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A Survey Report of Disease Fields of District; Swabi, Buner, Haripur and Mardan Province of Khyber Pakhtunkhwa

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Abstract. A survey of diseased fields of total (35) areas located in four different Districts of Khyber Pakhtun Khwa like Buner (4 areas), Swabi (23 areas) Mardan (3 areas) and Haripur (5areas) was carried out for estimation of losses and identification of root disease causing pathogens in 14 different economically important crops like Tobacco (*Nicotiana tabacum*), Ladyfinger (*Abelmoscus esculentus*), Chilli (*Capsicum anuum*), Eggplant (*Solanum melongena*), Maize (*Zea mays*), Tomato (*Solanum lycopersicum*), Wheat (*Triticum estivum*), Garlic (*Allium sativum*), Mustard (*Brassica compestres*), Clover (*Trifolium repens*), Onion (*Allium cepa*), Turnip (*Brassica rapa*), Radish (*Raphanus sativus*) and Pea (*Pisum sativum*). The most common root rot pathogens found in all the areas visited were *Alternaria alternate, A.solani, Rhizoctonia solani Macrophomina phaseolina* and species of Fusarium *viz*., *Fusarium solani* and *F.oxysporum*. Two species of root-knot nematode *Meloidogyne javanica* and *M. incognita* were also found causing root-knot disease. The eggplant was found upto 20-76% losses when an infection caused by the combined effect of *F. oxysporum, M.phaseolina. R. solani* and root-knot nematodes. Similarly, the loss of chiliplants was found 40-65% due to the combined effect of *F. solani, M.phaseolina*, *R. solani*, and root-knot nematodes. *Zea mays* crops were reported 50-77% losses due to *Drecslera* spp, *F.solani*, and *A. solani* Losses recorded by these root-rot and root-knot pathogens were found variable depending upon a combination of pathogens, temperature and soil types.

Keywords: colonization, infection, pathogens, root-rot, swabi

Introduction

Agriculture is the backbone of Pakistan's economy on which the population of the country is dependent and also accounts for 26% ofthe productivity of the country. Cotton, rice, wheat, sugarcane, vegetables, and fruits are the major crops of Pakistan (Rehman *et al*., 2015). Pathogenic organisms damage vegetable crops and reduce production by killing the plants thus making the products unmarketable (Shafique *et al*., 2016).

Losses of crops highly threaten the rural farmer's income as well as the food productivity of the world. Pests and diseases are the major cause of such losses (Avelino *et al*., 2015). Crop losses areavery remarkable problem in Pakistan and all over the world. Plant-parasitic nematodes caused losses of US$ 100 billion per year to world agriculture (Kayani *et al*., 2018; Tariq-Khan *et al*., 2017).

Losses caused by pathogens, pests, insects, bacteria, fungi, and viruses are favoured by poor infrastructure, Post-harvest handling and climate change. A mycotoxin is also a problem creator. Fungi releases mycotoxins which are continuously contaminating the maize crops in store houses as well as in fields. Mismanagement of mycotoxin contamination of maize affects humans as well as animal's health (Suleiman and Kurt, 2015).

The soil-borne plant pathogens infecting plant roots are one of the most important problems facing world agriculture that reduces yield and quality in economic crops (Aslam *et al*., 2017 a,b; Katan, 2017). In Pakistan, the pathogenic fungi and nematodes attacked different crops (Zarins and Shahina, 2010). The loss of vegetables in quantity and quality is due to their susceptibility to many soil and root diseases (Chehri *et al*., 2010). Among the most important plant pathogens, *Fusarium* and its most of the species recognized as major cause of root infection, reported in Sindh and Balochistan (Parveen *et al*., 2020), it causes great losses in grain crops globally (Savary *et al*., 2012).

Wheat, Rice, and Maize are the most demanding crops of the world (Suleiman *et al*., 2013). Almost 10.14

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billion metric tons of maize is currently producing worldwide (De Groote *et al*., 2013). A huge amount of (grain) maize is stored and harvested under humid and hot climate in tropics and subtropics because hot and humid climate conditions facilitates fungal growth of maize (Egal *et al*., 2005), foremost lack of knowledge of equipment and drying methods also lead to wastage (Weinberg *et al*., 2008)

Pakistan is facing anannual loss of eggplant (*Solanum melongena* L.) due to its high susceptibility to root rotting fungi *F. oxysporum*, *Macrophomina phaseolina*, *Fusarium solani* and root-knot nematode (*Meloidogyne* spp.) (Baloch *et al*., 2013). Almost 500 species of more than 100 families of plants are highly susceptible to *M. phaseolina* which include food source (maize and sorghum), vegetables (tomato, potato, onion and garlic) oil producers (sunflower, soybean and castor), pulses (green gram, mung bean, groundnut and sesame) and fiber producers (cotton) (Das *et al*., 2008). Infection caused to these crops remains in the soil for more than 4 years in the form of *sclerotia* (Islam *et al*., 2012). At the onset of favourable conditions, *sclerotia* penetrate the cell wall by producing hyphae and cause disease (Suleiman and Kurt, 2015).

In Pakistan, different plant species like Mango (Mohsan *et al*., 2011), Tomato (Akhtar *et al*., 2004) and *Aloe vera* (Bajwa *et al*., 2010) are affected by common disease caused bya black spot of *Alternaria*. Major plant pathogens are *Alternaria* species cause 20% losses and most serve the losses reach up to 80%. The leaves, stems, flowers and fruits are affecting by these pathogens (Nowicki *et al*., 2012), while 38.8% loss was reported of Okra in the area of Punjab (Husain *et al*., 2012). Losses ranged (6.75% to 15.5%) and root incidence ranged were estimated by root rot fungi in Multan. (Inam-ul-Haque *et al*., 2012).

Remarkable research on losses by soil-borne plant pathogens has not been done in Pakistan. The existing report, therefore, describes the estimation of losses caused by root rotting fungi and root-knot nematodes in some important crops grown in Khyber Pakhtunkhwa.

Survey of diseased fields for the assessment of crop losses. A survey of diseased fields of total (35) areas located in four different districts of Khyber Pakhtunkhwa like Buner including 4 different areas: (Nogram, Panjtar, Chengli and Buner), Swabi including 23 different locations (Seen Khel, Gohati, Bikot, Bamkhel, Saleem Khan, Maneri, Bikot, Yarhussain, Manki, Shahid Banda, Ismaila, Topi, Sudher, Dagai, Tordhor, Kernnal Sher khan, Dobian, Marghuz, Jalabai, Darra, Maini, Kunda, Shahmansoor and Kalu Khan) Mardan (Shahbaz Gallei, Takhat Baye and Sheik meltoon) and Haripur included 5 locations (Ghazi, Haripure, Bagh banda, Nelor, Parhala) was carried out for estimation of losses in different seasons due to root-knot nematodes and root infecting fungi in 14 different economically important crops. An interview was conducted from farmers to analyze the estimated production and actual production which was recorded.

Specimens of roots of plants infected with root-knot and root-rot pathogens were collected and examined in the laboratory for identification and isolation of organisms causing disease. From each field, five samples were collected which were then kept at 4 °C and the isolation has been done within 24 h.

Determination of crop losses percentage. The percentage of crop losses by root infecting fungi was determined by the following formula.

$$\text{Losses\%} = \frac{\text{Obtained yield (diseased plants)}}{\text{Standard yield of healthy plants}} \times 100$$

Isolation of fungi from roots. Root samples were washed under tap water and 1% Ca $(OCl)_2$ was used for surface sterilization. These samples were then transferred on PDA containing *Streptomycin* (0.2g/L) and penicillin (100000 units/L). Infection and colonization were confirmed after incubation of dishes for a time of 5 days at 28 °C.

Percentage of infection and colonization was calculated as follows:

$$\text{Infection \%} = \frac{\text{No. of plant infected by pathogen}}{\text{Total no. of plants}} \times 100$$

$$\text{Colonization \%} = \frac{\text{No. of root samples colonized by a pathogen}}{\text{Total no. of root sample of all plants}} \times 100$$

Identification of root-knot nematodes. For this purpose root showing infection was sliced into pieces and dissected using a stereo-microscope. Ten pieces from each sample showing pear-shaped females were collected and transferred to the slide, while samples with the

perennial pattern were cut from each female using a sharp razor in a dissecting microscope and after comparison with a known pattern of certain nematodes *Meloidogyne* species were identified after comparing with pattern provided according to Taylor and Sasser (1978).

Root-knot index (0-5 scale). ***Root-knot index:*** Infection of roots by knot forming nematode was estimated using a 0-5 scale described by Taylor and Sasser (1978).

Statistical analysis. Data has been analyzed statistically by finding out the Pearson Correlation of infection and colonization percentage and comparison of means losses of different economically important crops by using IBM SPSS STATISTICS (Sokal and Rohlf, 1995).

Results and Discussion

Estimation of crop losses with association of soil-borne plant pathogens in diseased filed. During the survey, fourteen different plant species were taken under consideration to check the losses percentage caused by soil-borne fungus and root-knot nematodes in different areas of Khyber Pakhtunkhawa.

Losses percentage varies among different areas from 10% to 77% (Table 1). 25 different pathogenic fungi were found responsible to causes losses in 14 different hosts, while maximum host was infected by M. phaseolina (8 hosts), Alternaria alternata (11 hosts), Fusarium solani (9 hosts), Rhizoctonia solani (10 hosts) Penecilium spp (8 hosts) and A. solani (8 hosts) (Table 2).

Among root-knot nematodes *Meloidogyne javanica* 4(R.K) and *M. incognita* 3(R.K) both were associated with chili and eggplant (Fig. 1).The maximum infection percentageof *M. phaseolina* (100%) was found associated with diseased roots of *Nicotiana tabacum*, while Pearson correlation (0.924) shown significant at P-value= 0.001 between percent infection and colonization which was responsible to cause 20 to 52% losses. The ladyfinger was associated with different pathogens, while infection percentage of *F. solani* was maximum 100% and Pearson correlation (0.765) revealed significant at P-value= 0.001 between percent infection and colonization which was and responsible 50 to 72% losses while mean differences of losses, (58) were found highly significant at P-value=0.001. Highest percent infection of *M. phaseolina* (100%) in chili and Pearson Correlation (0.766) shown significant at P-value= 0.001 between percent infection and colonization which caused 25 to 65% losses and mean differences of losses (50.5) was found highly significant at P-value =0.001. The maximum infection percentage of *R. solani* (100) and *F. oxyporum* (100) in eggplant and Pearson Correlation (0.78) revealed significant at P-value= 0.001 between percent infection and colonization which was responsible to cause 20 to 76% losses, while mean differences of losses (47) was found highly significant at P-value =0.001. The *Zea maize* was associated with different pathogens, while infection percentage of *Drecslera* spp was maximum 100% and Pearson Correlation (0.977) reveal significant at P-value= 0.01 between percent infection and colonization which was responsible 50 to 77% losses, while mean differences of losses (61.33) were found highly significant at P-value =0.05. Highest percent infection of *A. alternata*, *R. solani* and *F. solani* were (80%) in Tomato plant and Pearson Correlation (0.779) represented significant at P-value= 0.05 between percent infection and colonization which was to cause 14 to 62.5% losses. The wheat was associated with *A. alternata* was maximum 100% and Pearson Correlation (0.614) reveal significant at P-value= 0.001 between percent infection and colonization which was responsible 10 to 65% losses, while mean differences of losses (28.75) was found the highly significant at P-value =0.001. The highest percent infection of *A. solani* was (80%) in garlic plant to cause up 60% losses in Topi, while mean differences of losses (22.5) were found significant at P-value =0.05. The maximum infection percentage of *A. alternata* (80%), Pearson correlation (0.737) reveal significant at P-value= 0.01 between percent infection and colonization which was found associated with diseased roots of mustard and responsible to cause 15 to 40% losses, while mean differences of losses (28.29) was found highly significant at P-value =0.001.The clover was associated with different pathogens, while infection percentage of *M. phaseolina* wasa maximum 80% and responsible up to 48% losses in Topi, while mean differences of losses (33.25) was found significant at P-value =0.01. In onion infection percentage of *F. oxysporum* (80) and Pearson Correlation (0.647) reveal significant at P-value= 0.01 between percent infection and colonization which was responsible 20 to 60% losses, while mean differences of losses (27.63) were found highly significant at P-value =0.001. The Turnip was associated with different pathogens, while the infection percentage of *A. alternata* was a maximum of 80% and responsible up to 80% losses in Jalabi, while mean differences of losses (46.5) were found

Table 1. Losses caused by soil borne pathogens in some economic crops in different districts of Khyber Pakhtun Khwa.

Names of crops	Location	Area of cultivation Sq ft	Obtained yeild (Kg)	Standard yeild (Kg)	Losses %
	Panjtar	16335	400	500	20
Nicotiana tabacum	Seen khel	81675	1000	2100	52
(Tobacco)	Gohati	544.5	90	180	50
	Seen Khel	544.5	85	170	50
	Gohati	544.5	90	180	50
Abelmoscus esculantus	Nogram	10890	600	1500	66
(Ladyfinger)	Bamkhel	544.5	50	180	72
	SaleemKhan	816.75	90	230	60
	Bikot	38115	2500	5000	50
	Panjtar	544.5	98	150	65
	Gohati	272.25	4	10	60
	Nogram	544.5	13	25	48
Capsicum annum	Bamkhel	272.2	3	7	57
(Chili)	Saleemkhan	544.5	7	20	65
	Maneri	1089	30	50	40
	Kalu khan	5445	50	90	44
	Yar hussain	16335	600	800	25
	Nogram	10890	60	250	76
	Bamkhel	816.75	12	25	52
	Saleemkhan	10890	120	250	52
	Maneri	16335	100	280	64
Solanum melongena	Kalu khan	10890	200	250	20
(EggPlant)	Maneri	21780	280	400	30
	Kalu khan	2722.5	17	60	71
	Gohati	816.75	15	20	25
	Seen khel	544.5	9	18	50
	Manki	5445	700	1000	30
	Seen khel	43560	550	2400	77
Zea mays	Bikot	16335	300	700	57
(maize)	Gohati	1905.75	100	200	50
	Panjtar	10890	200	500	60
Solanum lycopersicum	Shaheed banda	544.5	150	400	62.5
(tomato)	Ismaila	10890	3000	3500	14
	Shahbaz gallei	27225	2300	2700	15
	Yarhussain	5445	2000	2500	20
	Parhala	5445	2700	3500	23
		54450	4400	5000	12
	Sudher	5445	2200	2500	12
	Nelor	10890	1500	2000	25
		21780	1500	3000	50
	Dagai	16335	1200	1500	20
	Tordher	10890	700	1200	42
		16335	2000	2500	20
Triticum estivum		27225	1000	2000	50
(Wheat)	Kernal Khan Sher	87120	1400	4000	65
		87120	2800	4000	40
	Dobian	43560	1200	2000	40
	Marghuz (2 fields)	43560	800	1000	20
		10890	600	1000	40
	Jalbai	5445	2000	3500	43
	Darra	5445	3000	4000	25

	Buner	27225	2800	3300	15
	Maini	54450	27000	30000	10
	Kunda	38115	2100	2400	13
	Darra	54450	2700	3000	10
	Ghazi	816.75	5	6	17
Allium sativum	Takhat Baye	5445	4	5	20
(Garlic)	Kunda	2178	17	20	15
	Tordher	27225	1750	2000	12.5
	Topi	861.7	200	500	60
	Dobian	21780	1500	2000	25
	Kalu khan	27225	1200	2000	40
Brassica compestres	Takhat Baye	3267	28	40	30
(Mustard)	Shahabaz galei	54450	2300	2700	15
	Bagh banda (Haripur)	8167.5	50	80	38
	Kunda	816.7	8	10	20
	Swabi	5445	8	15	47
Trifolium repens	Sudher	5445	10	15	33
(Clover)	Shaikh meltoon	5445	12	20	20
	Jalabai	5445	20	30	33
	Thorder	3267.0	120	200	40
	Chengli	5445	300	500	40
Allium cepa	Yarhussain	5445	400	500	20
(Onion)		10890	600	900	25
	Darra	5445	350	500	30
	Haripur	10890	400	1000	60
	Ghazi	21780	2500	3500	29
	Jalabai	5445	200	1000	80
Brassica rapa	Swabi	1780	200	700	67
(Turnip)	Sheikh meltoon	1089	50	80	37
	Shamansoor	1361.25	70	95	26
	Thorder	8167.5	700	1000	30
Raphanus sativus	Ghazi	1089	70	88	23
(Radish)	Kunda	544.5	35	45	22
	Haripur	27225	2000	2500	20
(*Pisum sativum*)	Miani	10890	800	1400	43
Pea	Jalabai	5445	150	400	62.5

Table 2. Root-rot and root-knot pathogens associated with some economic crops.

Names of crops	Location	Major pathogen associated with roots	Infection%	Colonization%
Nicotiana tabacum	Panjtar	*Macrophomina phaseolina*	100	40
(tobacco)		*Alternaria alternate*	20	4
		Fusarium solani	20	4
	Seen Khel	*M. phaseolina*	60	12
		F. solani	20	4
	Gohati	*M. phaseolina*	60	32
		F. solani	20	4
		Rhizoctonia solani	60	32
Abelmoscus esculantus	Seen Khel	*M.phaseolina*	100	40
(ladyfinger)	Gohati	*M. phaseolina*	100	31
		R. solani	60	13
		Drecslera. spp	20	8
	Nogram	*R. solani*	40	16

		F. solani	80	32
		F. oxysporum	20	4
		M. phaseolina	60	13
	Bamkhel	*F. solani*	100	80
		R. solani	60	36
		F. oxysporum	40	20
		M. phaseolina	60	32
	Saleem Khan	*R. solani*	80	24
		F. solani	60	20
		M. phaseolina	60	20
	Bikot	*M. phaseolina*	60	20
		R. solani	20	40
Capsicum annum (chili)	Panjtar	*M. phaseolina*	60	20
		A. alternate	20	4
		Meloidogyne javanica 4(RKI)		
	Gohati	*M. phaseolina*	100	32
		R. solani	20	4
		M. incognita 3(R.K)		
	Nogram	*R. solani*	60	12
		M. phaseolina	80	32
		F. solani	60	20
		F. oxysporum	20	4
	Bamkhel	*R. solani*	60	12
		F. solani	60	24
		M. phaseolina	60	28
		F.oxysporum	60	12
	Saleem khan	*M. phaseolina*	60	12
		R. solani	100	32
		F. solani	60	16
	Maneri	*M. phaseolina*	100	80
		R. solani	80	20
		F. solani	20	4
	Yar Hussain	*F. oxysporum*	80	16
		Phytophthora capsici	40	8
		Penicilium. spp	60	12
	Kalu khan	*R. solani*	80	32
		F. solani	60	12
		M. phaseolina	20	4
		F. oxysporum	20	4
Solanum melongena (Eggplant)	Nogram	*R. solani*	20	4
		F. solani	60	8
		M. phaseolina	20	4
		F. oxysporum	100	32
		M. Javanica (RKI 4)		
	Bamkhel	*R. solani*	60	12
		F. solani	60	12
		M. phaseolina	20	4
	Saleem khan	*R. solani*	100	32
		F. solani	40	12
		F. oxysporum	20	4
		M. phaseolina	20	4
	Maneri	*M. phasolina*	60	24
		F. solani	40	24
		M. incognita (RKI 3)		
	Kalu khan	*M. phaseolina*	80	64
		R. solani	40	32
		F. solani	20	4
	Maneri	*R. solani*	80	24

		F. oxysporum	20	4
	Kalu khan	*M. phaseolina*	80	36
		F. oxysporum	20	4
	Gohati	*M. phaseolina*	100	80
		F. solani	60	32
	Seen khel	*M. phasiolina*	60	32
		F. solani	20	4
Zea mays (Maize)	Seen khel	*A. solani*	20	4
		F. solani	20	4
		Drecslera. spp	100	32
	Bikot	*R. solani*	20	4
	Gohati	*Drecslera*. spp	60	12
Solanum lycopersicum (Tomato)	Panjtar	*M. phasiolina*	60	12
		A. alternata	80	32
		R. solani	20	4
	Shaheed banda	*M. phasiolina*	60	32
		A. alternata	20	4
		R. solani	80	64
	Ismaila	*F. solani*	80	32
		A. solani	80	32
		Erysiphe. spp	60	16
(*Triticum estivum*) Wheat	Shahbaz banda	*Rhizopus*. spp	60	24
		Mucor. spp	20	4
		Ascomycetes	20	4
	Yarhussain	*Penicilium*. spp	40	12
		Mucor. spp	20	8
	Parhala	*A. alternata*	100	20
		Erysiphe. spp	80	12
		Penicilium. spp	60	12
		Aspergillus niger	40	8
		A. alternata	60	12
		Erysiphe. spp	80	32
	Sudher	*Erysiphe*. spp	60	12
		A. alternate	60	32
		Penicilium. spp	80	16
	Nelor	*Penicilium.* spp	60	32
	Dagai	*Cladosporium*	20	4
		A. alternata	60	20
		A. solani	40	32
		Rhizopus. spp	20	4
	Tordher	*F. solani*	60	32
		A. alternate	80	40
		Penicilium. spp	40	8
		Cladoporium. spp	40	16
	Kernal Sher Khan	*Penicilium*. spp	80	40
		Mucar. *spp*	40	8
	Dobian	*Penicilium*. spp	20	4
		A. alternata	60	16
	Marghuz	*F. solani*	60	28
		A. alternate	80	24
		Penicilium. spp	40	8
		Cladoporium, spp	40	12
		Erysiphe. spp	40	20
	Maini	*A. solani*	80	16
		Penicilium. spp	40	16
		Erysiphe. spp	20	4
	Darra	*Erysiphe*. spp	80	16
		A. solani	40	8

		Aspergillus. spp	60	12
	Kunda	*A. solani*	80	16
		Penicilium	60	12
	Jalbai	*Erysiphe*. spp	40	8
		A. solani	60	4
		Candida vulgaris	20	4
		Penicilium. spp	40	8
	Ghazi	*A. alternata*	60	4
		R. solani	60	28
Allium sativum (Garlic)		*Mucor*. spp	60	12
		Aspergillus. spp	40	84
	Darra	*F. solani*	60	20
		A. solani	80	36
		Penicilium. spp	40	16
	Takhat Baye	*A. solani*	60	36
		Rhizopus. spp	40	16
		Albugo candida	20	8
		F. solani	40	16
	Kunda	*A. solani*	25	16
		Albugo candida	50	20
	Tordher	*Penicilium*. spp	40	8
		A. solani	80	52
		Rhizopus	60	28
		F. solani	60	20
	Topi	*A. solani*	80	32
		R. solani	60	44
		A. niger	20	8
(*Brassica compestress*) Mustard	Dobian	*Rhizopus*. spp	80	16
		Mucor. spp	40	8
		Penicilium. spp	20	4
	Kalu khan	*A. alternate*	80	38
		Penicilium. spp	20	8
	Takht Baye	*A. solani*	40	8
		M. phaseolina	60	12
		B. cineria	40	8
	Shabaz gallei	*Geotricum candidum*	60	18
		Rhizopus. spp	80	12
	Bagh Banda	*A. solani*	60	16
		Penicilium. spp	20	4
	Kunda	*Rhizopus*. spp	60	8
		M. phaseolina	60	20
Trifolium repens Clover	Swabi	*A. alternata*	60	40
		Penicilium. spp	40	32
	Jalabai	*M. phaseolina*	60	12
		A. alternata	40	24
		Erysiphe. spp	60	12
		Penicilium. spp	40	20
	Sudher	*M. phaseolina*	80	24
		A. alternata	40	8
		A. niger	60	12
		Penicilium. spp	60	12
	Sheikh meltoon	*A. flavus*	80	16
		R. solani	60	12
		Cladosporium. spp	40	8
		A. alternata	20	4
		Erysiphe. spp	020	44
(*Allium cepa*) Onion	Thorder	*Erysiphe*. spp	60	24

		A. solani	40	8
		Penicilium. spp	20	28
		C. vulgaris	40	8
	Chengli	*Oidium*. spp	60	24
		Penicilium. spp	80	24
	Haripur	*F. oxysporum*	80	32
		F. semitectum	60	20
		F. proliferatum	40	24
		A. solani	20	48
	Darra	*Oidium*. spp	60	24
		A. alternate	40	8
		Cladosporium. spp	40	8
		Penicilium. spp	80	28
	Yar hussain	*Penicilium*	80	28
		Alternaria. spp	40	8
		Cladosporium. spp	40	8
(*Brassica rapa*)Turnip	Jalabai	*M. phaseolina*	40	8
		B. cineria	40	8
		A. alternata	80	16
	Sheikh meltoon	*M. phaseolina*	80	16
		B. cineria	60	12
		A. alternata	60	12
	Swabi	*A. solani*	60	40
		R. solani	60	28
		A. flavus	60	12
		Mucor. spp	40	4
	Shah mansoor	*B. cineria*	60	12
		A. solani	20	4
		M. phaseolina	80	16
	Ghazi	*Rhizopus*. spp	40	20
		A. solani	60	32
		Erysiphe	80	20
		F. solani	80	16
Raphanus sativus (Radish)	Ghazi	*A. alternata*	40	8
		Penicilium. spp	20	4
		Rhizopus. spp	60	12
	Kunda	*A. solani*	40	8
		Penicilium. spp	20	4
		G.candidum	20	4
	Tordhor	*A.raphani*	40	8
		Penicilium. spp	80	16
		B. cineria	60	12
		Cladosporium. spp	40	8
Pisum sativum (Pea)	Haripur	*R. solani*	60	24
		F. moniliform	80	32
		F. solani	20	8
		A. flavus	20	4
		A. alternata	40	12
	Miani	*F. moniliform*	60	12
		R. solani	40	8
		A. flavus	20	4
		A. alternata	60	12
		Rhizopus. spp	40	8
		Penicilium. spp	20	8
	Jalabai	*R. solani*	40	8
		A. flavus	60	12
		A. alternata	60	12

Fig. 1. Root-knot infection caused by *Meloidogynae* spp in Brinjal and Chili plant.

significant at P-value =0.01. The radish was associated with different pathogens, while the infection percentage

Table 3. Pearson correlation of infection and colonization percentage of different economically importance of crops of Pakistan.

Scientific name of crop	Common name	Pearson correlation	P-value
Nicotiana tobacum	Tobacco	0.924**	0.001
Abelmoscus esculantus	Ladyfinger	0.765***	0.000
Capsicum annum	Chili	0.766***	0.000
Solanum melongena	Eggplant	0.78***	0.000
Zea mayz	Maize	0.977**	0.004
Solanum lycopersicum	Tomato	0.779*	0.013
Triticum estivum	Wheat	0.614***	0.000
Allium sativum	Garlic	0.325	0.161
Brassica compestres)	Mustard	0.737**	0.003
Trifolium repens	Clover	0.335	0.223
Allium cepa	Onion	0.647**	0.005
Brassica rapa	Turnip	0.377	0.136
Raphanus sativus	Radish	1.00**	0.000
Pisum sativum	Pea	0.798**	0.001

Note: * = P<0.05; ** = P<0.01; *** = P<0.001

Table 4. Comparison of means losses of different economically important crops of Pakistan.

Crop	Mean	Std deviation	t	P-value
Nicotiana tobacum	40.667	17.93	3.929	0.059
Abelmoscus	58***	9.55	14.87	0.000
Capsicum annum	50.5***	13.95	10.24	0.000
Solanum melongena	47***	19.88	7.48	0.000
Zea mayz	61.33*	14.01	7.58	0.017
Solanum Lycopersicum	45.5	27.31	2.89	0.102
Triticum estivum	28.75***	15.62	8.38	0.000
Allium sativum	22.42*	18.74	2.93	0.033
Brassica compestres)	28.29***	9.07	8.25	0.000
Trifolium repens	33.25**	11.03	6.03	0.009
Allium cepa	27.63***	9.84	7.94	0.000
Brassica rapa	46.5**	21.92	5.97	0.003
Raphanus sativus	25*	4.36	9.93	0.01
Pisum sativum	40.88*	17.48	4.68	0.018

Note: * = P<0.05; ** = P<0.01; *** = P<0.001

of *Rhizopus* spp. was amaximum of 60% and responsible up to 30% losses in Thorder, while mean differences of losses (25) was found significant at P-value =0.05. Maximum infection percentage of *F. moniliform* wasa maximum of 80% and Pearson correlation (0.798) reveal significant at P-value= 0.01 between percent infection and colonization which was responsible 20 to 62.5% losses in Pea plant, while mean differences of losses (40.88) was found significant at P-value =0.01. (Table 1- 4). The soil-borne pathogens have been received little attention which is caused the extent of losses (McDonald and Linde, 2002) and is very difficult to control (Haas and Defago, 2005). Fungi and root-knot nematodes attacking the roots of crop plants in Pakistan have been reported (Kayani and Mukhtar, 2018; Khan *et al*., 2017; Hussain *et al*., 2016). The most common root-rot pathogens found in all the visited areas in 14 different plant species were *M. phaseolina*, *R. solani*, *A. alternate*, *A.solani* and two species of *Fusarium* namely *F. oxysporum* and *F. solani*. While two species of root-knot nematode *M. incognita* and *M. javanica* were also found causing root knot disease.

In combination or alone these pathogens causing huge losses. Annual losses of over 10 million in tobacco (*N. tabacum*) from black shank have been reported in North Carolina alone (Mila and Radcliff, 2014). *M. phaseolina*, *R.solani* and *F. solani* were found responsible up to 52% in Seen Khel and 50% in Gohati in the fields of

tobacco plants. In ladyfinger (*E. esculentus*) maximum loss (72%) was recorded in the area of Bamkhel caused by *F. solani* with the combination of other fungi. Chilli fields located in the area of Panjtar were severely infected with the combine effects of *M. phaseolina* and *M. javanica* and responsible to cause 65% losses. Jalaluddin *et al*. (2008) reported that charcoal root rot disease caused by *Macrophomina phaseolina* in sunflower (*Helianthus annus*), more than 500 different hosts can infect by this pathogen (Khan, 2007). In chili pepper plant pathogens attack roots, stems, leaves and fruits and cause 70% to 100% yield losses (Liu and LU, 2003).

Eggplant in the area of Nogram was severely infected with the combine effect of *M. javanica* and *F. oxysporum* and responsible to cause 76% losses. Effect of *F. oxysporum* and *Meloidogyne* are known to increase disease severity in cotton (Starr *et al*.,1989), other crops (Fateh *et al*., 2017). Mukhtar *et al*.(2017a) reported losses of crops due to plant-parasitic nematodes were 100 billion per year to world agriculture. The association of fungi with pathogenic nematodes caused greater losses has been reported (Rivera and Aballay, 2008). Vascular wilt fungus *Fusarium* spp. have been recognized for many years and the association of root-knot nematodes and severity of *Fusarium* wilt of cotton was greater when *Meloidogyne incognita* infected plants (Atikinson, 1892). In 34 districts of Punjab, *Meloidogyne incognita* was found with ubiquitous distribution (Irum, 2009; Khan and Ahmad, 2000). The common incidence of these root rot pathogens in Pakistan is presumably due to a temperature of 25-35 °C favorable for the growth of these pathogens which prevails in most of the year. A temperature of 26-30 °C is optimum for the growth of *R. solani* 28-35 °C (Papavizas and Klag, 1970) for *M. phaseolina* (Dhingra and Sinclair, 1978) 25-30 °C for *F. oxysporum* and 27-30 °C for *F. solani* (Domsch *et al*.,1980), whereas, the root-knot nematodes (*Meloidogyne* spp.) are found to cause a 5% loss on aworld-wide basis (Cetintas and Yarba, 2010).

Conflict of Interest. The authors declare no conflict of interest.

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