Documentation of wheat diseases of the trans-himalayan Ladakh region of India

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Abstract

Ladakh is one of the most elevated inhabited regions of the world found in the cold arid trans-Himalayan region of India bordering with China and Pakistan. Like other such regions of the world, Ladakh is also highly vulnerable to climate change and severe environmental threats reducing crop productivity due to risk of agricultural pest and plant pathogens. This document provides the first thorough status of wheat diseases encountered in the region. This study, completed in 2004 and 2005, revealed that while wheat was grown at the 53 out of the total 95 locations surveyed, barley was grown at all the locations. Wheat diseases were investigated in 265 fields of the various blocks, *viz.*, Leh, Khaltsi, Kharu, Nobra, Nyoma and Durbuk of the Leh district and Kargil and Shargole blocks of Kargil district. Hotspots of the encountered diseases were also identified and marked that can be used as the suitable sites to screen wheat genotypes and to know consequences of climate change on the occurrence of wheat disease in the future. Yellow rust, powdery mildew, foliar blight, loose smut, foot/root rot, ear cockle, molya and tundu /spike blight/yellow ear rot diseases were encountered on wheat. However, yellow rust, ear cockle, tundu, molya and foot/root rot were recognized as the most destructive diseases of wheat. This basic work seems to be unique and has ample value to plant protection personnel, plant breeders, extension workers, farmers and policy makers of this region.

Keywords: Wheat diseases, geographical distribution, hotspots, loss appraisal, trans-himalayan Ladakh region

Introduction

Second to barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.) is the next most common cereal crop of Ladakh, encompassing 21 per cent of the total sown area of 22,443 hectares (Sharma and Mir, 1997; Anonymous, 2001). The wheat varieties Mansarovar, Sonam, Kailash and Singchen, commonly grown in this region, were released by the Regional Agricultural Research Station, Leh of Sher-e-Kashmir University of Agricultural Sciences and Technology-Kashmir. In addition to these varieties, some local land races, viz., Tukchumin, Sermotoktok and Tokarmo, are also grown. Wheat is used primarily to make chapatti and various bakery items, viz., bread, biscuits, cakes and cookies. Vaish *et al.* (2011) described the characteristics of the geography and landscape and various other features including the patterns of cereal cultivation in Ladakh. More than 97 per cent of the cultivated area of Leh is under mono-cropping system, whereas most of the area of Kargil district is under double cropping system. The double-cropped area has a longer period than that of the mono-cropped area to grow crops. The second crop of the double cropped area may include foxtail millet (*Setaria italica* L.) and some vegetable crops, *viz.*, turnip, radish, cabbage, and leafy vegetables.

The current studies were conducted during 2004 to 2005 at 95 locations in all the six blocks, *viz.*, Leh, Kharu, Khaltsi, Nobra, Nyoma and Durbuk within district Leh and Kargil and Shargole blocks of the district Kargil. The surveyed locations were observed for the cultivation of wheat and barley and assessments were made to record prevalence, incidence, severity and economic importance of wheat diseases that were encountered. The geographical distribution of the diseases, their hotspots and rank of their importance were studied. The sowing dates of wheat, probable periods of disease occurrence and the maximum development of the diseases were also recorded. The scientific implication of the present work lies in how this valuable information can be used for the effective management of wheat diseases. This work also emphasizes the need to survey regularly and assesses the risk with respect to future climate change.

Material and methods

Mapping of the surveyed area along with travel routes: The dates during which wheat disease status were studied in Leh, Khaltsi, Kharu, Nobra, Nyoma and Durbuk blocks of Leh district and Kargil and Shargole blocks

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of Kargil district were similar to those mentioned in the first documentation of the barley diseases in the Ladakh region compiled by Vaish *et al.* (2011). The diseases of wheat were also monitored during roving surveys since 2001, but systematic and intensive surveys were conducted from 2004 to 2005 under a project on studies on status of diseases of cereals, pulses and oil seed crops in high altitude cold arid region of India: Leh (Ladakh). The status studies were accomplished from 27th May-29th May, 27th July-1st August and 28th August-2nd September, 2004 in Leh, Kharu and Khaltsi blocks of the district Leh; however in the Nobra, Nyoma and Durbuk blocks of the district Leh and Kargil and Shargole blocks of the district Kargil from 1st July-8th July, 15th July-20thJuly and 25th July-30th July, 2005. The area surveyed, the routes travelled and altitude of the region were mapped using a map source software, Global Mapper-7 and the coordinate data collected by a Global Positioning System (GPS) device (make- Garmin, eTrex, Taipei, Taiwan). The topographical map was also supplemented using Shuttle Radar Topographic Mission (WRS-2) data paths 147-149 and the rows 36-37 to display topographical features of the region (Fig.1).

Geographical distribution of wheat cultivation and its diseases: The locations of wheat cultivation are depicted by open circles to distinguish them from the distribution of barley cultivation, which is marked by the filled circles. The varying magnitude of the severity of wheat diseases encountered at the various locations along with the hotspots (area of regular occurrence and high incidence and severity) in the region were recorded and are delineated on a map (Fig. 2). Various shapes are used to indicate each particular disease, while, various colours (green, yellow, and blue) are used to indicate the degree of severity. The red is used to show hotspots of the encountered diseases on the map. Hotspots of the encountered diseases were identified based on field investigations from 2004-2005. The information were collected from the farmers about the history of occurrence of the diseases and their high magnitude (i.e., high incidence and severity) during the course of survey studies. The different locations of the various blocks are also shown by the different colours.

Collection of plant samples, identification and scoring of diseases: Stops were made during the course of the survey if crops were present in the area. Observations were taken from five wheat fields at each location. Five wheat fields were observed at each location. The collection of the diseased samples, their diagnosis and the scoring of the wheat diseases encountered were performed according to the description and the methods for barley diseases by Vaish *et al.* (2011). The sowing periods of the wheat in a block along with the altitude were recorded. The probable periods of the occurrence of diseases and its maximum development along with the growth stages of the crop were also recorded. The growth stages of wheat were confirmed using the Zadoks' scale (Zadoks *et al.*, 1974).

The diseases were identified based on their typical symptoms under field conditions and further confirmed by microscopic observations. Pathogens were also isolated where deemed necessary. *Cochliobolus sativus* (Ito& Kurib) Drechs.ex Dast., *Alternaria alternata* (Fr.) Keissler and *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoemaker; *Puccinia striiformis* Westend. f. sp. *tritici* Eriks; *Blumeria graminis* (DC.) Speer f. sp. *tritici* Marchal; *Cochliobolus sativus* (Ito& Kurib) Drechs.ex Dast. and *Rhizoctonia solani* Kuhn; *Ustilago segetum* var. *tritici* (Pers.) Brun and *Heterodera avenae* (cereal cyst nematode) were identified as cause of foliar blight, yellow rust, powdery mildew, foot/root rot, loose smut and molya using the relevant laboratory techniques (Ainsworth and Sampson, 1950; Mundkur and Thirumalachar, 1952; Cooper, 1955; Cummins, 1959; Hesling, 1965; Mulvey, 1972; Duran, 1973; Eliss, 1976; Alcorn,1983; Ahmed *et al.*, 1986; Sivanesan, 1987; Alexopoulos *et al.,*1996; Sneh *et al.,* 1991). Ear cockle disease was identified by splitting open a water-soaked gall/cockle with a needle in cavity block (50 mm) containing 2 ml sterile distilled water to liberate the second stage juveniles (J_2s). These J_2s were examined and the pathogen was confirmed as *Anguina tritici* (Steinbuch) Filipjev (Thorne, 1961). Tundu disease, also known as spike blight/yellow ear rot, is caused by an association of *A. tritici* with *Clavibactor tritici.* The yellow gum-like substance exuding from the infected ears was confirmed as *Clavibactor tritici* (Carlson & Vidaver) Davis *et al.* by gram positive staining, yellow pigmentation, growth on a selective medium [CNS (25)] and various biochemical tests (Schaad *et al.,* 2001).

Disease prevalence was estimated according to the formula given by Iram and Ahmed (2005). The incidence and severity of loose smut, foliar diseases and cereal cyst nematode were recorded as described for barley diseases by Vaish *et al.* (2011).The incidence and severity of ear cockle and tundu/spike blight/yellow ear rot were also estimated according to the description given for loose and covered smut in barley (Vaish *et al.,* 2011). The modified Cobb's method, the per cent pustule coverage of green tissue and the reaction type, were used to score yellow rust (Peterson *et al.*, 1948). The various types of the rust reaction on wheat leaves was recorded viz., S=susceptible, MS=moderately susceptible, and MR=moderately resistant. A four category scale was followed to score the cereal cyst nematode that causes molya disease: VL (one cyst/plant=very low), L (2-3cyst/plant=low), M (5cyst/plant= medium) and H (more than 5cyst/plant = high).

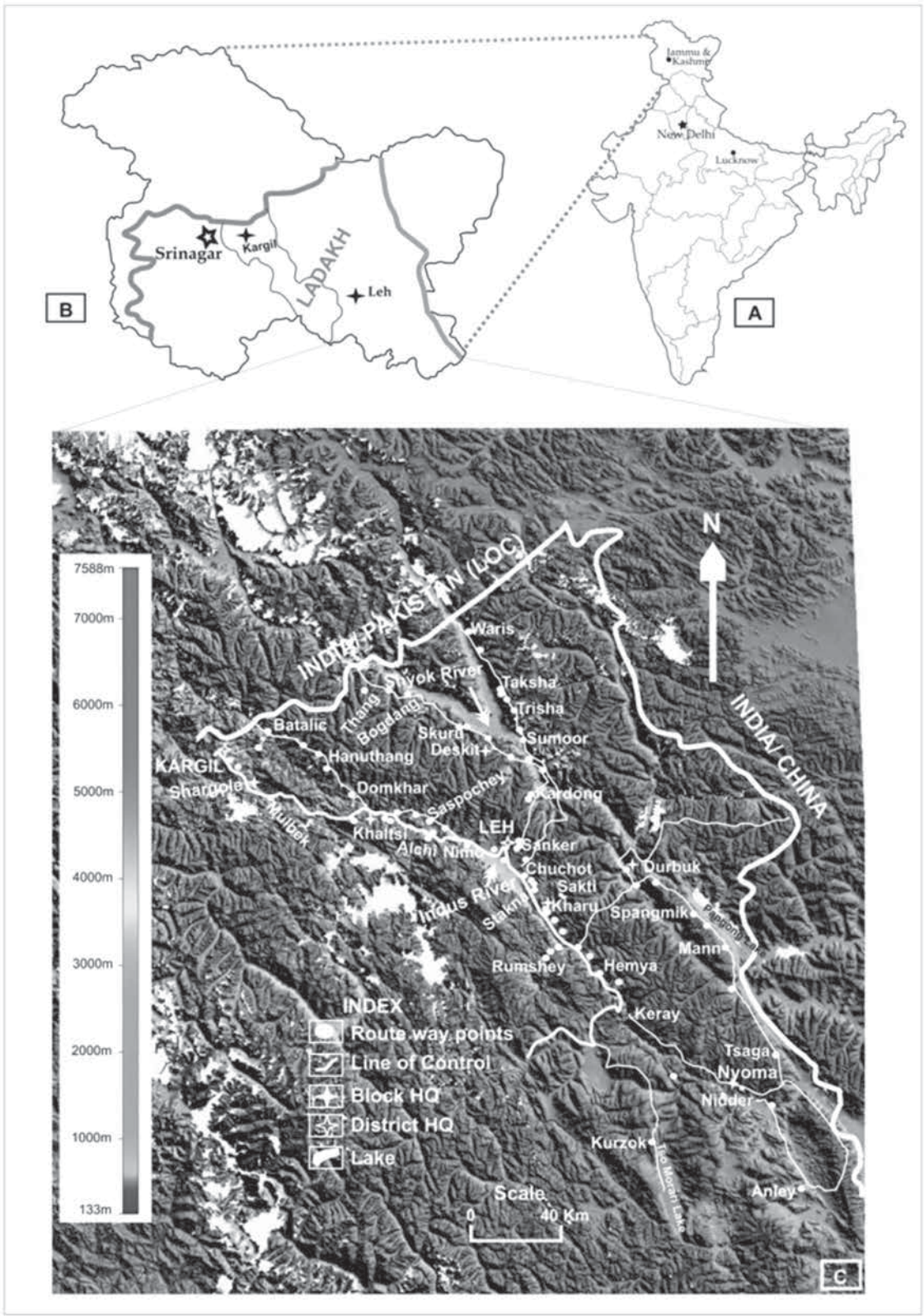

Fig. 1. Depicting area surveyed and routes followed in the Ladakh region of India along with altitudes of the surveyed locations and topographical features.

Appraisal of yield losses: The estimation of the yield losses due to foliar, foot/root rot and molya diseases was based on the comparison of yield of 25 infected vs. healthy spikes. Because of loose smut, ear cockle and tundu cause complete damage of the grain containing structures (ears/heads), losses were directly correlated to per cent incidence and per cent severity of these diseases. Therefore, the losses due to these diseases were equated to per cent incidence. However, the losses caused by the other diseases were graded as severely, moderately, and slightly infected. The wheat fields showing >20, 5-20 and < 5per cent disease incidence were marked as severely, moderately, and slightly infected fields, respectively. The amount of loss in the each category was estimated based on five representative fields having severe, moderate and slight infections.

Results and discussion

Geographical distribution of wheat cultivation in the region: The distribution of wheat cultivation is clearly distinguished from the distribution of barley cultivation in Fig. 2. Wheat was found growing mainly in Leh, Khaltsi, Nobra and Kharu blocks except at one location (Liktsey) of Nyoma block of Leh district. However, wheat was cultivated in all the locations inspected in the both blocks (i.e., Kargil and Shargole) of Kargil district. The cultivation of wheat was recorded at 53 locations out of the total 95 locations surveyed. In contrast, barley was grown at all the surveyed locations.

Further, the cultivation of wheat was confined to the locations at lower altitudes with longer growing seasons, but barley was grown at all the locations irrespective of the altitude or the length of the growing season in the entire Ladakh region. Surveyed wheat fields were in grain filling /ripening, seedling to stem elongation/ jointing, flowering and ear emergence/heading stages and showed their prevalence in 48, 20, 12 and 20 per cent fields, respectively.

Sowing periods and the occurrence of the diseases: The data on sowing periods and probable occurrences and growth stages of the crops are given in Tables 1 and 2, respectively. It was noted that early sowing is practiced in Khaltsi, Shargole, Nobra and Kargil blocks at lower altitudes, whereas, the locations within to Leh and Kharu at higher altitudes recorded late showings of the crop. The varying altitudes and resulting variations in crop-suitable environment were the main reasons to alter the sowing dates per periods.

The confluence of the weather favourable to disease development, the crop stage susceptible to disease and arrival of the pathogen inoculum predicted the occurrence and development of the diseases. The information concerning the sowing dates and probable periods of the occurrence and the development of the diseases can predict the presence of the crop and its diseases in the different parts of Ladakh.

Wheat diseases and their geographical distribution in the region: The incidence, maximum severity and prevalence of the encountered foliar, root, ear cockle, tundu/yellow ear rot and loose smut diseases of wheat are presented in Table 3. Their geographical distributions along with the hotspots are delineated in Fig.2. These diseases were observed in 265 wheat fields from 2004-2005 under the various 53 locations had wheat crop. Loose smut was the most prevalent wheat disease found in 207 of the 265 fields. The majority (97%) of the loose smut-infected fields had a low (<5%) incidence/severity of the disease, but, its highest severity (7.4%) was also recorded in some fields.

The second most prevalent problem was cereal cyst nematode that causes molya disease. It which was found in 139 fields and more than half of the fields inspected (53%) and exhibited a disease incidence between 5-20 per cent. Some (6%) of the cereal cyst nematode-infested fields revealed an infestation between 30-40 per cent with highest severity of 15-155 cysts per plant. The problem of cereal cyst nematode was present at 50 locations and there were 9 hotspots, viz., Skampuk, Hunder, Deskit, Skurbuchan, Thickshey, Shey, Chuchot, Rambirpora and Khaltsi. However, of the total 50 locations, 27 locations were moderately infested, and three locations were severely infested.

Foot per root rot was encountered in 96 fields at varying levels of disease incidence and showed the highest severity of 54 per cent. A disease incidence of less than 20 per cent was observed in nearly 79 per cent of the fields monitored.

This disease was present at 46 locations with hotspots at Basgo, Thickshey and Khalsar. The ear cockle nematode (ECN) was present in 66 fields with a maximum incidence of 38 per cent. Half of the ear cockle-infected crops had less than 10 per cent, while six fields had 30-40 per cent disease incidence. This disease was distributed over 31 locations. It was most severe in Spituk, Phyang, Nemo, Basgo and Liktsey.

Table 1. Sowing periods of wheat crop over the various surveyed blocks in the Trans- Himalayan Ladakh region of India

Block	Sowing period	Altitude (m.a.s.l.)
Leh	May(2nd week)-May(4th week)	3167-3722
Kharu	May(2nd week)-May(4th week)	3406-3744
Durbuk	Crop not sown	3948-4289
Nyoma	Crop not sown*	3576-4650
Nobra	March (2nd week) -April(1st week)-May(2nd week)	2887-3990
Khaltsi	March(1st week)-May(4th week)	2724-3635
Shargole	March (3rd week)- April (3rd week)	2978-3350
Kargil	March (3rd week)- April (2th week) – May (2th week)	2687-3787

*except at a location (Liktsey) towards Kharu

Bold figures, showing number of the month; italic figures, showing number of the week; figure in parenthesis, showing growth stages of wheat based on the Zadoks' scale during which occurrence and maximum development of the diseases can be seen subject to weather conditions

Tundu/spike blight/yellow ear rot a bacterial disease encountered in a region overlapping that covered by the ear cockle nematode that acts as a vector of the bacterium. This disease was recorded in 52 fields with a maximum incidence of 22.5 per cent, whereas; a disease incidence between 5 per cent and 10 per cent and 10 per cent and 20 per cent was also noticed in approximately 26 per cent and 21 per cent of the fields, respectively. This disease was present at 20 locations with hotspots at Spituk, Phyang, Nemo and Basgo.

Foliar blight, powdery mildew and yellow rust were observed in 54, 52 and 150 fields with maximum severity of 9, 7 and 80S (S-susceptible type reaction), respectively. Majority of powdery mildew infected-fields were rated at 3 and 5 severity grade on the 0-9 disease scoring scale, whereas the disease incidence varied between 10-20 per cent. The incidence of foliar blight varied from 5 to >60 per cent. In majority of fields, incidence of foliar blight varied between 10-20 per cent and revealed a maximum severity grade of 3. The yellow rust infected-fields exhibited great variability in terms of both the severity and incidence. Most of the yellow rust-infected fields confirmed a severity of 40S, followed by 10S and 20S.

The geographical distributions of yellow rust, foliar blight and powdery mildew revealed that these diseases were present at 49, 31 and 32 locations, respectively. There were 9 yellow rust hotspots; they include-Choglamsar,Chuchot, Shey, Thickshey, Rambirpora, Stakna, Nemo, Basgo and Kargil. The foliar blight hotspot appears to be at Kargil only. Beema and Dah were recognized as hotspots of powdery mildew.

Throughout the survey, viral diseases were absent. Wheat crop in the region revealed the symptoms of zinc deficiency with 12 per cent prevalence. The recorded diseases were arranged in a descending order by considering together their prevalence, incidence, severity and mode of survival (seed, soil, or air borne) because of all these factors play a key role in the development of the diseases. The diseases were ranked as follows: yellow rust > molya >foot/root rot > ear Cockle>tundu > loose smut > foliar blight > powdery mildew >zinc deficiency. The diseases were also ranked within each block (Table 4).

Estimation of yield losses: The losses due to foot/root rot, cereal cyst nematode, foliar blight, powdery mildew and yellow rust based on grain yield (g) of 25 spikes collected from farmers' fields are shown in Table 5.The encountered diseases caused varying amounts of losses in the severely, moderately and slightly infected fields. The losses to wheat yield owing to foot/root rot and the cereal cyst nematode varied from 4 per cent to 44 per cent and 5 per cent to 53 per cent, respectively. The maximum yield loss (5%–62%) was caused by yellow rust followed by foliar blight (3%–18%) and powdery mildew (3%–13%).The losses due to ear cockle, tundu and loose smut diseases were equated to their incidence in severely, moderately and slightly infected-fields (Table 5). In severely infected-wheat fields, ear cockle and tundu caused the maximum yield losses as much as 38 per cent and 22.5 per cent, respectively. Loose smut reduced wheat yield by as much as 5.5 per cent.

The distribution of wheat cultivation in Ladakh is mainly confined to four blocks viz., Khaltsi, Nobra, Leh and Kharu of Leh district. However, wheat is rarely cultivated at any location of Durbuk and Nyoma blocks except at a single location (Liktsey) of Nyoma block near Kharu block at lower altitudes.

Table 2. Most probable periods/ growth stages for the occurrence and maximum development of wheat diseases over various surveyed blocks of Ladakh region of India during 2004 to 2005

Block	Yellow/ Stripe rust *Puccinia striiformis* f.sp.*tritici*	Powdery mildew *Blumeria graminis* f.sp. *tritici*	Foliar blight *Cochliobolus sativus Bipsorokiniana Alternaria alternata*	Foot/ root rot *Rhizoctonia solani Cochliobolus sativus*	Ear cockle *Angina tritici*	Tundu /spike blight/ yellow era rot *Angina tritici Clavibactor tritici*	Loose smut *Ustilago segetum* var. *tritici*	Molya (cereal cyst nema tode) *Heterodera avenae*
Leh	**8**,*3*-**9**,*3* (50-91)	**6**,*3*-**8**,*3* (40-85)	**6**,*2*-**9**,*3* (30-91)	**6**,*2*-**8**,*4* (30-87)	(50-59)	(50-59)	(50-59)	**6**,*2*-**8**,*2* (30-85)
Kharu	**8**,*3*-**9**,*3* (50-91)	**6**,*3*-**8**,*3* (40-85)	**6**,*2*-**9**,*3* (30-91)	**6**,*2*-**8**,*4* (30-87)	(50-59)	(50-59)	(50-59)	**6**,*2*-**8**,*2* (30-85)
Khaltsi	**6**,*3*-**9**,*2* (50-91)	*5*,*4*-**7**,*4* (40-85)	*5*,*2*-**9**,*2* (30-91)	*5*,*2*-**7**,*4* (30-87)	(50-59)	(50-59)	(50-59)	*5*,*2*-**7**,*2* (30-85)
Nobra	*5*,*3*-**6**,*4*-**8**,*3* (50-91)	*5*,*1*-**6**,*3*-8,*1* (40-85)	**4**,*3*-**5**,*3*-**8**,*3* (30-91)	**4**,*4*-**5**,*3*-**7**,*4* (30-87)	(50-59)	(50-59)	(50-59)	**4**,*4*-**5**,*3*-**7**,*2* (30-85)
Shargole	**6**,*3*-**8**,*3* (50-91)	*5*,*4*-**8**,*1* (40-85)	*5*,*3*-**8**,*3* (30-91)	*5*,*3* - **7**,*4* (30-87)	(50-59)	(50-59)	(50-59)	*5*,*3* – **7**,*2* (30-85)
Kargil	**6**,*3*-**8**,*3* (50-91)	*5*,*4*-**8**,*1* (40-85)	*5*,*3*-**8**,*3* (30-91)	*5*,*3* - **7**,*4* (30-87)	(50-59)	(50-59)	(50-59)	*5*,*3* – **7**,*2* (30-85)

Table 3. Number of infested fields, disease incidence, maximum severity and prevalence of foliar, foot/root rot, ear cockle, tundu, cereal cyst nematode and loose smut diseases of wheat encountered in trans-Himalayan Ladakh region of India during 2004 to 2005

Disease	No. of infested field[a]	Disease incidence (%)										Highest severity[b]	Disease prevalence (%)
		<1	1-3	3-5	5-10	10-20	20-30	30-40	40-50	50-60	>60		
	150	-	-	-	11 (7.3)	32 (21.3)	24 (16.0)	25 (16.6)	17 (11.3)	14 (9.3)	27(18.0)	**80S**	
	3	-	-	-	1	2	-	-	-	-	-	10MR	
	2	-	-	-	-	1	1	-	-	-	-	10MS	
Yellow/ stripe rust	3	-	-	-	-	1	2	-	-	-	-	20MS	
Puccinia striiformis f.sp.*tritici*	32	-	-	-	9	21	2	-	-	-	-	10S	56.6
	29	-	-	-	1	7	16	-	2	3		20S	
	40	-	-	-	-	-	3	22	7	3	5	40S	
	25	-	-	-	-	-	-	3	8	7	7	60S	
	9	-	-	-	-	-	-	-	-	1	8	70S	
	7	-	-	-	-	-	-	-	-	-	7	80S	
	52	-	-	-	7 (13.5)	20 (38.5)	9 (17.3)	8 (15.4)	5 (9.6)	1 (1.9)	2 (3.8)	**7**	
Powdery mildew	34	-	-	-	7	20	5	2	-	-	-	3	19.6
Blumeria graminis f.sp. *tritici*	10	-	-	-	-	-	4	3	2	1	-	5	
	8	-	-	-	-	-	-	3	3	-	2	7	
	54	-	-	-	8 (14.8)	20 (37.0)	11(20.4)	6 (11.1)	4 (7.4)	3 (5.6)	2 (3.7)	**9**	
Foliar blight *Cochliobolus*	28	-	-	-	8	16	4	-	-	-	-	3	
sativus Bipolaris sorokiniana	17	-	-	-	-	4	7	6	-	-	-	5	20.4
Alternaria alternata	7	-	-	-	-	-	-	-	4	3	-	7	
	2	-	-	-	-	-	-	-	-	-	2	9	
Foot/root rot *Rhizoctonia solani Cochliobolus sativus*	**96**	-	5 (5.2)	12 (12.5)	27 (28.1)	32 (33.3)	12 (12.5)	3 (3.1)	3 (3.1)	2 (2.1)	-	**54****	36.2
Loose smut: *Ustilago segetum* var. *tritici*	**207**	85 (41.1)	88 (42.5)	29 (14.0)	5 (2.4)	-	-	-	-	-	-	**7.4****	78.1
Ear cockle (seed gall nematode) *Angina tritici*	**66**	-	6 (9.1)	8 (12.1)	19 (28.8)	16 (24.2)	11 (16.7)	6 (9.1)	-	-	-	**38.0****	24.9
Tundu /spike blight/yellow era rot *Angina tritici* *Clavibactor tritici*	**52**	5 (9.6)	7 (13.5)	8 (15.4)	14 (26.9)	11 (21.2)	7 (13.5)	-	-	-	-	**22.5****	19.6
Molya (cereal cyst nematode) *Heterodera avenae*	**139**	-	-	18 (14.2)	51(34.6)	39(26.8)	18(14.2)	8(6.3)	5(3.9)	-	-	**H**	52.5
Zinc deficiency symptoms	**32**	-	-	-	-	-	-	-	-	-	-	**-**	12.1

*[a]', out of 265 fields inspected; [b]', rust: % pustule coverage of green tissue(severity) and reaction type(response); reaction type, S= susceptible, MS= moderately susceptible, MR= moderately resistant; foliar diseases(0-9 scale);**, highest per cent of ear or plants infected; figures in parentheses, showing per cent of fields under the disease incidence group over number of fields infested; H, high severity (>5cysts/plant, however, number of cyst/plant varied from 15-155)*

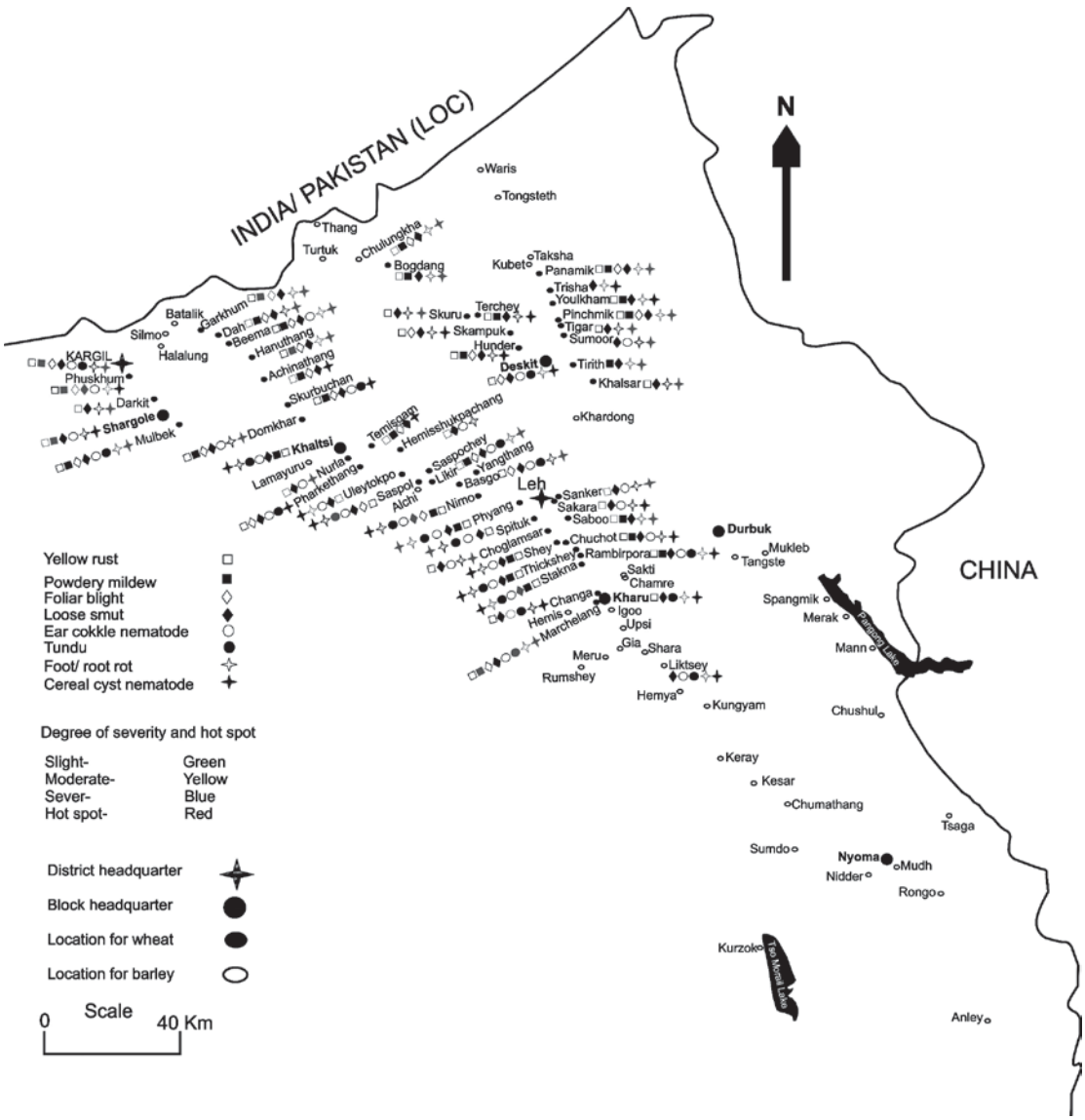

Fig.2. Showing distribution of wheat and barley cultivation, disease specific geographical locations and hotspots of the encountered diseases in the Ladakh region of India.

Table 4. Ranking of the encountered diseases of wheat for the surveyed blocks of Ladakh during 2004 to 2005

Name of the block	Ranking of disease
Leh	Yellow rust > Ear Cockle>Tundu > Cereal cyst nematode >Foot/root rot > Loose smut > foliar blight > powdery mildew
Kharu	Yellow rust > Cereal cyst nematode >Foot/root rot > Ear Cockle>Tundu > Loose smut > powdery mildew> foliar blight
Khaltsi	Yellow rust > Ear Cockle>Tundu >Cereal cyst nematode > Foot/root rot > Loose smut > Foliar blight > Powdery mildew
Nobra	Yellow rust >Cereal cyst nematode > Foot/root rot > Loose smut > Foliar blight > Powdery mildew >Tundu> Ear Cockle
Shargole	Yellow rust > Cereal cyst nematode >Foot/root rot > Foliar blight > Tundu > Loose smut > Powdery mildew
Kargil	Yellow rust > Cereal cyst nematode >Foot/root rot > Foliar blight > Tundu > Loose smut > Powdery mildew

Wheat grains infected with spores of loose smut and contaminated with galls of *A. tritici* (the ear cockle nematode) and *Clavibactor tritici* are commonly used as seed. These seeds are never treated against loose smut nor cleaned to remove galls of *A. tritici*. The higher prevalence of these diseases may be attributed to such practices. The wide spread occurrence and severity of *H. avenae* and foot/ root rot of wheat may be attributed to light textured sandy loam soils with gravels, low organic content and use of glaciers melted water for irrigation (Sharma and Mir, 1997; Bhattacharyya *et al*., 2008). Meagher (1977) also reported the severe occurrence of cereal cyst nematode in lighter soils. Further, dispersal of cysts of *H. avenae* could also occur through movement of soil with high velocity driven wind. Frequent occurrence of zinc deficiency symptoms in wheat crop appears to be due to leakage of mineral and non- availability of zinc to plants (Sharma and Mir, 1997).

Regular occurrence of yellow rust of wheat in the Ladakh region is a common thing due to the prevailing favorable environment i.e., low temperature and high relative humidity. It has also been experienced during six successive cropping seasons in this region that the rapid development and spread of yellow rust of wheat and barley at higher altitude is associated with occurrence of wind driven rain splashes from last week of July to first week of September (Unpublished). Vaish and Mir (2005) observed the maximum development of yellow rust of barley in Leh (Ladakh) during 3rd week of August to 3rd week of September that coincided with the heading to ripening stage when minimum and maximum temperatures and relative humidity were 6.4-9.1^{0}C, 22.4-27.4^{0}C and 77.0-86.1 per cent, respectively. Similarly, prevalence of stripe rust in the cooler part of the country in the foothills of Himalayas and adjoining plains was also recorded (Joshi *et al.*,1986).

It was observed during the study that the fields with higher incidence and severity of yellow rust and powdery mildew were along the river Indus and other sources of glacial melted water. It might be attributed to high humidity compared to the fields away from such sources. Development of powdery mildew of wheat and barley requires high humidity >95 per cent (Newton, 1993) which is contrary to other powdery mildew pathogens as their conidia have high water content and able to germinate at low level of humidity. Generally, the temperature conditions are very favourable for powdery mildews in Ladakh region as this disease occurs every year on several crop plants, fruit trees and flower and weed plants. Hence, it has been observed as the most common disease in this region. Moreover, the spread of the disease seems to be associated with the existing ideal conditions i.e., optimum temperature, moisture stress and wind velocity.

Table 5. Mean grain yield losses caused by foliar, foot/root rot, cereal cyst nematode, ear cockle, tundu and loose smut diseases of wheat in each category in the Ladakh region of India during 2004 to 2005

Disease	Grain yield per 25 spikes (g)*			
	Healthy crop	Severely infected crop	Moderately infected crop	Slightly infected crop
Yellow rust	71.08±0.15	26.70±1.20 (62)	62.1±0.14 (13)	67.86±0.19 (5)
Powdery mildew	68.62±0.19	59.47±0.17 (13)	63.74±0.22 (7)	66.68±0.12 (3)
Foliar blight	69.2±0.12	57.07±0.13 (18)	63.91±0.13 (8)	67.09±0.13 (3)
Molya (Cereal cyst nematode)	67.24±1.96	31.82±0.92 (53)	55.53±1.23 (17)	63.66±0.54 (5)
Foot/root rot	70.67±1.88	39.94±0.42 (44)	59.57±0.32 (16)	67.56±0.44 (4)
*Yield reduction (%)**				
Ear cockle†	69.69±1.08	31.5±6.5	8.0± 3.5	2.2±1.0
Tundu /spike blight/yellow era rot†	73.53±2.88	18.0±4.5	7.2±3.8	3.1±1.78
Loose smut†	72.88±1.32	-	-	3.5±2.2

Figure in parentheses, showing per cent reduction in grain yield over healthy crop and adjusted to whole figure; ± , standard deviation; *, mean of the five most representing fields for each category; -, not observed; † , per cent reduction in yield is directly equated to percent incidence and severity as loose smut, ear cockle and tundu per spike blight per yellow ear rot of wheat cause complete damage of grain containing structures (ears/ heads)

Yarwood (1950) also determined that high water content of powdery mildew conidia could cause the conidia to germinate at low atmospheric humidity while the spores of most other fungi could not germinate. Conidial germination of powdery mildew is considerably stimulated by their respective hosts under moisture stress (Yarwood, 1936). Powdery mildew of wheat (*B. graminis* f.sp. *tritici*) is amongst the diseases which is restricted to hills of North and South India experiencing frequent epidemics (Joshi *et al*., 1986). Similarly, severe powdery mildew of barley occurs in hills of north India.

Serious losses due to foot/root rot in a severely infected field might be attributed to decrease in plant height and spike length by 40 and 50-70 per cent respectively. Grain shrinkage due to reduced photosynthesis is considered as the chief cause for yield decline caused by powdery mildew and yellow rust. Discoloration and shrinkage of grains may be related to the losses caused by foliar blight. Crop yield losses caused by the encountered diseases in relation to the areas or blocks might be related to number of diseases and their severity (Fig. 2).

The anticipated yield losses owing to diseases at the different locations of a block would be fruitful in building a policy for their management. Keeping in view the above facts and observations, following recommendations are given to enhance the productivity of wheat crop in the Ladakh region:

- Sowing of seed should be done following treating the seed lot with the recommended fungicides, smutted ears must be removed during heading stage and exiting seed lot should be replaced if possible with resistant cultivars to manage loose smut of wheat.
- Seed lots must be cleaned using modern seed sanitation techniques such as gravity table seed processing, sieving, or freshwater /saline water flotation against ear cockle and tundu/ spike blight disease.
- Irrigation water should be managed properly along with application of organic amendments and effective bio-agents to curb foot/root rot disease.
- Two to three years crop rotation with non-host crops (e.g., mustard, lentil, carrot, and onion commonly grown in the region) along with management of irrigation water should be followed to minimize the losses caused by *H. avenae.*
- Preference must be given to the resistant varieties for the management of foliar diseases.
- Zinc sulfate should be applied in the deficient soil for the correction of zinc deficiency symptoms.

Acknowledgement

The research paper is an outcome of the research project (APCess/3030565185) financed by Indian Council of Agricultural Research. Mr. Fajul Rehman (Field-cum-Laboratory Attendant-FCLA), Namgyal (FCLA) and Rikjin Safal (FCLA) have provided their valuable help during the course of field and laboratory work with their intense attention and dedication.

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