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Evaluating the Potentials of some Cereals as Rotation Crops for the Management of Root-knot Nematodes Infecting Tomato var Roma VF in Plateau State

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ABSTRACT: The potentials of three cereal crops: maize, sorghum and millet, for the management of root-knot nematodes (Meloidogyne incognita and M. javanica) infecting tomato var Roma VF were evaluated in crop rotation trials between September, 2012 and December, 2014. These were incorporated into three rotation designs:
Design1(maize→sorghum→millet→tomato),
Design2(sorghum→millet→maize→tomato),and
Design 3 (millet→maize→sorghum→tomato). The research was carried out in the Botanical garden of Federal College of Education, Pankshin, in a field found to be infested with these root-knot nematodes. A Complete Randomised Block Design (RCBD) with four treatments and four replications was used in this investigation. Agronomic and yield parameters such as root-knot nematode population in roots and rhizospheres, fresh shoot and root weights, shoot height and fresh fruit yield were evaluated. The results show that the mean root-knot nematode populations decreased progressively year after year, implying the effectiveness of the rotation crops. Correlation analyses, however, indicated a negative relationship between root-knot nematode populations (roots and rhizospheres) and mean fresh fruit yield, fresh root weight and mean plant shoot height. However, there was a positive correlation between root-knot nematode populations (root and rhizospheres) and fresh mean fresh root weight. Design 1 gave the highest reduction in the mean root-knot nematode populations, followed by Design 3 while Design 2 had the least effect on the root-knot nematode populations. Design 1 is thus recommended as the best rotation approach for the management of root-knot nematodes infecting tomato var Roma VF.

Keywords: root-knot; rotation design; management; rhizospheres; rotation crops.

I. INTRODUCTION

Tomato (Lycopersicon esculentum Mill), a member of the family Solanaceae, also known as the night shade family is indigenous to South America, and it is grown all over the world following the Spanish colonization of America [14]. It is one of the most important vegetables worldwide; popularly grown widely for its edible fruits [7]. It is the world's largest vegetable crop after Irish potato, having about 100 genera and more than 2,800 species [11]. Tomato is widely cultivated in over 140 countries of the world with an annual production of 162 million tonnes/hectares [9]. Nigeria is the second largest producer of tomatoes in Africa with 26,000 ha yielding 879,000 tonnes of fresh fruits annually [9]. Nigeria is ranked 16th on the global tomato production scale, and she accounts for 10.8% of Africa's and 1.2% of total world production of tomatoes [9].

1.1. Economic importance of Tomatoes

Tomatoes provide abundant vitamins and minerals. They are high in vitamins A, B and C and also contain good amounts of potassium, iron, and phosphorus [34]. One medium-sized tomato provides about 40% of Recommendation Daily Allowance (RDA) of vitamin C (ascorbic acid), 20% the RDA of vitamin A, substantial amount of potassium, dietary fibre, calcium and iron, magnesium, thiamine, riboflavin and niacin; yet it contains only about 35 calories [23] and a substantial amount of Vitamin K. Therefore, it is essential for sperm production and for the building and health of cartilage, joints, skin and blood vessels. Vitamin C helps in maintaining healthy immune system. The fruit contain antioxidants, vitamins and minerals, and can be processed into juices, ketchup and puree/paste. It can be eaten raw in salads or cooked [6].

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In Nigeria, production of tomato is generally in relation on to demand. The low yield of tomato is as a result of attacks by many pests, notable among which are the root-knot nematodes [20, 31]. In Nigeria a yield loss of between 28-68 % was reported [2]. The yield losses by root-knot nematodes are mainly due to build-up of inoculum of the nematode and repeated cultivation of the same cultivars in the same land every year. The production of tomato (Lycopersicum esculentum Mill), a common crop in Plateau State which is a major source of nutrients to man and income-generating to its growers, is impaired largely by plant parasitic nematodes especially, root knot nematodes. Root-knot nematodes, Meloidogyne incognita and M. javanica, are common in Plateau [6,18, 37,38]. They threaten crop production, thereby constituting economic loss as the economy of Plateau State is mainly agro based.

1.2. Control of root – knot nematodes

Several methods have been suggested globally to manage root-knot nematode affecting tomato production. Chemical, biological and cultural methods have been tried and different levels of successes have been recorded. The ultimate goal of controlling various Meloidogyne spp. in the soil is to protect the crop from exposure to secondary infections, and to achieve maximum crop yield at the end of the growing season at a low cost [5,17]. However, once soils are infested with root-knot nematodes, control is extremely difficult, also due to varieties of suitable hosts.

Although the use of nematicides is generally recommended for the control of plant diseases caused by nematodes, their relatively high costs, non-availability at the time of need, the hazards they pose to human as well as on non-target organisms discourage users [1, 16, 32]. Besides, in 2005, the EU banned the use of methyl bromide which was the most effective nematicidal agent. The use of other nematicides has been restricted or withdrawn recently [35]. Similarly, the use of resistant cultivars and nematicides are the main strategies to abate yield losses caused by root-knot nematodes [10, 29]. In addition to the target pest, they also kill a lot of beneficial micro-organisms in the rhizosphere and contaminate soil and water in plant parts. As a result of this, alternative methods of disease control that have been evaluated and developed for control of root-knot nematodes which include cover cropping, biochemical control, host resistance, organic amendments and crop rotation involving poor hosts are being advanced.

Soil amendments of different kinds used as nutrient sources for crop production have been found to be effective in the control of root-knot diseases of plants. Adding amendments to soil may alter many factors that affect nematodes directly: soil structure, particle aggregation, pH, salinity, levels of carbon dioxide, oxygen, and other chemicals [21]. Control of root-knot nematodes using both cow dung and poultry droppings had earlier been achieved [22].

The two problems with growing the same (or similar) crops in the same area year after year (monocropping) is that the nutrients in the soil become unbalanced/depleted and that pests and diseases which affect such crops will increase. The yield losses caused by root-knot nematodes are due to the build-up of inoculum of the pathogen [15], and continuous growing of similar okra varieties in the same field year after year [13].

To this effect, it becomes necessary to find alternative control strategies which are not only effective but safe to farmers, consumers and the environment. They should be easily accessible at affordable cost to the farmers. One among these strategies is crop rotation, where poor hosts (non-hosts or resistant crops) are planted and alternated with susceptible crops [4] year after year in a systematic manner. Crops such as Maize, millet and sorghum are very common and highly appreciated in Plateau, and they are found to be resistant to root-knot nematodes (Meloidogyne spp.) [33]. This makes their adoption as rotation crops for the management of root-knot nematodes (Meloidogyne incognita and M. javanica) a cheap and viable option, considering the environmental safety and other health concerns.

II. METHODOLOGY

A three-year crop rotation trial was conducted in the Biology Garden of Federal College of Education, Pankshin, Pankshin Local Government Area of Plateau State for the control of root-knot nematodes (Meloidogyne incognita and M. javanica) infecting tomato var Roma VF. The research lasted from September 2012 to December 2014. In this research, field experiments were conducted in which tomato (Lycopersicon esculentum Mill. Var Roma VF) was used as target crop. Maize (Zea mays), millet (Pennisetum vulgare)and sorghum (Sorghum bicolar) were incorporated in three different rotation designs. The choice of the rotation crops was because they have been known to be poor hosts to root-knot nematode (Meloidogyne species) infection [24]. Seeds of all these crops were obtained from the local farmers within Pankshin and environs. The research was arranged in a Randomized Complete Block Design (RCBD) in a systematic manner, with four treatments and four replications. Here, blocks represented replications while treatment represented crop rotation designs.

Source of Planting Material

Seeds of tomatoes var Roma VF were obtained from Pankshin Monday Market and raised in nurseries in the first week of October 2012 prior to the preliminary crop rotation trials. They were then allowed to grow on the nurseries for a period of four weeks. Afterwards, the seedlings were transplanted with a space of 30 - 50 cm distance between two successive plants. The plants were irrigated twice every week. The target plants were allowed to grow for six weeks before evaluation of parameters was done.

Cropping Sequences/Rotation Designs

The three crop rotation designs were:
Design 1:-M →S→Mi →T;
Design 2:-S →Mi →M →T
Design 3:-Mi →M →S →T.
Where:
M → Maize Mi→ Millet
S → Sorghum T → Tomato
The crop rotations were:
Rotation 1→First rotation year
Rotation 2→Second rotation year
Rotation 3 →Third rotation year

Extraction of Nematodes

Modified Baermann Funnel technique (tray method) was employed for the extraction of root knot nematodes from both the soils and whole roots of the tomato. The whole roots were teased using needle and forceps prior to the application of Modified Baermann Funnel method for the isolation of root-knot nematodes [12].

Meloidogyne spp. was separated on the basis of perennial patterns of mature females using the manual for the identification of agriculturally important Plant Parasitic Nematodes [12]. Data on cumulative average counts of root knot nematodes, plant heights, fruit yield, fresh shoot weight, and fresh root weight of the target crop were subjected to two-way Analysis of Variance (ANOVA). Means were separated using Least Significant Difference (P=0.05) from each sample.

Results

The results revealed that root-knot nematodes are associated with the roots of the target crop (Table 1).

Table 1: Preliminary investigation involving the target crop (Tomato var Roma VF)

	Blocks					
Parameter Assessed	1	2	3	4	Total	Mean
Tomato(roots)	200	180	150	250	780	195.00
Tomato (soil)	100	250	150	200	700	175.00
Fresh Fruit Yield	1,650	3,450	3,150	2,750	11,000	2,750.00
Fresh Mean Height	18	19	19	19	75	18.75
Fresh Shoot Weight	85	115	107	118	425	106.25
Fresh Root Weight	37	45	39	40	161	40.25

There is a progressive decrease in the cumulative mean of root-knot nematode (Meloidogyne spp.) populations in the roots of tomato (var. Roma VF) from rotations 1 to 3 (Table 2). Among the designs, design 1 (maize-sorghum-millet-tomato) had the highest cumulative mean of root-knot nematode population. There is a significant difference ($P<0.05$) in cumulative mean of nematodes among rotation years.

Among Designs, Design 2 had significantly higher mean of the population of nematodes in roots than Design 1; while Designs 1 and 3; and 2 and 3 did not differ from each other in mean population of nematodes (Table 4).

Table 2: Effect of Rotation Designs on Cumulative Mean of Root-Knot Nematode Population (100g) of Tomato var Roma VF Roots.

Designs	Rotation 1	Rotation 2	Rotation 3	Total	Mean LSD(p=0.05)
1	180	162	131	473	157.67
2	208	181	157	546	182.00
3	185	157	142	484	161.33
Control	260	260	260	780	260.00
Total	833	760	690	2283	761.00
Mean	208.25	190.00	172.50	570.75	

	19.73
LSD(p=0.05)	17.10

Pairs of means that differ by more than their LSD are significantly different (p<0.05).

Key:
Design 1→maize→sorghum→millet →tomato (MSMiT)
Design 2→sorghum→millet→maize→tomato (SMiMT)
Design 3→ millet→maize→sorghum→tomato (MiMST)
Rotation 1 → First rotation year
Rotation 2 →Second rotation year
Rotation 3 →Third rotation year

The results in table 3 indicated that there is a progressive decrease in the cumulative mean of root-knot nematode population from rotations 1 to 3. Among the designs, a similar trend was observed as design 1 had the least cumulative mean root-knot nematode population, with design 2 having the highest cumulative mean root-knot nematode (Meloidogyne spp.) populations in the tomato rhizospheres (Table 3). There is a significant difference (P< 0.05) in the cumulative mean of root-knot nematodes population among the rotation years and designs. Rotation 1 had a significantly higher cumulative mean of root-knot nematodes population in the tomato rhizospheres than other rotation years.

Table 3: Effects of Rotation Designs on cumulative mean Root-Knot nematode Population (100g) of tomato var roma VF rhizospheres

Designs	Rotation 1	Rotation 2	Rotation 3	Total	Mean LSD(p=0.05)
1	128	112	103	343	114.33
2	160	147	130	437	145.67
3	135	122	122	379	126.33
Control	175	175	175	525	175.00
Total	598	556	529	1683	561.00
Mean	149.50	139.00	132.25	420.75	10.87
LSD(p=0.05)					9.41

Pairs of means that differ by more than their LSD are significantly different (p<0.05).

The cumulative mean of fresh fruit yield from rotations 1 to 3 showed that there was a general progressive increase in the fresh fruit yields among the rotation years, with rotation 3 having the highest mean of fresh fruit yield. Among the designs, it was observed that design 1(maize→ sorghum→ millet→ tomato) had the highest cumulative mean fresh fruit yield followed by designs 3 (millet→ maize→ sorghum→ tomato) and 2 (sorghum→ millet→ maize→ tomato).

It was generally observed that the control had a significantly lower mean of fresh fruit yield compared with the designs. Statistical analysis showed that there was a significant difference (P< 0.05) in the cumulative mean of fresh fruit yield in both designs and rotation years (Table 4).

Table 4: Effects of Different Rotation Designs on cumulative mean fresh fruit yields of tomato var roma VF

Designs	Rotation 1	Rotation 2	Rotation 3	Total	Mean LSD(p=0.05)
1	5,316.00	5,377.50	6,975.00	17,668.50	5,889.50
2	2,699.00	3,562.50	5,103.00	11,364.50	3,788.20
3	4,076.00	5,567.50	7,188.00	16,831.50	5,611.00
Control	2,750.00	2,750.00	2,750.00	8,250.00	2,750.00
Total	14,841.00	17,257.50	22,013.00	54,114.50	18,038.80
Mean	3,711.00	4,314.40	4,455.00	13,528.60	
					1,119.30
LSD(p=0.05)					969.40

Pairs of means that differ by more than their LSD are significantly different (p<0.05).

The cumulative mean heights of tomato var roma VF plants showed that design1 (maize→sorghum→millet→tomato) had the highest cumulative mean plant heights followed by designs2(sorghum→millet→maize→tomato) then design 3 (millet→maize→sorghum→tomato).

The statistical analysis showed that the cumulative mean heights of tomato var roma VF plants did not differ from each other among the rotation years and the control (P>0.05), although rotations 2 and 3 had a significantly higher cumulative mean plant heights than rotation 1. However, there was a significant difference (P<0.05) in the cumulative mean heights of tomato var roma VF plants among the designs (Table 5).

Table 5: Effect of Different Rotation Designs on cumulative mean shoot length (cm) of Tomato var Roma VF

Designs	Rotation 1	Rotation 2	Rotation 3	Total	Mean (p=0.05).	LSD
1	23.60	29.40	28.40	81.40	27.10	
2	23.80	26.50	26.20	76.50	25.50	
3	23.20	27.70	27.70	78.60	26.20	
Control	19.00	18.80	18.70	56.50	18.80	
Total	89.60	102.40	101.00	293.10	97.70	
Mean	22.40	25.60	25.30	73.30		NS
LSD(p=0.05)					2.34	

Pairs of means that differ by more than their LSD are significantly different (p<0.05).

The result indicated that there was a progressive increase in the cumulative mean weight of fresh shoot from rotations 1 to 3 (Table 6). However, there was no significant difference (P>0.05) in the cumulative mean of fresh shoot weights among the three designs. It was observed that design 1 (maize→sorghum→millet→tomato) had the highest cumulative mean of fresh shoot weights followed by design 3 (millet →maize→ sorghum→ tomato); design 2 (sorghum→ millet→ maize→ tomato) having the least cumulative mean fresh shoot weight.

Statistical analysis, however indicated that there was no significant difference (P>0.05) in the cumulative mean fresh shoot weights among the designs. Design 3 had a significantly higher cumulative mean of fresh shoot weights than designs 1 and 2.

Table 6: Effect of Different Rotation Designs on cumulative mean of fresh root weight (g) of Tomato var Roma VF Plants

Designs	Rotation 1	Rotation 2	Rotation 3	Total	Mean LSD(p=0.05)	
1	94.50	162.60	189.30	446.40	148.80	
2	132.30	139.30	159.70	431.30	143.76	
3	152.30	162.40	184.60	499.30	166.43	
Control	106.40	106.30	106.40	319.20	106.40	
Total	485.50	570.60	640.20	1696.20	565.40	
Mean	121.40	142.65	160.10	424.10		NS
LSD(p=0.05)					NS	

Pairs of means that differ by more than their LSD are significantly different (p<0.05).

The result indicated that there was a general decrease in the cumulative mean of fresh root weight of tomato among the rotation years; from rotation 1 to 3 (Table 7). Besides, the results from the designs indicated that design 2 (sorghum→millet→maize →tomato) had the highest cumulative mean of fresh root weight followed by design 3 (millet→ maize→ sorghum→ tomato); design 1 (maize → sorghum→ millet→ tomato) had the lowest cumulative mean of fresh root weight. Design 2 had a significantly higher cumulative mean than design 1.

Statistical analysis indicated that there was significant difference (P<0.05) in the cumulative mean of fresh root weight among the designs compared with the control. Although rotation 1 had a significantly higher cumulative mean, statistical analysis indicated that there was no significant difference (P>0.05) among the rotation years.

Table 7: Effects of Different Rotation Designs on Cumulative mean of fresh root weight (g) of Tomato var Roma VF Plants

Designs	Rotation1	Rotation 2	Rotation 3	Total	Mean (p=0.05)	LSD
1	19.60	15.20	11.70	46.50	15.50	
2	26.00	20.10	15.80	61.90	20.63	
3	21.50	17.50	16.60	55.60	18.53	
Control	27.30	35.00	29.00	91.30	30.43	
Total	94.40	87.80	73.10	255.3	85.10	
Mean	23.60	22.00	18.28	63.83		NS
LSD(p=0.05)					4.72	

Pairs of means that differ by more than their LSD are significantly different ($p<0.05$).

III. DISCUSSION

The results of this research indicated a significant decrease ($p<0.05$) in the cumulative mean of root-knot nematode population from rotations 1 to 3 due to the effects of the rotation crops. This could be attributed to efficacy of the rotation crops and designs in reducing the root-knot nematode populations in the rotation years. The use of these crops is based on several principles such as use of non-host crops, crops with suppressive effect due to their exudates and secondary metabolites, N fixing plants, plants with high residual matter, and the plants' adaptability to the specific environs. Plants release secondary metabolites in significant amounts at varying stages of plant growth. Some of the reported metabolites include; Benzoxazinoids: 2,4-Dihydroxy-7-methoxy-2H-1,4- benzoxazin-3(4H)-one (DIMBOA) which is the most common benzoxazinoid found in wheat and wild barley among other cereals [8].

The subsequent decline in the root-knot nematode population resulted in higher yields and fresh shoot weights across the rotation years. According to [30], the initial inoculum levels of root-knot nematodes had a significant effect on the growth and yield of tomato. This shows that when the inoculum levels are high, greater number of juveniles are able to infect the plant roots which results in reduced nutrient and water uptake by the roots and consequently, poor growth. Successful interaction between plants and root-knot nematodes is determined by their higher population threshold level in the soil, environmental factors such as soil type, texture and pore size, cropping pattern and history, nematode and crop race, nematode distribution pattern and its multiplication [27]. Several factors contribute to the pathogenicity of a nematode on a particular host. These factors include ability to perceive and be attracted to the host, penetrate the host, locate the feeding site, initiate the development of feeding site, and obtain sufficient nutrients to develop to adulthood and reproduce. Besides, the degree of root galling depends on the nematode population, Meloidogyne species, host plant species and the prevailing environmental condition.

The mean of fresh fruit yields of the target crop were higher in the rotation years as well as rotation designs following the rotation crops. The progressively higher fresh fruit yields over the control confirm that the rotation crops were effective in lowering the root-knot nematode populations. The results conform to the findings of [28] who reported that plants heavily infested with root-knot nematodes exhibited stunted growth and poor yield, and in some cases the plants die even before maturity. Root-knot Nematode feeding results in cellular, metabolic and structural changes within plant cells and tissues. These physiological and physical changes to the plant can reduce crop yield and quality [3].

The increased response of the tomato plants to the different rotation crops in terms of plant height might be because of the ability of these crops to create a suitable nutritional and other soil conditions for plant growth and development and possible provision of protection from root-knot nematodes. The increase in plant height is due to the reduction in the number of galls and decrease in the activities of the root-knot nematode juveniles.

The growth of plant is also inversely proportional to the population density of root-knot nematode hence, [25] also reported significant decrease of plant height with increase in the inoculum density of root-knot nematodes in tomato. Root-knot nematode affects the water and nutrients absorption and translocation in host plants; photosynthesis rate decrease in infected plants which is negatively correlated with inoculum levels; the photosynthetic products move toward the roots specifically into giant cells which are developed by the nematode infections and support nematode development and reproduction.

The study demonstrated that there was a progressive decrease in the fresh roots of tomato var roma VF root weight as a result of nematode parasitism increases; whereas shoot weight declines, shifting the root-shoot balance [26]. This result corroborates the work by [19] who reported that gall formation and proliferation of lateral roots in root knot nematode infected roots were due to the formation of galls or abnormal secretion of growth hormones induced by root knot nematodes. [36] studied the relationship between population densities of M. incognita and crop yield in tomato and found that there was greater increase in the fresh weight of tomato roots with increase in inoculum density. This explains the relatively higher root weight of the infected target plant. This shows that the presence of Meloidgyne incognita increased the weight of root in tomato plants as a result of galls produced in the roots. Besides, the increased fresh root weight in the control design also suggests that the target plants attest to this report.

IV. CONCLUSION

The use of maize, millet and sorghum as rotation crops was found to be effective strategy for reducing root-knot nematode (Meloidogyne incognita and M. javanica) infestation potential in soils, thereby protecting subsequent susceptible crops. However, the presence of these root-knot nematode species put agricultural production in the study area at risk, given the fact that most farmers do not know about their existence in their farms.

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