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Importance of Major Diseases of Bread Wheat (*Triticum aestivum* L.) and Their Association with Altitude in the Central Part of Ethiopia

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Abstract: A study of the wheat diseases importance in different locations and associated factors has been limited in Ethiopia. As a result, the goal of this study was to determine major wheat diseases distribution and intensity in the central highland of Ethiopia and their association with altitude. Zones, Districts, and Kebeles were selected using a systematic sampling technique. The survey data were analyzed by using descriptive statistics. Pearson correlation was used to examine the relationship between disease intensity and the independent variables, and regression analysis was used to estimate the magnitudes of the association. A total of 60 fields were examined, with the occurrence of eight diseases such as leaf blotch, glume blotch, stem rust, yellow rust, leaf rust, fusarium head blight, and tanspot. There was a positive ($r = 0.5$) ($p < 0.001$) association between leaf blotch severity and growth stages, but not between incidence and growth stages, nor between leaf blotch incidence and altitude. Leaf blotch incidence was positively linked ($r=3$) ($p < 0.05$) with growth stage. The severity of gmlume blotch had a negative correlation ($r = -0.37$) ($p < 0.001$) with altitude but not with growth stages. The severity of Sr was found to be a substantial negative correlation ($r = -0.7$) ($p < 0.001$) with altitude and again showed a strong negative correlation ($r=-0.66$) with growth stages. Both altitude ($r=-0.3$) and growth stages ($r=-0.4$) ($p < 0.001$) have a significant negative correlation with Fusarium head blight severity (FHB). Wheat diseases epidemics in current research areas require more attention and an integrated management strategy should be addressed.

Keywords: Central Part, Diseases, Intensity, Prevalence, Wheat

1. Introduction

Ethiopia is only second to South Africa in terms of wheat (*Triticum aestivum L.*) production in Sub-Saharan Africa. Cereal crops make a substantial contribution to the country's food security [24]. Wheat is Ethiopia's fourth most important food crop, with 1.7 million hectares planted and 5.8 million metric tons produced. It is grown by nearly 5 million families in Ethiopia [24], demonstrating how closely it is linked to every element of Ethiopian life, particularly food and feed (for animals). Wheat's domestic demand has risen considerably in recent decades [25].

Oromia is one of Ethiopia's most important wheat-producing regions; with 1million hectares under cultivation and a total yield of 3.3t /ha. Amhara region was the second-largest wheat-producing region with 0.6 million hectares under cultivation and a total yield of 2.8t/ha. Oromia's and Amhara's yields, on the other hand, are lower than the global and national average of 3.65 t/ha and 3.05t/ha respectively [12].

The primary problems with agriculture, specifically with wheat production, are biotic and abiotic stresses. Of these biotic stresses, wheat diseases caused by fungi have continued to devastate this crop in all parts of the world since ancient times [3] and are still the most destructive pathogens in all provinces of Ethiopia [2].

Up to 20 funguses, one bacterium, and all nematodes were discovered among these diseases. Yellow rust (*Puccinia striiformis f. sp. tritici*), stem rust (*Puccinia graminis f. sp. tritici*), leaf rust (*P. triticina*) and Septoria diseases are prevalent throughout Ethiopia (Ayele *et al*., 2008). Currently, multiple documents have reported the distribution of leaf blotch (*Zymoseptoria tritici*), Stem rust, leaf rust, yellow rust, and Fusarium head blight in various parts of Ethiopia [2, 8, 18, 20, 32, 34].

TKTTF race was responsible for the 2013 outbreak of wheat stem rust, which resulted in yield losses of up to 100% and average losses of about 50% [25]. If yellow rust infection begins extremely early in the crop development stage and the disease continues to progress throughout the growing season, susceptible cultivars may experience yield losses of up to 100% [5, 19]. Yield losses of up to 50% have been recorded in fields with wheat cultivars susceptible to leaf blotch during severe epidemics [14], and even yield losses of more than 60% for wheat as a whole under favorable disease conditions. Furthermore, due of the frequency and severity of Lb infestations, significant wheat production areas in Ethiopia had a 36% to 41% decrease in wheat productivity [33]. FHB resulted in yield losses of 30–70% in Argentina in 2012 [26], 11.6-39.8% in Brazil between 2000 and 2010 [28], and 10–70% in China [37]. Grain yield losses from yellow spot or septoria nodorum blotch infections ranged from 18% to 31% [9].

Therefore, disease surveillance and monitoring are critical for long-term wheat production; it's critical to determine the geographical and temporal dynamism of the environment and climate change. Seasonal disease monitoring is crucial not only for determining how and when epidemics may arise but also for planning and creating effective control methods, such as breeding plans suited to each condition [17]. Disease resistance levels of cultivars or landraces can be determined using data gathered from surveys. The most common disease (seed-borne, soil-borne, or air-borne) and its relationship may aid in the development of management measures for each area [23].

The status of Tan spot and Glume blotch haven't been reported in our country and again, the assosation of these diseases with altitude needs more study in Ethiopia. In Ethiopian central region, particularly the Northern Shewa, wheat diseases distribution in terms of season and place is mostly limited. As a result, there is a need for this field study to understand what is going on in farmer fields, which diseases are prevalent, when and where diseases emerge, and how they spread over time, as well as to understand pathogen changes and advice breeding plans. Monitor changes over time, identify disease hotspots and use data to drive control and mitigation. As a result, the objectives of this study was to assess the impact of diseases on wheat production, the geographical dynamisms of fungal wheat diseases based on (severity and incidence), diseases assotion with altitude in central part of Ethiopia.

2. Materials and Methods

2.1. Description of the Survey Areas

Field Survey of wheat was conducted in the central highlands of Ethiopia including three shewa zones (South West Shewa, North Shewa, and West Shewa), during the cropping season of 2021 for the assessment of wheat diseases.

2.2. Diseases Assessment Strategies

The study of wheat diseases was conducted from flowering to maturity. Zones, Districts, and Kebeles from the regions were selected by systematic sampling method. Kebeles within each District and farms inside each Kebeles were assessed at 5-10 km intervals along the main, available, and accessible roadside.

2.3. Diseases Assessment

Depending on the size of the field, three to five 1 m^2 quadrants were tossed at random 15-meter intervals along the section. Fourteen plants were randomly picked from each quadrant and examined for the incidence and severity of wheat diseases. Similaly, disease prevalence was calculated by dividing the number of affected fields with the total number of fields investigated. Incidence and severity were recorded to determine disease intensity during field disease surveys. In a surveyed field, the disease incidence of each diseases represents an estimate of the proportion of wheat plants affected with a certain wheat disease [11]. To determine disease severity of each diseases, the average amount of infection on each plant was employed as described below.

Wheat blotch disease: leaf blotch incidence and severity were conducted from four quadrant for each of the field. Then the average of four quadrants reprents the intensity of each field. Severity was measured on a two-digit scale [29]. The first digit (0-9) represents the Leaf blotch (Lb) caused by Leaf blotch upward migration on the plant, and the second digit (0-9) determines the severity of the total foliar infection on the upper four leaf whole plant [14]. We scored the double digit: for the plant height was 80cm and disease was reach at 40cm of plant height the first digit 5 scale was given. Then, from the top of four leaf of the plant the percent of infection was given as a second digit; on those leaf disease infection was reach 70% then the 7 scale was given for second digit. Then lastly, the 57 duble digit was scored. Its severity index was determined by the formula [30]; Blotch severity index $= \frac{D1}{Y1} * \frac{D2}{Y2} * 100$.

Where, D1 represents Lb upward movement, whereas D2 is the severity. Y1 represents the maximum Lb upward movement and Y2 represents the maximum severity. Disease incidence of Lb disease was calucalted as the ratio of diseased plant to the total plant assessed in each quadrants. To calculate the disease severity and incidence of glume blotch (*Parastagnospora nodurum*) and Tan spot (*Pyrenophora tritici-repentis*) the same method with leaf blotch was used.

Wheat rust disease: The modified Cobb scale [27], was used to calculate the disease severity and incidence of each field, which takes the average of all sampled plants in a the quadrants of surveyed field. Stem rust: the incidence of this disease was obtained from the ratio of diseased plant to total plants were accessed. The severity of this disease was scored from the percent of stem infected to total plant in the quadrants. The same concept was used for leaf and yellow rust to access the incidence and severity of these diseases.

Fusarium head blight: the incidence of this disease was scored as the ratio of disease plant to total assessed plant form each quadatrants [35]. The severity was scored based on the percent of head infected per plant in the quadrants for each field; then the average of each quadrants represents each field [10].

Disease prevalence: the diseases prevalence of all diseases were calculated in the same manner. The ratio of infected field to total accessed field per kebele was used as prevalence of these diseases.

3. Data Analysis

Descriptive analysis was done for the wheat diseases analysis. The association between wheat diseases intensity and altitude, and crop growth stages was investigated using Pearson correlation, and the magnitudes of diseases intensity were predicted using linear regressions in the statistical software Meet MINITAB Release 17 for Windows.

4. Results

4.1. Disease Prevalence and Distribution

A wheat disease survey was conducted during the main cropping season of 2021 at Western Shewa, southwestern and North Shewa zone of Ethiopia.

4.1.1. Western Shewa

In the surveyed areas, wheat leaf blotch caused by *Zymoseptoria tritici* was the most common disease from all of the assessed diseases. Up to 100% and 63% leaf blotch prevalence and glume blotch were scored respectively. Up to 69% prevalence of Tan spot caused by *Pyrenophora tritici-repentis* was recorded. Next to leaf blotch, yellow rust was prevealent at Western Shewa zone. The prevalence of yellow rust and stem rust were 81% and 63%, respectively. The prevalence of fusarium head blight and leaf rust were 19% and 13%, corspondingly (Figure 1).

4.1.2. South West Shewa

Again, in the South Western Shewa zone, leaf blotch was the most common one. In 60 fields, the mean prevalence of leaf blotch was 100%; whereas, glume blotch was 60% and tan spots was found to be 30%. The same as leaf blotch, the highest prevalence (100%) of stem rust were recorded. The prevalence of fusarium head blight, leaf rust, and yellow rust were 0%, 0%, and 10%, respectively (Figure 1).

4.1.3. North Shewa

More over, leaf blotch was the most common in the North Shewa. Leaf blotch, glume blotch, and Tan spot were found to have a prevalence of 97%, 24%, and 24%, respectively. In the North Shewa, the prevalence of yellow rust was 59%. Both head blight and stem rust were absent, but the prevalence of leaf rust was 3% (Figure 1).

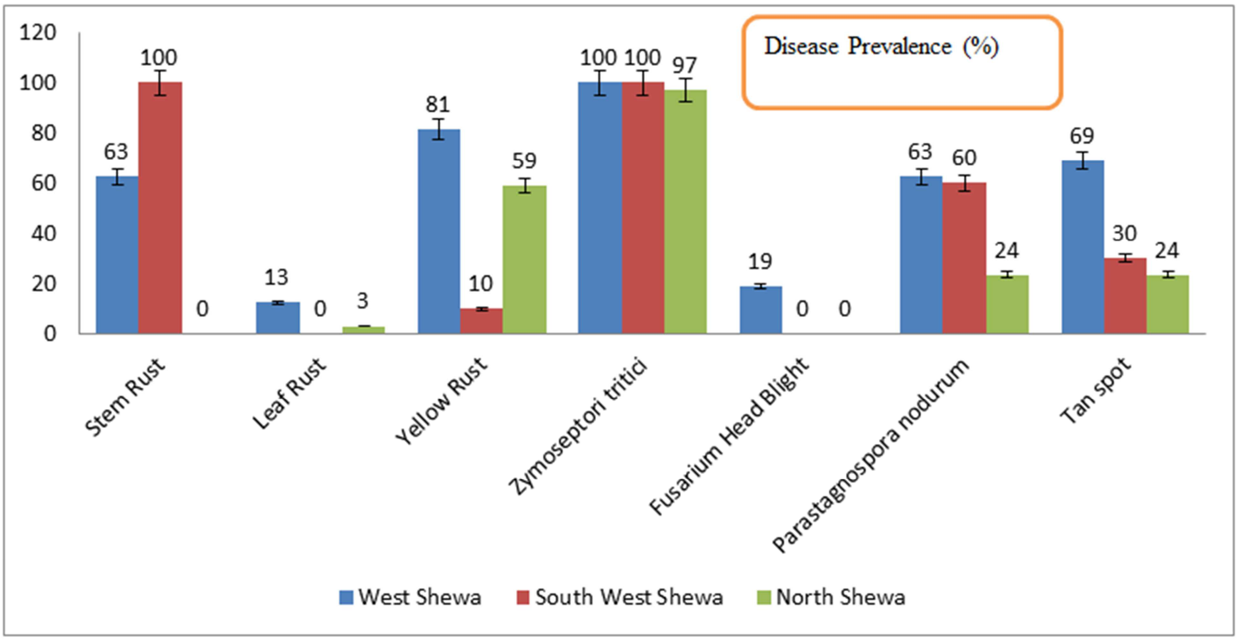


Figure 1. *Disease prevalence among the three zones, during the 2021 cropping season.*

4.2. Disease Intensity

4.2.1. West Shewa

The most common disease was leaf blotch; its incidence and severity were 65% and 55%. Yellow rust was also common, with a 36% incidence and 32% severity. The incidence of Tan spot was (11%). Furthermore, the incidence and severity of glume blotch were 7% and 10%, while stem rust was 4% and 6% repectively. Leaf rust was found to have a 1% incidence and a 0% severity, whereas fusarium head blight was found to have a 2% incidence and a 0% severity (Figures 2 and 3).

4.2.2. South West Shewa

Stem rust was the most common, with 72% incidence and 28% severity. In comparison, the incidence and severity of leaf blotch were 63% and70% corspondingly. Up to 16% incidence and 24% severity of glme blotch were recoreded, whereas, 10% incidence and 9% severity of yellow rust were scored. Fusarium head blight and leaf rust were not found this zone (Figures 2 and 3).

4.2.3. North Shewa

The incidence of leaf blotch was 71% and severity was 42%. The incidence and severity of glume blotch were 10% and 8% respectively, whereas, yellow rust 21% and 14%. There were no signs of stem rust, leaf rust, or Fusarium head blight (Figures 2 and 3).

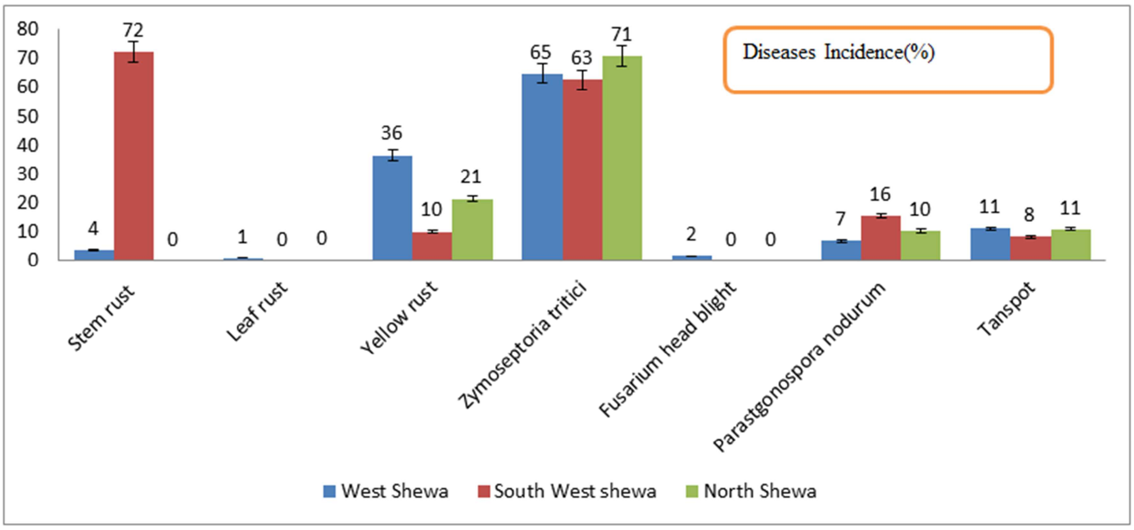


Figure 2. *Disease Incidence among the three zones, during 2021 cropping season.*

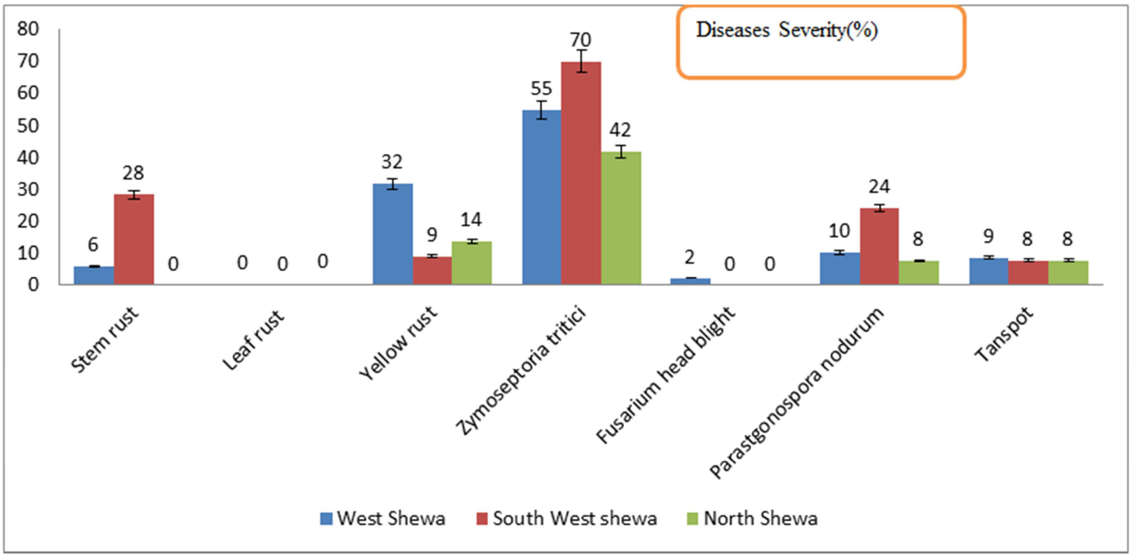


Figure 3. *Disease Severity among the three zones, during the 2021 cropping season.*

4.3. Diseases Intensity Among Districts

The incidence of leaf blotch was found to be a 100% in eleven districts (Ejere, Adeaberga, Enchini, Wuchale, Debrabrhan, Sheno, Sokoru, Nifasamba, Sholagebaya, Gorfo, and Beheret),. In everse the incidence of Jihura andKinbibit districts were 11%. The next most severe cases of leaf blotch were found in three districts, with scores of more than 80% (Adeberga, Melkawas, and Sheno). On other hand, the severity of Jihur and Kinbibit districts were 11%. In the Wuchale district, the incidence and severity of glume blotch were 81% and 52%. Glume blotch was not found in most the districts. Wuchale district showed the highest 91% incidence and a 62% severity in reverse most of the districts demonstrated the lowest 0% incidence and severity of Tan spot. Two districts (Kersamalima and Batu) exhibited the highest incidence and severity of stem rust, with 87% and 90%

incidence and 29% and 40% severity, respectively. Stem rust was not found in the majority of the examined locations. Except for the districts of Ambo and Sululta, none of them showed leaf rust incidence and severity. Yellow rust was most common in Sululta, with an incidence of 85% and severity of 70%. Next to Sululta, Chancho had the highest yellow rust incidence of 80%, while Duber had the highest yellow rust severity of 43%. Except for the Tokekutaye district, none of them showed signs of Fusarium head blight (Table 1).

4.4. Response of Wheat Cultivars to Diseases

According to the survey data, different diseases were identified as one of the most significant biotic restrictions impacting wheat productivity in the central highlands of Ethiopia. The majority of wheat cultivars were damaged by the diseases to varying degrees (Figures 4 and 5).

4.5. Blotch and Fusarium Head Blight Diseases

All of the grown wheat cultivars were infected with Leaf blotch. For ten cultivars, the max incidence (100%) was recorded. Paven-76 had the highest mean incidence (87%), followed by Local (62%). The mean incidence of Leaf blotch was particularly high in Kubsa (61%), Danda'a (59%) whereas low mean incidence (17%) in Hidase variety (Figure 4). Paven-76 and Alidoro bread wheat cultivars were found to have the most severe disease (100%). Furthermore, Local and Kubsa had a maximum severity of 96% and 80%, respectively. In contrast, Kakaba variety showed less severity at 34% (Figure 5). The disease low or non-existent intensity level on Kakaba could be owing to the types' relative resistance or tolerance to the disease.

Paven-76, Alidoro, Digalu, Et-13, Kakaba, and Kubsa were not impacted by Glume blotch among the planted wheat cultivars. Local variety had the highest incidence (25%) (Figure 4). On the other hand, the majority of the cultivars had a low (0%) mean incidence and severity. The disease was found to be the most severe (20%) in Danda'a bread wheat cultivar among the rest cultivars.

Tan spot did not influence the farmed wheat cultivars Et-13, Kubsa, Digalu, and Alidoro. The Danda'a cultivar had the lowest rate of incidence (14%). On the other hand, the majority of cultivars exhibited a low (0%) mean incidence and severity of Tan spot disease (Figures 4 and 5). Local bread wheat cultivar was found to have moderate severity (24%).

Among grown wheat cultivars, Fusarium head blight did not affect Paven-76, Ogolcho, Local, Kubsa, Kakaba, Hidase, Et-13, and Alidoro. The Digalu variety had the greatest incidence of all the cultivars observed, with a moderate mean incidence range (5%) and severity of 3%. The majority of cultivars showed a low (0%) mean incidence and severity of Fusarium head blight (Figures 4 and 5).

4.6. Rust Diseases

Et-13, Alidoro, Hidase, and Paven-76 were not damaged by stem rust among the grown bread wheat cultivars. For Ogolcho variety, the highest incidence (17%) was found among the cultivars. Stem rust, on the other hand, was not found in the majority of cultivars (Figures 4 and 5). The disease was found to be the most severe (27%) in Kubsa bread wheat cultivar of the total cultivars.

Leaf rust did not affect the planted wheat cultivars Local, Ogolcho, Paven-76, Kubsa Kakaba, Hidase, and Alidoro. Et-13 cultivar had the highest mean incidence (8%) and the severity of 5% of the rest cultivars. The majority of cultivars, on the other hand, were free of leaf rust (Figures 4 and 5). Paven-76, a farmed wheat cultivar, was not damaged by Yellow rust. Ogolcho cultivar had the highest mean incidence of 59% and the most severe (73%). On the other hand, the majority of the cultivars had a low (0%) mean incidence and severity (Figures 4 and 5).

Association of wheat diseases with altitude, and growth stages.

There was a positive correlation ($r = 0.5$) and a highly significant difference ($p < 0.001$) between Leaf blotch severity and growth stages, but not between incidence and growth stages, nor between Leaf blotch incidence and altitude. Significantly, the growth stage was strongly linked ($r=3$) with Zt incidence. Altitude was found to have a significant positive link with the ZTB severity index ($r = 0.3$), but not with incidence (Tables 2 and 3). According to our current data, an increase in altitude in meters is associated with greater severity of disease ($p < 0.05$).

The severity of Glume blotch had a negative correlation ($r = -0.37$) and a very significant difference ($p < 0.001$) with altitude, but not with growth stages (Tables 2 and 3). According to our current data, an increase in altitude in meters was associated with a significant reduction in disease severity ($p < 0.001$). There was no significant link between this disease incidence and growth stage or altitude.

The severity of Sr (stem rust) had a strong negative association ($r = -0.7$) with altitude and a very significant difference ($p < 0.001$) in the incidence, as well as a strong negative correlation ($r=-0.66$) with altitude (Tables 2 and 3). According to our current data, an increase in altitude in meters resulted in a substantial decrease in Sr disease severity and incidence ($p < 0.001$). There was no significant association between disease Sr incidence and growth stage. The severity of yellow rust and leaf rust disease did not appear to be related to altitude or growth stage. This is most likely due to a variety of causes.

Both altitude ($r=-0.3$) and growth stages ($r=-0.4$) had a significant negative connection with Fusarium head blight severity ($p < 0.001$). It was substantially associated adversely with both altitude ($r=-0.35$) and growth stages ($r=-0.4$) ($p < 0.001$) (Tables 2 and 3).

4.7. Wheat Diseases Prediction

The incidence of Leaf blotch was found to have a positive relationship with altitude, meaning that for every 1 meter of altitude attained, the disease incidence increased by 0.03%. Leaf blotch severity decreased by 0.032% as the growth stage increased. The incidence of Glume blotch was shown to have a negative relationship with altitude, indicating that as altitude increased by 1 meter, the disease incidence decreased by 0.01%. As the growth stage increased, the severity of Glume blotch decreased by 0.03%. The incidence of stem rust was discovered to have a negative association with height, suggesting that the disease incidence decreased by 0.03% for every 1 meter of altitude gained. As the growth stage progressed, the severity of stem rust decreased by 0.07%. The severity of leaf and yellow rust could be altered minimally (Figure 6).

Table 1. *Disease intensity of the surveyed districts.*

Districts	LbI	LbS	GbI	GbS	TsI	TsS	SrI	SrS	LrI	LrS	YrI	YrS	FhbI	FhbS	Alt (m)
Tokekutaye	47	50	1	5	0	0	6	13	0	0	41	45	5	7	1956.5-2433.2
Ambo	85	22	22	22	32	22	5	8	5	4	30	12	0	0	2321.5
Dandi	44	62	7	25	7	7	8	7	0	0	58	45	0	0	2183.2-2270.4
Welmera	71	66	3	5	13	11	0	0	3	0	23	14	0	0	2449.3-2507.4
Ejere	100	56	0	0	71	51	0	0	0	0	0	0	0	0	2614.4
Adeaberga	100	82	51	21	0	0	0	0	0	0	25	40	0	0	2599.9
Inchini	100	16	0	0	0	0	0	0	0	0	60	40	0	0	2616.5
Sebetawas	66	76	28	38	11	9	57	27	0	0	33	30	0	0	2167-2304.6
Melkawas	81	84	21	31	0	0	70	16	0	0	0	0	0	0	2034.5
Kersamalima	51	57	4	17	0	0	87	29	0	0	0	0	0	0	2073.2-2309.4
Batu	62	64	0	0	0	0	90	40	0	0	0	0	0	0	2103.5
Becho	66	76	21	21	26	26	65	28	0	0	0	0	0	0	2115
Sululta	51	53	0	0	0	0	0	0	5	8	85	70	0	0	2504-2601
Chancho	94	77	0	0	0	0	0	0	0	0	80	40	0	0	2690
Duber	56	53	6	11	6	11	0	0	0	0	45	43	0	0	2613
Mukaturi	90	48	14	7	17	7	0	0	0	0	15	10	0	0	2565-2618
Wuchale	100	77	81	52	91	62	0	0	0	0	0	0	0	0	2551
Wayunasyadebir	67	51	34	31	34	31	0	0	0	0	25	20	0	0	2608-2620
Deneba	56	19	6	6	0	0	0	0	0	0	3	1	0	0	2648-2664
Moretinajiru	26	14	18	11	15	8	0	0	0	0	21	9	0	0	2636-2694
Jihur	11	11	0	0	11	11	0	0	0	0	0	0	0	0	2638
Abechu	96	26	0	0	21	11	0	0	0	0	3	1	0	0	2775-2805
Angola	100	34	0	0	0	0	0	0	0	0	40	24	0	0	2776
Debrabrahan	71	45	0	0	0	0	0	0	0	0	40	16	0	0	2829
Chacha	77	43	10	7	0	0	0	0	0	0	10	2	0	0	2762-2790
Kinbibit	11	11	0	0	0	0	0	0	0	0	0	0	0	0	2790-2822
Sheno	100	87	0	0	0	0	0	0	0	0	0	0	0	0	2922
Senbo	91	25	0	0	0	0	0	0	0	0	0	0	0	0	2862
Sokoru	100	46	0	0	0	0	0	0	0	0	20	4	0	0	2839
Nifasamba	100	63	0	0	0	0	0	0	0	0	0	0	0	0	2815
Sholagebaya	100	33	0	0	0	0	0	0	0	0	0	0	0	0	2839
Gorfo	100	72	0	0	0	0	0	0	0	0	0	0	0	0	3035
Beheret	100	58	0	0	0	0	0	0	0	0	40	16	0	0	2939

West Shewa districts are: Tokekutaye, Ambo, Welmera, Dandi, Inchini, and Adeaberga

South West Shewa are: Kersamalima, Sebetawas, Melkawas, Batu and Becho

Norrth Sheaw are: Beret, Gorfo, Sholagebaya, Nifasamba, Sokoru, Senbo, Sheno, Kinbibit, Chach, Debrabrahan, Angola, Abechu, Jihur, Moritenajiru, Deneba, Wuchale, Wayunasiyadebeir, Mukaturi, Sulualta, Chancho and Duber

Leaf blotch Incidence (LbI), Glume blotch Incidence (GbI), Tan spot Incidence (TsI), Stem rust Incidence (SrI), Yellow rust Incidence (YrI), Leaf rust Incidence (LrI), Fusarium head blight Incidence (FhbI), Altitude (Alt)

Leaf blotch Severity (LbS), Glume blotch Severity (GbS), Tan spot Severity (TsS), Stem rust Severity (SrS), Yellow rust Severity (YrS), Leaf rust Severity (LrS), Fusarium head blight Severity (FhbS)

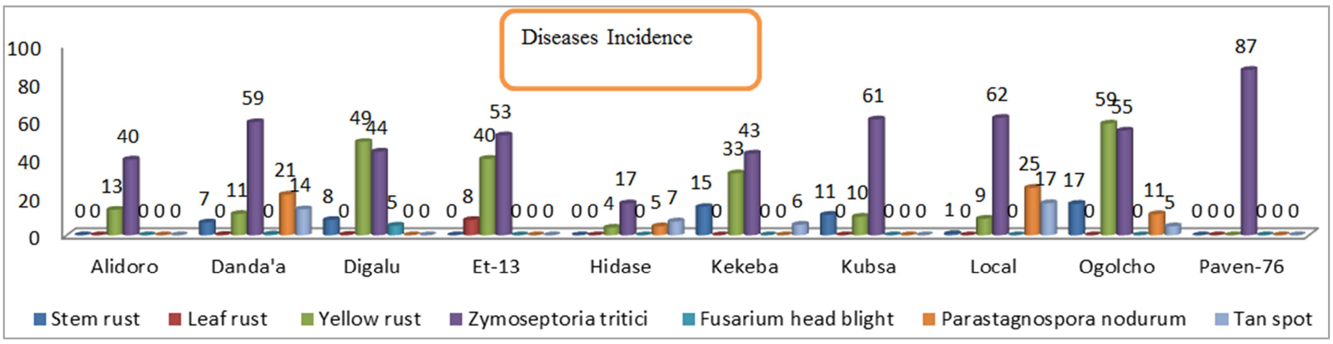


Figure 4. *Disease Incidence among the varieties, during 2021 cropping season.*

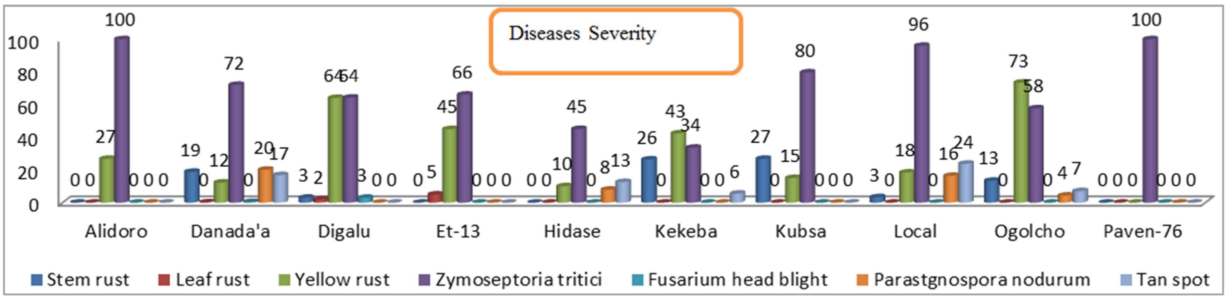
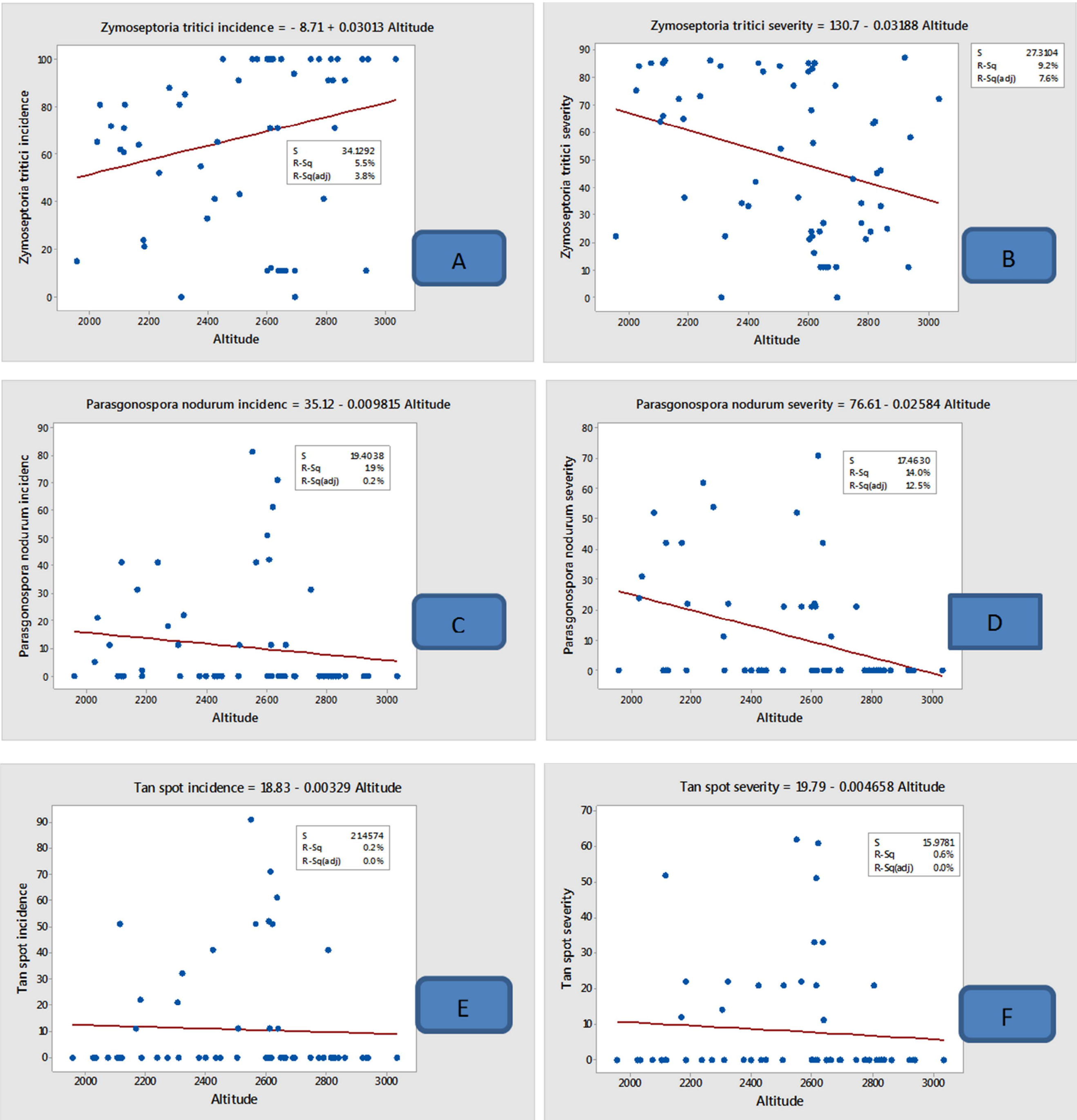


Figure 5. *Disease Severity among the varieties, during 2021 cropping season.*



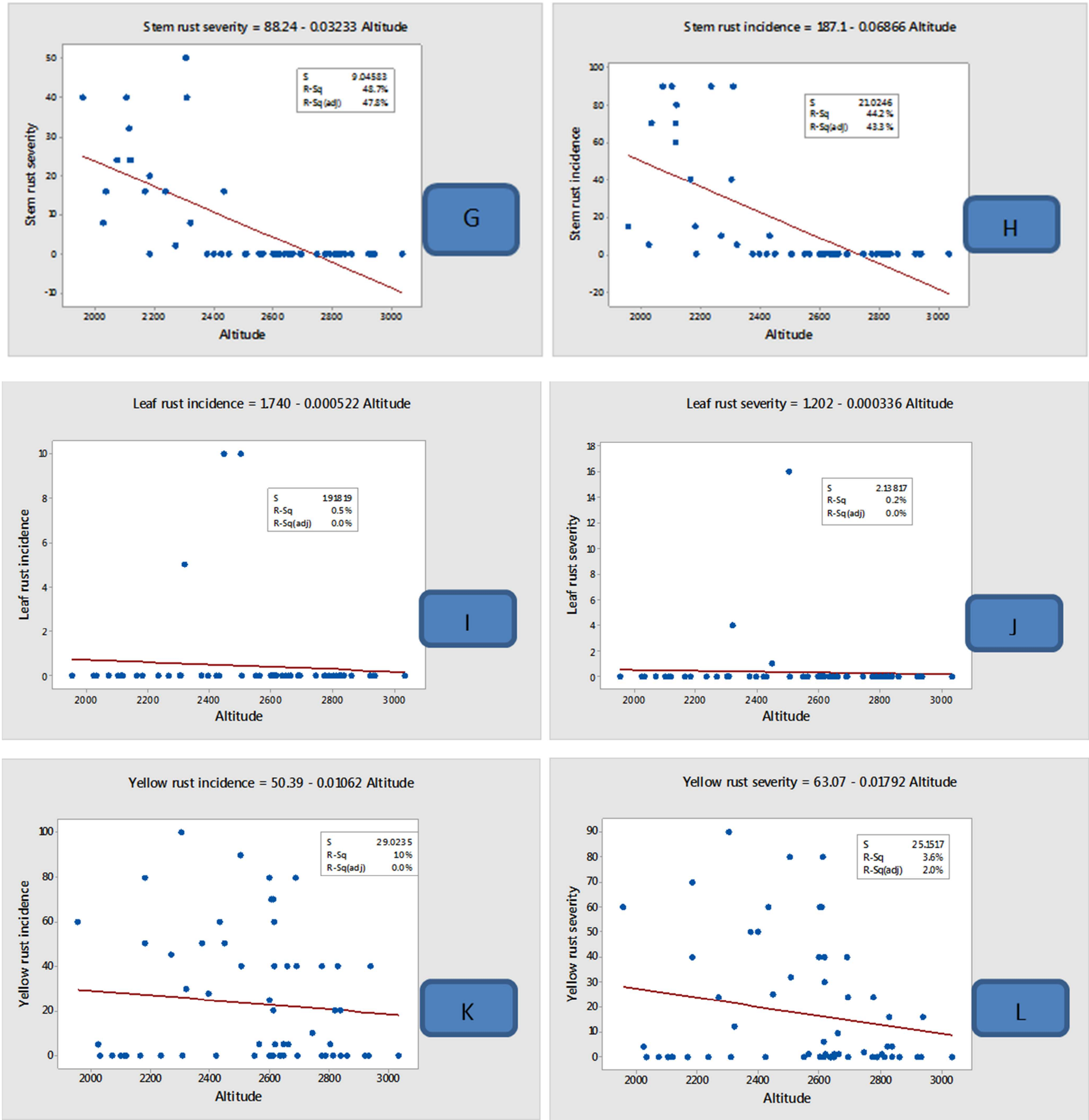


Figure 6. *Prediction of wheat diseases magnitude-based on altitude: A and B. Zymoseptoria tritici incidence and severity, C and D. Parastagnospora nodurum incidence and severity, E and F. Tan spot incidence and severity, G and H. Stem rust incidence and severity, I and J. leaf rust incidence and severity, K and L. yellow rust incidence and severity.*

Table 2. *Pearson's correlation coefficients of wheat disease s incidence over, altitude, and crop growth stages.*

	Alt	GS	Sr	Lr	Yr	Zt	FI	Pn
Gs	-011ns							
Sr	-0.66***	0.2ns						
Lr	-0.07ns	0.12ns	-0.096ns					
Yr	-0.099ns	0.083ns	-0.24ns	0.3**				
Lb	0.23ns	03**	-012ns	0.2ns	-0.09ns			
FI	-0.35***	-0.4***	-0.02ns	-0.04ns	0.13ns	-0.23**		
Gb	-0.137	0.054 ns	0.082ns	-0.067ns	-0.178 ns	0.243ns	-0.095ns	
Ts	-0.04ns	-0.13ns	-0.09ns	-0.04ns	-0.15ns	0.21ns	-0.1ns	0.67***

Leaf blotch (Lb), Glume blotch (Gb), Tan spot (Ts), Stem rust (Sr), Yellow rust (Yr), Leaf rust (Lr), Fusarium head blight (Fhb), Altitude (Alt), Growth stage (Gs)

***Table 3.** Pearson's correlation coefficients of wheat disease s severity over, altitude, and crop growth stages.*

	Alt	GS	Sr	Lr	Yr	Zt	FI	Pn
Gs	-0.11ns							
Sr	-0.7***	0.04ns						
Lr	-0.04ns	0.08ns	-0.06ns					
Yr	-0.2ns	0.07ns	0.12ns	0.4**				
Lb	0.3**	0.5***	-0.2ns	0.13ns	-0.08ns			
FI	-0.3***	-0.4***	-0.3***	-0.02ns	0.23ns	-0.12**		
Gb	-0.37***	0.2ns	0.12ns	-0.06ns	-0.16ns	0.4***	-0.07ns	
Ts	-0.1ns	-0.07ns	0.015ns	-0.04ns	-0.13ns	0.17ns	-0.1ns	0.5***

Leaf blotch (Lb), Glume blotch (Gb), Tan spot (Ts), Stem rust (Sr), Yellow rust (Yr), Leaf rust (Lr), Fusarium head blight (Fhb), Altitude (Alt), Growth stage (Gs)

5. Discussions

Wheat diseases are the most economically important and difficult for farmers to defend against all the biotic limitations that limit wheat output. This is mostly due to the pathogen's complexity, as well as climate change, and the fact that fungicides are either unavailable or too expensive for small-scale growers. Over 30 fungal pathogens damaged wheat in various agro-ecologies and farming methods in Ethiopia, according to previous study evaluations on wheat diseases [7]. Furthermore, due to climatic change and other biophysical factors, the impact and distribution of diseases shifted. As a result, regular disease evaluation and pathogen identification are critical to our ability to safeguard crops and are the first step in the process [31].

As a result, the purpose of this research was to investigate the spatial and temporal dynamics of wheat diseases in central parts of Ethiopia to create single and/or coordinated protection methods. The intensity of wheat diseases vary among sites, based on agro-ecologies (favorable weather conditions), a cultivars used, and specific production practices, according to this study. According to our survey results, the disease was widespread throughout the central highlands of Ethiopia, affecting many different places. In previous survey reports in the regions, different fungal diseases of wheat were recognized as having the greatest impact on wheat production [7].

In the current study, Tan spot has been found with three blotch species (*Zymoseptoria tritici*, *Parastagnospora nodurum*, and *P. avenae* Frank & sp. *tritici* Johns), with *Z. tritici* being the most common, notably in central highland of Ethiopia. However, we could differentiate the two species of glume blotch based on the laboratory work. The two species causes Glume blotch: *Parastagnospora nodurum*, and *P. avenae* Frank & sp. *tritici* Johns symptom was not different from each other. Based on irregular rectangular chlorotic lesions appearing on leaves, this investigation confirmed Leaf blotch as the most harmful species. The necrotic lesions are depressed and greyish-green in appearance, with pycnidium formations forming in a line parallel to the stomatal pattern [13, 14]. The disease was widespread in a large number of districts and affected a wide range of wheat cultivars.

From the three zones were surveyed, North Shewa had the greatest leaf blotch disease incidence (71%) in 2021. Furthermore, the severity of the infection was reflected in the extent of the damage in the field, which was widespread in many areas. The magnitude of the harm is mostly linked to the wheat-based mono-cropping system, as well as the widespread release and cultivation of bread wheat genotypes with similar genetic origins (parentage commonality) or sensitive variations [15]. Furthermore, favorable climatic circumstances (regular rains and mild temperatures) may play a crucial role in its development [13]. The occurrence and intensity of leaf blotch in some districts were greater in wheat fields found at elevations (>1956.5 (Table 1). When the growth stages of wheat increase the Leaf blotch intensity was also increased in the current study. The result is the same with [1] because of senescence, the positive correlation indicates that the severity of the Leaf blotch increased as the crop stage proceeded. Because the crop loses its physical and chemical barriers as it matures, the disease can easily infiltrate and develop on the crop [6]. This finding is consistent with a previous study that found Leaf blotch disease to be widespread in central Ethiopia's highlands [1], [32], as well as in Tigray, Southern Nations, Nationalities, and People's Region and Amhara highlands [8, 34].

According to the current findings (Figure 6 A and B), the incidence of Leaf blotch increased with increasing elevations during the on-time cropping season, although the severity of the disease decreased. In the previous study, however, there was no correlation between altitude and Leaf blotch intensity [1]. West Shewa had the highest Glume blotch incidence and severity, with 16% and 24%, respectively. As the altitude increased, its magnitude reduced (Figures 6 C and D). At West Shewa, the incidence and severity of tan spots were higher (11% and 8%) (Table 1), and its magnitude was similar at all altitudes. This is the first report on the relationship between altitude and Glume blotch and Tans pot (Figures 6 E and F). Only one farmer's field was infected with Fusarium head blight.

In 2021, South West Shewa had the highest incidence of stem rust disease (72%) among the three zones were surveyed. Stem rust was more common and intense in wheat fields found at elevations (>1956.5) in some districts (Table 1). In the same result [22], the current work indicates that for all three rusts (stem, stripe, and leaf), disease intensity is linearly proportional to the altitude. This knowledge could be utilized to improve future management methods by deploying rust-resistant cultivars at different altitudes. In the same as our result (Figures 6 G and H), stem rust (in terms of disease incidence or severity) diminishes with rising altitudes (Tables 2 and 3) during the on-time cropping season [22]. In the current study, the altitude increment in meters can cause the reduction of stem rust intensity which the same with [36]. The distribution and intensity of stem rust were most apparent under irrigation in the altitude range of (560–1264) m.a.s.l., and its pressure was highest in the range of (560–1064) m.a.s.l [36]. The intensity of leaf rust was relatively low in all three zones were surveyed. Leaf rust (in terms of disease incidence or severity) decreases with rising altitudes during the on-time cropping season, similar to our findings (Figures 6I and J) [22]. West Shewa had the highest yellow rust incidence and severity, with 36% and 32%, respectively. As the altitude increased, its magnitude reduced (Figures 6K and L). To our knowledge, the hotspot locations of those diseases have not been determined; although other reports have suggested that this is the fact. The long-term surveillance data were used in this study highlights some geographical hotspots within Ethiopia, notably stem and stripe rust [22]. The key drivers causing these disease hotspots are unknown but likely to be a combination of the suitable environment (moisture, temperature) and the presence of susceptible hosts.

The current study indicates Leaf blotch impacted about 90% of wheat genotypes to varying degrees. [34] also indicated that 76% of the cultivated varieties were affected by this disease. This author also suggested that Local combinations, Danda'a, and Kubsa were the most susceptible farmed types, with at least 80% disease severity. In our result, Danda’a 72% severity and Kubsa 80% severity were recorded. According to the current study, Pavon -76 very was infected by Leaf blotch, again this cultivars also suscebtible to many of Leaf blotch isolates at seedling growth stage [2]. In general, the current finding is consistent with previous findings in that, despite numerous host resistance studies of bread and durum wheat to Leaf blotch, no high-level resistance variety or line has been identified, and only partial resistance or varieties that can tolerate the disease and produce reasonable yields have been reported [16]. According to several studies, this disease has become increasingly prevalent over time as a result of inappropriate rust and Leaf blotch disease control strategy [1, 4, 21].

Our result indicates that the outbreak of rust with the cultivars planted; the stem rust was more during cultivation of Kakaba and Ogolcho cultivars, leaf rust severe on Et-13 cultivar, yellow rust again on Ogolcho cultivar. This result was the same with [22] suggested the hotspot for stem rust correlates to the area impacted by the epidemic as well as the main areas planted to the susceptible Digalu cultivar. Furthermore, preliminary stem rust results show that in the southern half of the country, optimal elevation ranges (a surrogate for optimal temperatures) and clay-rich soils (e.g., vertisols that have high water retention capacity and thus high moisture content later in the growing season) are common.

6. Conclusion

Leaf blotch, stem rust, yellow rust, and fusarium of wheat are all becoming increasingly common fungal diseases of wheat varieties in Ethiopia's central region. The incidence and field severity of Leaf blotch and rust on wheat in the examined zone were mostly influenced by altitude and total rainfall from flowering to hard dough stages. Different wheat cultivars can impact the severity and incidence of these diseases. In comparison to earlier reports, the survey work revealed gradual progress in wheat disease status, particularly Leaf blotch. As a result, disease management in the surveyed areas should focus on the use of the disease-free wheat seed, fungicide efficacy evaluation, and screening of bread wheat genotypes for these diseases.

Conflict of Interest

The authors declare that they have no conflict of interest.

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