

Distribution rate of wheat stem rust (*Puccinia graminis* f.sp. *tritici*) at North shewa, Hadiya and East shewa Zone, Ethiopia

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Abstract

The field survey, for disease assessment was carried out during 2019 cropping season in three major wheat growing zone at North Shewa, East Shewa and Hadiya Zones which are purposely selected based on wheat production potential and highly suitable environment for the disease development. Fifty-five fields were assessed, of this stem rust was observed at 35 fields about (63.64%), but 20 fields with (36.36%) were not infected. The disease intensity ranged up to complete infection of surveyed fields depending on different agro-ecology. Among assessed fields at Hadiya; 9 were affected by 56.25%, 7 fields at East shewa by 38.89% and 19 fields at North shewa zones by 90.48% were affected by stem rust. The highest disease incidence (57.94%) was recorded in East Shewa zone but; the lowest disease incidence (30%) was recorded Hadiya zone. Similarly, the highest disease severity (26.75%) was recorded at North Shewa zone and Hadiya zone with the same value. The highest prevalence (73.33%) of stem rust was recorded at the high altitude > 2300 m.a.s.l, whereas lowest prevalence of 56% was recorded at low altitude. Kubsa variety was found at 20 fields with 36.36% severity was observed much more fields than others. During the assessment Hidase variety at Hadiya zone which is severely infected with severity level of 60S in the field. Highest disease incidence (100%) was recorded in field cultivated with Hidase and Tesfaye variety while; the lowest disease incidences (0) were recorded farms cultivated with Mangudo, land race and kubsa at different locations variety. The highest disease incidence (100%) was observed in the matured growth stage but the lowest (58.06%) was recorded dough stage. No significantly differences between dough stage and Milk stage (α : 0.05) were recorded. The highest severity was recorded on wheat at dough stage (42.78%). There was highly significant ($p < 0.05$) among the regions, districts within the zones and kebeles within the districts.

Keywords: Cultivars; Diversity; Incidence; Races; Rust and Severity

Introduction

Wheat is a source of food for about 40% of the world population (FAO, 2017) [1]. With more than 220 million hectares planted annually, wheat is the most widely cultivated cereal in the world. The crop is grown at an altitude ranging from 1500 to 3000 (m.a.s.l) preferably 1,900 and 2,700 m.a.s.l between 6-16°N latitude and 35-42° E longitudes. Ethiopia is the largest wheat producer in sub-Saharan Africa with about 0.75 million ha of durum and bread wheat. Ethiopia has experienced production of both bread and durum wheat cultivated in the highlands of the country largely in the areas like East, Central and North West parts [2]. In Ethiopia, wheat is cultivated on over 1, 75 million hectares and with an annual production of 4.84 million metric tons. Wheat contributes about 15.33% of the grain production in the country [3].

In terms production wheat is ranked third next to Maize and teff with total of 30.08% (94,927,708.34 quintals), 17.12% (54,034,790.51 quintals) and 15.33% (48,380,740.91 quintals) of the grain production, in the same order [3]. While, in terms of area coverage fourth after teff (*Eragrostis tef* (Zucc.) Trotter), maize (*Zea mays* L) and sorghum (*Sorghum bicolor* (L.) Moench). The Average yield of wheat in Ethiopia is increasing from 2.56 t/ha in 2015 to 2.764t/ha in 2019 [3] which is well below the world mean of 3.5 t ha⁻¹ Currently, wheat production is constrained by various wheat diseases caused by fungal, bacterial, and viral pathogens. Cereal rust fungi (*Puccinia* spp.) are among the most studied plant disease-causing agents, as they affect cereals and grasses in all parts of the world, potentially causing devastating yield losses. There are several areas worldwide in which each of the rusts can cause severe losses [4].

Among the rust diseases on wheat, stem rust (*Puccinia graminis* f.sp. *tritici*Eriks. & E.Henn), leaves rust (*P. triticina*Eriks) and stripe rust (*P. striiformis*Westend. f.sp. *tritici*Eriks) are the most important

diseases reducing wheat production in Ethiopia. Stem rust causes up to 100% yield losses over wide areas during epidemic years [5]. A stem rust pustule (uredinium) can produce 10000 urediniospores per day Aeciospores infect wheat similarly to urediniospores and used as source of inoculum of wheat stem rust. It serves as a consistent and early source of aeciospores and a breeding ground for new pathogenic races of the fungus. The existence of barberry plants in Ethiopia was reported from around Debresina and Menagesha areas [6] Bread and Durum as cultivated wheat and triticale are the primary hosts of wheat stem rust.

Most highlands of Ethiopia are considered as a hot spot for the development of stem rust complex races. This indicated the presence of broad races with wider virulence spectrum within the Pgt population in Ethiopia. Several historical events were happened in parts of Ethiopia in recent stem rust caused great losses: stem rust epidemics in 1975 on variety Laketch; in 1992/93, on variety Enkoy; in 1994, on variety Kubsa; and, in 2013, on variety Digelu. Since the pathogen inoculum survives for several years due to favorable environmental conditions, adult plant resistances are highly at risk [7]. Epidemics of wheat rusts occur across continent due to the widespread urediniospores [8]. In

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general, in order to combat the effects of stem rust disease on wheat production, it is advisable to use improved genotypes which have effectively resistant to the disease. Moreover, since resistant genes are periodically broken by the newly evolving wheat stem rust races favored by many factors, identification of available resistant genes in durum wheat cultivars and variability of races across different area is very important. According to [9] and Park et al. [10] race surveys serves important evidence to decide the gene combinations to be considered by breeding programs using major gene resistance. The assessment is aimed: to assess the prevalence, incidence and severity of stem rust in north shewa zone major wheat production area of Ethiopia.

Materials and Methods

Assessment of wheat stem rust in the field

The field survey, for the assessment of disease intensity and distribution/virulence diversity of *Puccinia graminis* f.sp. *tritici* races was carried out during 2019 cropping season in three major wheat growing zone at North Shewa, East Shewa and Hadiya Zones which are purposely selected based on wheat production potential and highly suitable environment for the disease development. From each zone 21 farms were assessed at North shewa, 16 fields from Hadiya 18 fields were from East shewa. Considering the aforementioned criteria, from each zone, three districts were selected. From each district, 3-4 kebele's were selected and from each kebele's, 1-3 farms were assessed at 5-20 km interval following main and feeder (accessible) roadsides. In addition to farmer's field, the Farmer's Training Center and wheat research stations with different crop growth stages based on Zadoks cereal growth stage (0-9) key.

Disease data collection

Stem rust severity, incidence and prevalence assessment was made at five points with diagonals ("W" pattern) of the field using (1m²) quadrant used to calculate average values. The disease data's was based on the formul

$$\text{Disease Prevalence(\%)} = (\text{Number of infected fields}) / (\text{Total number of fields assessed}) * 100$$

a: Data's such as percentage distribution, agro ecology of study area (altitudinal ranges); stem rust prevalence, incidence severity and sown wheat cultivated were collected. According to this scale at 100; the actual leaf/stem covered by rust pustule is 37%.

$$\text{Disease incidence (\%)} = (\text{Number of diseased plants}) / (\text{Total number plants in the quadrant}) * 100$$

The severity of the disease was examined on randomly selected five plants in quadrant as a percentage of stem area infection by rust disease according to modified Cobb scale after Peterson et al. [11] (Figure 1). Geographical data such as Latitude (N), Longitude (E) and Elevation (mm) of were using Garmin 600 model GPS recorded. A. Percentage occupied by uredinia. B. Rust severities by Peterson et al. (1948) [11]. Source: [12]

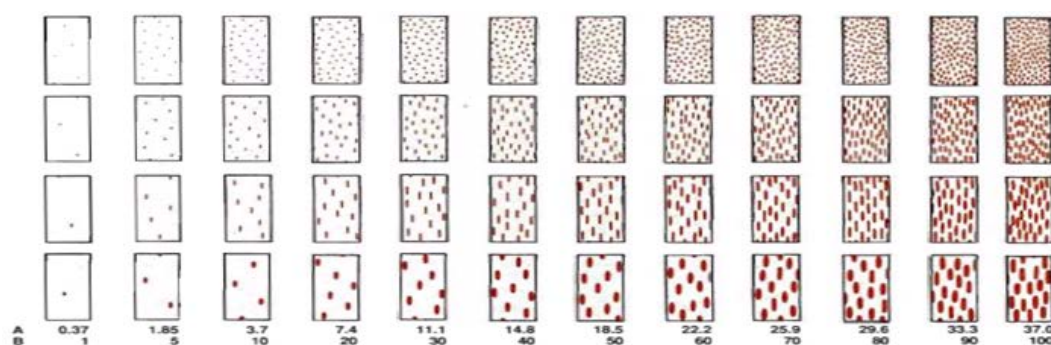


Figure 1. Rust severity estimation on leaves and stem of wheat.

Data analysis

Disease incidence and severity data obtained from field survey were analyzed using three stage nested design with the model: $Y^{ijk} = \mu + \tau_i + \beta_j^{(i)} + \gamma_k^{(ij)} + \epsilon^{(ijk)}$

Where: γ^{ijk} is disease intensity; k (peasant association); (j) district; zone (i), μ (overall mean); τ_i is the effect of the ith zone, $\beta_j^{(i)}$ is the effect of the jth district within the ith zone, and $\gamma_k^{(ij)}$ is the effect of the kth peasant association within the jth district and ith zone, and $\epsilon^{(ijk)}$ is the error term. Means were separated using LSD test at the alpha level of (5%) using SAS software version 9.1. The associations of disease incidence and severity with independent variables viz. altitude, variety growth stage and cultivars were computed using simple Pearson correlation analysis using SAS software version 9.1. One way ANOVA was used and means were separated using LSD test at (p=α: 0.01). Means that differ significantly separated using critical difference in each category viz., checks, test entries, tests and checks.

Result And Discussions

Distribution and Occurrence of Wheat Stem Rust

Wheat stem rust incidence was observed at all assessed areas of North shewa, East shewa and Hadiya zone (Table 1). nationality of the country with different disease intensity. The disease intensity ranged up to complete infection of surveyed fields depending on different agro-ecology. Out of fifty-five assessed fields, the stem rust was observed on 35 about (63.64%), but 20 fields with (36.36%) were not infected. Among assessed 9 fields Hadiya; were affected 56.25%, East shewa 7 fields 38.89% and North shewa zones 19 were 90.48% were affected by stem rust. The disease was prevalent in all assessed districts was significantly different (p < 0.01). The high disease prevalence 100% was recorded at north shewa at Moretena Jihur districts while the lowest 0% east shewa was recorded at Lume district (Table 2). There is wide distribution of stem rust disease across the districts and zones.

The highest disease incidence (57.94%) was recorded in East Shewa zone but; the lowest disease incidence (30%) was recorded Hadiya zone. Similarly, the highest disease severity (26.75%) was recorded at North Shewa zone and Hadiya zone with the same value followed by East shewa zone (18.22%) (Figure 2). Several wheat stem rust epidemics have been recorded in Ethiopia at many zones due to ecological location and climatic conditions of the country as well as continuous cultivation of wheat during the year providing green bridge for survival of inoculum [13]. In agreement with reports Agro-ecological variation, cultivated varieties and weather variability such as temperature and relative humidity favors for the development stem rust epidemics.

Accordingly there was a significant difference (P<0.05) by incidence and severity among districts. The highest rust incidence

Table 1: Description of study areas.

Zone	Districts	Coordinates		Altitude (m.a.s.l)	Temperature (°C)		RF (mm)
		N	E		Min.	Max.	
East shewa zone	Ada'a	08° 44'	38°58'	1950	8°C	28°C	851
	Gimbichu	8°58'	39°06'	2450	9°C	29°C	1200
	Lume	8°12'	39°17"	1900	9.2 °C	29.3°C	951
Hadiya zone	Lemo	7°30"	37°55"	2001	13 °C	26°C	1150
	Misha	7° 56'	38°52"	2143	10.5°C	22.5°C	869
	Duna	7°20"	37°39'	2453	12°C	24°C	932
North shewa zone	MoretenaJiru	9°36"	39°38'	2828	6.1°C	24°C	890
	Basona werana	10° 41'	39° 47'	2828	13.5 °C	21.5°C	1000
	Minjar	8° 45"	39° 15"	2120	13 °C	29°C	854

Table 2: Stem rust prevalence of across districts.

Zones	Districts	Altitude ranges (m.a.s.l)	No of fields assessed	Fields infected	Prevalence (%)
Hadiya	Duna	2495-2546	3	1	33.33
	Misha	2386-2613	6	3	50
	Lemo	2180-2280	7	5	71.43
Subtotal/Mean	-	2180-2613	16	9	56.25
East shewa	Ada'a	1874-1957	8	4	50
	Lume	1811-2094	5	0	0
	Gimbichu	2297-2443	5	3	60
Subtotal/Mean	-	1811-2443	18	7	38.89
North shewa	Minjar	1796-2147	5	4	80
	Basonawarena	2768-2867	8	7	87.5
	Moretenajirru	2651-2669	8	8	100
Subtotal/Mean	-	1796-2867	21	19	90.48
Mean range	-	-	55	35	61.88

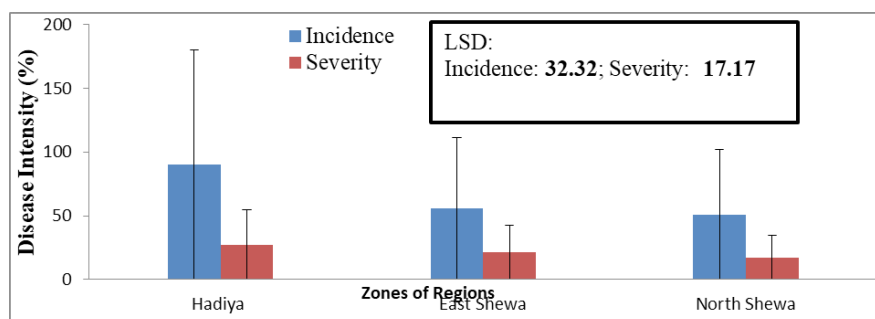


Figure 2. The distribution of wheat stem rust at different zones.

(100%) was recorded at Lemo districts however; the lowest disease incidence (25.00%) was recorded at MoretenaJirru and Basonawarena district. In relation to disease severity; the highest (40) was recorded at Hadiya zone of Lemo district while; the lowest (9.38) was obtained at N.shewazone of Basonawarena district (Table 3). According to Muluken et al. [14] reported the mean incidence and severity of stem rust reached at 0.63% and 0.5% respectively at Lemo district in 2017 main cropping season (Figure 3).

Distribution and intensity of wheat stem rust across peasant associations

Comparison district indicated that, highest incidence (100%) of the disease were recorded at the kebele's assessed at Barkuncho, Misha, Morsuto, Guna and Hage; Ambichogode, Belesa, Ajotayisa and Senalisana, Gole, Girmi and Habruseftu, Shewa genet and Memherhager districts. The lowest disease incidence was obtained 5% at Angolella. The highest stem rust severity was 60% at Lemo districts of AjoTayisakebelewhile; the lowest stem rust severity

was recorded at Mangudo and Tadecha with severity of 2.5% each locations. Low temperature at high altitude and high temperature at mid- altitude increases the importance of wheat stem rust at the areas when assessment is conducted (Table 4) and also the locality fall in the altitude range of 2180-2613 m.a.s.l. According to Peterson [15] and Tamen et al. [16] reported that warm temperature and long period of moisture content favors stem rust severely to occur.

Distribution and prevalence of wheat stem rust across altitude ranges

According to the traditional classification system of agro ecological zones; 500-1500 m lowlands, 1500-2300m mid-lands and 2300-3200 m.a.s.l which highland (Ferede et al., 2013) [17]. The current survey was carried out at altitude ranges of 1802-2867 m.a.s.l. From total fields examined, 45.46% of the fields were fall in mid altitudes ranging from 1802 to 2300 m.a.s.l while; 54.55% were in the high altitude ranged from 2301-2867 m.a.s.l (Table 5). There was a variation ($p < 0.05$) among altitude classes in terms of incidence and severity of wheat stem

Table 3: Mean incidence and severity of wheat stem rust across the districts.

Zones	Districts	N	Range	Incidence	Range	Severity
Hadiya	Lemo	7	0-100	100a	0-70	40.00a
	Misha	6	0-100	86.67a	0-45	15.00bcde
	Duna	3	0-100	83.33a	0-70	26.67abcd
East Shewa	Gimbichu	5	0-100	71.00ab	0-35	14.00cde
	Ada'aa	8	0-100	50.63bc	0-60	21.25bcde
	Lume	5	0-70	45.00bc	0-40	29.00abc
North Shewa	Minjar	5	100	100a	0-50	32.00ab
	MoretenaJirru	8	0-100	27.50c	0-25	10.62de
	Basona warena	8	0-80	25.00c	0-40	9.38e
LSD				32.32		17.17

*Means with the same letter(s) within the column are not significantly different at p<0.05.



Figure 3. Symptoms of wheat stem rust captured during survey.

Table 4: Incidence and severity of wheat stem rust across different kebele's of the districts.

Zones	Districts	Peasant associations	Field assessed	Incidence %	Severity %
Hadiya	Duna	Barkunch	2	80cab	37.5cadb
		Kankicho	1	90ab	5f
	Misha	Abushra	2	60cadbe	5f
		Morsuto	2	100a	30fcadb
		Guna	1	100a	5f
	Lemo	Hage	1	100a	15fadb
		Ambichogode	2	100a	40cab
		Bellessa	2	100a	57.5a
		Ajotayis	1	100a	60a
	East shewa	Ada'a	Senalisa	2	100a
Kality			2	90ab	42.5ab
Gandagorba			2	75cadb	35cadb
Tadechaa			2	20cde	2.5f
Lume		Denkaka	2	17.5cde	5f
		Golbagode	2	67.5cadbe	40cab
		Tullure'	1	20cde	30fcadb
		Dhakabora	1	30cdbe	25fadb
Gimbichu		Sharradibandiba	1	40cadbe	10fcd
		Girmi	2	62.5cadbe	20fadb
	Lemlemcheffe	1	30cdbe	10fcd	
	Habruseftu	1	100a	15fadb	
North Shewa	Minjar	Gole	1	100a	5f
		Shewagenet	2	100a	22.5fadb
	Basona warena	Memhirhager	3	100a	38.33cadb
		Angolella	2	5e	5f
		Bakelo	2	50cadbe	12.5fadb
		Saria	2	15cde	10fcd
	Moretnajirru	Atakilt	2	30cdbe	10fcd
		Bollo	2	12.5de	10fcd
		Denaton	2	40cadbe	7.5fd
		Gerba	2	50cadbe	22.5fadb
		Mangudo	2	7.5e	2.5f
		Lsd		65.05	31.58

*Means with the same letter(s) within the column are not significantly different at p<0.05.

Table 5: The intensity of stem rust across different altitudinal ranges.

Altitude range (m.a.s.l)	Class name	Fields assessed	Prevalence (%)	Incidence (%)		Severity (%)	
				Range	Mean	Range	Mean
1500-2300 (m.a.s.l)	Mid-Altitude	25	56	0-100	30.10a	0-70	25.59a
2300-3200 (m.a.s.l)	High-Altitude	30	73.33	0-100	24.73b	0-70	14.30b
Range		55		0-100		0-70	
LSD (0.05)					5.12		4.34
CV (%)					4.70		3.41

*Means with the same letter(s) within the column are not significantly different at $p < 0.05$.

Table 6: Mean incidence and severity of wheat stem rust by varieties.

Field Reactions of Wheat Varieties				
Variety	Response	Number of field assessed	Incidence	Severity
Hidase	MS-S	5	100a	43ab
Tesfaye	S	1	100a	60a
Kubsa	0-MS-S	20	55.75b	16.50c
Landrace	MR-MS-S	2	100a	5c
Mangudo	0-MR-MS-S	16	51.25b	19.06c
Kakaba	MS-S	11	58.18ab	21.36bc
LSD	-	-	42.94	22.81

*Means with the same letter(s) within the column are not significantly different at $p < 0.05$.

Table 7: The incidence and severity of stem rust comparing by wheat growth stage.

Growth Stage	Response	Number of fields assessed	Incidence (%)		Severity (%)	
			Range	Mean	Range	Mean
Matured	MS-S	6	100	100a	0-70	38.33a
Dough	MS-S	31	0-100	58.06b	0-70	42.78a
Milk	MR-MS-S	18	0-100	63.24b	0-40	15b
Booting	--	---	---	---	-----	-----
Range			0-100		0-70	
LSD(0.05)				32.93		12.51

*Means with the same letter(s) within the column are not significantly different at $p < 0.05$.

rust. The highest prevalence (73.33%) of stem rust was recorded at the high altitude where as a prevalence of 56% was recorded at low altitude. This study showed that stem rust is important at all altitudes nowadays.

In agreement with reports, the highest level of infection 50% disease severity and 100% disease incidence has been reported in the altitude ranges from 1600 to 2500 m.a.s.l. This shows stem rust is also becoming important at higher elevations due to association of with climate change, widespread, susceptible commercial varieties and appearance of new virulent races.

Assessment of wheat stem rust by wheat variety

Assessment of wheat stem rust was conducted at major wheat production areas. In most assessed areas farmers were using both improved and landraces; ratio of 96.36% released varieties and 3.64% grown other cultivars. Majority of farms were rotated with chickpea, tef, lentil and peanut. Five varieties were obtained during the survey, namely; Hidase, Tesfaye, Kubsa, Landrace, Mangudo and Kakaba. Number of wheat cultivars in respective to the percentage is indicated in the Table 6. Conversely, Kubsa variety was found at 20 fields with 36.36% severity was observed. There were significant difference observed between Tesfaye, Kakaba, Hidase and Mangudo which are released varieties as shown in Table 6. Among allkubsa is produced at East shewa zone, Mangudo being produced at North shewa zone and Hidase is being produced at Hadiya zone in large coverage. Where: R-resistant, MR- moderately resistant, MS- moderately susceptible and

S- susceptible. During the assessment Hidase variety at Hadiya zone which is severely infected with severity level of 60S in the field. The host reaction during the assessment fields was scored using "R" to resistance, "MR" to indicate moderate resistance; "MS" to moderately susceptible (Figure 1) and 'S' to indicate full susceptibility [12]. There was a significant difference ($p < 0.05$) in disease incidence among cultivated varieties. The highest disease incidence (100%) was recorded in field cultivated with Hidase and Tesfaye variety while; the lowest zero disease incidences were recorded farms cultivated with Mangudo, land race and kubsa at different locations variety. Similarly, there was a significant difference ($p < 0.05$) among varieties grown in disease severity (Table 6).

Occurrence of wheat stem rust by wheat growth stages

Growth stage is important parameter to be considered when wheat stem rust is being assessed to obtain clear data on effects caused by wheat stem rust for comparison of varieties, locations and years. Infected fields per their percentage according to growth stage: 18/32.73%, 31/56.36%, and 6/10.91% were assessed at milk, dough and Matured, respectively (Table 7). The highest disease incidence (100%) was observed in the matured growth stage but the lowest (58.06%) was recorded dough stage. No significantly differences between dough stage and Milk stage ($\alpha: 0.05$) (Table 7). The highest severity was recorded on wheat at dough stage (42.78%) followed by matured stage however; lowest disease severity (15%) was recorded on dough growth stage. The

variation in the levels of wheat stem rust infections depended on the growth stages.

In the study area, wheat was grown in wide ranging agro-ecological zones that have been cultivated at varied dates [18]. Approved that planting date greatly reduces the degree of disease severity for the cultivars that had the highest disease severity in early planted stands. Specifically delay planting may provide as a successful management method. For some diseases, early planting results in less disease development than late planting [19]. For many diseases of fall-planted crops, however, early planting can increase exposure to autumn inoculum, and thus infection.

Summary and Conclusion

The disease intensity ranged up to complete infection of surveyed fields depending on different agro-ecology. There is wide distribution of stem rust disease across the districts and zones. The high disease prevalence 100% was recorded at north shewa at Moretenajihur districts while the lowest 0% east shewa was recorded at Lume district. The highest rust incidence (100%) was recorded at Lemo districts however; the lowest disease incidence (25.00%) was recorded at Moretenajirru and Basonawarena district. In relation to disease severity; the highest (40) was recorded at Hadiya zone of Lemo district while; the lowest (9.38) was obtained at N.shewa zone of Basonawarena district. Comparison district indicated that, highest incidence (100%) of the disease were recorded at the kebele's assessed at Barkuncho, Misha, Morsuto, Guna and Hage; Ambichogode, Belesa, Ajotayisa and Senalisana, Gole, Girmi and Habruseftu, Shewa genet and Memherhager districts. Low temperature at high altitude and high temperature at mid- altitude increases the importance of wheat stem rust at the areas when assessment is conducted with the altitude range of 2180-2613 m.a.s.l. This study showed that stem rust is important at all altitudes nowadays. The variation in the levels of wheat stem rust infections depended on the growth stages.

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