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RESEARCH ARTICLE

EVALUATION OF WHEAT (*Triticum aestivum* L.) GENOTYPES FOR YIELD AND RUST RESISTANCE UNDER RAINFED CONDITIONS IN MID HILLS OF NEPAL

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ABSTRACT

Wheat, the third major staple crop of Nepal has been suffered from many diseases. Various diseases are the major limiting factors of considerable wheat production; one of them is rust. There are three types of rust in wheat, leaf rust, stripe rust and stem rust (Black rust). However, the major biotic constrains are yellow rust in hills and leaf rust in plains of Nepal. Severity of leaf rust gradually increasing year after year in hills of Nepal also. In order to identify the high yielder, rusts resistant wheat genotypes for mid hills of Nepal, an experiment was carried out at Agricultural Research Station, Dailekh during 2014-2015. It was designed in Randomized complete block design (RCBD), composed of twenty wheat genotypes with three replications. Each plot was made eight rows of three meter long. Manually harvested middle six rows leaving one row both side as a boarder. Rust scoring was done thrice in seven days interval. Average coefficient of infection (ACI) was calculated. The highest ACI was 63.3 followed by 57.5 of genotypes WK 1481 and WK 2214 respectively for stripe rust. Similarly, the highest ACI was found 52.33, 18.33 and 18.33 in genotype WK 2437, WK 2381 and WK 2214 respectively for leaf rust. The grain yield was found highest (5549 $kgha^{-1}$) in genotype WK 2278.

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INTRODUCTION

Wheat is the world's most important crop after maize and highly significant in terms of food security. It contributes to about 41% of cereal calories from direct consumption worldwide (Shiferaw *et al*., 2013). It is used to make food, feed, beverages and biofuel (Lupton, 1987). Among cultivated wheat, bread wheat is one of the main staple foods in the world. Globally, its production is estimated to 680 million tons per year planted on about 225 million hectares (Sharma *et al*., 2013). Wheat is produced in a wide range of climates although it is most favourably adapted to cool, dry environments and least favourably adapted to warm, moist climates (Lupton, 1987).

Wheat is the third most important cereal crop after rice and maize in Nepal. Wheat occupies 0.7 million ha area and produces 1.56 million tons of wheat with 2243 kg/ha productivity. Terai (plain area) of Nepal represents about 58% of total wheat area and contributes more than 71 % of total wheat production in the country, followed by hills 34% and mountain 8% of wheat area and contributes 25% and 4% to the total wheat production (NWRP, 2012-13). The present national average wheat productivity is 2156 kg/ha. Wheat (*Triticum aestivum* L.) world's most extensively grown crop and is third important cereal crop cultivated after rice and maize in Nepal occupying 20% of total cereal area and contributes 20% of the total cereal production in the country. Total area of production 779523 ha and total production is 1831879 mt whereas, the national average yield is only 2.4 t/ha (MoA, 2012/13). There are several biotic constraints which reduce wheat yield. Among them disease is one of the major constraints, seven diseases have been identified as the major constraints in various wheat growing areas of Nepal. These include Stripe rust (*Puccinia striiformis*), Leaf rust (*P. recondite tritici*), helminthosporium leaf blight (HLB), a complex of spot blotch (caused by *Bipolaris sorokiniana* Sacc in Sorok.), Tan spot (Caused by *Pyrenophora tritici repentis* Died,) Loose smut (*Ustilago segatum tritici*) and Powdery mildew (*Erysiphe graminis f, sp, tritici*) (Bhandari *et al*., 2005). In Nepal the loss in garin yield due to leaf rust has been estimated to be 14 per cent with moderate level of infection and 20 per cent when there is high rust severity (Bhatta, 1995). Similarly, grain loss upto 30 per cent has been

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recorded in susceptible variety RR21 at mid hills of Nepal by stripe rust when infection occurred at flowering stage (Bhatta, 1995).

Rust fungi are parasitic and obligate biotrophs that survive, develop and reproduce on living plant tissue. There are about 7 000 species of rust fungi that cause diseases on cereal crops and ornamental plants (Mohanan, 2010). These species interact with their specific hosts in a "gene for gene mode depending on the presence or absence of avirulence gene(s) in the pathogen and resistance gene(s) in the host" (Eckardt, 2006). Flor (1971) stated that incompatibility between host and pathogen occurs only if a resistance gene and its corresponding avirulence gene interacts.

Rust fungi have life cycles with up to five different spore stages. Many rusts require two separate host plants to complete their life cycle and are known to be heteroecious while others are autoecious, completing their life cycle on one host plant (Eckardt, 2006). Successful infection occurs when rust fungi develop special infection structures (haustoria) that penetrate the host cell and damage the plant by using its nutrients (Hahn and Mendgen, 2001).

Wheat leaf rust, also called brown rust, is caused by *P. triticina* (Curtis *et al*., 2002) and is the most common and widely distributed foliar disease of wheat (Mebrate *et al*., 2008). It causes great losses during warm and dry summers and multiplies fast when dew or misty conditions prevail (Bartos *et al.*, 2002). Stripe rust, caused by *P. striiformis.* f. sp. *tritici* is an important constraint to wheat production in cool environments and is the most damaging to grain among the three rust diseases of wheat (Singh *et al*., 2000). Moisture and low temperatures favour the occurrence of stripe rust and it also occurs in tropical areas of higher altitude (Boshoff *et al*., 2002). Despite its historical incidence in cooler climates, devastating stripe rust epidemics have now been reported from warmer regions where the disease was considered unimportant (Hovmøller *et al*., 2011).

In hills of Nepal there are several Berberis species which are naturally infected and continuously supplies *Puccinia striiformis* inoculums as alternate hosts of *Puccinia striiformis* f. sp. *tritici.* It is difficult to control disease by using fungicides and tolerant variety become susceptible after some years. Resistance breeding for major diseases in wheat has been employed in the country and some resistant varieties have been released over the years. Development of resistant variety minimizes the use of fungicide, reduces the cost of cultivation and also protects environment. Very low attention is required in terms of diseases management after the cultivation. Such variety should have a durable resistance. However, the interaction between the host and pathogen which causes change in the virulence of the pathogen is the major factor for the breakdown of resistance in the host.

MATERIALS AND METHODS

The experiment was carried out at Agricultural Research Station, Kimugaun, Dailekh, Nepal. This station is situated in Narayan Municipality-7, Kimugaun of the Dailekh district which is 2.3 km away from the district headquarter, Dailekh. Geographically, the station is located at an altitude of 1250-1355 m above mean sea level with 28.8479' North latitude and 81.7225' East longitude. The materials were selected from Agricultural Botany Division, Khumaltar, Lalitpur. The experiment comprised twenty advanced wheat genotypes with three replications. The experiment was laid out in randomized complete block design (Gomez & Gomez, 1983) with three replications. Each entry was planted with 8 rows of 3 meter. Manually harvested six rows each plot leaving each row both sides of each plot as a boarder row. Chemical fertilizer 120:60:40 Kg, NPK.ha-^{1} applied. Half dose of nitrogen and all P and K was applied at the time of planting while remaining half does of N was applied at time of weeding and other cultural practices were used as general cultivation practices of wheat. The rust disease will be recording according to the modified cob's scale (Peterson *et al.,* 1948).

The leaf and stripe rust intensities in wheat based on severity (percentage of rust infection on plants) and field response (type of disease reaction). This recording process relies upon the visual observation and it is common to use the following intervals.

Trace, 5, 10, 20, 40, 60, 100 percent infection.

Field response will be recording the following letters.
0: No visible infection on plant.
R: Resistant; visible chlorosis or necrosis, no uredia are present.
MR: Moderately resistant; small uredia are present and surrounded by either chlorotic or necrotic areas.
M: Intermediate; variable sized uredia are present some with chlorosis, necrosis or both.
MS: Moderately susceptible; Medium sized uredia are present and possibly surrounded by chlorotic areas.
S: Susceptible; Large uredia are present generally with little or no chlorosis and no necrosis. Severity and field response regarding are usually combined.
tR=Trace severity with a resistant field response.
5MR= 5% severity with a moderately resistant field response.
60 S= 60% severity with a susceptible field response.
Each plot was manually harvested. Days to heading, days to maturity, plant height, spike per meter square, grain per spike yield and test weight were recorded. The obtained data were analysed using CropStat 7.2 software and MS Excel.

RESULTS AND DISCUSSION

Days to Heading

Difference among wheat genotype in the duration of the period between sowing and heading are largely governed by their sensitivity to photoperiod and vernalisation (Slafer *et al.,* 1995). The number of days taken to 50% heading by the genotype under study showed non significant (Table 1). The genotype WK 2438 found to be earlier among the tested genotypes (99 days) which gave good yield (4187 kgha^{-1}) and had no rust. Similarly, genotype WK 2437, (99 days) was found to 50% heading but ACI value of both rust was high (Table 1). Early genotypes are favourable to escape disease late and season drought as most of the Nepalese hill's farmers there is no irrigation facilities, there is no more yield loss even infection occur in ripening stage of crop. The early maturing winter wheat varieties grown in Louisiana usually escape serious losses caused by stem rust (Clayton, 2015).

Days to maturity

Days to maturity among the tested genotypes were found highly significant. The Genotype WK 2438 was found early maturing (141 days). It was also free from rust (ACI 0) for stripe and leaf rust. It gave also good yields 4187 kgha^{-1} (Table 1). Similar results, like Triumph 64, Chisholm, Karl 92 and AGSECO 7853 are susceptible to rust but appear to tolerate infection better than other varieties because they fill from the stem or awns, very early varieties may escape severe losses by maturing before rust can build up to high levels (Robert 2015). Maturity duration of any variety plays an important role in the acceptance or rejection of the genotypes. In Nepal, farmers are most frequently reluctant to accept a variety which has a better yields but late in maturity (Tiwari *et al.,* 1995).

Plant height

Statistical analysis of the data showed non significant differences ($P \leq 0.05$) among genotypes for plant height (Table 1). Mean value of the data in indicated that the higher plant height (163.3 cm) was found in WK 2248 followed by WK 2278 (125.25 cm). Ashiq *et al.,* (1995) reported that differences in plant height are due to the differences in their genetic makeup. The same result was reported by Hassan *et al.,* 1998. Since 1960, many semi-dwarf high yielding wheat varieties were released and its adaptation rate was very high till the early 1980 (Byerlee *et al.,* 1993) and (Heisay *et al*., 2002). In Nepal tall varieties are mostly grown in rainfed areas of high altitudes where farmer need both grain and higher straw yield for thatching and livestock feeding (Tiwari *et al.,* 1995) while these genotypes showed more drought tolerance as compared to dwarf genotypes. Such genotypes will be included in breeding program for rainfed areas in high altitudes of Nepal.

Spike per meter square

The grain yield is directly proportional to the effective spike per meter square. Statistical analysis for this character showed highly significant differences ($P \leq 0.05$). The genotypes WK 2408 (478) were found more spike per meter square followed by WK 2214 (466), WK 2272 (451) and WK 2278(436). Those genotypes also found tolerant to stripe rust also. But genotype 2408 showed 7.33 and 4.66 ACI of stripe and leaf rust respectively (Table 1).

Grain per spike

The grain per spike were found non significant among the tested genotypes. However the genotype WK 2278 gave highest grains per spike (59). This genotype also gave the highest grain yield (5549 kg ha^{-1}) and showed field resistant to the both rust followed by WK 2408 (53) and NL 1223 (53). But genotype WK 2408 showed lower ACI 7.33 and 4.66 for yellow and stripe rust respectively (Table 1).

Test weight (1000 grain weight)

The test weight is the most important yield attributing characters in determining the yield potential of a genotype. This varies with the genetic background of a genotype. Statistical analysis of the data showed highly significant differences ($P \leq 0.05$) among genotypes for test weight (Table 1). The maximum test weight (50.67 gm) was given by genotype WK 2214. This genotype was free from stripe rust but the ACI of leaf rust was 57.5. Similarly, WK 2352 gave 50.33 gm test weight and it was free from both rust (Table 1 and 2). Alavi *et al*. (2013) in investigate of wheat cultivars tolerance to drought stress found that role of test weight for increase grain yield is higher than other yield components.

Grain Yield

Statistical analysis for grain yield showed highly significant differences ($P \leq 0.05$). Higher grain yield is the biggest reason for incorporating CIMMYT germplasm in wheat Breeding Program (Smale *et al.,* 1998).

Table 1. Observed mean value of wheat genotypes during 2014-2015

Genotype	Heading (Day)	Maturity (Day)	Plant height (cm)	Spike/m^2	Grain per Spike	Test weight (gm)	Yield ha^{-1} (kg)	Stripe rust (ACI)*	Leaf rust (ACI)*
WK 2208	107	153	118.4	420	51	35.67	3242	4.67	0
WK 2248	105	148	163.3	331	49	43.33	3557	0.67	19
WK 2272	110	153	93.4	451	51	42.67	4111	0.67	17.5
WK 2278	108	154	125.5	436	59	42.33	5549	0	0
WK 1204	109	153	89.33	373	51	46	3859	3.5	21
WK 2408	109	152	92.87	478	53	37	4404	7.33	4.66
WK 2414	109	147	93.6	414	49	42.33	4012	10.67	0
WK 2352	108	152	117.5	251	45	50.33	3499	0	0
WK 2353	111	148	99.33	382	45.47	38	3671	3.33	0
Chayakura	105	152	97.53	293	49	49	3626	0	48.33
WK 2355	108	154	93.8	466	51	39.33	4402	2.67	0
WK 2359	105	149	117.9	386	48	48	4152	3.33	26.67
WK 2381	108	150	94.47	360	48	39.67	2696	18.33	0
WK 2388	110	143	101.8	204	51	32.67	2933	0.67	12
WK 1481	106	152	128.7	333	55	48.67	3948	8.33	63.33
WK 2437	99	142	91.73	416	44	48.33	3845	52.33	28.33
WK 2438	99	141	92.8	330	45	49	4187	0	0
NL 1223	106	150	98.07	318	53	39	3416	11	25
WK 2214	101	148	112.2	466	52	50.67	4206	0	57.5
WK 2257	106	149	101.2	434	46	47.67	2917	0	14.33
Grand Mean	107	150	106.2	379	48	43.48	3812	7.292	16.88
LSD $_{0.05}$	10.34	5.402	41.59	137.4	13.68	6.089	1248	14.88	27.5
C.V.%	6	2	24	22	17	8	20	123	99
F-test	NS	HS	NS	HS	NS	HS	S	HS	HS

*Average coefficient of infection, NS= Non significant, S= Significant, HS= highly significant

Table 2. Severity and field response of wheat genotypes against stripe and leaf rusts during 2014

S.No.	Genotype	Stripe Rust			Leaf Rust		
		Rep I	Rep II	Rep III	Rep I	Rep II	Rep III
1	WK2208	10MS	5 MS	10 MS	0	0	0
2	WK 2248	0	0	0	30S	30 MS	30 MS
3	WK 2272	0	0	0	20S	15 S	20 S
4	WK 2278	0	0	0	0	0	0
5	WK 1204	0	0	5 S	30S	20S	30 MS
6	WK 2408	20S	20 S	5MS	10MS	10 MS	10 MS
7	WK 2414	30MS	20 MS	20 MS	0	0	0
8	WK 2352	0	0	0	0	0	0
9	WK 2353	5MS	10 MS	10 MS	0	0	0
10	Chyakhura # 1	0	0	0	100S	10 S	40 S
11	WK 2355	5MS	10 MS	5 MS	0	0	0
12	WK 2359	0	0	0	40S	50 S	30 S
13	WK 2381	30S	30 S	40 S	0	0	0
14	WK 2388	0	0	5 MS	20MS	15 MS	20 MS
15	WK 1481	0	0	0	100S	100 S	20 S
16	WK 2437	100S	100S	30 MS	40S	40 S	30 S
17	WK 2438	0	0	0	0	0	0
18	NL 1223	20MS	10 MS	20 MS	40S	30 S	20 S
19	WK 2214	0	0	0	100S	90 S	30 S
20	WK 2257	0	0	0	10S	10 MS	40 S

MS= Moderately susceptible, S= Susceptible

Annex 1: Monthly meteorological data of Dailekh during the experiment

Month	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)	Rainfall (mm)	RH %
October	25.3	15.1	35.7	86.2
November	23.3	10.8	7.4	80.4
December	18.9	7.0	0	76.1
January	18.6	6.4	46.2	77.1
February	19.2	7.3	45.6	73.7
March	25.2	10.8	25.2	66.95
April	29.7	14.7	1.6	57.85

Source: Annual Report (2013/14), Agricultural Research Station, Dailekh.

The genotype WK 2278 produced (5549 kg^{-1}ha) grain yield followed by WK 2408 (4404 kg^{-1}ha), Wk 2355 (4402 kg^{-1}ha), WK 2214 (4206 kg^{-1ha}) and WK 2438 (4187 kg^{-1ha}). However, the genotypes which were free from stripe rust with good yield could be the future variety of mid hills of Nepal (Table 1). Some genotypes showed less or free from leaf rust could be the future variety where leaf rust prevails. The genotype WK 2278, WK 2438 and WK 2352 showed no ACI for both rust and it was a high yielder among the tested genotypes. The WK 2214 also gave good yield (4206 kg^{-1}ha) even the ACI of leaf rust 57.5 and it could be a good vriety in hills where stripe rust prevails. The losses in yield due to stripe rust varied 4.2-68.8 per cent depending on the resistance of variety. Maximum yield reduction of 68.3 per cent was observed in old cultivar (Madhu *et al*., 2012). But in case of leaf rust loss was found less than the stripe rust.

Disease reaction

One of the main objectives of this study is to select, wheat varieties which are resistant to strip rust and leaf rust with superior yielder of mid hills of Nepal and disease reaction is the second most important reason after grain yield. The losses from Stripe rust have been minimum after the release and dissemination of some wheat varieties with Yr 9 gene till last decade (Bhatta 1995). Genotypes in this experiment showed different level of susceptibility and resistance to stripe rust and leaf rust. Less than 10% (10 MS) strip rust infection has been reported as the highest resistance and less than 5% (5 MS) is the effective resistance of the wheat variety/line/gerrmplasm (Peterson *et al.,* 1948). The genotype WK 2248, WK 2272, WK 2278, WK 1204, WK 2214, WK 2257, Chyakhura # 1, WK 2359, WK 2388, WK 1481, WK 2438 and WK 2352 were found to complete resistant against stripe rust in natural epiphytotic condition. The genotypes WK 2208, WK2278, WK2414, WK2352, WK2353, WK 2355 and WK 2438 were found completely resistant to leaf rust but genotypes WK 2208, WK2414, WK2353 and WK 2355 also showed the highest resistant to effective resistant against stripe rust. Such a genotype could be the future variety of this region of Nepal.

Conclusion

The genotypes showed highest resistant to effective resistant to both rust and good yield and yield attributing characters can be used for future variety of respective rust predominant area of mid hills of Nepal. Some genotypes showing good resistant may be utilized resistance transferred using cyclic breeding program into commercial varieties to meet the immediate challenged posed by rust in this region of Nepal.

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