in the lath house experiment. Each of the 15 treatment had 5 potted plants which were replicated randomly three times. The field plots measured 1.5 by 1 m and a spacing of 30 × 15 cm was used making a total of 40 plants. In both lath-house and field experiment inoculation with the nematodes was done before planting. Inoculation was done by pipetting 100 root-knot nematodes masses suspension using a graduated pipette and covered lightly. One week after inoculation the extracts were applied at 50ml per pot/plant using a syringe. A final application was done four weeks after the first application.

Results

Comparative Effects of the Leaf Extracts of Neem, Tithonia, Tephrosia and Vydate (Oxamyl 10% L) on French bean Yield in Lath-house Pots and Field Experiment

Number of Pods in Lath house Potted Plants

It was observed that French beans number of pods among different extract treatments differed significantly (P=0.05) at 55, 63, 69 and 76 DAE. The results of this study showed that crude extracts treated French beans plants produced significantly higher French bean number of pods compared to untreated controls infested with root-knot nematodes. From the lath house study the untreated control attained the least number of pods at 9.5 and 9.7 pods respectively in trial I and trial II. (Table 1).

Number of Pods in a Field Experiment

In the field the number of pods under selected extracts treatments to *Meloidogyne* spp. differed significantly ($p < 0.05$) among the different treatments. The extract produced significantly high French bean number of pods, which was statistically significant compared to untreated control. Untreated controls recorded the least mean number of pods at 9.4 and 9.5, respectively in trial I and trial II. Neem at 100 ml/L attained the highest average mean number of pods at 17.4 and 17.6 respectively in trial I and trial II. Oxymyl (positive control) attained 15.3 and 15.5 pods respectively in trial I and trial II (Table 2)

Table 1: Effects of Different Extracts on Lath house Number of Pods
Trial I

	Extracts Concentration Rate															
DAE	N25	N50	N10	Nb25	Nb50	Nb10	T25	T50	T10	Te25	Te50	Te10	Oxy	CN	Cwit	MSD
55	22ac*	24.6a	23.6ab	24.6a	23.3ac	21.1ec	22.6ac	19.7de	20.4ce	21.0ec	18.4e	22.2acd	22.1ec	24.2a	15.1f	21.25
62	21.7a	22.3a	20.4a	21.3a	20.7a	22.1a	20.1a	24.2a	22.6a	22.8a	20.6a	20.86a	20.2a	21.1a	16.3b	4.81
69	16.0ab	17.0a	10.4ac	14.2ab	15.6ab	14.2ab	16.2ab	16.8a	16.4ab	15.8ab	15.8ab	7.93bc	13.2abc	10.4ab	4.93c	8.61
76	11.2ab	13.7ab	18.3ab	11.46ab	17.2ab	15.6ab	16.7ab	15.7ab	19.1a	17.3ab	18.2ab	17.3ab	17.9ab	15.6ab	10.2b	5.95
83	8.6a	8.0a	8.8a	7.9a	7.2a	7.2ab	4.8ab	4.2ab	5.8ab	9.8a	7.8a	7.3a	7.1ab	6.2ab	1.4b	5.9
Trial II																
55	20.1ac	25.1a	24.0ab	25.2a	24.2ac	22.1ec	23.2ac	20.1de	21.1e	22.1ce	19.1ad	23.1ac	23.1ec	25.1a	14.2f	20.11
62	21.2a	23.1a	21.2a	21.3a	20.7a	22.1a	21.2a	22.1a	23.1a	22.8a	21.1a	21.1a	20.1a	22.2a	16.2b	5.11
69	17.0ab	17.1a	17.1ac	14.2ab	15.2ab	15.2ab	17.2ab	13.2ab	10.4ab	8.55ab	13.2ab	9.32bc	14.23ab	11.2ab	5.12c	9.33
76	13.2ab	11.5ab	19.2ab	12,1ab	18.2ab	16.2ab	19.1a	15.7ab	21.1a	18.3ab	19.2ab	18.3ab	18.1ab	15.3b	11.2b	5.54
83	7.5a	7.5a	7.4a	7.9a	6.9a	7.6ab	5.2ab	4.4ab	5.9ab	8.4a	8.5a	6.9a	6.8ab	5.8ab	2.1b	4.7

*Means with the same letter(s) along the row for DAP and the column for Extracts are not significantly different at P≤0.05 by Tukey's test. KEY: N =Neem, T =Tithonia, Te =Tephrosia, Oxy =Oxamyl, CNO =Control, C with =Control with nematodes, the numbers 25, 50, and 100 represent concentration of extract in ml/L

Table 2: Effects of Different Extracts on Field Number of Pod
Trial I

	Extracts Concentration Rates															
DAE	N25	N50	N100	Nb25	Nb50	Nb100	T25	T50	T100	Te25	Te50	Te100	Oxy	CNO	CWith	MSD
55	22.ce*	20.3ce	21.6de	22.6ac	21.7ec	23.5ac	24.3a	24.5a	24.1ab	24.5a	24.1ab	22.3ec	19.9f	21.6ed	14.1g	1.87
62	20.7ab	21.0ab	20.3ab	21.4a	17.4b	21.6a	20.1ab	21.6a	21.7a	22.3cd	23.0ac	21.6ce	19.9f	21.6ec	14.1g	1.8
69	13.6ab	14.1ab	13.4ab	14.7ab	13.6ab	11.06bc	13.3ab	15.3ab	12.8ac	16.8a	17.2a	17.4a	15.6ab	13.5ab	7.2c	5.7
76	11.5cd	17.6ab	13.3bc	17.0ac	15.6ac	18.3ab	17.7ab	16.7ac	16.7ac	19.4a	13.3bc	18.7ab	15.8ac	15.16ac	6.7d	4.7
83	7.5a	8.1a	9.8a	6.9a	8.5a	6.4a	6.6a	6.9a	7.7a	8.3a	7.3a	8.0a	5.7a	7.6a	5.2a	4.7
TRIAL 2																
55	22.1ce	20.5ce	21.7de	22.7ac	21.8ec	23.7ac	24.7a	24.6a	22.3ec	24.1ab	24.2ab	23.6ac	21.1f	21.5ed	14.4g	1.9
62	20.4ab	20.4ab	21.2ab	21.5a	17.5b	21.8a	20.3ab	21.8a	23.3ac	22.4cd	23.1ac	21.5ce	19.8f	21.5ec	14.6g	4.3
69	13.5ab	14.3ab	13.6ab	21.5ab	13.6ab	11.2bc	13.5ab	15.5ab	12.8ac	16.5a	13.1bc	18.3ab	15.5ab	13.3ab	6.9c	5.3
76	11.8cd	15.7ac	19.5a	13.4bc	15.8ac	18.5ab	17.9ab	16.7ac	16.3ac	19.3a	13.6bc	18.3ab	15.6ac	15.2ac	6.3d	4.4
83	7.3a	8.2a	9.4a	6.3a	8.2a	6.2a	6.2a	6.2a	7.2a	8.1a	7.1a	7.8a	5.9a	7.5a	5.3a	4.5

*Means with the same letter(s) along the row for DAP and the column for Extracts are not significantly different at P≤0.05 by Tukey's test.
KEY: N =Neem, T =Tithonia, Te =Tephrosia, Oxy =Oxamyl, CNO =Control, C with =Control with nematodes, the numbers 25, 50, and 100 represent concentration of extract in ml/L

Fresh Pod Weight in a Lath house Potted Plants

From the study it was observed that French beans pods weight differed significantly among the different extracts treatments at 69, 76 and 83 DAP under lath house experiment. The results of this study showed that French beans plants treated with the extract produced significantly higher French bean pods weight when compared to the untreated root-knot nematode infested plants. From the study it was observed that the untreated control treatment attained the least pods weight of 24.9 and 28.0 in trial I and trial II respectively. Neem at 50 ml/L attained the highest average mean pods weight of 50.9 in both trial I and trial II Oxymyl **(**positive control) attained an average weight of 48.7 and 49.3 in trial I and trial II respectively neem, tithonia and Oxymyl compared in suppression of which resulted in increase in French bean pod weight (Table 3). This can be attributed to better control of the root knot nematodes especially in early stages therefore allowing the French bean crop to grow with vigor resulting in French bean pod weight increase. In both trials, Oxamyl gave lower French bean pod weight. Although Tephrosia would be expected to boost French bean pod weight, it seems their effect was overwhelmed by the significantly high populations. Generally French beans pod weight from plots treated with the extracts were higher than the untreated control showing the potential of increasing pod weight.

Pods Weight in a Field Experiment

In the field experiment French beans pods weight under extracts treatments differed significantly (*P*=0.05). The study showed that the untreated control treatment severely infested by the root-knot nematodes attained the least pods weight of 28.3 and 32.6 in trial I and trial II respectively. Neembecidine at 100 ml/L treatments attained the highest pod weight of 60.5 in trial I while Tephrosia treatments at 100 ml/L attained the highest pods weight of 62.2. Oxymyl **(**positive control) attained pod weight of 58.2 and 59.0 in trial I and trial II respectively (Table 4). In both trials, Oxamyl gave lower French bean pod weight. Although Tephrosia would be expected to boost French bean pod weight, it seems their effect was overwhelmed by the significantly high root-knot nematodes populations. Generally French beans pod weight from plots treated with the extracts were higher than the untreated control showing the potential of increasing pod weight.

Root Galling in a Field Experiment

The results of these study indicated that root-knot nematodes galling indices among the extracts showed were significantly different (*P*=0.05) with the untreated control recording the highest root galling index at 10.3 and 10.6 galls respectively in trial I and trial II respectively. The highest reduction in root galling index was recorded under the plots treated with Neem at both 50 ml/L and 100 ml/L at 1 gall in both trial I and trial II. 3.3 and 3.1 galls were observed in Oxymyl (positive synthetic control) treated plots in trial I and trial II respectively. (Table 5)

Number of Pods in Lath house Potted Plants

It was observed that French beans number of pods among different crude extract treatments differed significantly (*P*=0.05) at 55, 63, 69 and 76 DAE .The results of this study showed that crude extracts treated French beans plants produced significantly higher French bean number of pods compared to untreated controls infested with root-knot nematodes. From the lath house study the untreated control attained the least number of pods at 9.5 and 9.7 pods respectively in trial I and trial II. (Table 5)

Table 3: Effects of Different Extracts on Lath house Pods Weight
Trial I

	Extracts Concentration Rate														
DAE	N25	N50	N100	Nb25	Nb50	Nb100	T25	T50	T100	Te25	Te50	Te100	Oxy	CNO	CWith	MSD
55	59.3a*	64.1a	61.6a	55.6ab	59.5a	61.5a	63.4a	58.5a	44.8ab	56.6ab	56.4ab	62.1a	62.2a	57.8a	35.5b	21.2
62	64.1a	63.7a	64.1a	63.5a	57.4a	65.6a	54.1a	58.2a	58.9a	59.7a	57.6a	55.8a	57.6a	58.2a	30.5b	27.05
69	50.7ab	52.8ab	45.7ab	56.4a	53.6ab	46.8ab	51.4ab	55.5ab	59.8a	54.4ab	49.7ab	28.6bc	43.5ab	46.3ab	15.5c	27.05
76	46.5a	48.2a	53.7a	22.9b	50.6a	46.4ab	46.2ab	44.9ab	48.4a	49.8a	48.4a	52.6a	45.3ab	53.3a	30.1ab	26.0
83	31.2a	25.9a	27.7a	22.9ab	29.0a	23.5a	15.8ab	17.7ab	21.4ab	26.0a	26.3a	54.4ab	19.3ab	4.16b	28.6bc	30.5
TRIAL 2																
55	55.3a	64.1a	61.6a	55.6ab	59.5a	61.5a	63.4a	58.5a	44.8ab	56.6ab	56.4ab	62.1a	62.2a	57.8a	35.5b	21.2
62	64.1a	63.7a	64.1a	63.5a	57.4a	65.6a	54.1a	58.2a	58.9a	59.7a	57.6a	55.8a	57.6a	58.2a	30.5b	27.05
69	51.7ab	52.8ab	45.7ab	56.4a	53.6ab	46.8ab	51.4ab	55.5ab	59.8a	54.4ab	49.7ab	28.6bc	43.5ab	46.3ab	15.5c	27.05
76	46.5a	48.2a	53.7a	22.9b	50.6a	46.4ab	46.2ab	44.9ab	48.4a	49.8a	48.4a	52.6a	45.3ab	53.3a	30.1ab	26.0
83	31.2a	25.9a	27.7a	22.9ab	29.0a	23.5a	15.8ab	17.7ab	21.4ab	26.0a	26.3a	54.4ab	19.3ab	4.16b	28.6bc	30.5

*Means with the same letter(s) along the row for DAP and the column for Extracts are not significantly different at P≤0.05 by Tukey's test. KEY: N =Neem, T =Tithonia, Te =Tephrosia, Oxy =Oxamyl, CNO =Control, C with =Control with nematodes, the numbers 25, 50, and 100 represent concentration of extract in ml/L

Table 4: Effects of Different Extracts on Field Pods Weight
Trial I

	Extracts Concentration Rate															
DAE	N25	N50	N100	Nb25	Nb50	Nb100	T25	T50	T100	Te25	Te50	Te100	Oxy	CNO	CWith	MSD
55	67.0a*	73.4a	71.1a	72.0a	70.2a	74.1a	73.2a	70.9a	71.1a	67.7a	69.2a	74.0a	69.2a	69.2a	29.9b	18.5
62	69.2a	71.0a	73.3a	73.4a	62.6a	72.6a	67.4a	66.8a	73.0a	72.5a	69.0a	65.2a	69.2a	68.9a	32.4b	19.0
69	54.3a	48.1a	47.3a	49.7a	50.0a	46.2a	46.9a	51.9a	44.3a	52.9a	51.5a	53.1a	48.2a	53.82a	26.7b	16.4
76	57.1a	63.3a	65.5a	63.7a	64.2a	66.5a	63.2a	63.3a	58.09a	62.0a	60.1a	64.2a	64.3a	57.7a	20.2b	16.7
83	35.2ab	37.5ab	42.1ab	37.5ab	41.4ab	43.1a	38.0ab	40.4ab	39.1ab	41.3ab	39.4ab	42.0ab	40.5ab	39.2ab	32.3b	20.1
TRIAL 2																
55	67.1a	73.2a	71.2a	72.2a	70.1a	73.3a	70.7a	71.3a	72.2a	72.2a	72.1a	75.8a	72.1a	70.3a	30.5b	19.6
62	69.5a	71.4a	73.5a	73.5a	63.4a	73.5	68.9a	65.9a	73.4a	74.5a	69.7a	66.8a	70.1a	69.5a	33.2b	18.6
69	53.3a	47.5a	46.3a	48.6a	49.3a	45.8a	50.1a	48.7a	44.6a	51.2a	50a	62.6a	48.2a	53.82a	46.9b	16.8
76	57.1a	63.3a	65.5a	63.7a	64.2a	66.5a	63.2a	63.3a	58.09a	62.0a	60.1a	64.2a	64.3a	57.7a	20.2b	35.2
83	35.2ab	37.5ab	42.1ab	37.5ab	41.4ab	43.1a	38.0ab	40.4ab	39.1ab	41.3ab	39.4ab	42.0ab	40.5ab	39.2ab	32.3b	19.0

*Means with the same letter(s) along the row for DAP and the column for Extracts are not significantly different at P≤0.05 by Tukey's test.
KEY: N =Neem, T =Tithonia, Te =Tephrosia, Oxy =Oxamyl, CNO =Control, C with =Control with nematodes, the numbers 25, 50, and 100 represent concentration of extract in ml/L

Table 5: Effects of Different Extracts on Root galling Indices in the lath house and field experiment

TRIAL 1 (lath house)

Extracts Concentration Rate															
N25	N50	N100	Nb25	Nb50	Nb100	T25	T50	T100	Te25	Te50	Te100	Oxy	CNO	CWith	MSD
*1c	1.6c	1c	1.8c	1.7c	2.7c	2.4c	2.8c	2.8c	4.6bc	3.4bc	1.9c	1.8c	1.1.c	14.4a	3.2
TRIAL2															
*1.5c	1.6c	1.5c	1.9c	1.9c	2.8c	2.4c	2.8c	2.8c	4.9bc	3.4bc	2.1c	1.8c	1.4.c	17.4a	2.9

TRIAL 1 (Field Experiment)

Extracts Concentration Rate															
N25	N50	N100	Nb25	Nb50	Nb100	T25	T50	T100	Te25	Te50	Te10	Oxy	CNO	CWith	MSD
2.4bc*	2.1bc	2.1bc	1.1c	1.0c	1.5c	1.1c	3.13bc	4.8b	3.0bc	3.2bc	2.7bc	3.3bc	3.4cb	10.3a	2.9
TRIAL 2															
2.1bc	1.2b	1.2b	1.4bc	1.2c	1.4c	1.7c	2.4bc	2.3b	2.5bc	2.4b	2.2bc	3.0b	3.0b	10.8a	2.6

*Means with the same letter(s) along the row for DAP and the column for Extracts are not significantly different at P≤0.05 by Tukey's test.
KEY: N =Neem, T =Tithonia, Te =Tephrosia, Oxy =Oxamyl, CNO =Control, C with =Control with nematodes, the numbers 25, 50, and 100 represent concentration of extract in ml/L

Discussion

Effects of Different Extracts on French bean Yield

The presence of the nematode on the Frenchbeans plants significantly affected their yield. Crude plant extract inoculated plants had 50% higher yields than plants which were not inoculated with the extracts. Yield in terms of pod number and pod weight from French beans treated with the crude plant extracts were significantly better than yields from plants treated with Oxamyl. The findings of this study also compares with those of Sidhu *et al.* (2017) who reported that application of botanical extracts increases yields and may help manage root-knot nematode populations in infested fields. Probably neem, tithonia and tephrosia extracts above their ability to suppress plant parasitic nematodes by changing the soil chemical properties probably they also changed the physical properties and enriched the soil with beneficial microflora.

These changes in the soil properties probably negatively affected the growth or multiplication of the nematodes in the French beans. The findings of this research are also in agreement with those of Aiyadurai *et al*. (2018) who suggested that plant parasitic nematodes can be controlled by application of botanicals. Water and nutrition are important vital components in French bean production life and their limited supply or unavailability is one of the major abiotic factors that adversely affect French beans production in many ways. Proper nutrition is the basic need of every living organism as the nutrients are not only required for better plant growth and development, but they are also helpful to alleviate different kinds of abiotic stresses like drought stress. However, recent trends indicate that productivity and fertility of soils are globally declining due to degradation and intensive use of soils without consideration of proper soil management practices and use of synthetic chemicals (Muhammad *et al*., 2017).

Studies by Sikora *et al*. (2018) indicated that root-knot nematodes inhibits or slows down photosynthetic carbon fixation which directly inhibit plant metabolism. It is possible that French-beans plants treated with higher crude extracts level compared to low extract levels and untreated plants experienced better and high metabolism and consequently better growth. From the study it was noted that the crude extracts significantly .increased the pod number and pod weight of French bean plants per plant when compared to the untreated control .This results of these study compares with those by Rajesh *et al.* (2017) who reported that crude extracts from Neem leaf extracts at 100 ml/L and Tithonia 100 ml/L were most effective and increased the yield significantly.

From the study it was noted that the increase in French bean yield was more when compared with the chemical nematicides. Neembecidine leaf extracts at all levels of concentration followed the neem in improving the French beans yield. The least yield was obtained from the severely infested untreated control. In all botanical extracts application, yields of French bean per plant increased with the increase in concentration. On average tephrosia leaf extracts, were the least effective in increasing the yield of French bean per plants.

The importance of organic horticultural production, which avoids synthetic nematicides applications, increased the research on botanical pesticides with potential use for nematode management (Mishra *et al*., 2018). In this study application of plant extract was found to reduce root-knot nematode galling indices on French beans root system and thus the final nematode population density in the soil was significantly lowered over the untreated control. With the increase in level of botanical extract concentration, a corresponding significant reduction was observed in the number of galls and nematode population over untreated control. Root-knot infestation stunted all untreated

plants and reduced leaf production as well as French bean yield.

The effects of the tested botanical extracts against infestation of root-knot nematode and yield of French beans plant were different, in some cases. The differences in the toxicity of different botanical extracts could be due to the differences in the chemical compositions and concentrations of toxic components. Crude extract treated plots when compared to the positive control (Oxamyl) a synthetic nematicides controls yielded significantly heavier pod weight at harvest. Also extract treatments gave a 100% increase in both pod number and pod weight over the untreated control in which most of the plants withered away and died. These yield benefits can be attributed to increased root knot nematode control in the soil by the crude extracts amendments.

Organic amendments have been reported to improve plant tolerance to nematode damage and in turn promote better yields (Pavaraj *et al*., 2018). Although Oxamyl suppressed root-knot nematodes RKN population satisfactorily, lower results were obtained when compared to the crude extracts treatment application observed in terms of crop yield. The lower results in Oxamyl when compared to crude extracts could be attributed to the fact that Oxamyl is a broad-spectrum fumigant in terms of activity and thus could have eliminated all the beneficial soil micro-organisms that would have been useful in checking the nematodes population and also in maintaining the soil biology.

Effects of Different Extracts on Root galling Indices

The extent of galling on roots (root-knot index) is a means for detecting the infestation of Meloidogyne species in the roots and the damage or severity caused. In this study, all the Plant extracts were highly effective in reducing root-knot index when compared with untreated plants. The extracts reduced root galling significantly and were at par with Oxamyl (synthetic nematicides). The study showed that among the crude extracts treatment evaluated, there were variations in root-knot nematode damages.

The low galling indices in extract treated control treatments indicated low damages on the roots in French beans, this confirms earlier studies that these extracts are potent in managing the root-knot (Mcsorley, 2018). Root gall index appeared to be a useful parameter in evaluating the efficacy of the crude extracts formulation on *Meloidogyne indica*. The study revealed that the extracts evaluated improved plant status, exerted significant control on the root-knot nematodes and reduced the root galling indices in French beans. It was observed that French bean performance was best in plants treated with Neem and closely followed by those treated with neembecidine. These results agrees with those obtained results are in agreement with findings by Pavaraj *et al*. (2018) who reported that leaf extracts of Neem, Tithonia and Tephrosia significantly reduce root-knot nematodes.

Conclusion

The study provides empirical data confirming the use of botanicals for improved French bean production as a food security crop, although the treatments are in high demand in ethno medicinal practices, they appear to have a higher potential in the control of *M. incognita* and have proved to be favorable alternatives to synthetic nematicides pesticides in vegetable crop production. The introduction of crude botanical extracts as an option in the management of parasitic nematodes has become a major component in sustainable management of soil health and productivity. Eco-friendly nematicides used in the experiment led to root-knot nematode suppression which did not differ significantly from Vydate (synthetic nematicides). This study illustrates that agricultural utilization of phytochemicals although currently under trial and development in many situations, offers tremendous potential in the control of root-knot nematodes. Although the plants in

this study are locally used in ethno medicinal practices without toxicological residue effects and as such could serve as alternatives in a sustainable organic farming system to meet global demand in food production.

Recommendations

Since botanical extracts are effective in root-knot nematode suppression, they are recommended for incorporation into integrated nematode management in French bean production. Since the extracts were comparable to Synthetic nematicides in root-knot nematode management, they can be considered for use as an alternative. More studies on the integration of botanical extracts and other control agents on the activities of plant parasitic nematodes and other soil borne pest in crop production systems are highly recommended.

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