International Journal of Applied Agricultural Sciences
2023; 9(2): 48-54
http://www.sciencepublishinggroup.com/j/ijaas
doi: 10.11648/j.ijaas.20230902.13
ISSN: 2469-7877 (Print); ISSN: 2469-7885 (Online)

Diversity of Pathotypes of Leaf Rust (*Puccinia triticina*) Pathogen in Wheat Crop in Nepal

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To cite this article:

Suraj Baidya, Subash Chandra Bhardwaj, Deepak Bhandari. Diversity of Pathotypes of Leaf Rust (*Puccinia triticina*) Pathogen in Wheat Crop in Nepal. *International Journal of Applied Agricultural Sciences.* Vol. 9, No. 2, 2023, pp. 48-54. doi: 10.11648/j.ijaas.20230902.13

Received: February 23, 2023; **Accepted**: March 20, 2023; **Published**: March 31, 2023

Abstract: Wheat (*Triticum aestivum*) is third most important crop in Nepal after rice and maize. The area of cultivation of wheat is increasing compare to last decade but its productivity could not be increased significantly due to many biotic and abiotic factors. Among them, rust disease is major biotic constraint. Leaf rust (*Puccinia triticina*) is an economically important disease which occurs on major wheat growing areas of plain and hill of the country. The leaf rust disease monitoring and samples collection were done from 32 districts across the wheat growing area. Rust infected leaves were folded such that rust pustules preserved inside without destroying spores. Excess leaf moisture was removed by keeping them in room temperature with shade drying. Proper dried samples were kept in paper envelop and diagnosed pathotypes at Indian Institute of Wheat and Barley Research (IIWBR), Indian Council of Agricultural Research (ICAR), Regional Station, Flowerdale, Shimla, India. urediospores were revived on 2% water agar and multiplied in susceptible host Agra Local. The fresh urediospores of each sample was collected from susceptible host and inoculated on 5-7 days old seedlings of the standard differential sets. The pathotypes of pathogen was diagnosed on the base on disease infection type showed in the differential sets. Pathotypes 57R39 121R63-1, 21R55, 109R31-1, 121R60-1, 93R15 and 93R39 were commonly observed in both plain and hills. Similarly, the pathotypes 125R23-1, 109R63 and 21R63 were recorded in lower belt whereas, pathotypes 5R13, 49R39, 125R28, 21R31 and 93R47 were found only at hilly regions. The pathotypes 21R55, 121R63-1, 121R63-1and 5R37 were recorded in successive years in most of the wheat growing area. Twenty one different pathotypes of *P. triticina* occur in different parts of the country. The evolving of different pathotypes diversity of pathogens may be caused by selection pressure due to same genetic materials of wheat genotypes grown in the country and conducive environment. Hence, monitoring rust pathotypes is a one of the necessary step for successful planning to manage the rust disease by developing resistant wheat genotypes.

Keywords: Leaf Rust, Pathogen, Pathotypes, *Puccinia triticina*, Wheat

1. Introduction

Wheat (*Triticum aestivum* L.) crop comes third important cereal crop after rice and maize in the country. The national average production and productivity of wheat are 2.16 million metric tons and 3.09 t/ha respectively [9]. The area of cultivation is slightly increased compare to last decade but its productivity could not be increased significantly due to several factors. Among them, rust and foliar blight are the major constrain. Among the rust disease both yellow and leaf rust are the major in which leaf rust is responsible to cause significant yields loss in wheat crops mainly in Terai/plain and also some parts of hills of the country.

On an average, wheat covers 22% of the total cereal cultivated area and contributes 17.3% of total cereal production in which hill areas represents 44% of the total its production. The majority of hills and mountain districts are often food deficit and wheat is a major crop that carries potential to increase food self sufficiency in traditional hill system where significant area remains fallow during the winter [1]. In the last decades, National Wheat Research Program (NWRP) has released several high yielding with rust resistance wheat genotypes to cope up with the problem of food deficiency in the country [12].

Leaf rust (*Puccinia triticina*) is an economically important disease mainly in river basin and Terai/plain foot hills. This disease was considered as number one disease in wheat early 70s when RR21, Kalyansona was cultivated widely [7]. Leaf rust (pathotype 57 and 12 groups) was seen in late 60's in Kalyansona and local cultivars and declined in some years after release of RR21. The pathogen spectrum changed and began to attack RR21 as well. Leaf rust pathotype groups 12, 77 and 104 are the common pathotypes prevalence in the country [6]. Similarly, in group 12, the pathotypes namely, 12-2, 77-2, 77-5, and in group 104, the pathotype 104 -3 were common in 80's. In 90's, pathotypes groups of leaf rust pathotypes namely, 12, 77, 104, and 106 were commonly recorded from different parts of wheat growing areas of the country. In 2000's, pathotype groups 12-5, 77-5 and 104-2 were predominant than others. Since, last few years, the pathotypes 77-5 and 104-2 became dominant in Kathmandu valley and mid hills of the country. The epidemic of new pathotype/s in every wheat growing season in different wheat growing areas might be due to spread of fungal spores in the common epidemiologic zones/regions. Hence, monitoring of rust pathogens is one of the essential activities for developing resistant genotypes for the management of the disease.

2. Methodology

An extensive monitoring of leaf rust disease was carried out across the wheat growing area of the country to find out virulence spectrum of different pathotypes with Global Positioning System (GPS) information of each location. The survey was covered 32 districts under seven different provinces from the elevation of 69 meter to 3164 meter. The districts were namely, Teharthum, Morang, Sunsari, Dhanusha, Mahottari, Makawanpur, Chitwan, Nawalparasi, Rupandehi, Dang, Doti, Dailekh, Jumla, Bajang, Kaski, Kathmandu, Lalitpur, Bhaktapur, Kavrepalanchok, Sindhupalchok, Dolkha, Pyuthan, Rautahat, Kailali, Siraha, Bara, Dhankuta, Surkhet, Saptari, Nawalpur, Dhading and Mustang. During monitoring, rust infected leaves were collected from the locations and folded them in such way that the rust pustules were preserved inside without destroying the spores. The samples were kept in room temperature to remove excess leaf moisture with shade drying for 24 hours. After proper drying the samples, two to three leaves samples were kept in paper envelop and sent to Indian Institute of Wheat and Barley Research (IIWBR), Indian Council of Agriculture Research (ICAR), regional station, Flowerdale, Shimla, India for diagnosis the pathotypes of *P. triticina* pathogen. Rust spores were revived on 2% water agar and multiplied in Agra Local. A small quantity (10 mg) of rust urediospores were suspended in light weight non phytotoxic 1-2ml paraffin oil (saltrol) mixed thoroughly and inoculated on standard differentials (Table 1) by spraying the spore suspension with the help of a conical glass automizer connected with a compressor pump. The inoculated plants were fine sprayed with water and incubated for 48 hours in a glass chamber placed under the glass house benches. The plants were then transferred on to the glasshouse cemented benches and immediately dusted with elemental dust powder of sulphur to avoid powdery mildew infection. The temperature of glasshouse was maintained at 22±2°C for leaf rust disease.

The response of host-pathogen interactions were recorded after 12-14 days for leaf rust. Based on infection type in differential lines, pathotypes were analyzed [10].

Table 1. *List of Standard differential set for leaf rust pathotypes of wheat rust pathogen (P. triticina) analysis.*

Set 0	Set A	Set B
IWP 94 (*Lr23*+)	*Lr14a*	Loros (*Lr2c*)
Kharchia mutant (*Lr9*)	*Lr24*	Webstar (*Lr2c*)
Raj 3765 (Lr13+10+)	*Lr18*	Democrat (*Lr3*)
PBW 343 (*Lr26+34+*)	*Lr13*	Thew (*Lr20*)
UP 2338 (*Lr26+34+*)	*Lr17*	Malakoff (*Lr1*)
K 8804 (*Lr26+23+*)	*Lr15*	Benno (*Lr26*)
Raj 1555	*Lr10*	HP 1633 (*Lr9*)
HD 2189 (*Lr13+34+*)	*Lr19*	
Agra Local	*Lr28*	

Soruce: Mehtaensis [17]

3. Result

Diversity of pathotypes of *P. triticina* pathogen was observed in the samples. There were six different pathotype groups of leaf rust recorded during 2014 to 2020 AD. They were 12, 52, 77, 104, 106 and 162 groups. All together 21 different pathotypes under these six groups were diagnosed in different time intervals from various locations. They are namely, 12-2, 12-3, 12-4, 12-5, 52-4, 77-1, 77-2, 77-3, 77-5, 77-6, 77-8, 77-9, 77-11, 77A, 104A, 104B, 104-2, 104-3, 106, 162A and 162-2. In which, the pathotypes, 12-5, 77-5, 162-2 and 104-2 were frequently recorded in successive years than other pathotypes (Table 2).

The pathotypes, 77A, 77-1, 77-3, 77-6 and 104-3 were more dominant in Terai/plain region whereas pathotypes 12-4, 77-2, 77-5, 77-9, 104-2, 106 and 162-2 were common in both hill and Terai regions. The pathotypes variant was high at hill area than the plain area (Figure 2). Pathotypes 77-1, 104-3, 12A, 12-4, 77-2, 77-5, 77-11, 104A and 162-1 were recorded since last decade whereas pathotypes 77 and 108-1 did not observed in last few years (Figure 1).

Table 2. *Distribution of pathotypes of leaf rust pathogens across the wheat growing area of the country.*

S.N.	Pathotypes			District	Year
	Old	New	International equivalent*		
1	12-2	1R5	FHTQL	Kavrepalanchok	2013/14
	12-3	49R37	FHTRL	Lalitpur	2013/14
	12-4	69R13	FGTTN	Bhaktapur, Dolkha	2013/14
	77-1	109R63	THTTQ	Rupandehi, Chitwan	2013/14
	77-3	125R55	THTTB	Chitwan	2013/14
	77-6	121R55-1	THTTL	Kaski	2013/14
	77-8	253R31	TQHPT	Dolkha	2013/14
	104-2	21R55	PHTTL	Sindhupalchok, Kathmandu, Lalitpur	2013/14
2	12-5	29R45	FHTKL	Kathmandu, Bhaktapur, Dolkha	2014/15
	77-5	121R63-1	THTTS	Dolkha	2014/15
	104B	29R23	MGTQN	Terharthum	2014/15
	12-4	69R13	FGTTN	Kathmandu	2014/15
	104-2	21R55	PHTTL	Bhaktapur	2014/15
	77-1	109R63	THTTQ	Kaski	2014/15
	77-2	109R31-1	TGTTQ	Saptahari, Siraha, Dolkha	2014/15
	77A	109R31	TGTKQ	Morang	2014/15
	104-3	21R63	PHTTL	Makawanpur, Dhanusha, Chitwan	2014/15
3	77-5	121R63-1	THTTS	Sunsari	2015/16
	104-2	21R55	PHTTL	Dhading, Dailekh	2015/16
	104-3	21R63	PHTKL	Kaski, Chitwan	2015/16
	106	0R9	BBBBB	Sindhupalchok, Rupandehi, Terharthum	2015/16
4	77-5	121R63-1	THTTS	Terharthum, Nawalparasi	2016/17
	12-4	69R13	FGTTN	Mohatari, Dang	2016/17
	12-5	29R45	FHTPM	Siraha, Saptari	2016/17
	104-2	21R55	PHTTL	Dang, Jumla	2016/17
5	77-5	121R63-1	THTTS	Surkhet, Doti, Mustang, Dolkha	2017/18
	77-9	121R60-1	MHTKL	Dolkha, Kavrepalanchok, Sindhupalchok, Mustang	2017/18
	104-2	21R55	PHTTL	Chitwan, Kaski, Dhanusha, Jumla, Mustang	2017/18
	162-2	93R39	KHTTL	Dang, Doti, Mohatori, Siraha, Mustang	2017/18
6	77-5	121R63	THTTM	Kathmandu, Dolkha, Kailali, Doti	2018/19
	77-9	121R60-1	MHTKL	Nawalpur, Sunsari, Kailali, Bara, Chitwan	2018/19
7	143	61R47	KHTPM	Dhankuta	2019/20
	77-9	121R60-1	MHTKL	Dolkha, Dailekh, Pyuthan, Bajang, Chitwan, Dang	2019/20
	104A	21R31	MGTDF	Dailekh	2019/20
	52-4	121R60-1,7	SGTKS	Pyuthan, Dhanusha, Makwanpur, Rautahat, Kailali	2019/20
	162A	93R15	KGTSB	Dailekh	2019/20
	77-11	125R28	MHTKP	Doti, Dolkha, Kathmandu, Sindhupalchok, Sunsari	2019/20

*The Indian pathotypes are equivalent with North American notation [8]

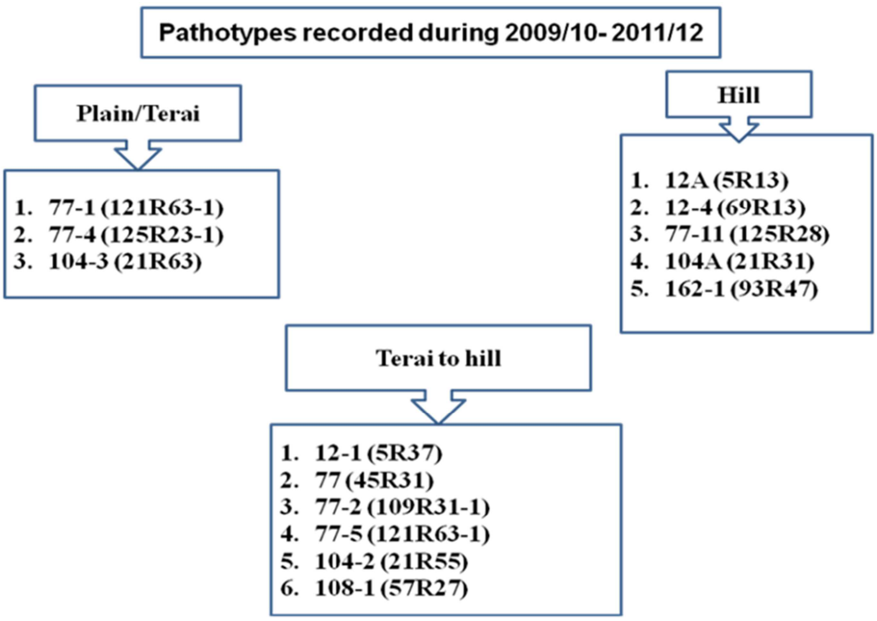

Figure 1. *Pathotypes of leaf rust pathogens recorded during 2009/10- 2011/12.*

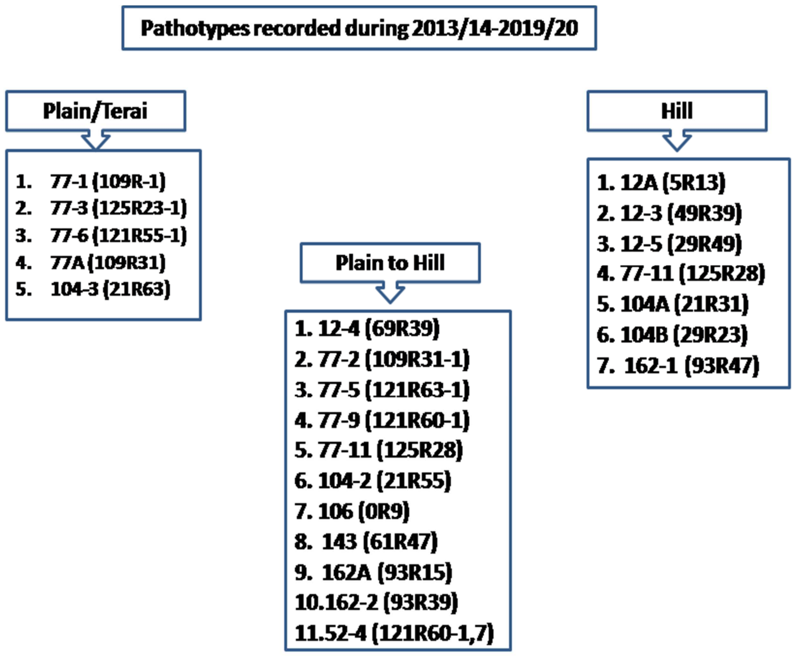

Figure 2. *Pathotypes of leaf rust pathogens recorded during 2013/14-2019/20.*

The evolutionary trend of three common pathotype groups i.e., 12, 77 and 104 were presented in figures 3, 4 & 5. The virulence of pathotypes in general is recessive that is why it is depicted in figures 1, 2 and 3 in letters (*vir.lr*). The small *vir.lr* indicates the corresponding virulence gene/s of leaf rust pathogen. For example, pathotype 12 was virulent on *lr3* gene, it was evolved 12-1 and 12-2 pathotype when the pathotype had additional capacity to virulent on *lr26* gene and *lr23* gene respectively. Later on the 12 group was evolved in 12-5 when it was virulent on *lr3*, *lr13*, *lr23* and *lr26* genes (Figure 3). In 70's, 77 pathotype group which was virulent to *lr1, lr3, lr15* and *lr20* observed in the country. Now, new pathotypes such as 77-6 and 77-11 were evolved when this pathotypes became additional feature for virulent on *lr10*, *lr23* with *vir.lr26* and *avir.lr26* respectively. Similarly, 77-9 dominant pathotypes became evolved with feature for virulent to many resistant gene/s such as *lr23, lr26, lr34, lr36, lr40, lr44, lr46* and *lr67* (Figure 4). Similarly, Within three decades pathotype 104 group of leaf rust pathogen having virulent nature to *lr1* and *lr3* became evolve to 104-1, 104-2 and 104-3 when it was possessed virulent on *lr20* and *lr23, lr23* and *lr26* and *lr20, lr23* and *lr26* genes (Figure 5).

Other than these three main groups of pathotypes, there was also recorded the distribution of pathotypes derivatives of 162 group. Likewise, pathotype 52, 106 and 143 groups were also reported from some parts of the country.

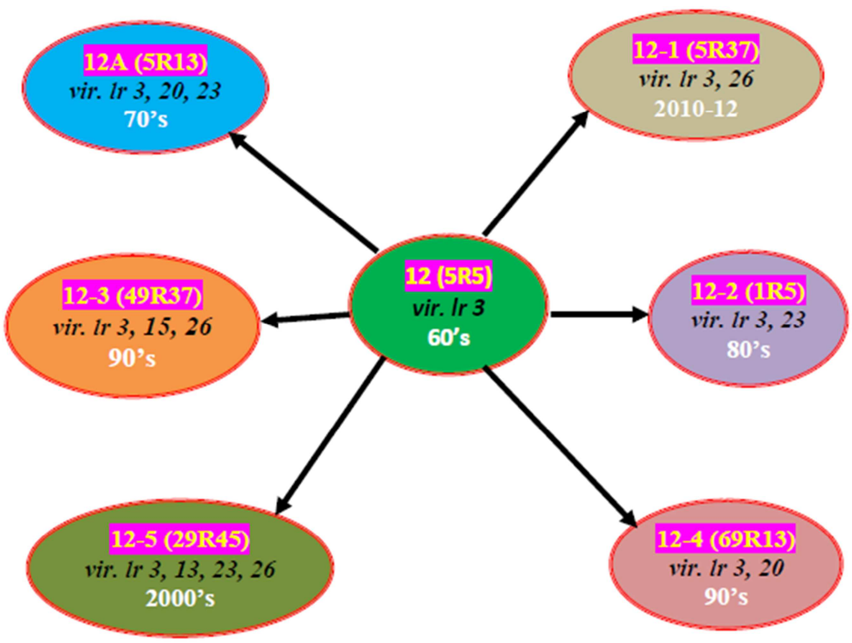

Figure 3. *Evolution of pathotype 12 group of P. triticina pathogen in the country.*

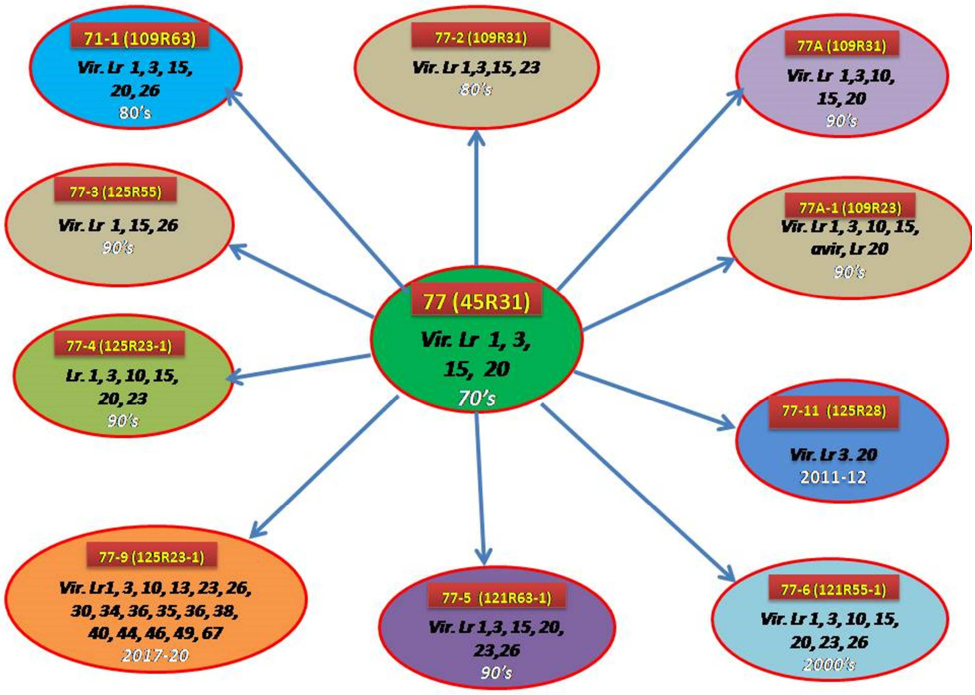

Figure 4. *Evolution of pathotype 77groups of P. triticina pathogen in the country.*

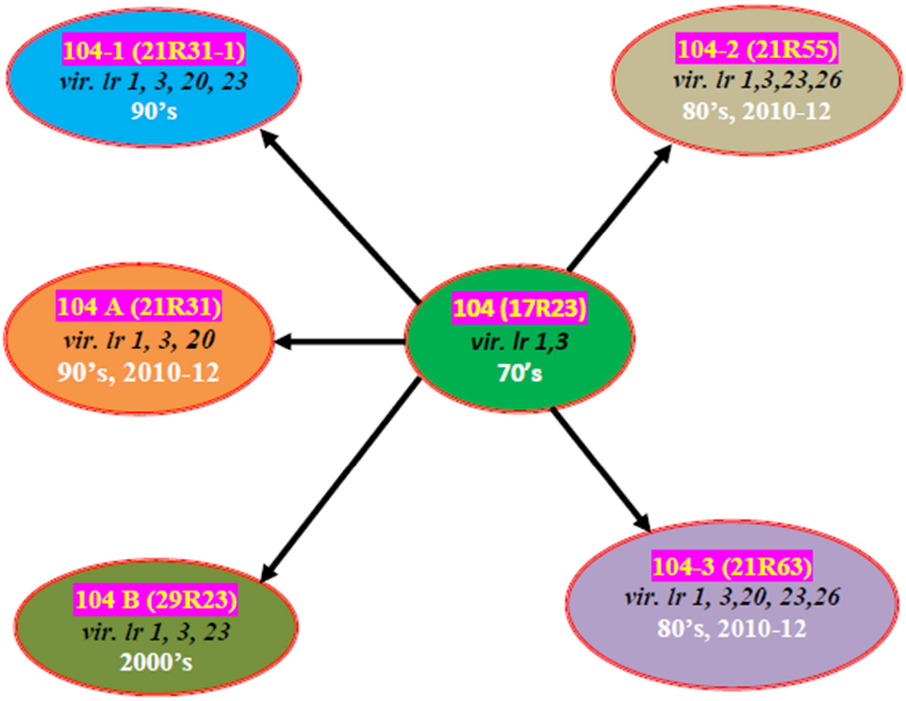

Figure 5. *Evolution of pathotype 104 group of P. triticina pathogen in the country.*

4. Discussion

Monitoring of wheat diseases is the most important event to know the status of the diseases of particular crops in surveyed areas. This should be regular and is required for effective deployment of wheat varieties and planning research priority. Surveillance of wheat diseases has been continued since last many years and information about pathotypes diversity of pathogen has also been recorded. The information showed that there is high diversity of pathotypes distributing since last decade at various locations of wheat growing areas of the country. The distribution pattern of pathotypes was also vary with altitude. Some of them, were only recorded in plain area and some were only recorded in hill area but most of them were common for both plain and hill regions (Figures 1 & 2). Some pathotypes were observed continuously since last decade and few were newly evolved like 77-9, 52-4 and 162-2. The pathotypes 104-2 (21R55), 77-5 (121R63-1), 12-4 (69R13) and 12-5 (29R49) have been recorded almost every year from different locations. Out of twenty one pathotypes, eleven were distributed in both plain and hill areas. The pathotypes diversity had more in hill area as compared to plain area. Around one fifth and one third of total pathotypes recorded in plain and hill areas respectively. The trend of evolution of different pathotypes showed ineffective of many genes with leaf pathotypes [2]. Virulence to wheat lines with *lr1, lr3, lr10, lr13, lr15, lr20, lr23* and *lr26* were most common in each year. The *lr* genes namely, *lr1, lr3, lr10, lr13, lr15, lr20, lr23, lr26* were found ineffective with the leaf rust pathotypes and the genotypes which had leaf rust genes like *lr19*, *lr34, lr46, lr48, lr49, lr67* and combination of more than one resistant gene/s showed tolerant to resistant with different pathotypes [11]. Many Nepalese genotypes had these gene/s, however, they performed tolerant against the leaf rust, and it might be due to presence of more than one gene in the genotypes. The gene *lr13* and *lr26* are found ineffective but they found durable type of reaction when combine with other gene/s. According to Bhardwaj [3], resistant gene *lr13* is also known to have durable types of resistance and therefore could play important role for additional resistance in wheat genotypes over the different pathotypes. Similarly, *lr1* was also not effective against virulence pathotypes of the leaf rust but showed resistant character when combination with other genes like *lr13*, *lr26* and other [18, 13]. Similarly, most dominant pathotype 77-9 had virulent on many resistant genes such as *lr1, lr3, lr10, lr11, lr12, lr13, lr14, lr23, lr26 lr30, lr33, lr34, lr36, lr37, l438, lr40, lr44, lr46, lr49* and *lr*67. However, the pathotypes showed avirulent to *lr24, lr25, lr29, lr32. lr39, lr45, lr47*, and *lr80* gene/s [17]. Due to incidence of this virulent pathotype many resistant genotypes became susceptible to leaf rust in many part of the country. Prevalence of different pathotypes of leaf rust pathogens, there are need to diversify of genotypes having different resistant genes for better management of year round epidemic of pathotypes derivatives and also to sustain yield of the genotypes for longer period of time [4].

The diversity of pathotypes and the recurrence of some pathotypes in most of the wheat season in the country is consistent with over summer survival of *P. triticina* within the country. This could be due to same genetic materials cultivated in same epidemiological regions and climate change with increase in temperature during wheat season. According to gene for gene theory of Flor [5], it was soon realized that the differential system of identification of pathotypes requires modification of order to suit to the changed situations. In addition, numerous procedures were also suggested which are based on near-isogenic or single known resistant genes helps to know the details of avirulence/virulence structure of the pathotypes. Since rusts are airborne, shifty pathogens and are able to cause epiphytotics, therefore, breeding for rust resistance has been challenging. Due to the changing or evolution of pathogen with respect to host pathogen interaction, at first some genotypes were immune or resistant to rust disease became susceptible. A pathotype was avirulent on known gene became virulent later due to newly evolved pathotype/s.

Disease situation are commonly vary with different year depending on the conducive climatic environment since last several years across the country. An average the leaf rust disease situation in last few years showed that around 80% of total samples found moderate to high disease reaction. The incidence level of leaf rust disease was nearly two third samples belongs to hill and rest from plain. The severity of disease in plain was low to moderate whereas severity level was moderate to high in hill area. In high hill, the severity level of disease was moderate level since last few years [15]. During 2014 to 2016, leaf rust was found severe at several places of mid hills including the Kathmandu valley and adjoining district of the valley. The level of disease was moderate to high (40MS-100S) in plain to river basin areas of the country [14]. The incidence and severity of disease were also vary in provinces. In province Koshi, the severity was low to high level. In Madesh province, around 80% samples of leaf rust was in low severity and rest 20% had moderate severity level. Similarly, in Bagmati province, leaf rust severity was low to high level. Likewise, in Gandaki province, the leaf rust, 50% of samples were high level and rest 25% each was low to moderate level. In Lumbini province, low to high level of leaf rust disease was recorded. In Karnali province, more than 50% samples of leaf rust was low level of severity and rest was medium to high severity. In Sudhur Pachhim province, leaf rust was low to high level of severity [16].

Rust pathogen is widely occurred with different severity level across the country and the scenario of rust pathotypes and their reaction are usually vary in every year depending upon the genetic materials planted and also the congenial climate condition. The severity of disease was commonly high in local or old genotypes than comparatively newly released genotypes. High population diversity of pathogen is observed in the *P. triticina* populations in the country. The Himalayan ranges in northern belt of the country and also availability of year round wheat crops (both main season and summer wheat) at high altitude areas may also serve as the source for the recurrence of rust for the Indo Gangatic plain and other part of the world. Hence, there are needed to do regular monitoring and understanding the population of rust pathogens in the Himalayan ranges to combat against rust disease with collaborationin national, regional and global organization. Continuous monitoring of rust pathogens presence is one of the necessary steps for successful planning to manage the rusts by deploying effective genes in breeding program. It is also important to keep attention on emerging new derivatives having different virulence level and also their migration pathway within the country and also one country to others. There are need to collaborative activity to Introduce different genetic sources for diversification of resistance genes is also an importance strategic planning to manage the rust disease within the country. Regular monitoring and field survey at different locations of plain and hill regions would be helpful to dig out the actual situation of disease and also successful planning to manage them by applying different means of control as integrated approaches on time.

5. Conclusion

Since last decade, more than twenty pathotypes of *P. triticina* have been evolved in different time interval in various parts wheat growing area of the country. The disease severity and incidence levels are also varying with locations and genotypes. Some pathogens are recorded from plain to hill areas and some of them are concentrated either in plain and hill areas only. The change in virulence spectrum of rust pathogens may be caused by selection pressure with host pathogen interaction due to same genetic background of wheat genotypes grown in the country and also neighbor countries. The resistance of a line/genotype with single effective resistance gene can easily overcome by pathogen. The year round evolution of different group of pathotypes with their derivatives indicate that the regular monitoring is an importance activity should be carried out regularly in each year to find out real situation of rust epidemic in different parts of the country for their proper management on time.

Acknowledgements

The authors thankful to all the plant pathologist and wheat breeders of Agriculture Research Stations, Directorate of Agricultural Research of different provinces and National Wheat Research Program, Bhairahawa for their valuable time to collect leaf samples from different wheat growing area for pathotypes analysis. We also thank to technicians of National Plant Pathology Research Centre (NPPRC), Khumaltar for their assist on sample collection and processing.

References

[1] Anonymous (2016). Annual Report 2003/04. Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur.

[2] Baidya S, SM Shrestha, BN Mahto, SC Bhardwaj, HK Manandhar, RB Thapa, S Sharma and AK Joshi. (2014). Pattern of Pathogen diversity in *Puccinia triticina* on Wheat in Nepal. Poster Presented in Borlaug Global Rust Initiative (BGRI) 2014, Technical Workshop be held in Ciudad Obregon, Mexico from 22nd -25th March, 2014.

[3] Bhardwaj, SC., Prashar, M, Kumar, Subodh and Datta, D. (2006). Virulence and diversity of *Puccinia triticina* on wheat in India during 2002-04. *Indian J. Agric. Sci*. 76: 302-306.

[4] Browning, JA. (1988). Current thinking on the use of diversity to buffer small grain against highly epidemic and variable foliar pathogens: Problems and future prospects 76-90pp. *In:* Breeding strategies for Resistance to Rust of wheat. N. W. Simmonds and S. Rajaram, eds. CIMMYT, Maxico.

[5] Flor, HH. (1955). Host parasitic interaction in flax rust- its genetics and other implications. Phytopathology 45: 680-685.

[6] Karki, C. B. 1972. Wheat disease report. Paper presented at the biannual winter crop workshop, Department of Agriculture, Lalitpur, Nepal.

[7] Karki CB and S Sharma. (1990). Paper presented in Winter Crops Workshop held at National Wheat Development Program, Bhairahawa, Nepal. September 10-14, 1990.

[8] McVey, D. V., Nazim, M., Leonard, K. J. and Long, D. L. (2004). Patterns of diversity in *Puccinia triticina* on wheat in Egypt and the United States in 1998-2000. *Plant Dis.* 88: 271-279.

[9] MoAD. (2021). Statistical information of Nepalese Agriculture, Agribusiness Promotion and Statistics Division. Singha Durbar, Kathmandu.

[10] Nayer S. K., Tandon J. P., Kumar J., Prashar M., Bhardwaj S. C., Goel L. B., and Nagarajan S. 1994. Basis of rust resistance in Indian Wheats. Research Bulletin No. 1, Regional Station, DWR, Flowerdale, Shimla-171002, India, 32pp.

[11] Nayer SK, S. Nagarajan, M. Prashar, SC. Bhardwaj, SK. Jain and D. Dhatta. (2001). Revised Catalogue of genes that accord resistance to P*uccinia* species in wheat. Research Bulletin No. 3: 48pp. Directorate of Wheat Research, Regional Station, Flowerdale, Shimla -171002 (India).

[12] NWRP. (2021). Annual Report 2076/77 (2019/20). National Wheat Research Program, NWRP, Nepal Agricultural Research Council, NARC, Bhairahawa, Rupendehi, Nepal.

[13] Park, RF, and Felsenstein, FG. (1998). Physiological specialization and pathotype distribution of *Puccinia recondita* in Western Europe, 1995. Plant Pathology 47: 157-164pp.

[14] PPD. (2017). Annual Report 2073/74 (2016/17). Plant Pathology Division (PPD), NARC (S Baidya, S Manandhar, B Pant eds.) Khumaltar, Lalitpur, Nepal.

[15] PPD. (2018). Annual Report 2074/75 (2017/18). Plant Pathology Division (PPD), NARC (S Baidya, B Pant, S Manandhar eds.) Khumaltar, Lalitpur, Nepal.

[16] PPD. (2019). Annual Report 2075/76 (2018/19). Plant Pathology Division (PPD), NARC (S Baidya, PB Magar, S Manandhar eds.) Khumaltar, Lalitpur, Nepal.

[17] Prasad P, Gangwar OP, Kumar S, Lata C, Adhikari S, Bhardwaj SC. (2021). Mehtaensis. Six-monthly newsletter. ICAR-Indian Institute of Wheat and Barley Research, Regional Station. 41 (2): 1-35.

[18] Pretorius, ZA, Roux, J Le. and Drijepondt, SC. (1990). Occurrence and pathogenicity of *Puccinia recondite* f. sp. *tritici* on wheat in South Africa during 1988. Phytophylactica 22: 225-228pp.