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Evaluation of Wheat Genotypes for Yellow Rust Resistance in Field Condition of Foot Hill of Nepal

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Abstract

Stripe rust (Yellow rust), is one of the important foliar disease of wheat caused by Puccinia striiformis f. sp. Tritici in Nepal limiting the production of wheat. Previously this disease is considered as disease of cooler places but virulent strains of yellow rust are also adapted to higher temperature posing threat to wheat cultivated all around Nepal. Development of resistance genotypes is the most effective means of managing disease, especially in developing countries. For assessment of yellow rust severity an experiment was done at Kamalamai-04, Phant, of Sindhuli district, Nepal in farmers field during November 2017 to April 2018. Thirty promising wheat genotypes including two resistant WK 1204 and Dhaulagiri and two susceptible Morocco and RR 21 checks were experimented in Alpha lattice design with 3 replications. Data of field response of genotypes to yellow rust, maximum severity and AUDPC were calculated. Sixteen genotypes including Morocco and RR 21 showed susceptible (S) response while 5 genotypes showed moderately susceptible (MS) and 2 genotypes showed moderately resistant to moderately susceptible (MR-MS) field response to yellow rust. Genotypes WK 2832, NL 1340, NL 1342, NL 1338, BL 4837 and WK 1204 showed moderately resistant (MR) and NL 1336 resistant (R) response. Highest disease severity (89.88%), and mean AUDPC (289.72) was found in Morocco and least severity (1.50%), and mean AUDPC (2.33) in NL 1336. Regression analysis showed 67 % variation in thousand kernel weight and 73% variation in grain yield is due to yellow rust.

Key words: Yellow Rust, Severity, AUDPC, Regression.

Introduction

Wheat is the number one winter cereal and the third most important crop after rice and maize in Nepal. It is cultivated in rotation with rice and maize. It occupies 735,850 ha of land and has production of 1,879,191 metric tons yielding 2,554 (CBS, 2015). It is widely adapted with its coverage in all the three agro-climatic regions of the country, ranging from sea level to 4000 masl. Though the wheat area was expanded over the last decade, its productivity is constrained by various abiotic and biotic stresses.

Rust is the major biotic constraint, followed by spot blotch, kernel bunt and powdery mildew, while drought, post anthesis heat stress and less availability of fertilizer and pesticides are the major abiotic constraints (Chatrath, Mishra, Ortiz Ferrara, Singh, & Joshi, 2007) (Thapa-Parajuli & Devkota, 2016).

Yellow rust infection is by the obligatory parasitic fungus Puccinia striiformis f. sp. tritici, is one of the major devastating diseases of wheat in several areas around the globe (Wan, Chen, & He, 2007) (Chen, 2005). Stripe rust has shown its existence in nearly 61 countries of six continent except Antarctica (Waqar et al., 2018). In Nepal, it was first recorded in 1964 in local wheat (Sarala Sharma et al., 2015). From the ancient time, yellow rust has caused and is present time causing significant and drastic losses on susceptible wheat cultivars worldwide (Wellings, 2010). In Asia, approximately 46% yield reduction are caused by epidemics of yellow rust (Waqar et al., 2018).

Nepal faced periodic epidemics in the past years due to heavy outbreak of yellow rust disease. The during seventies, when local genotypes were extensively cultivated, yellow rust disease was most prevalent. Yellow rust was principally considered as a wheat disease associated with higher elevations, cooler climates (2°C - 15°C), and Northern latitudes. But recent outbreaks of new strains have changed the previous concept with prevalence of virulent strains of disease that are more adapted to higher temperature and symptoms seen in the countries closer to equator (ICARADA, 2011). Until now, the devastating disease has been controlled partly by cultivating genetically resistant varieties and partially by spraying fungicides on wheat crop. Cultivation of resistance genotype to disease is the most economic and environmentally sound measure to reduce losses. This paper aims to provide severity of yellow rust and yield variation in wheat due to yellow rust.

Materials and Methods

The experiment was conducted at the farmer's field of Kamalamai-04, Phant, of Sindhuli district, Nepal, from November 2017 to April 2018. The research site was located at 27.647680 N latitude and 84.347500 E longitudes and at an altitude of 537 meters above sea level. Climatically, Sindhuli lies in humid sub-tropical region with weekly mean maximum temperature ranging from 15.60C– 27.80C and minimum temperature form 1.1 0C– 12.8 0C. Highest rainfall was recorded at 1st week of April (42.6mm) and total rainfall was 200.7mm during the research period. Thirty wheat genotypes were used as plant material in this study (Table 1). Wheat seeds were obtained from National Wheat Research Program, Bhairahwa. The experiment was conducted in Alpha lattice design with three replications, each replication consisting 6 blocks with 5 plots in each block. Individual plot size was 3 m x 2 m (6 m2). Row to row spacing was 25 cm where 8 rows of 3 m length in each plot was made. Three spreader rows of seed mixture of susceptible check Morocco and RR 21 were maintained on each sides of the experimental block. The planting was done in Nov. 27, 2017. The chemical fertilizers were applied at the rate of 120:60:60 kg NPK per hectare. First irrigation was done at the crown root initiation (CRI) stage second at the time of booting stage and third at grain filling stage.

Entry	Genotypes	Entry	Genotypes	Entry	Genotypes
1	BL 4833	11	NL 1334	21	WK 2799
2	BL 4837	12	NL 1335	22	WK 2820
3	BL 4845	13	NL 1336	23	WK 2832
4	BL 4850	14	NL 1337	24	WK 2846
5	BL 4863	15	NL 1338	25	WK 2847
6	NL 1329	16	NL 1339	26	WK 2884
7	NL 1330	17	NL 1340	27	RR 21*
8	NL 1331	18	NL 1341	28	Morocco*
9	NL 1332	19	NL 1342	29	Dhaulagiri#
10	NL 1333	20	WK 2793	30	WK1204#

Table 1: List of 30 wheat genotypes used in the study

* Susceptible and # resistant checks

Randomly selected 12 plants (2 plants/row from middle 6 rows) were tagged per plot for disease scoring. Disease was recorded from the flag leaf of all sample plants.

Disease assessment

Disease scoring

Stripe rust severity was measured as percentage of flag leaf area covered with the rust according to the modified Cobb's scale (Peterson, Campbell, & Hannah, 1948) during 23 February, 2018 to 23 March, 2018 in plots at 7 days intervals after appearance of the first disease symptoms on flag leaf (Table 2).

Response	Description
O	No visible infection on plants.
O	No visible infection on plants.
MR	Moderately resistant: small uredia are present and surrounded by either chlorotic or necrotic area.
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

Table 2: Modified cob's scale of (Peterson et al., 1948) for describing disease severity of stripe rust on wheat

Estimation of area under disease progress curve

Disease scoring was done with modified Cob's at Zadock´s scale of wheat growth. Average coefficient of infection (ACI in each variety was computed by multiplying disease severity with response coefficient as defined by disease response level (Table 3) as below:

With these average coefficients of infection, areas under disease progress curve (AUDPC) from two successive dates of observation of each variety were calculated. AUDPC gives a quantitative measure of epidemic development and intensity of disease (Reynolds and Neher, 1997), and the variety having the lowest AUDPC values was categorized as most resistant.

AUDPC was calculated using the following formula as previously used by Das et al. (1992).

$$AUDPC = \sum_{i=1}^{n-1} \left([\{(Yi + Yi+1)/2\}] \times [t(i+1) - ti)\right]$$

Where, Yi is the yellow rust severity on the ith date, ti day, and n is the number of dates on which yellow rust was recorded.

Disease description*	Disease response Level	Code	Response coefficient (CI value)
-No visible infection	No disease	Tr	0
-Visible chlorosis or necrosis, no uredia	Resistant	R	0.2
-Small uredia surrounded by chlorotic/ necrotic areas	Resistant to moderately resistant	RMR	0.3
-Uredia medium size with no necrotic margins but possibly some distinct chlorosis	Moderately resistant	MR	0.4
-Large uredia with necrosis and little or no chlorosis	Moderately resistant to moderately susceptible	MRMS	0.6
	Moderately Susceptible	MS	0.8
	Moderately susceptible to susceptible	MS-S	0.9
	Susceptible	S	1

Table 3: Response coefficient of wheat plant against stripe rust in field (Afzal et al., 2009)

* (Afzal et al., 2009)

Result and Discussion

Development of yellow rust and response of wheat genotypes

Different genotypes tested under natural infections on farmers field showed different response to yellow rust. Symptoms first started to appear from 23 February, 2018 (90 Days after sowing) on plants of spreader rows (mixture of susceptible varieties RR 21 and Morocco). Among 30 genotypes (Table 4) symptoms of yellow rust in genotypes Morocco (90.61 DAS) and RR 21 (90.85 DAS) appeared first, followed by NL 1333 (91.63 DAS) and BL 4863 (91.63 DAS). In genotypes BL 4837, WK 1204 and NL 1336 disease seen 111.34 DAS, 112.40 DAS and 117.01 DAS respectively (Table 4).

Yellow rust incident in wheat genotypes showed highly significant variation among studied genotypes. At the later growth stage all genotypes except NL 1336, WK 1204, BL 4837, NL 1338, NL 1342, NL 1340 and WK 2832 showed moderately susceptible to susceptible response. Disease occurred earlier in genotypes Morocco (90.61 DAS) and RR 21 (90.85 DAS) and delay onset of disease was seen in WK 1204 (112.40 DAS) and NL 1336 (117.01 DAS). This clearly showed that the evaluated genotypes vary in their level of disease resistance and the degree of disease development. The disease incident ranges from 1% (for resistant) to 90% (for highly susceptible). Disease scoring detects that initial incidence of yellow rust have little or no effect on the final severity of the genotypes. Initially, the increment of disease on WK 2799 was higher and other genotypes was slower (till to March 16), then after disease increment on varieties Morocco and RR 21 was sharper followed by WK 2799. Similar type of findings was seen in research conducted by (Taye, Fininsa, & Woldeab, 2014).

Field response of yellow rust

In genotypes Morocco, RR 21, WK 2799, WK 2793, NL 1333, NL 1332, NL 1329, BL 4863, BL 4850, WK 2847, WK 2820, NL 1339, NL 1337, NL 1335, NL 1334 and BL 4845 large uredia were seen in flag leaf with no any chlorosis so according (Peterson et al., 1948) those genotypes showed susceptible (S) field response followed by genotypes having medium sized uredia in flag leaf termed as moderately susceptible (MS) seen in genotypes BL 4833, NL 1330, NL 1341, Dhaulagiri and WK 2846. While NL 1331 and WK 2884 showed small to medium sized uredia in their flag leaf having moderately resistant to moderately susceptible (MR-MS) field response. In genotypes WK 2832, NL 1340, NL 1342, NL 1338, BL 4837 and WK 1204 small sized uredia was seen and it was confirmed that those genotypes showed moderately resistant (MR) field response. Only chlorosis was seen in flag leaf of genotype NL 1336 showed resistant (R) field response to yellow rust. (Table 4)

Yellow rust severity

At field condition very low to high disease severity percentage was recorded from experimented genotypes. In susceptible check Morocco (89.88%) and RR 21 (87.17%) highest disease severity was seen whereas in resistant check WK 1204 has (6.12%) severity was seen and in Dhaulagiri 37.67% of severity was seen in that agroclimatic condition.

There was highly significant ($P<0.01$) difference on final disease severity on flag leaf of different genotypes. Final disease severity was seen in the range of 89.88% to 1.50%. Significantly highest final disease severity was seen in Morocco (89.88%) followed by RR 21 (87.17%) and NL 1333 (83.08%) while in genotypes NL 1342, WK 1204, and NL 1336 had significantly lowest severity 7.98%, 6.12%, 1.50% respectively on flag leaf.

Based on final rust severity we obtained three ranges i.e., 0-30%, 31-60% and >60%, resistant to moderately resistant, moderately susceptible and susceptible type (Table 4). Genotypes having less than 30 % relative severity are BL 4833, BL 4837, NL 1330, NL 1331, NL 1336, NL 1338, NL 1340, NL 1342, WK 2832, WK 2884, WK 1204. Genotypes having relative severity more than 30% to 60 are categorized as moderately susceptible which includes genotypes NL

1341, WK 2846 and Dhaulagiri. Sixteen lines including Morocco displayed disease severity more than 60%. Relative severity represents the cumulative result of all resistance factors during the progress of epidemic.

Genotype	RA (DAS)	MS%	AUDPC	FR
BL 4833	95.62g-i	21.61h-j	114.34l-n	30MS
BL 4837	111.34b	9.21kl	39.67mn	20MR
BL 4845	93.97i-k	56.51f	569.34g-i	60S
BL 4850	94.07i-k	80.19a-c	679d-g	80S
BL 4863	91.95k-n	79.67a-c	736.17b-f	80S
NL 1329	93.96i-l	79.97a-c	781.67a-d	80S
NL 1330	98.89de	23.67hi	140lm	30MS
NL 1331	97.18e-h	14.76i-k	109.67l-n	30MR-MS
NL 1332	94.67ij	80.55a-c	749a-e	80S
NL 1333	91.64l-n	83.08a-c	691.84d-f	80S
NL 1334	95.67f-i	62.9ef	553hi	60S
NL 1335	97.53e-g	64.08ef	466.67i	60S
NL 1336	117.02a	1.5l	7n	5R
NL 1337	95.65f-i	63.58ef	541.34hi	60S
NL 1338	100.46d	8.8kl	60.67mn	20MR
NL 1339	94.89h-j	66.16d-f	634.67e-h	70S
NL 1340	97.38e-g	12.35jk	100.34l-n	30MR
NL 1341	97.92e-g	31.84gh	186.67kl	40MS
NL 1342	108.06c	7.99kl	65.34l-n	20MR
WK 2793	93.91i-l	75.95cd	690.67d-g	80S
WK 2799	92.01k-n	77.44bc	822.5a-c	80S
WK 2820	92.87j-n	65.9d-f	625.34f-h	70S
WK 2832	97.96ef	11.08kl	67.67l-n	30MR
WK 2846	94.66ij	40.17g	147lm	50MS
WK 2847	93.15j-m	72.93c-e	290.27jk	70S
WK 2884	97.25e-g	26.59h	708.17c-f	40MR-MS
RR 21	90.86mn	87.18ab	834.17ab	90S
Morocco	90.62n	89.88a	869.17a	90S
Dhaulagiri	94.08i-k	37.67g	336j	50MS
WK 1204	112.41b	6.12kl	25.67mn	15MR
Grand Mean	97.25	47.98	421.43	
CV%	1.42	12.82	17.62	
LSD	2.19	10.83		
F test	***	***		

Table 4 : Disease appearance days after sowing (DAS), maximum disease severity and field response of yellow rust on 30 wheat genotypes during November 2017 to April 2018 at Kamalamai-04, Phant, Sindhuli.

Significant traits are denoted by * for p < .05, ** for p < .01, and *** for p < .001. RAD = Rust appearance date, MS= Maximum severity, AUDPC= Area under disease progressive curve FR= Field response

Area under disease progressive curve

AUDPC was calculated using the average coefficient of infection (ACI) data of all the four scorings taken on flag leaves of each variety. Highest audpc value was found in Morocco (869.17) followed by RR 21 (834.17) and WK 2799 (822.5). Lower AUDPC value was found in BL 4837 (39.67), followed by resistant check WK 1204 (25.67) and least AUDPC was found in NL 1336 genotype (7).

Due to different genetic background, crop situation, prevailing agro-climatic conditions, host nutrition difference etc., differential rate of disease development may have been recorded in different genotypes. Rate of disease progress was less in NL 1336 and WK 1204 compared to other varieties (Morocco, RR 21 and WK 2799) indicating their higher level of partial resistance in these varieties. Initially, the differences in yellow rust severity among the wheat varieties were not so pronounced, but over time, it progressed faster in Morocco and RR 21 compared to other varieties. It indicates that they have got more susceptible genes compared to other varieties. Karki (2014) reported that WK 1204 had lowest AUDPC value and Morocco was very susceptible and had higher AUDPC value than other varieties.

Regression analysis

Regression between mean AUDPC and TKW

There was significant (p≤0.01) negative linear relationship between mean AUDPC and thousand kernel weight (Figure 9). According to the linear regression equation if there was a unit increase in mean AUDPC on flag leaf then thousand kernel weight would have been decreased by 0.0384 times. According to the coefficient of determination, about 67% variation in thousand kernel weight was due to mean AUDPC on flag leaf and remaining portion due to other factors.

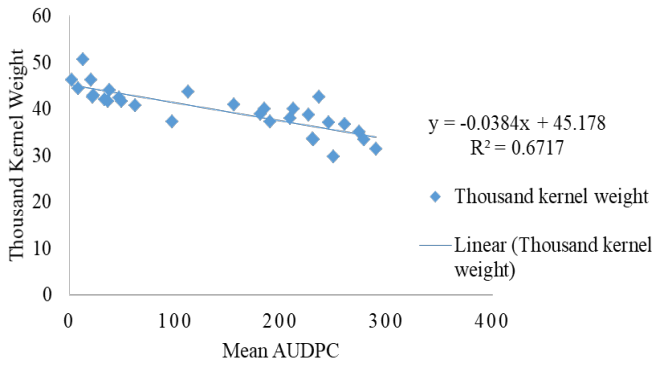

Figure 1: Estimated linear relationship between mean AUDPC and thousand kernel weight in different 30 wheat genotypes due to yellow rust during November 2017 to April 2018 at Kamalamai-04, Phant, Sindhuli.

Regression between mean AUDPC and grain yield

There was significant (p≤0.01) negative linear relationship between mean AUDPC and grain yield (Figure 10). According to the linear regression equation if there was a unit increase in mean AUDPC on flag leaf then yield would have been decreased by 0.0046 times. According to the coefficient of determination, about 73% variation in yield was due to mean AUDPC on flag leaf and remaining portion due to other factors.

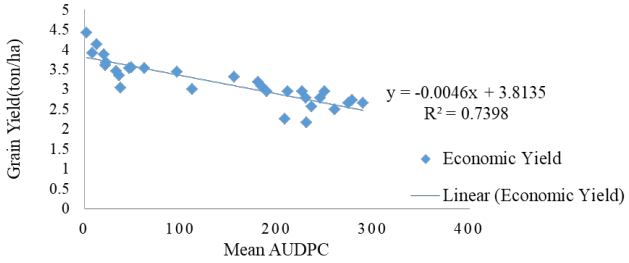

Figure 2 : Estimated linear relationship between mean AUDPC and yield in different 30 wheat genotypes due to yellow rust during November 2017 to April 2018 at Kamalamai-04, Phant, Sindhuli.

Conclusion

Among 30 genotypes; 16 showed Susceptible, 5 moderately susceptible, 2 moderately resistant to moderately susceptible, 6 moderately resistant and 1 resistant response to yellow rust those genotypes contains various types of yellow rust resistant genes that can be exploited for various types of yellow rust resistant genes for gene pyramiding. Highest disease severity (89.88%) and mean AUDPC (289.72) was found in Morocco and least disease severity (1.5%) and mean AUDPC (2.33) was found in NL 1336. The NL 1336 showed resistant field response to yellow rust having least mean AUDPC and least severity percentage. The genotypes BL 4833, BL 4837, NL 1330, NL 1331, NL 1336, NL 1338, NL 1340, NL 1342, WK 2832, WK 2884 and WK 1204 having low relative severity and AUDPC can be used in breeding program for development of durable yellow rust resistant cultivar.

Conflict of Interest

There no is any conflict of interest between authors.

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