Research Article

Virulence and Distribution Trends of Root-Knot Nematode (RKN) Fauna on Summer Vegetables in District Bagh, Azad Jammu and Kashmir (Pakistan)

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Abstract | Root-knot nematodes (RKNs) are important group of plant parasitic nematodes belong to genus *Meloidogyne* with extensive host range. A comprehensive survey study was carried out to document host and non-host plants in cultivated fields of Bagh district, Azad Jammu and Kashmir. Total of 111 vegetable fields from 82 locations of study areas was surveyed during summer 2013, 2014, 2016 and 2017. Okra, Eggplant, tomato, cucumber, chilies, beans and cucurbits were found most frequently cultivated vegetables in the area. RKN was found on 80 fields, with 68 out of 82 surveyed locations with 72% field incidence. Okra was found with highest field infestation with 47.3% followed by cucurbits on 20% and tomato on 17.4% while zero infestation on chilies. Species were identified based on perineal pattern morphology. *M. javanica* was identified as predominant species of the study area. RKN tropical species was found on *M. incognita* 37%, *M. javanica* 38% and *M. arenaria* 28% sites parasitizing vegetable crops. Host preference of *M. javanica* and *M. incognita* was detected in mixed field conditions as *M. javanica* preferred okra as host while *M. incognita* reproduced maximum on tomato. Common beans were found most susceptible host providing survival opportunity to RKN due its heavy intercropping with field crops and vegetables. Understanding regarding pathogen survival under adverse conditions will help the scientists to develop new approaches for sustainable yield.

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Introduction

The root-knot nematodes (RKN) are considered as the most economically damaging group of plant parasitic nematodes composed of more than 100 described species. Major tropical species are *M. incognita, M. arenaria, M. javanica;* while *M. hapla*, *M. chitwoodi* and *M. fallax* are considered as temperate area species and attack on variety of crops and vegetables (Elling, 2013) and reduce the quality and quantity of produce worldwide (Nchore *et al*., 2011). Estimated losses due to RKN per year are approximately $100 billion (Oka *et al*., 2000) which is 12.3% of world yield (Ravichandra, 2008). RKNs infect

broad range of different herbaceous and woody plants resulting in severe losses to agriculturally important crops (Moens *et al*., 2010). The ratio of yield losses in tropical region is higher as compared to temperate and cold climate. The crops that are reported as the most susceptible to RKN include tomato, potato, eggplant, legumes, okra, cucurbits, mint and field crops like cotton, groundnut, tobacco, sugarcane, rice, soybean and maize, and fruit trees like citrus, cherry and peaches in all parts of Pakistan (Hussain, 2011).

Nematodes produce specific symptoms which can be observed on roots and above ground parts of plants include; chlorosis, stunted growth, mosaic like patterns on tomato, poor yield and sometime overall crop failure; whereas galls or knots on roots of the infected plants (Oka *et al*., 2000; Khan, 2018). The plants with nematode infection of roots exhibit reduced root system with a few feeder roots (Anwar and Javed, 2010). Nematode population is influenced by biological factors, soil texture and its structure (Asif *et al*., 2015). The pathogen multiplication results in increased infections more readily at a temperature ranging between 25-30°C preferably in light-textured sandy soils having a pH range between 4.0 to 8.0 (Sikora and Fernández, 2005). During short life cycle of six to eight weeks root-knot nematode populations usually reach up to maximum level in the presence of a suitable host with varying degrees of susceptibility (Shurtleff and Averre, 2000). Root-knot nematode distribution must be continuously monitored due to its broad host range and emergence of new aggressive species such as *M. enterolobii* parasitizing variety of crops in variety of environment.

District Bagh is geographically situated on 73.79°E and 33.97°N in Azad Jammu and Kashmir. Topography of entire Bagh district is a mountainous with moderate slopes. Climate varies with altitude, which is comparatively hotter in foothills and moderate to cold toward height. Temperature range during summer is 32-40°C with an average rainfall of 1500 mm. On slopes the terracing type there is farming and vegetables are grown mostly for household use on small pieces of land. Present study was designed with focus on understanding root-knot nematode distribution and virulence trends in natural agro-ecological system and their survival in Bagh district of Azad Jammu and Kashmir. The study helped the local farmers to understand the RKN issue and their management.

Materials and Methods

Soil sampling

The detailed survey study for distribution and occurrence of root-knot nematode in vegetable fields was carried out during summer 2013-2014 and 2016-2017. The plants were observed for reduced growth and 20 plants were selected per site to observe the root-knots in roots systems. One kg of soil from infested root zones was taken; infested roots and soil were then packed separately into polyethylene bags, labeled properly, put into the wooden boxes for further transporting to the Department of Plant Pathology, Faculty of Agriculture, University of the Poonch, Rawalakot. All details of sampling sites either positive or negative were enlisted along with the host plant, and previous crop history was recorded (Table 2). Disease severity was estimated by visual observations and comparison with rating scale 0-9 (Bridge and Page, 1980) during field visit.

Nematode identification

RKN species identification was done by using the perineal pattern factorial keys provided by Eisenback and Griffin (1987) and Jepson (1987) along with digital micrographs and morphometric parameters (Eisenback *et al*., 1981; Jepson, 1987). Mature females were removed from infected root samples with the help of needle and placed in watch-glass containing water. Females were then transferred into petridish containing 45% lactic acid and left for 2 hours. Using a fine sharp dissecting needle, perineal patterns of the mature females were cut and trimmed under binocular stereo-microscope and transferred to a drop of glycerin already put on the slide, covered with a cover-slip and observed under compound microscope. Twenty perineal patterns for each sample population were examined for identification and species profiling in one population.

Nematode purification

For purification of nematode culture each female was mechanically excised from the roots with the help of needles under stereomicroscope and egg masses were separated. Single egg mass was then treated with Clorox solution for disintegration of gelatinous matrix and release of eggs in Petri plates. Eggs were then rinsed with fresh water to remove effects of Clorox by consecutive washings. The eggs were put at room temperature for hatching and then hatched second stage juveniles (J2) were transferred to the

susceptible host plant (Money maker or eggplant) for culture multiplication. The inoculated plants were kept at 25±2°C in 16:8 hours light dark interval of for the propagation and population build up (Barker, 1985). Proper moisture was maintained for soil samples to save the nematode fauna from killing due to lack of moisture, excessive heating and sunlight were carefully avoided. The incidence of root-knot nematode was estimated by following formula.

$$\text{Incidence} = \frac{\text{Total positive}}{\text{Total observed site}} \times 100$$

Results and Discussion

Distribution of root-knot nematodes in district Bagh Azad Jammu and Kashmir (AJK)

Survey results of the whole district revealed that a variety of vegetables are being cultivated for household and commercial purpose. A total of 111 fields from 82 geographical locations with mixed vegetables were observed and results were summarized, expressing the picture of RKN presence in the study area (Table 2). RKNs were found frequently distributed on most of the surveyed areas of the district with specific host range (Table 2). The overall 72% incidence was estimated, where crop-wise maximum incidence of 47.3% was found on okra with average galling index (GI) of 5.1 and minimum 3.9% field infestation on cucumber with average GI of 6.0 (Tables 1 and 2). The host range of root-knot nematode was found different among the vegetable crops with pathogenic variation on different locations revealed that the RKN has diversity in its parasitic behavior (Table 2). A map was also prepared which shows the distribution trend of RKN in district Bagh (Figure 1). Perineal pattern morphology was key to identify the RKN species. *M. javanica* was encountered as major leading species on okra followed by *M. incognita*. Population estimation based on perineal pattern observation reveals that the two leading species of the RKN- *M. incognita* and *M. javanica* prefer specific host even in mixed populations and mixed vegetable cropping. *M. javanica* found preferring okra in field conditions as host while tomato was preferred by *M. incognita*. Surprisingly the cucumber which is considered host in the tropical region was observed as the least preferred host may be because it emits some volatiles in low temperature areas which might have reduced the infection by RKN. Chilies showed no infection signs of RKN infection in the study area, which needs to be verified and explored as to whether the host has some qualitative substances which checks the infection or the populations of RKN present in the area do not have the quality to incite infection in root system of chilies. Positive inference for the presence can be made regarding natural biotic or abiotic factors which may be responsible for reduced infection. It must be further explored for identification of the candidate genes for resistance through field experimentation and genetic approach regarding pathogenicity and the resistance in the host. Based on this study observation, it can be predicted that chilies have some active resistance mechanism, may be environment-associated or any other reasons that are functional in temperate areas and nonfunctional in the tropical regions? Further exploration can help us to understand the real reason which could possibly be exploited for future agriculture production and ecofriendly management of plant parasitic nematodes.

Severity infection of root-knot nematodes on vegetables

Maximum disease and reproduction of RKN was found on okra and beans roots where the disease severity (GI) was recorded a maximum 9 followed by 8 (Tables 1 and 2). The disease severity data of 47 locations shows that disease index is high and threatening to crop yield at all positive sites. On 11 sampled sites the severity of infection was very high (7-9) according to galling index rating scale (Bridge and Page, 1980). Surprisingly the galling index was found high in some locations with relatively high elevation and altitude from the sea level with low temperatures (Table 2). Okra was most preferred host among vegetables grown while disease severity was found high on tomato roots (Table 2). *M. javanica* preferred okra as host, which might be due to specific metabolites. Reproduction of RKN fauna in nature on tomato root system was found high when compared to other host plants including okra; which further supports the understanding of tomato as host plant for culture multiplication. On native cucumber strains, GI was found low as compared to other vegetables as in only 3 fields, the crop was found infested with RKN among 76 surveyed cucumber fields (Table 2). The variation in severity of RKN might be due to fluctuation in the air temperatures, soil temperatures, soil texture, along other biological factors prevalent into the soil.

Tropical root-knot nematode species *M. javanica, M. incognita* and *M. arenaria* were found as major

Table 1: *Crop wise Summary of root-knot nematode (RKN) Incidence on vegetables grown in district Bagh, Azad Jammu and Kashmir.*

Crop	Surveyed fields	Fields with RKN infestation	Incidence %age	Galling index (GI)	Average GI
Eggplant	59	7	11.8%	1-6	4.1±1.68
Tomato	86	15	17.4%	2-8	5.5±2.03
Cucumber	76	3	3.9%	5-8	6.0±1.73
Okra	93	44	47.3%	1-9	5.1±2.26
Chilies	38	0	0%	0-0	0.0
Beans	12	8	66.6%	3-9	5.1±2.85
Cucurbits	15	3	20%	5-7	6.3±1.15
Total	111	80	72.07%	--	--

Details of the survey for each vegetable against their locations is given in Table 2.

Table 2: *Distribution of root–knot nematode species (RKNs) and their association with economically important plants in district Bagh Azad Jammu and Kashmir.*

S. No	Location	RKN +/–	Host crop	Mi	Mj	Ma	GI	Non host vegetables in nematode infested fields
1	Harighel	+	Okra	–	+	–	6	Cucumber, Mung Bean, Eggplant, Bottle Gourd
2	Mang Bajri	+	Okra	–	+	–	4	Eggplant, Okra, Tomato
3	Dar Arja	+	Okra	–	–	+	3	Tomato
4	Arja	+	Okra	+	+	+	8	Chilies, Eggplant, Cucumber
5	Chala Camp Arja	+	Tomato	+	–	–	7	Cucumber, Okra, Chilies
6	Chala Khas	–	–	–	–	–	–	Eggplant, Tomato, Cucumber, Okra
7	Ghaziabad	+	Okra	–	–	+	5	Tomato, Cucumber, Tomato
		+	Eggplant	–	+	–	6	
8	Neela But	+	Okra	+	+	–	2	Tomato
9	Saleyan D. kot	+	Tomato	–	+	–	7	Eggplant, Okra, Cucumber
10	Dheerkot	+	Okra	–	+	–	5	Tomato, Eggplant
11	Thob (Sudhoi)	+	Okra	+	–	–	4	Chilies, Eggplant
12	Thob (Tran)	+	Tomato	+	–	–	5	Bottle Gourd, Eggplant
13	Thob (Khas)	+	Okra	–	–	+	9	Tomato, Cucumber
14	Thob	+	Beans	+	–	–	3	Okra, Eggplant, Cucumber
15	Sir Sayydan	+	Tomato	+	–	–	7	Eggplant, Cucumber, Okra, Tomato
		+	Okra	–	+	–	2	
16	Pader Sayydan	+	Tomato	+	–	–	7	Okra, Chilies, Eggplant
		+	Cucumber	–	+	–	5	Okra, Chilies, Eggplant
		–	–	–	–	–	–	Tomato, Eggplant, Chilies
17	Hullar Sayydan	–	–	–	–	–	–	Tomato, Fresh Bean, Cucumber
18	Numan Pora	–	–	–	–	–	-	Egg plant, Chilies
19	Dhaki N. Pora	+	Okra	+	–	–	2	Mustard, Eggplant
20	Choke Patrata	+	Okra	–	–	+	9	Cucumber, Tomato
21	Bhandi N.Pora	–	–	–	–	–	–	Tomato, Okra, Cucumber
22	Ravli	+	Okra	+	+	–	3	Chilies, Cucumber, Eggplant
		+	Tomato	+	–	+	3	
		+	Beans	–	+	+	9	
23	Baysarra Ravli	+	Okra	–	+	–	4	Cucumber, Eggplant
		+	Tomato	–	–	+	3	Cucumber, Eggplant
		–	–	–	–	–	–	Cucumber, Tomato, Okra
24	Hama Mora	+	Cucumber	+	–	–	5	Okra, Tomato
25	Sanger (Khoteiyan)	–	–	–	–	–	–	Tomato, Chilies, Eggplant, Cucumber

S. No	Location	RKN +/–	Host crop	Mi	Mj	Ma	GI	Non host vegetables in nematode infested fields
26	Sanger Khote	–	–	–	–	–	–	Tomato, Cucumber, Okra
27	Kothian	–	–	–	–	–	–	Tomato, Okra, Cucumber, Chilies
		+	Okra	–	+	–	6	Tomato, Cucumber, Chili
28	Ghael Sayydan	+	Beans	+	–	+	3	Cucumber, Okra, Tomato
29	Ghael Chaperin	+	Okra	–	+	–	4	Tomato, Eggplant
		+	Beans	–	–	+	3	Tomato, Cucumber
30	Ghael Gala	+	Okra	+	–	–	4	Tomato, Cucumber
31	Rairra	–	-	–	–	–	–	Tomato, Okra, Eggplant, Cucumber, Bottle gourd, Chilies
		+	Beans	+	–	–	3	Tomato, Okra, Cucumber
32	Qaderabad	–	–	–	–	–	–	Tomato, Okra, Cucumber
		–	–	–	–	–	–	Tomato, Eggplant, Chilies
		+	Tomato	–	+	–	5	Cucumber, Bottle gourd
33	Chatter No2	+	Eggplant	–	+	–	5	Tomato, Okra, Cucumber
34	Dhulli (Narr)	+	Tomato	–	–	+	2	Okra, Cucumber
35	Dhulli	+	Cucurbits	–	–	+	7	Tomato, Okra
		+	Beans	–	+	–	6	Tomato, Okra, Cucumber
36	Kothian	–	–	–	–	–	–	Tomato, Okra, Cucumber, Chilies
		+	Okra	–	+	–	6	Tomato, Cucumber, Chili
37	Lohar Bela	+	Okra	–	–	+	8	Cucumber, Tomato, Bottle Gourd
38	Lasdana	–	–	–	–	–	–	Tomato, Okra, Eggplant, Cucumber, Bottle gourd, Chilies
39	Chatter No.2	+	Okra	–	+	–	9	Tomato, Cucumber
40	Chatter Padder	+	Cucurbits	+	–	–	5	Tomato, Okra, Cucumber
41	Rair Bun	+	Tomato	–	+	+	4	Okra, Eggplant, Cucumber
42	Beerpani	+	Okra	–	–	+	4	Tomato, Mung Bean
43	Beerpani (Surol)	+	Eggplant	+	–	+	5	Tomato, Okra, Cucumber
44	Beerpani (Naker)	+	Okra	+	–	+	7	Tomato, Mustard, Cucumber
45	Bani Maldara	+	Okra	–	+	–	3	Eggplant, Tomato
		–	–	–	–	–	–	Chilies, Cucumber, Okra
46	Choki Kotteri	–	–	–	–	–	–	Okra, Eggplant, Cucumber
47	Sawanj	–	–	–	–	–	–	Tomato, Okra, Cucumber, Chilies, Eggplant
		–	–	–	–	–	–	
48	Bhont Bhain	+	Eggplant	+	–	–	5	Okra, Cucumber, Bottle gourd
		–	–	–	–	–	–	Okra, Cucumber
49		+	Okra	–	+	–	3	Cucumber, Tomato
	Chatter No1	+	Okra	–	+	–	2	Tomato, Cucumber
		+	Cucurbits	+	–	–	7	Eggplant
50	Khrrel Maldlian	+	Eggplant	–	+	–	4	Tomato, Okra, Cucumber
		–	–	–	–	–	–	Tomato, Okra
51	Paniali	+	Okra	+	–	–	3	Tomato, Mustard
52	Sudhangali	+	Eggplant	+	–	–	3	Okra, Cucumber
		+	Tomato	+	–	–	3	Okra, Cucumber
53	Shaheed Ghala	–	–	–	–	–	–	Eggplant, Cucumber, Mustard
		+	Tomato	+	–	–	8	Okra, Cucumber
54	Beesbagla	–	–	–	–	–	–	Tomato, Okra, Cucumber,
		+	Beans	–	+	+	6	Bottle gourd, Eggplant, Chilies
55	Channat	+	Eggplant	+	–	–	1	Tomato, Okra, Cucumber

S. No	Location	RKN +/–	Host crop	Mi	Mj	Ma	GI	Non host vegetables in nematode infested fields
56	Mallot	–	–	–	–	–	–	Tomato, Okra, Egg Plant, Cucumber, Bottle gourd, Chilies, Fresh Bean, Pumpkin
57	Mallot (Qureen)	+	Beans	+	–	–	9	Okra, Tomato, Cucumber, Bottle gourd
58	Saver Mutvali	+	Tomato	+	–	–	8	Okra, Cucumber, Fresh Beans
59	Nariola	+	Okra	–	+	–	4	Tomato, Chilies, Egg Plant
		+	Cucumber	–	–	+	8	Okra, Eggplant
		–	–	–	–	–	–	Okra, Tomato, Cucumber,
60	Kasanda	–	–	–	–	–	–	Okra, Eggplant, Cucumber, Bottlegourd
61	Chamati	+	Okra	+	–	–	8	Tomato, Eggplant, Chilies
62	Sohawa	+	Okra	–	+	–	7	Cucumber, Bottle gourd, Chilies
63	Lowerkot	+	Okra	–	+	–	8	Tomato, Cucumber, Chilies
		–	–	–	–	–	–	Okra, Tomato, Cucumber, Chilies
64	Paleen-batti	+	Okra	+	–	–	6	Tomato, Cucumber, Chilies
		–	–	–	–	–	–	Eggplant, Cucumber, Okra
65	Awera	+	Okra	–	–	+	6	Tomato, Eggplant, Chilies
66	Serian Awera	–	–	–	–	–	–	Tomato, Eggplant, Chilies
		+	Okra	–	+	–	5	Eggplant, Bottle Guard, Chilies
67	Cheralla	+	Okra	–	+	–	6	Tomato, Eggplant, Chilies
68	Narakot	+	Okra	–	–	+	2	Tomato, Chilies, Eggplant
69	Taien	+	Okra	–	+	+	7	Mustard, Chilies, Tomato
70	TaienKhas	+	Okra	–	+	–	6	Tomato, Cucumber
71	Chamankot	+	Okra	–	+	–	4	Cucumber, Tomato, Chili
		–	–	–	–	–	–	Okra, Tomato, Eggplant
72	Chittratopi	+	Tomato	–	+	+	6	Eggplant, Okra, Cucumber
73	Ban Bhak	+	Tomato	–	–	+	7	Chili, Eggplant, Okra,
74	Thanda Pani	+	Okra	–	–	+	1	Tomato, Eggplant
75	Sangher (D. Kot)	+	Okra	+	–	–	4	Tomato, Eggplant, Cucumber
76	Skandrabad	+	Okra	+	–	–	5	Cucumber, Eggplant, Tomato
77	Numb Sayydan	+	Okra	–	+	–	8	Chilies, Cucumber, Tomato
78	Numb	–	–	–	–	–	–	Okra, Tomato, Cucumber, Bottle Gourd, Eggplant. Chilies
79	Manderi	+	Okra	+	–	–	7	Cucumber, Tomato, Chili
80	Manderi (Tope)	–	–	–	–	–	–	Okra, Tomato, Chilies, Eggplant
81	Sasser	+	Okra	+	–	–	9	Eggplant, Tomato
82	Sasser (Nara)	–	–	–	–	–	–	Tomato, Cucumber, Eggplant, Mustard Leaves, Chilies, Okra.

Serial numbers are the sampled sites shown in the map Figure 1; Some locations were sampled with more than one field per location to avoid any escape of the root-knot nematode infested plant. Mi: Meloidogyne incognita; Mj: Meloidogyne javanica; Ma: Meloidogyne arenaria.

root-knot nematode species form district Bagh AJK although some perineal pattern variants were found similar to temperate area species; however, overlapping of the perineal pattern morphology is very common phenomenon. Populations were found as *M. incognita* or *M. javanica*, or as mixed populations of all the three major species with multiple combinations. During survey okra, tomato, cucumber, eggplant, cucurbits, and beans were found infested with RKN whereas garlic, bitter gourd, chilies, potatoes were found without RKN infestation. Some plants were recognized as non-hosts in the area although they were already reported as hosts. Various other factors that influence the distribution, incidence, severity and reproduction of root-knot nematodes include soil texture, structure, moisture, pH and cropping sequence (Taylor *et al.*, 1982; David, 1985). Population dynamics of special occurrence and incidence were same when measured on different altitudes on various hosts (Kayani *et al.*, 2013; Tariq-Khan *et al.*, 2017, 2020a, b). In this survey

study overall RKN incidence was 72.07%, in a total of 111 surveyed fields from 82 locations (Tables 1 and 2); and the distribution pattern is shown (Figure 1). Among 80 RKN positive locations, 31 locations had 1-4 galling index, on 21 sites it was 5-6 and on 24 locations galling index was 7-9 (Table 2). It indicates a high relevance of RKN as pathogen to the household kitchen gardening in the area and a level of looming threat that can be posed in near future. Total results on RKN are summarized, as highest on okra with 44 infested fields with galling index (GI) ranging from 1-9 (Table 1). RKN were found with tendency to reproduce in mild temperature and the capacity to overcome the naturally temperature sensitive resistance in the plants that become ineffective under high temperature regimes. This study suggests that legumes might be playing vital role in the multiplication and survival of RKN fauna due to extensive intercropping pattern in the area among field and horticultural crops as well as the wild legumes flora which is frequently found in this hilly area. It is therefore hypothesized that this flora of pasture lands might be serving as volunteer alternate host plants and the nematodes might be transferred to cultivated lands through mechanical means, and erosion as RKN spreader.

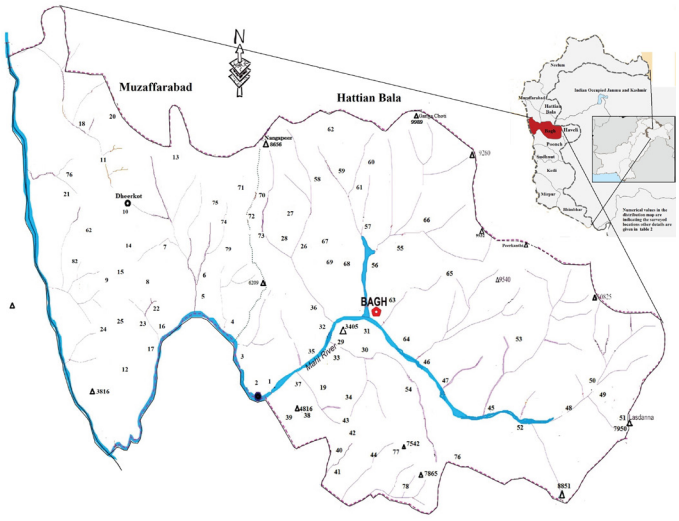

Figure 1: *Distribution sites details of root-knot nematodes (RKN) from District Bagh Azad Jammu and Kashmir.*

In this study, RKN was found distributed in all parts of the study district, i-e., 80 fields out of 111 visited fields in 82 geographical locations were found infested (Figure 1, Table 2) with an incidence of 72% (Table 1). Same distribution trend was reported from Muzaffarabad district of AJK with 64% field infestation (Tariq-Khan *et al.*, 2017) while on okra disease severity was less in Bagh as compared to Muzaffarabad and Poonch division as a whole (Tariq-Khan *et al.*, 2020a, b). The trend of infestation in Bagh was more and less same on tomato, beans and eggplant (Tariq-Khan *et al.*, 2020a). RKN fauna was found unable to infect chilies in study area or the host has found some escaping mechanism to deter the pathogen in the area. Exploring details of any mechanism of this avoidance or resistance whether physiological or physical barrier to infestation in this temperate agroecosystem. In this study the pathogenic preference was detected for population build up on okra and tomatoes under natural conditions in mix culture (Tables 1 and 2) and distribution map explains the natural spread in the district (Figure 1). This trend was a new findling and the reason behind it is the uniqueness of the cropping pattern of kitchen gardening in AJK. Piece of land used for decades and even in some cases more than half a century as mixed vegetable. This trend of cropping may have made the nematodes fauna opportunistic and may have successfully modified its parasitic behavior in the study area and beyond in AJK. This distribution study provides information regarding plants as non host in the study area and having microbiome impact suppressing RKN infestation, just like sorghum which is RKN suppressor and increases organic matter in soil (Quader *et al.*, 2001). Suppressive crops on one hand suppress one type of PPN while provide opportunity to other one genus to build up. For successful nematode control strategy, it seems imperative that comprehensive picture of the plant parasitic nematode diversity must be explored before incorporation of any control measure to avoid economical losses.

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Novelty Statement

Root-knot nematodes are having the potential to infest economically important crops in tropical and temperate areas equally. RKN was found highly aggressive on cultivated legumes in cooler studied area and wild legumes found in pasteur lands are hypothesized best alternative host for pathogen survival under extremely cold climatic conditions.

RKN species were found having host preference in natural agro-ecosystem.

Author's Contributions

MTK supervision, research data collection help, manuscript preparation. Syed Zanib Ali Gardezi and Abu Daud Ahmad Khan research survey, data collection, data compiling and data interpretation. Muhammad Ilyas supervisory team member and editing of manuscript. Ishaq Ahmad research field area help to contact the farmers, and student supervision.

Conflict of interest

The authors have declared no conflict of interest.

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