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**Research Article**

# Screening of wheat (*Triticum aestivum* L.) genotypes for rust-resistance and assessment on prevalence and distribution of the rust diseases in wheat production fields

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## ABSTRACT

Evaluation of 45 wheat genotypes was performed to quantify genetic responses to inoculation of rust pathogens in aqueous suspension at the early vegetative stage. The study was conducted in field conditions at Plant Pathology Division, Nepal Agricultural Research Council, Lalitpur, Nepal in winter, 2013. Results showed large variations of rust resistance on wheat genotypes. Thirty-six genotypes were susceptible to yellow rust (YR), 18 had high severity, 7 had moderate severity, 6 had low severity, 5 had trace reactions, while 9 were rust-resistant. Old varieties (Lerma-52, Kalayansona, RR-21, NL-30, HD-1982, UP-262, Lumbini, Vinayak, Vaskar, Nepal-297, Nepal-251, BL-1135, Annapurna-4, Achyut, Rohini, and BL-1473) had high severities of YR, but relatively recent cultivars had medium severities. YR was severe (100S) in genotypes HD-1982, Vaskar, Vijay, and Rohini followed by RR-21, NL-30, UP-262, Nepal-297, BL-1135, and Annapurna-4 (90S). The pipeline cultivars: Aditya, NL-971, BL-3503, BL-3623, NL-1008, NL-1064, Becard#1, and Chyakhura-1 had trace to moderate reactions of YR with low severity indices. But varieties Vijay and NL-1055 showed high severity of YR (100S and 80S, respectively). Overall, leaf rust (LR) was minor and stem rust (SR) developed in traces on a single genotype (Annapurna-1). A survey of wheat rusts across 66 production fields revealed the prevalence of YR and LR at high levels, but none on SR. The occurrence of LR was higher than YR; 48.48% *vs.* 36.36% of assessed fields, respectively. YR was a primary concern of rust diseases with most fields under high severity (62.5%) and incidence (54.16%) levels. LR had low incidence and moderate severity levels. A considerable gap exists between an extension of such research outcomes and the producers, who demonstrated little know-how on wheat rusts and varieties. These results may support and enhance varietal selection, breeding programs, and effective management and control strategies against wheat rust diseases.

**Keywords:** Yellow rust, leaf rust, genotypes, resistance, severity, incidence

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## INTRODUCTION

Wheat (*Triticum aestivum* L.) is grown globally and is the world's second most important cereal crop (Pant *et al.*, 2020). It ranks third among the cereal crops after rice and maize in Nepal. However, wheat crop is the most preferred food crop second to rice in Nepal (Tripathi

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*et al*., 2012). Wheat is utilized in the form of flour or whole-meal and consumed as several products such as noodles, pancakes, chapattis, porridge, bread, etc. It is a traditional crop of the mid and far-western hill region of Nepal where some local landraces are still grown. Until the early 1960s', wheat cultivation was limited predominantly to hilly regions. But the introduction of the semi-dwarf varieties from Mexico during the mid-1960s' led to a tremendous increase of area and production in the plain regions of Tarai and other parts (NARSC, 1989).

Wheat has the widest adaptation of all cereal crops and is grown in some 100 countries around the globe as far as Finland in the north and Argentina in the south (Oleson, 1999). Bread wheat (*Triticum aestivum*) covers about 90% of the world wheat acreage while only 9% is covered by Durum wheat (*Triticum durum*); also called Marconi wheat (Joshi & Regmi, 1988). It is grown between the latitudes of 30°and 60°N and 27°and 40°S, mostly in temperate zones as wheat is a crop of the temperate region (Joshi & Regmi, 1988). The optimum growing temperature is about 25°C with minimum and maximum growth temperatures of 3-4°C and 30-32°C, respectively (Curtis, 2002). Wheat cultivation range in altitudes from a sea level to 4572 m in Tibet (Kent, 1983). In Nepal, the altitude of wheat cultivation varies from about 70m in the plain regions of Tarai to 4000 m in the hill region with 7, 65,317 ha acreage; production of 18, 46,142 Mt; and productivity of 2.4 Mt $ha^{-1}$ (MoAD, 2012). About 7, 47,190 ha (97.63%) of the total area is covered by the improved variety and 18,085 ha (2.36%) by local wheat varieties. The irrigated wheat acreage accounted for 4, 85,045 ha (63.36%) whereas 2, 80,230 ha (36.61%) lands were rainfed (MoAD, 2012). More than 85% (5, 67,000 ha) of wheat grown in the country follows rice (NARC, 2005).

The establishment of the National Wheat Development Program (NWDP) under the Division of Agricultural Botany at Khumaltar in 1972, was the first step in organized wheat research in Nepal. Later the NWDP shifted to Bhairahawa Agricultural Farm in 1975. In 1990, NWDP was segregated out from the Department of Agriculture and re-structured under the Nepal Agricultural Research Council (NARC) into its present form as National Wheat Research Program (NWRP). All together 34 wheat varieties had been released to the date which is recommended for the specific domain/regions. 'Lerma-52' was the first released variety (1960) in the history of wheat in Nepal. It was the first of any cereal crops to be released then. In 2012, Gaura and Dhaulagiri were released for mid and high hill regions. There were 540 landraces and 10 wild relatives of wheat in Nepal (Joshi *et al*., 2006). However, only 22 varieties are under cultivation whereas 12 varieties had faded out because of susceptibility to different diseases (Tripathi *et al*., 2012). New races of disease pathogens evolve either through mutation or sexual recombination and invade the crop variety (Joshi & Regmi, 1988). Therefore, most crop species become susceptible to disease over time and require due

Globally, 128 different diseases were recorded on wheat crop (CAB International, 2007) and in Nepal; there were 26 different wheat diseases including both major and minor types (Mahto *et al*., 2010). Diseases associated with the wheat crop are of four types namely, fungal, bacterial, nematode, and viral diseases. Wheat rusts (yellow rust / stripe rust, leaf rust / brown rust, and stem rust / black rust) are the important fungal diseases among the major diseases of wheat crop. Each year about 20% of the wheat, that otherwise would be available for food and feed is lost to disease (Joshi & Regmi, 1988). Nepal is regarded as the point of source for the recurrence of leaf rust in the Indo Gangetic plain (Mahto *et al*., 2001). The changing climate scenario and diverse microclimatic environments in the country have posed new challenges of increased biotic stresses, for example, diseases like yellow rust, leaf rust, stem rust, and spot blotch in wheat crop (Tripathi *et al*., 2012) and the resurgence of new races of rust pathogens in wheat production in Nepal (Joshi *et al*., 2012). Therefore, a periodic evaluation of wheat genotypes against rust diseases and assessment of their occurrences, magnitude, and spread in field conditions is critical for management of the diseases and enhanced breeding efforts.

**Stripe Rust / Yellow Rust (***Puccinia striformis*)

There were 29 different pathotypes of *P. striformis* on record (Mahto & Baidya, 2012). Stripe rust or yellow rust disease was reported as principally a disease of wheat grown in cooler climate conditions (2 to 15°C); generally associated with higher elevations, northern latitudes, or cooler conditions (Singh *et al*. 2002). The disease can be found in all highland and temperate areas where cereals are grown (Prescott *et al*., 1986). It was a serious disease of the high and mid-hill regions of Nepal > 1220 m altitude. The primary hosts for yellow rust pathogen were wheat, barley, triticale, and other related grass species (Prescott *et al*., 1986). It had a wider host range infecting rye and over 18 genera of grasses that serve as reservoirs for the fungus (Joshi & Regmi, 1988). An alternate host for yellow rust disease pathogen include *Barberis chinensis* (Jin *et al*., 2010).

The disease develops rapidly when free moisture (rain or dew) occurs, and the temperature range between 10-20°C. But at temperature >25°C, production of urediospores of yellow rust disease was reduced or ceased and black teliospores were often produced (Prescott *et al*., 1986). Severe infections can cause yield losses primarily with a reduced number of kernels per spike, test weight, and kernel quality (Prescott *et al*., 1986). When infection occurs early in the season followed by a long period of cool weather conditions, a severe epidemic may develop with heavy losses in yield and had been occurring in epidemic form since 1985 (Joshi & Regmi, 1988).

Manandhar *et al*. (1989) described that yellow rust was the major problem to the wheat cultivation in the hills and generally caused yield losses of 15-20%. Further, Mahto and Baidya (2012) reported that yellow rust was a major disease which posed a serious threat to wheat cultivation and occurred mostly in mid and lower hills, river basin and valleys causing 30-80% grain yield losses. Occasionally, many local and susceptible genotypes were fully destroyed without any grain formation. Devkota (1996) quoted that yellow rust was one of the major diseases of national importance. Yellow rust race *7E150* was the most common while the most frequent resistant genes present in Nepalese wheat genotypes were *Yr*2 and *Yr*9 of yellow rust . Also, *Yr*2, *Yr*$2^+$, *Yr*7, *Yr*9, and *Yr*18 genes for yellow rust resistance were found to be present in Nepalese wheat (NARC, 1997). Two yellow rust resistant varieties were released in the year 2012 *viz.* Gaura (BL-3235) and Dhaulagiri (BL-3503) for the hill region. Several others (BL-3623, BL-3555) were evaluated and promoted in the pipeline for different ecological zones (Tripathi *et al*., 2012).

**Leaf / Brown Rust** (*Puccinia triticina f. sp. Tritici)*

More than 150 physiologic races of *P. triticina* were known (Shurtleff *et al*., 1978). As many as 22 different pathotypes of *P. triticina* had been recorded in Nepal infecting many of the resistant gene/s in Nepalese wheat lines (Mahto & Baidya, 2012). The disease spread in the regions where temperate cereals were grown (Prescott *et al*., 1986). It was found throughout Tarai, inner Tarai, Tars, and lower elevations < 762 m. (Joshi & Regmi, 1988). Primary hosts for the leaf rust pathogen include bread and durum wheat (Singh *et al*., 2002) while alternate host includes *Thalictrum* sp., species of *Anchusa*, *Anemonella*, and *Isopyrum*, and weak parasite on certain cultivars of barley, *Aegilops* and *Agropyron* species (Joshi & Regmi, 1988).

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Leaf rust likely appears in the epidemic form when weather conditions during the growing season is mild and moist. Leaf rust developed rapidly between 15 and 22$^{o}$C when moisture was not limiting. Late planting was more likely to favor the development of the disease (Joshi & Regmi, 1988). Severe early infections were associated with significant yield losses, mostly by reducing the number of kernels per spike, test weights, and kernel quality (Prescott *et al*., 1986). In case of severe attacks, the wheat matured early producing light and shriveled grains and reduced both quality and quantity of produce (Saha, 2002).

Mahto and Karn (2010) reported, leaf rust caused by *Puccinia triticina,* as one of the major diseases of wheat in Nepal, especially in the Tarai region. Bhatta (1996) too mentioned leaf rust as the major disease of wheat in the mid-hills besides, in Tarai and losses in grain yield were estimated to be 14% with moderate severity and 20% at high severity level. Leaf rust was at an epidemic level during the 1960s and 1970s in Nepal, but its severity and incidence declined after the release of a series of rust-resistant wheat varieties (Karki & Nayar, 1998). A leaf rust race, 77-2 was the most common race whereas the most frequent resistant genes present in Nepalese wheat genotypes then were *Lr*13, *Lr*23, and *Lr*26 (Devkota, 1996). Also, a report stated leaf rust as the major disease of national importance in the Tarai region. Nepalese wheat also possessed *Lr*1, *Lr*3, *Lr*10, *Lr*13, *Lr*14s, *Lr*16, *Lr*23, *Lr* 26, and *Lr*34 genes for leaf rust resistance (NARC, 1997).

**Stem / Black Rust** (*Puccinia graminis f. sp. Tritici)*

There were more than 340 physiologic races of the stem rust pathogen associated to *tritici* (Shurtleff *et al*., 1978). Stem rust was found where temperate cereals are grown. In Nepal, it occurred throughout Tarai on a moderate scale. But it was not a major problem in Nepal (Joshi & Regmi, 1988). The primary hosts for stem rust pathogen were wheat, barley, triticale, and many other related species (Singh *et al*., 2002). The alternate host includes Barberries (*Berberis vulgaris, Berberis canadensis, Berberis fendleri)*, certain species of Mahonia, some barley, rye, and oat cultivars and some grasses (wild barley and *Aegilops* sp.) were also parasitized and were potential sources of primary inoculum (Joshi & Regmi, 1988).

The disease developed rapidly with free moisture (rain or dew) and high-temperature conditions. It developed optimally near 20°C and is seriously hampered < 15°C and > 40°C. Late planting or delayed crop maturity favored the disease (Joshi & Regmi, 1988). In early infection stages, the effects can be severe with reduced tillers, grain weight, and quality. Total crop loss can occur under conducive conditions for disease development (Prescott *et al*., 1986). It can cause losses up to 50% in a short period when conditions for its development are favorable (Singh *et al*., 2002).

Stem rust was a minor and sporadic disease in the country. Stem rust was reported only in some parts of the western and mid-western regions of Nepal. Severe case of stem rust had been observed in Kathmandu valley (Mahto & Baidya, 2012). According to Sharma *et al*. (2011), stem rust occurred very late during normal wheat harvests and was not significant in terms of economic damage. Nevertheless, two Ug99 resistant varieties; Francolin (NL-1073) and Danphe#1 (NL-1064) were identified for a release.

In this study, a varietal display trial was conducted with the objective of screening rust resistant or tolerant genotypes to enhance varietal selection and breeding efforts towards better management and/or control measures. Concomitantly, we intended to assess the prevalence and distribution of wheat rusts in actual fields under production settings to correspond with the varietal screening study.

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## MATERIALS AND METHODS

### Experimental design and information

The varietal screening trial was conducted at the Nepal Agricultural Research Council, Khumaltar, Nepal. A total of 45 different released and pipeline wheat cultivars including one Triticale (Rye × Wheat) were selected as test genotypes and each genotype was planted on the slightly raised plots (2 m × 1 m) in four rows at the spacing of 0.25 m. Additionally, a survey on the wheat rusts was undertaken across a total of 66 sites at Bhaktapur district by personal interview method using a semi-structured questionnaire combined with field observations.

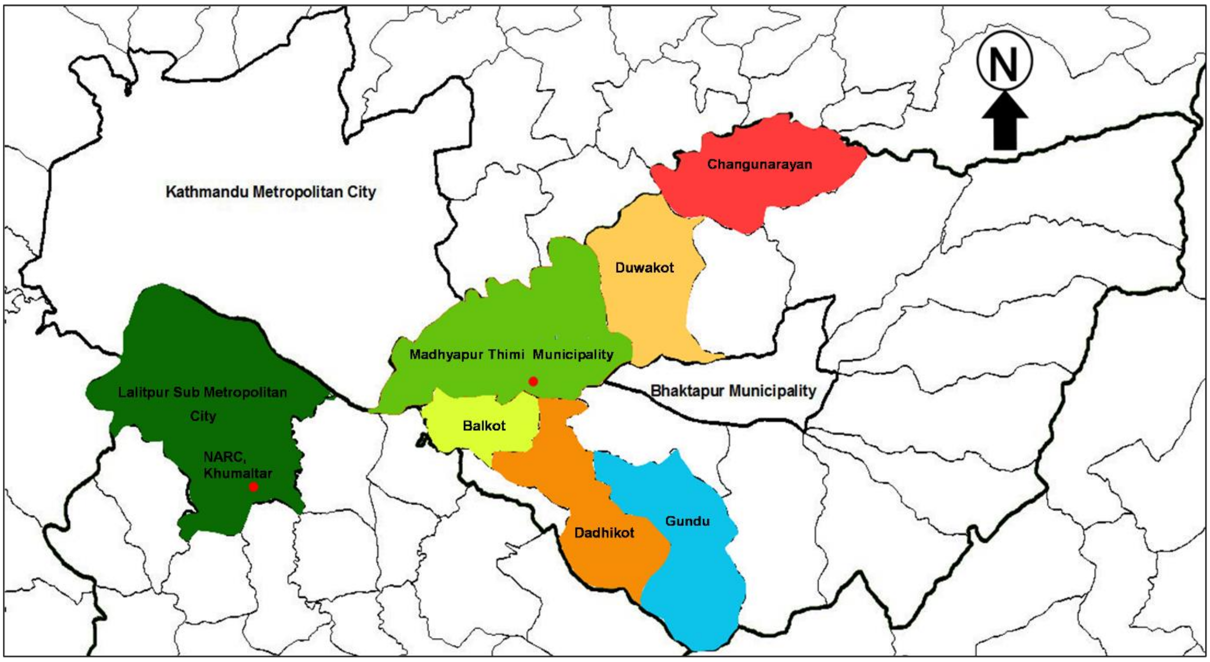


**Figure 1: Map showing the location of the research site and the survey locations.**

### Experimental procedures

The sowing of the wheat genotypes was done on December 4, 2012 and fertilized at the rate of 120:60:60 kg/ha N:P: K (Nitrogen, Phosphorus, and Potassium). Irrigation was provided twice; each before and after sowing. Weeding was done once during the wheat season.

**Table 1. Geo-coordinates for the locations of research site and survey sites**

| Sites | Latitude | Longitude | Altitude |
|---|---|---|---|
| Varietal display trial | | | |
| NARC, Khumaltar | 27°39’21.69’’ N | 85°19’47.98’’ E | 1337 m |
| Survey locations | | | |
| Gundu VDC | 27°38’29.68’’ N | 85°24’51.53’’ E | 1426 m |
| Changunarayan VDC | 27°43’35.25’’ N | 85°24’27.90’’ E | 1381m |
| Dadhikot VDC | 27°38’25.22’’ N | 85°24’00.02’’ E | 1406 m |
| Balkot VDC | 27o39’48.76’’ N | 85°22’41.56’’ E | 1326 m |
| Duwakot VDC | 27°41’42.09’’ N | 85°24’09.88’’ E | 1372 m |
| Thimi municipality | 27°40’36.33’’ N | 85°22’27.86’’ E | 1318 m |

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**Inoculation of yellow rust disease pathogen**

An aqueous suspension of freshly collected urediospores of rust diseases was prepared in distilled water and sprayed uniformly over test genotypes using an ultra-low volume sprayer during the evening time on February 1$^{st}$ week.

**Scoring of rust diseases in the field**

Scoring of wheat rust diseases was based upon severity (percentage of rust infection on the plants) and field response (a type of disease reaction) as developed by Loegering. Scoring for rust diseases was done on April 16, 2013.

Severity was recorded as a percentage, according to the modified Cobb scale. The recording process relied on visual observations. It was common to use the intervals: Trace, 5, 10, 20, 40, 60, and 100% for severity recordings.

Field response was recorded using the following denotations using letters:

0: No visible infection on plants.
R **Resistant:** visible chlorosis or necrosis, *no uredia* were present.
MR **Moderately Resistant;** *small uredia* were present and surrounded **by** either chlorotic or necrotic areas.
M **Intermediate;** *variable-sized uredia* were present, some with chlorosis, necrosis, or both.
MS **Moderately Susceptible;** *medium-sized uredia* were present and possibly surrounded by chlorotic areas.
S **Susceptible;** *large uredia* were present, with little or no chlorosis and no necrosis.

Severity and field response readings were usually combined.
For example, 10MR = 10% severity with a moderately resistant field response.
Source: CIMMYT (2008)

## RESULTS

In a field research trial, genotypic responses to rust resistance showed large a variation in incidence and severity levels (Table 2). Evaluation of wheat genotypes in varietal research trial showed yellow rust to be a major disease among wheat rust diseases. Yellow rust disease was found in 36 of 45 tested genotypes in the field trial (Table 2). Among them 18 had high severity of yellow rust, 7 had medium severity, 6 had low severity and 5 had trace responses (Table 3) while 9 of the wheat genotypes had no infections of yellow rust. The promising lines or the pipeline varieties *viz.*, Aditya (10MR), NL 971 (10MR), BL-3503 (20MS, MR), BL-3623 (TR, TMR), NL-1008 (10MR, R), NL-1064 (20MR), Becard#1 (10MR) and Chyakhura-1 (TMR) showed low severity and resistant to moderately resistant or trace responses to yellow rust. But the promising varieties like Vijay and NL 1055 showed high severity of yellow rust with 100S and 80S scores respectively under Khumaltar conditions.

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**Table 2: Rust disease scores for wheat genotypes during evaluation trial 2012/13**

| Wheat Genotypes | Growth stage | Disease Scores | | | Remarks |
|---|---|---|---|---|---|
| | | YR | LR | SR | |
| Lerma-52 | Late milking | 70S, MS | - | - | Drying of plants |
| Lermarojo-64 | Late milking (dry) | 20MS, S | - | - | |
| Kalyansona | Late milking | 80S | - | - | Leaf drying |
| Pitic-62 | Mid milking | TR | - | - | |
| RR21 | Milking | 90S | - | - | |
| NL 30 | Mid milking | 90S | - | - | Dried, head drying and awn infection |
| HD 1982 | Mid milking | 100S | - | - | Head drying |
| UP 262 | Mid milking | 90S | - | - | Awn and glume infection |
| Lumbini | Late milking | 80S | - | - | Awn and glume infection |
| Triveni | Milking | 20S, MS | - | - | Awn and glume infection |
| Vinayak | Mid milking | 80S | - | - | Awn and glume infection |
| Siddhartha | Milking | 20MS | | - | |
| Vaskar | Milking | 100S | - | - | |
| Nepal 297 | Mid milking | 90S | - | - | Awn and glume infection |
| Nepal 251 | Mid milking | 80S | - | - | |
| Annapurna-1 | Mid milking | 10MR, MS | TMS | MR | |
| Annapurna-2 | Early milking | 40S, MS | - | - | |
| Annapurna-3 | Early milking | 30MS, S | - | - | |
| BL 1022 | Early milking | 10MS, MR | 5S | ? | |
| BL 1135 | Mid milking | 90S | - | - | |
| Annapurna-4 | Mid milking | 90S | - | - | Severe infection including awn and glume |
| Achyut | Early milking | 70S | - | - | Awn and glume infection |
| Rohini | Mid milking | 100S | - | - | Awn and glume infection |
| Kanti | Milking | TR | - | - | |
| Pasang Lhamu | Mid milking | - | TR? | - | |
| BL 1473 | Mid milking | 50S | - | - | Awn and glume infection |
| Gautam | Early milking | TR | TMR | - | |
| WK 1204 | Early milking | - | TMR | - | |
| Aditya | Early milking | 10MR | - | - | |
| Vijay | Early milking | 100S | - | - | Awn and glume infection |
| NL 971 | Mid milking | 10MR | - | - | |
| BL 3235 | Early milking | - | 5S, MS | - | |
| BL 3503 | Mid milking | 20MS, MR | - | - | |
| BL 3623 | Early milking | TR, TMR | - | - | |
| BL 3872 | Early milking | - | TMS | - | |
| NL 1055 | Mid milking | 80S | - | - | Awn infection |
| NL 1008 | Mid milking | 10MR, R | - | - | Glume infection |

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| | | | | |
|---|---|---|---|---|
| NL 1064 | Mid milking | 20 MR | - | - |
| NL 1073 | Late milking | - | - | - |
| Triticale | Early milking | - | - | - |
| Durum | Milking | - | - | - |
| Becard#1 | Mid milking | 10 MR | - | - |
| Chyakhura-1 | Milking | TMR | - | - |
| WK 936 | Early milking | - | 5S | - |
| WK 1481 | Mid milking | - | - | - |

*Note:*

*YR = Yellow Rust* *LR = Leaf Rust* *SR = Stem Rust*
*S = Susceptible* *MS= Moderately Susceptible* *MR = Moderately Resistant*
*TMR = Trace Moderately Resistant* *TR = Trace Resistant* *? = May be*
*TMS = Trace Moderately Susceptible* *R = Resistant*

Released varieties; Lerma-52, Kalayansona, RR-21, NL-30, HD-1982, UP-262, Lumbini, Vinayak, Vaskar, Nepal-297, Nepal-251, BL-1135, Annapurna-4, Achyut, Rohini, BL-1473, and Vijay showed high severity of yellow rust. But genotypes Pasang Lhamu, WK-1204, BL-3235, BL-3872, WL-1073, Durum, WK-936, and WK-1481 had no yellow rust infections while varieties Gautam, Kanti, and Pitic 62 had trace resistant (TR) to yellow rust (Table 2). Genotypes Lermarojo-64, Triveni, Siddhartha, Annapurna-2, and Annapurna-3 showed medium severity and infection types of S, MS, or MR singly or in combinations. Yellow rust scores were high in cultivars HD-1982, Vaskar, Vijay, and Rohini (100S) followed by varieties RR-21, NL-30, UP-262, Nepal-297, BL-1135, and Annapurna-4 (90S). Awn and glume were also infected in several varieties such as NL-30, UP-262, Lumbini, Triveni, Vinayak, Nepal-297, Annapurna-4, Achyut, Rohini, BL-1473, Vijay, NL-1055 (awn), and NL-1008 (glume) in case of yellow rust.

**Table 3: Grouping of wheat genotypes based on the incidence and severity levels of different wheat rust diseases**

| Disease | Varieties and disease severities | | | |
|---|---|---|---|---|
| | High > 40% | Medium 20-40% | Low < 20% | Trace |
| Yellow rust | HD-1982, Vaskar, Rohini Vijaya, RR-21, Nepal-297, UP-262, NL-30, BL-1135, Nepal-251, Annapurna-4, Kalayansona, Lumbini, Achyut, Vinayak, NL-1055, BL-1473, Lerma-52 | Lermarojo-64, Triveni, Siddhartha, Annapurna-2 and 3, BL-3503, NL-1064 | Annapurna-1, BL-1022, Aditya, NL-971, NL-1008, Becard#1 | Pitic-62, Kanti, Gautam, BL 3623, Chyakhura-1 |
| Total | 18 | 7 | 6 | 5 |
| Leaf rust | - | - | BL-3235, WK-936 | Annapurna -1, Gautam, Pasang Lhamu, WK-1204, BL-3872 |
| Total | 0 | 0 | 2 | 5 |
| Stem rust | - | - | - | Annapurna-1 |
| Total | 0 | 0 | 0 | 1 |

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Leaf rust in the varietal evaluation trial was insignificant with low severity levels in some cultivars *viz.*, BL-1022 (5S), WK-936 (5S), BL-3235 (5S, MS), Annapurna-1 (TMS), WK 1204 (TMR), Gautam (TMR) and BL-3872 (TMS) (Table 3). Also, the incidence of the leaf rust disease was very low with symptoms on seven genotypes. Stem rust was negligible or apparent with MR infection type on variety Annapurna-1 and the symptoms for the disease were inconclusive in variety BL-1022 (Table 2).

**Survey of wheat rusts in production fields**

A total of 66 sites were surveyed and 48.48% showed leaf rust, 36.36% showed yellow rust and 24.24% showed no rust infections (Table 4). Six sites were observed with both yellow and leaf rusts to some extent and different levels. However, 16 of the investigated sites were free of wheat rusts. Infections of yellow rust showed a high percentage at high severity and high incidence levels (Table 4). The occurrence of yellow rust was measured at high (62.5%), medium (16.67%), and low (0.83%) severity levels. While 54.16%, 41.67%, and 4.17% of monitored sites had high, medium, and low incidence levels, respectively. Yellow rust was severe up to 100S mostly in the Balkot areas while in the Dadhikot region, both leaf and yellow rust were prevalent at low to high severity levels.

**Table 4: Tabulation of Yellow rust and Leaf rust disease cases by incidence and severity levels measured in the production fields**

| | # Incidence (%) | | | | # Severity (%) | | | |
|---|---|---|---|---|---|---|---|---|
| Disease | High | Medium | Low | Total | High | Medium | Low | Total |
| Yellow rust | 13 (54.16) | 10 (41.67) | 1 (4.17%) | 24 (100.00) | 15 (62.5) | 4 (16.67) | 5 (20.83) | 24 (100.00) |
| Leaf rust | 6 (18.75) | 12 (37.50) | 14 (43.75) | 32 (100.00) | 8 (25.00) | 8 (25.00) | 16 (50.00) | 32 (100.00) |

In contrast to yellow rust, leaf rust infections had the highest percentage at low severity and medium incidence levels (Table 4). The high, medium and low severities shared 25%, 25%, and 50%, respectively. Likewise, 18.75%, 37.5%, and 43.75% had leaf rust at high, medium, and low incidence levels, respectively (Table 4). Leaf rust was severe at some fields of Dadhikot with 70-80S, 50S, MS, and at Balkot with 50S, MS. Similarly, leaf rust was common with low to moderate levels of severity in the Thimi and Gundu region (Figure 2). However, the fields at Duwakot were mostly free of rust diseases except few with traces of symptoms of leaf rust (Figure 2). Also, at Changunarayan, there were fewer leaf rust incidences with low severity and a single field with a high level of yellow rust (60S).

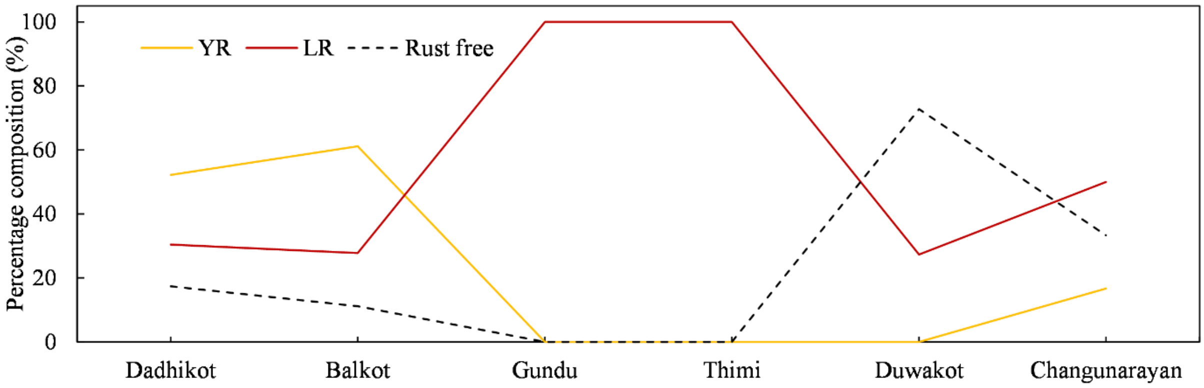


**Figure 2: Composition and distribution of wheat rusts by types in each survey location.**

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Wheat producers lacked technical and managerial know-how on wheat diseases; only 25% of the respondents had some information on wheat diseases. Producers had little knowledge of wheat varietal information; 77.1% had no information on the cultivated varieties.

## DISCUSSION

Yellow rust was widespread in the trial with 36 out of 45 genotypes with varied infection and severity levels. Similar findings by Joshi *et al*. (1988) were reported and mentioned yellow rust to be a serious disease of high and mid-hills of Nepal >1220 m. Similarly, Mahto and Baidya (2012) mentioned that yellow rust was a major disease that posed a serious threat to wheat cultivation in the mid-and lower hills, river basins, and valleys. These reports elucidated that our research location at Khumaltar, Lalitpur; in the Kathmandu Valley of the mid-hill region was a favorable domain with conducive conditions for yellow rust infection and development. Yellow rust disease was the major rust disease with high severity on half of the infected genotypes. Similar findings were common in the past with frequent epidemics of yellow rust in Nepal (NARI, 2010a). The study locations for varietal screening and survey were reported to be among the top-most yellow rust-prone districts in the country (Sharma *et al*., 2011b). All these reports coincide with the findings of high incidences and severity of the yellow rust in the varietal trial and survey locations.

The released varieties like Lerma-52, Kalayansona, RR-21, NL-30, HD-1982, UP-262, Lumbini, Vinayak, Vaskar, Nepal-297, Nepal-251, BL-1135, Annapurna-4, Achyut, Rohini, and BL-1473 had high severity with susceptible disease reaction (S). Similar results with high susceptibility of yellow rust on Sonalika (RR 21), Annapurna 1, 3 and 4, Nepal 297, and BL 1473 were reported by Agriculture Botany Division, NARC (2010a). Genotypes Lermarojo-64, Triveni, Siddhartha, Annapurna-2, and Annapurna-3 had medium severity of yellow rust. But the cultivars like HD-1982, Vaskar, Vijay, and Rohini (100S), RR-21, NL-30, UP-262, Nepal-297, BL-1135, and Annapurna-4 (the 90S) had high severity of yellow rust. Among these, most were released a long ago and findings on responses to wheat rusts are supported by Joshi *et al*. (1988), who reported increased varietal susceptibility to diseases after certain years of released date from new bio races of disease pathogens invading the variety. Also, Sharma *et al*. (2011) reported yellow rust to be common and virulent in RR-21, Nepal-297, Annapurna-1, and Annapurna-4 varieties, congruent to our results.

The promising lines or the pipeline varieties *viz.*, Aditya (10MR), NL-971 (10MR), BL-3503 (20MS, MR), BL-3623 (TR, TMR), NL-1008 (10MR, R), NL-1064 (20MR), Becard#1 (10MR) and Chyakhura-1 (TMR) had low severity and resistant to moderately or trace resistant disease response against the yellow rust. Results also, showed that Pasang Lhamu and WK-1204 had no wheat rusts, and varieties like Gautam, Kanti, and Pitic-62 had only trace resistant responses (TR). These findings agree with earlier reports describing that cultivars Gautam, WK-1204, Pasang Lhamu, Aditya, NL-971, BL-3063 (Vijay), BL-3623, BL-3235 (Gaura), and BL-3503 (Dhaulagiri) were recently released and resistant to yellow rust (Sharma *et al*., 2011; Sharma *et al*., 2011c & Tripathi *et al*., 2012). Further, Sharma (2011) mentioned WK-1204 was the high yielding and disease resistant cultivar for the mid-hill areas and Kathmandu valley. Also, it reported Pasang Lhamu to be resistant to yellow rust for more than a decade long period then and the same for Gautam variety in low hills and river basin areas. Moreover, Danphe (NL-1064) was moderately resistant to the yellow rust disease (NARI., 2010b). But the promising varieties like Vijay and NL-1055 showed high severity of yellow rust disease with 100S and 80S scores, respectively. These findings indicate that not all newer varieties are

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resistant to wheat rusts and should be considered in the varietal selection and improvement works in the future.

Nine of the wheat genotypes showed no rust infections and potential resistance to wheat rusts. This may also be due to the absence of virulent races / pathotypes specific to these genotypes. In other words, the pathotypes in inoculants used in the study possibly lacked virulence to these genotypes. Although these findings will need further screening and field evaluations, results are promising for improved varietal selection for rust resistance as an effective management / control tool against the wheat rust diseases.

Mahto and Baidya (2012) mentioned leaf rust to be most widespread and regularly in low altitude regions, but a minor disease in the hill region of Nepal. We found similar findings with insignificant occurrences of leaf rust at low severities on few cultivars. Further, Karki and Karki (1996) found a late-stage incidence of leaf rust towards maturity and limited the severity in several varieties and breeding lines in the nurseries.

Joshi and Regmi (1988) mentioned that stem rust is not a major issue besides, its occurrence at a moderate scale in plain regions of Nepal. Also, Mahto and Baidya (2012) mentioned stem rust to be a minor and sporadic disease in Nepal, which further strengthens and supports the results on the stem rust disease. Our results with no stem rust infections except for variety Annapurna -1 without any measurable effect is consistent with these previous findings.

**An environmental condition during wheat growing season and wheat rusts**

Temperature, as well as humidity, was considered as the important climatic factors affecting the establishment and subsequent growth of rust pathogens. A free film of water on the host surface influences uredospore's germination, and production or penetration of fungal hyphae. Temperature was described as a major deciding factor in the development and spread of wheat rusts in the Indian sub-continent (Joshi, 1986).

Temperatures during the wheat growing season (Figure 3A), largely coincided with the environmental conditions favorable for yellow rust infection and development (Table 5). The germination and penetration of yellow rust pathogen were reported to be optimum at 9-13°C and 12-15°C for growth and sporulation. The average monthly mean temperatures during the wheat growing season were 10.9, 9.2, 12.6, 15.6, and 18.8°C (Figure 3A). The environmental condition was highly conducive for the yellow rust during the wheat growing season. Joshi (1986) explained that plant-surface water was essential for the germination and penetration of wheat-rusts pathogens. Similar conditions prevailed during the wheat-growing period characterized by high relative humidity (RH) and precipitation. (Figure 3B). The daily precipitation averaged on a month-basis increased from 4 mm (January) to 9 mm (April). Besides, relative humidity remained about 70-80% nearly the entire growing season except for the maturity stage.

Temperature conditions favored very litter for leaf rust germination, penetration, growth, and sporulation during the wheat growing season. The optimum temperature (20-25°C) required for the growth and development of leaf rust pathogen lagged throughout the wheat growing season. Hence, it justifies the low leaf rust incidences and severity among most genotypes tested in the varietal trial and survey sites.

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**Table 5: Climatic conditions conducive for the development of wheat rusts**

| Stage | Temperature (°C) | | | Light | Free water |
|---|---|---|---|---|---|
| | Minimum | Optimum | Maximum | | |
| Leaf rust | | | | | |
| Germination | 2 | 20 | 30 | Low | Essential |
| Penetration | 10 | 20 | 30 | No effect | Essential |
| Growth | 2 | 25 | 35 | High | None |
| Sporulation | 10 | 25 | 35 | High | None |
| Stem rust | | | | | |
| Germination | 2 | 15-24 | 30 | Low | Essential |
| Penetration | 15 | 29 | 35 | High | Essential |
| Growth | 5 | 30 | 40 | High | None |
| Sporulation | 15 | 30 | 40 | High | None |
| Yellow rust | | | | | |
| Germination | 0 | 9-13 | 23 | Low | Essential |
| Penetration | 2 | 9-13 | 23 | Low | Essential |
| Growth | 3 | 12-15 | 20 | High | None |
| Sporulation | 5 | 12-15 | 20 | High | None |

*Source: Singh et al. (2002).*

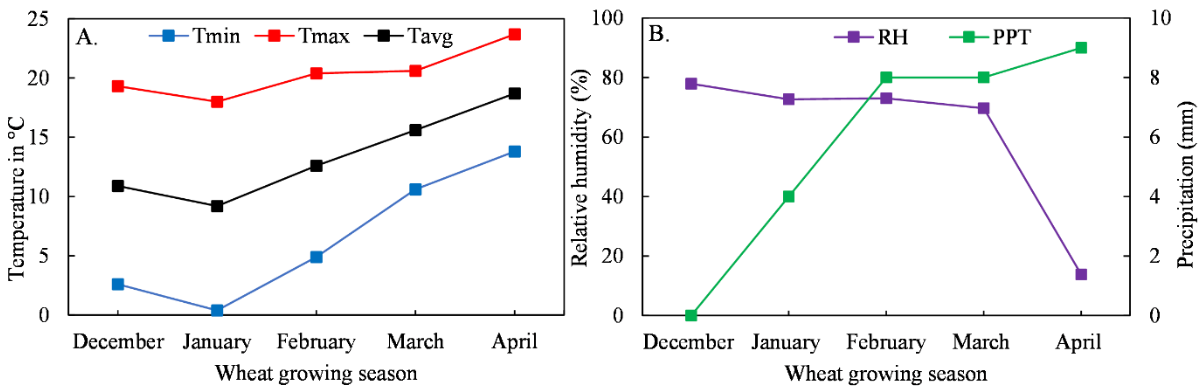


**Figure 3: A. Monthly averaged maximum (Tmax), mean (Tavg), and minimum (Tmin) temperatures and B. Daily relative humidity and precipitation averaged monthly during the wheat season (2012/13) at Khumaltar, Lalitpur, Nepal.**

For the stem rust, the optimum temperature for germination and growth is 15-24°C and 30°C, respectively. But even the highest maximum temperature for the entire growing season was only 23.7°C which shows that the optimum temperature requirements for germination and growth of stem rust spores were not available. Thus, nearly a complete absence of stem rust in the varietal research trial and survey sites is easily understood.

## CONCLUSION

Wheat cultivars had a wide genetic variability on rust resistance among the 45 tested genotypes; older varieties were more susceptible than relatively recent new cultivars. However, the newer varieties are not completely resistant to the wheat rusts and validate the periodic requirement

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of testing the cultivars against the diseases. The yellow rust disease was major among all rust diseases with high incidences and severities and is a potential risk for yield loss in wheat production in Nepal. Although leaf rust was common in both varietal trials and surveys, they were under the moderate incidence levels with low severities. Stem rust was negligible in both varietal evaluation and survey. Outcomes from the study will support and enhance the varietal improvement program for the management and control of wheat rust diseases.

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**Authors' contribution**

Shrestha, R. performed the survey and research measurements, processed the data, and drafted the manuscript. Mahto, B.N. conceived and designed the experiment and supervised the project as a major supervisor.

**Conflict of author**

The authors in this paper declare the inexistence of any form of conflict of interests.

## REFERENCES

Bhatta, M.R. (1996). Present status of wheat improvement research in Nepal and the breeding strategies. In: National winter crops technology workshop: Proceedings of wheat research report National wheat research program. *Eds.* Devkota, R.N., and E.E. Saari, E.E. Siddhartha Nagar, Bhairahawa, 7-10 September 1995. Nepal Agricultural Research Council (NARC) and International Maize and Wheat Improvement Center (CIMMYT), 28-29.

CAB International. (2007). Crop protection compendium. [CD] Wallingford, UK: CAB International.

CIMMYT.(2008). Rust scoring guide. Netherlands: Research Institute for Plant Protection (IPO).

Curtis, B.C. (2002). Wheat in world. In: Bread wheat improvement and production plant production and protection series Eds. Curtis, B.C., and Rajaram, S. Rome: Food and Agriculture Organization of United Nations, Rome, Italy, *30*, 1-50.

Devkota, R.N. (1996). Progress in wheat research and production in Nepal. In: National winter crops technology workshop: Proceedings of wheat research reports National wheat research program. Eds. Devkota, R.N. and Saari, E.E. Siddhartha Nagar, Bhairahawa, 7-10 September 1995. Nepal Agricultural Research Council (NARC) and International Maize and Wheat Improvement Center (CIMMYT), 5-10.

Jin, Y., Szabo, L.J., & Carson, M. (2010). Century old mystery of *Puccinia striformis* life history solved with the identification of *berberis* as an alternate host. St. Paul 55108: University of Minnesota.

Joshi, A.K., Singh, R.P., & Braun, H.J. (2012). Challenges to wheat production in South Asia: regional perspectives. In: Contingency planning for management of wheat rust diseases: South Asia regional workshop. Hotel Soaltee Crown Plaza, Kathmandu, 20-21 December 2012. Kathmandu: Government of Nepal, Italian Development Co-operation, and FAO, 8-9.

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v4i2.33741
Joshi, B.K., Mudwai, A., & Bhat, M.R. (2006). Wheat genetic resources in Nepal. *Nepal Agriculture Research Journal, 7*, 1-4.

Joshi, L.M. (1986). Perpetuation and dissemination of wheat rusts in India. In: Problems and progress of wheat pathology in South Asia. Eds. Joshi, L.M., Singh, D.V., and Srivastava, K.D. New Delhi: Kapoor Art Press.

Joshi, M., & Regmi, K.R. (1988). Trainer's manual. Kathmandu: Manpower Development Agriculture Project.

Karki, C.B., & Karki, P.B. (1996). Wheat Disease Report. In: National winter crops technology workshop: Proceedings of wheat research reports National Wheat Research Program. Eds. Devkota, R.N. and Saari, E.E. Siddhartha Nagar, Bhairahawa, 7-10 September 1995. Nepal Agricultural Research Council (NARC) and International Maize and Wheat Improvement Center (CIMMYT), 269-270.

Karki, C.B., & Nayar, S.K. (1998). Probable genes for leaf rust resistance in some wheat cultivars grown in Nepal. *Nepal Agricultural Research Journal, 2*(1), 83-84.

Kent, N.L. (1983). Wheat of the world. In: Technology of cereals; an introduction for students of food and agriculture. 3rd ed. Oxford: Pergamon Press.

Mahto, B.N., & Baidya, S. (2012). Status of wheat rust disease and their management in Nepal. In: Contingency planning for management of wheat rust diseases: South Asia regional workshop. Hotel Soaltee Crown Plaza, Kathmandu, 20-21 December 2012. Kathmandu: Government of Nepal, Italian Development Co-operation, and FAO, 14-15.

Mahto, B.N., & Karn, P.L. (2010). Basis of leaf rust resistance in Nepalese wheat and future strategy. *Journal of Plant Protection Society, 2*, 24-28.

Mahto, B.N., Nayar, S.K., & Nagarajan, S. (2001). Postulation of LR genes in the Bread wheat materials of Nepal using Indian pathotypes. *Indian Phytopathology, 54*(3), 319-322.

Manadhar, H.K., Shrestha, K., & Amatya, P. (1989). Seed borne fungal diseases. In: Plant diseases seed production and seed health testing in Nepal; proceedings of first HMG/DANIDA/FAO training course in seed health testing techniques. Eds. Mathur, S.B., Amatya, P., Shrestha, K., and Manandhar, H.K. Khumaltar, Lalitpur: Central Division of Plant Pathology.

MoAD (2012). Statistical information on agriculture 2011/12. Singh Durbar, Kathmandu, Nepal. Agri-business Promotion and Statistics Division, Ministry of Agriculture Development, Government of Nepal.

NARC (1997). 25 years of wheat research in Nepal (1972-1997). Nepal Agricultural Research Council, National Wheat Research Program, 1-13.

NARC (2005). NARC annual report 2001/2002. Khumaltar-Kathmandu: Communication, Publication, and Documentation Division, 15-34.

NARI (2010a). Annual report 2066/67 (2009/10). Lalitpur: Nepal Agriculture Research Council, National Agriculture Research Institute, Agriculture Botany Division, National Agriculture Research Institute, Nepal Agriculture Research Council, Lalitpur, 5-10

NARI (2010b). Annual report FY 2066/2067 (2009/2010). Lalitpur, Plant Pathology Division, Nepal Agricultural Research Council, National Agricultural Research Institute, Nepal Agricultural Research Council, 15-21.

NARSC (1989). NARSC annual report 1987/88 (2044/45). Khumaltar, Lalitpur, Nepal: National Agricultural Research and Services Center, 48-66.

Oleson, B.T. (1999). World wheat production, utilization, and trade. In: Wheat production, properties, and quality. Eds. Bushuk, W., and Rasper, V.F. Chapman and Hall: Cambridge University Press.

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v4i2.33741

Pant, K.R., Ojha, B.R., Thapa, D.B., Kharel, R., Gautam, N.R., & Shrestha, J. (2020). Evaluation of biofortified spring wheat genotypes for yield and micronutrient contents. Fundamental and Applied Agriculture 5(1):78–87. doi: 10.5455/faa.79404

Prescott, J.M., Burnett, P.A., & Saari, E.E. (1986). Wheat diseases and pests: A guide for field identification. Mexico, CIMMYT.

Sharma, S. (2011). Management of yellow rust disease of wheat in hills of Nepal; background and objective. In: Management of yellow rust disease of wheat in hills of Nepal final technical report. Eds. Sharma, S., Batsa, B.K., Manandhar, S., and Poudel, R.S. Khumaltar, Lalitpur, Nepal: Plant Pathology Division, National Agriculture Research Institute, Nepal Agricultural Research Council, NARDF 512/2007/2008, 1-310.

Sharma, S., Baidya, M.L., Joshi, A.K., Thapa, D.B., Bhatta, M.R., Baidya, S. Joshi, S., & Poudel, R.S. (2011b). On farm evaluation of identified superior resistant genotypes using PVS approach and genetic diversity enhancement. In: Management of yellow rust disease of wheat in hills of Nepal final technical report. Eds. Sharma, S., Batsa, B.K., Manandhar, S., and Poudel, R.S. Khumaltar, Lalitpur: Plant Pathology Division, National Agriculture Research Institute, Nepal Agricultural Research Council, NARDF 512/2007/2008, 8-11.

Sharma, S., Bhatta, M.R., Thapa, D.B., Gautam, N.R., Bhandari, D., & Joshi, A.K. (2012). Successes in wheat rust management in Nepal. In: Contingency planning for management of wheat rust diseases. South Asia Regional workshop. Hotel Soaltee Crown Plaza, Kathmandu, 20-21 December 2012. Kathmandu: Government of Nepal, Italian Development Co-operation, and FAO, 12-13.

Sharma, S., Joshi, A.K., Baidya, M.L., & Manandhar, H.K. (2011c). Partners Meeting. In: Management of yellow rust disease of wheat in hills of Nepal final technical report. Eds. Sharma, S., Batsa, B.K., Manandhar, S., and Poudel, R.S. Khumaltar, Lalitpur: Plant Pathology Division, National Agriculture Research Institute, Nepal Agricultural Research Council, NARDF 512/2007/2008, 41-48.

Shurtleff, M.C., Jacobsen, B.J., & Schiller, C.T. (1978). A report on plant diseases leaf rust of wheat. Illinois: University of Illinois, No. 110.

Singh, R.P., Espino, J.H., & Roelfs, A.P. (2002). The Wheat Rusts. In: Bread wheat improvement and production. Eds. Curtis, B.C., and Rajaram, S. Rome: Plant Production and Protection Series. Food and Agriculture Organization of United Nations, Rome, Italy, *30, 1-25*.

Tripathi, J., Pokhrel, S., & Upadhyay, S.R. (2012). Wheat production and improvement in Nepal; status, organizational setting, and prospects. In: Contingency planning for management of wheat rust diseases: South Asia regional workshop. Hotel Soaltee Crown Plaza, Kathmandu, 20-21 December 2012. Kathmandu: Government of Nepal, Italian Development Co-operation, and FAO, 2-13.