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Distribution and Importance of Common Rust of Maize (*Puccinia sorghi* Schw.) in Hararghe Highlands, Eastern Ethiopia

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Abstract: Maize is an important staple crop in Ethiopia. However, its production is threatened by a number of diseases among which common rust caused by *Puccinia sorghi*, is the most destructive foliar disease of the crop in the country. Data are useful to gain insight into the occurrence, distribution, relative importance of plant diseases and the association of these diseases with cropping systems, environmental factors and cultural practices. Therefore, field surveys were conducted during 2013 and 2014 main cropping seasons in Hararghe highlands, Ethiopia to investigate the prevalence, intensity and importance of common rust of maize. In both years, a total of 230 maize fields were surveyed in eastern and western Hararghe zones. In order to incorporate different altitudinal ranges and analyze the survey data, a three-stage nested design was used. Among the surveyed maize fields, 85% of them were infested with the disease. The mean disease incidence in two years ranged from 75% in the eastern Hararghe to 100% in the western Hararghe zone and the severity ranged from 25% to 65%, respectively. Combined analysis over the years also showed that the mean incidence and severity of common rust of maize were significantly associated with the zones ($\chi2=15$, df=1, $P=0.0001$). The highest mean common rust incidence (95%) and severity (55%) were recorded for Boke, Chiro, Oda Bultum and Tullo districts in the western Hararghe zone whilst Deder, Chelenko, Haramaya and Kombolcha districts of the eastern Hararghe zone had the lowest mean incidence (45%) and severity (25%) scores, respectively. Higher epidemic frequency of the disease was also associated with intermediate and humid areas (Tullo, Boke and Oda Bultum districts) ($\chi2=30$, df=7, $P=0.0001$). The prevalence, intensity, and importance of the disease was also correlated with cropping systems, altitude, weather variables and varieties used during the survey time ($r=0.55$; $r=0.45$; $r=0.25$ *and* $r=0.50$), respectively. It is, thus, concluded, that common rust (*Puccinia sorghi* Schw.) is the most widely distributed and important foliar disease of maize in Hararghe highlands.

Keywords: Ecology; Epidemiology; Eastern Hararghe Zone; Incidence; Prevalence; Severity; Western Hararghe Zone

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in larger parts of the world including Ethiopia (Abate *et al*., 2015; FAO, 2017). In Ethiopia it is a staple food crop and one of the main sources of calories in major maize producing regions. It is cultivated on about 2.135 million hectares of land in the country (CSA, 2018). The national average yield of maize under subsistence production is about 3665 kg/ha (CSA, 2018). This is too much below the world's average yield (Tilahun *et al*., 2017). This low yield is attributed to foliar diseases and insect pests such as stalk borers (Dagne *et al*., 2008; Girma *et al*., 2015; Zelalem *et al*., 2018).

In Ethiopia, the production of maize is threatened by a number of biotic and abiotic factors. Among the biotic factors, common rust caused by *Puccinia sorghi*, is the most destructive foliar disease of maize in the country. In maize growing regions of Ethiopia, the disease has become a potential threat to maize cultivation (Tewabech *et al.,* 2012). It appears from the early stages of maize growth and if proper management is not adopted in time, it damages the plant causing higher yield losses (Assefa *et al*., 1993; Netsanet, 2005; Daniel, 2008; Tewabech *et al*., 2012).

Common rust causes extensive yellowing and premature desiccation of maize foliage, resulting in leaf necrosis, and complete destruction of the photosynthetic areas. In extreme cases, heavy rust infestations may result in stunting, incomplete ear tip fill and pustules on ear husks, reducing marketability and yield. The disease occurs in several maize producing areas in the country, resulting in grain yield reductions up to 23% (Fininsa, 2001) and 60.5% yield loss was also noted for susceptible cultivars such as CML- 202 (Deyle *et al.,* 2012).

Common rust of maize caused a yield loss of 12-60% (Utpal *et al*., 2012) in Asia and occurs in all maize growing areas of the world (Bello *et al*., 2012; Wang *et al.,* 2014). Similarly, in eastern Ethiopia, Netsanet (2005) reported a disease severity of up to 35% and relative yield loss of 29% in unsprayed plots due to this pathogen. Currently, common rust has also become the most important threat to maize production in maize

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growing areas of Ethiopia causing significant yield losses (Tewabech *et al*., 2012).

In developing countries like Ethiopia, one of the bottlenecks, which are responsible for lowering the yielding potential of maize, is the usage of varieties with inferior genes, which are susceptible to diseases, insects, weeds, low yielding and inferior quality. In addition, lack of adequate investment and skilled manpower to improve varieties for high yield and disease resistance as well as, diminishing land and water resources and environmental stresses are reducing yielding potential of the crop (Shiferaw *et al*., 2014).

In Hararghe highlands of eastern Ethiopia, where maize is grown among the major cereals, in the high rainfall areas such as (Chiro, Doba, Tullo, Mesela, Gemechis, Kuni, Boke, Habro, Darolabu, Deder, Chelenko, Haramaya and Kombolcha) foliar diseases and soil fertility depletion are major problems constraining crop productivity. Intercropping is widely used in these areas by combining maize or sorghum with the perennial narcotic crop like khat (*Catha edulis* Forsk) and common bean which further exposes the soil to rampant nutrient depletion and high disease epidemics leading to poor crop yield (Heluf *et al*., 1999; Fininsa, 2001; Ararsa, 2012). In this area, maize is grown on soils devoid of basic crop nutrients being exposed to foliar diseases such as common rust. Hence, the genetic potential of hybrids deployed in this region will not be fully exploited (Bekeko, 2013; Bekeko, 2014).

Maize yield is highly variable in rainfed environments of Ethiopia and it is still very low (often less than 4 t/ha., CSA, 2018). Therefore, developing and deploying maize varieties combining high yield potential and tolerance to major foliar diseases, is vital to reduce the risks associated with planting under rainfed conditions in the highlands of the country (Brummer *et al*., 2011). Most of the maize varieties growing in eastern Ethiopia are prone to the disease, which inflicts heavy yield losses under favorable weather conditions (Bekeko, 2014; Tilahun *et al*., 2017; Zelalem *et al*., 2018).

Most of the local cultivars, composites and novel hybrid maize varieties growing in this area showed susceptibility to this disease which can potentially affect the food security of the community. Previous surveys in other regions of Ethiopia have examined the association of the disease with cropping systems and some cultural practices. Jeger (2004) and Madden *et al*. (2007) indicated the importance of the knowledge of epidemiological features of plant diseases in providing useful information for understanding the biology of their causal agents, and its role as the basis for the establishment, planning and monitoring of effective disease management strategies. Understanding disease epidemiology as it is affected by different variables is also useful to design ecologically sustainable disease management tactics and strategies (Madden *et al*., 2007).

Survey data are useful to gain insight into the occurrence, distribution, relative importance of plant diseases and the association of these diseases with cropping systems, environmental factors and cultural practices (Rusuka *et al*., 1997).

However, little documented information is available to gain insights into occurrence, distribution, and the relative importance of maize rust in the eastern highlands of Ethiopia.

This research was, therefore, conducted to determine the prevalence and relative importance of common rust of maize in Hararghe highlands, eastern Ethiopia.

2. Materials and Methods

2.1. Description of the Survey Procedures

Field surveys were conducted in different agro-ecological zones of eastern Ethiopia (eastern and western Hararghe zones) during the 2013 and 2014 main cropping seasons. The survey route followed major roads to towns and localities in each zone. A total of 230 farmers' fields in eight districts were assessed for the prevalence, intensity and importance of common rust of maize.

Fields were randomly selected at the interval of 5-10 km along the main and accessible rural roads. Within selected fields, three quadrants (4 m * 4 m) diagonally spaced about 10 m apart were sampled. All plants in each quadrant were used as sampling units. When necessary, the sample size (the number of observed fields per district) was adjusted to suit the crop distribution. Similarly, the sample units (the number of quadrants) were adjusted to suit the field size. All of the sampled fields belonged to smallholder farmers, research farms and private investors. Each field was visited once in each of the two years during which the survey was conducted.

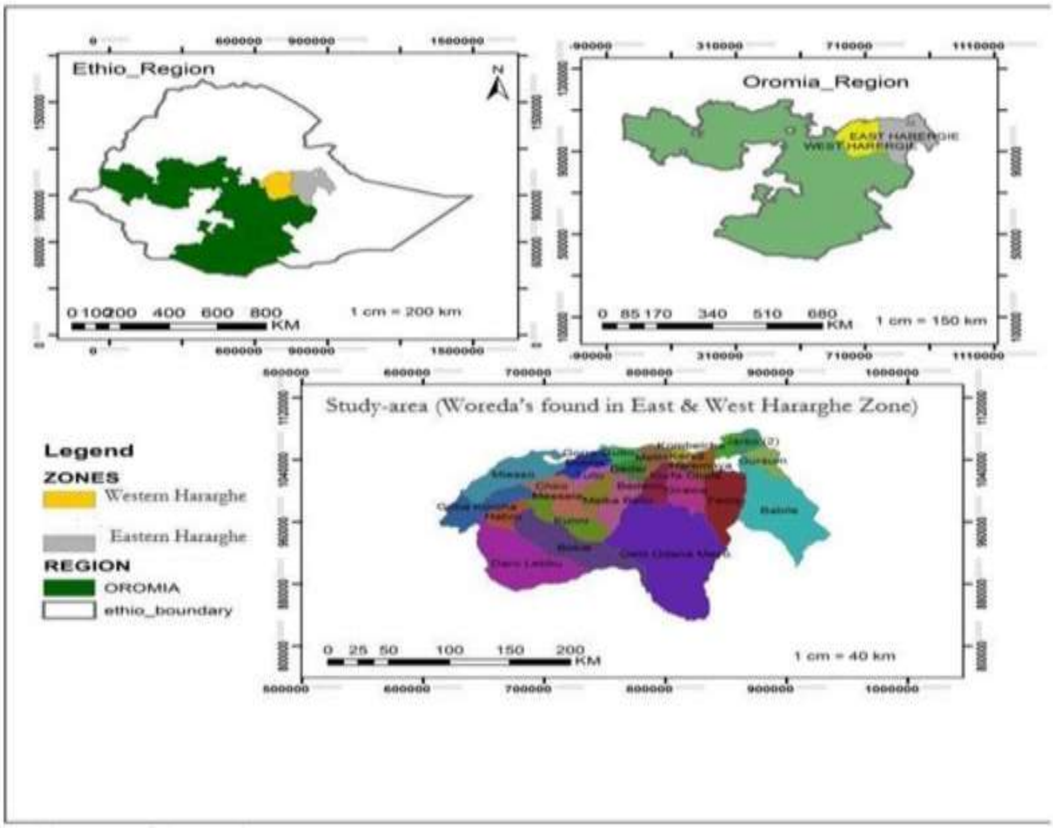

Fig.1: Geographic map of the study area

2.2. Prevalence, incidence and severity of common rust of maize

The survey covered the most important maize growing districts in eastern and western Hararghe Zones with frequent intensity of the work pauses at different intervals depending on the variability of fields in terms of altitude and cropping systems. Size of the survey site and availability and accessibility of maize fields was given due consideration in deciding where to stop and intensify the work on survey routes. Disease prevalence was assessed by determining the number of fields where common rust of maize was recorded in relation to the number of fields sampled in different localities. Disease assessment was made on 40 randomly selected plants in each field. Common rust of maize incidence was assessed as:

$$\text{Disease incidence} = \frac{\text{Sum of all numerical ratings}}{\text{Total No. of plant inspected}} \text{ x100}$$

Disease severity: Common rust of maize severity was rated according to Dey *et al.* (2012) using 1-5 scales: 1 = no symptoms; 2 = moderate lesion development below the leaf subtending the ear; 3 = heavy lesion development on and below the leaf subtending the ear with a few lesions above it; 4 = severe lesion development on all but the uppermost leaves, which may have a few lesions; and 5 = all leaves dead. The survey was conducted at the stages of booting and physiological maturity stages to assess and rate the average leaf area of maize covered by the common rust of maize pustules from 40 randomly selected diseased plants per field. The numerical rating was converted to percentage severity index (PSI) using the following equation suggested by Wheeler (1969):

$$\text{PSI} = \frac{\text{Sum of all numerical ratings}}{\text{Total No. of rated} \times \text{Maximum disease score on scale}} \text{ x100}$$

2.3. Data Analysis

Data was first checked for various ANOVA assumptions. The mean incidence and severity data were calculated for each district. The field survey data for common rust of maize (incidence and severity) was analyzed using a three-stage nested design. Mean common rust of maize incidence and severity of each zone were used to make comparison among the surveyed districts within two zones. Chi square test was employed to determine the distribution of the disease and correlation analysis was made to determine the association of common rust of maize epidemics, incidence and severity with different districts, weather variables, varieties and cropping systems within zones. All the statistical analyses were carried out using SAS V

9.2 and the Least Significant Difference (LSD) test was used for mean comparison (Gomez, 1984).

3. Results and Discussion

3.1. Prevalence and Intensity of Common Rust of Maize

Analysis of the results of disease intensity indicated that common rust of maize was prevalent in all maize producing districts of the surveyed districts in the region. The lowest mean incidence is74.25% for Kombolcha and the highest mean incidence is 95.25 % for Boke indicating the disease was the most destructive during the survey seasons (Table 1). The highest prevalence of common maize rust (89.3%) was recorded for Tullo district, followed by Boke, Oda Bultum and Chiro districts of the western Hararghe Zone which had severity of 95%, 90% and 85% respectively, while the lowest prevalence of common rust of maize (55%) was recorded for Deder, Chelenko, Haramaya and Kombolcha districts, east Hararghe zone (Table 1).

Table 1. Incidence and severity (mean values) of common rust of maize (*Puccinia sorghi*) on maize at Hararghe highlands, under field conditions (2013 and 2014 data).

Location	Altitude (m.a.s.l)	Mean of CRM incidence (%)	Mean of CRM severity (%)
Chiro	1850 - 2300	90.00	65.10
Kuni	2150 - 2460	85.77	70.40
Tullo	1850 - 2200	89.34	75.57
Boke	1650- 2300	95.25	65.25
Deder	1700- 2150	80.50	55.50
Chelenko	1750- 2000	75.00	45.85
Haramaya	1850- 2200	82.50	35.50
Kombolcha	1850- 2300	74.25	40.50
Mean		84.13	56.70
CV		9.50	13.25

Note: m.a.s.l = Meters above seal level; CRM = common rust of maize

In general, common rust of maize was the most prevalent (85%) in all of the 230 maize farms surveyed from eastern and western Hararghe zones in 2013 and 2014. The higher prevalence of common rust of maize during the survey seasons in all assessed districts could be attributed to the favorable environmental conditions coupled with cultivation of susceptible maize cultivars worsened the problem to maximum. A common rust of maize epidemics is favored by high rainfall and relative humidity, with warm temperatures, and the presence of larger amounts of inoculums in the region (Tewabech *et al*., 1993).

The other most possible reasons for the variation in common rust distribution in the region could be the variability in weather conditions. As a result, producers can have an impact on the prevalence and intensity of this disease by deciding from a number of management strategies including host plant resistance, cultural practices (adjusting planting date, plant density, crop rotation and tillage practices) and careful use of foliar-applied fungicides (Fininsa, 2001).

The previous study of Tewabech *et al*. (2012) reported that the presence of increased prevalence of common rust in the major maize producing regions of Western, Southern, Northwestern, Eastern, Southeastern parts of Ethiopia. According to the report, common rust of maize has become the principal maize disease since 1993 in Ethiopia.

3.2. Incidence and Severity of Common Rust of Maize Across Zones

Analysis of the result of incidence and severity data revealed that common rust of maize was the most prevalent in the entire surveyed zones but with varying intensity.

Table 2. Distribution of common rust of maize in wester Hararghe zone (mean values) in 2013 and 2014 main cropping seasons.

Distribution level	Boke		Oda Bultum		Tullo		$\chi 2$ test
	n	%	n	%	n	%	
High	92	94.8	85	100	92	93.9	
Medium	5	5.2	0	0	6	6.1	5.695*
Low	0	0	0	0	0	0	
Over all sample	97	100	85	100	98	100	

The mean incidence and severity of the disease varied significantly from zone to zone (Tables 2). There was a statistically significant ($p<0.001$) difference between the zones in terms of incidence of the disease (Table 2). The mean incidence in the two zones ranged from 57.6-65.6% (Table 3). It was also revealed that the disease occurred in the entire assessed districts having different agro-ecologies and was the most prevalent in all the surveyed maize farms. Combined analysis over the years also revealed that the mean incidence and severity of the disease significantly varied from district to district with a wider frequency of distribution ($\chi2=16.5$, df=8).

Higher incidence of common rust of maize was observed for Boke (95%) and Tullo (94%) followed by Oda Bultum (82%) and Chiro (75%) districts. The wider distribution and the higher incidence of the disease in western Hararghe zone could be attributed to the occurrence of intermediate rainfall, variation in altitude, adopted cropping systems and varieties planted by farmers and lack of crop rotation in the zone that are favorable for the growth and development of the fungus leading to its sporadic epidemics (Netsanet *et al*., 2005; Mohammed *et al*., 2014).

Table 3. Incidence and severity of common rust of maize *(Puccinia sorghi)* on farmer's field in eastern and western Hararghe Zones 2013 and 2014 main cropping seasons in major maize producing districts.

Zone	Location	Altitude (m.a.s.l)	Incidence of CRM (%) July to August	Severity of CRM (%) Sept to October
Western Hararghe	Chrio	1470	20	8
		1500	15	10
		1580	15	10
		1880	35	30
		2300	45	35
		1900	35	30
		1480	20	10
		1750	15	10
	Mean		25	17.8
	Kuni	1750	25	15
		2225	75	58
		2000	70	55
		2100	70	50
		2050	72	45
		9000	65	45
		1870	55	35
		1800	50	35
	Mean		60.25	42.25
Eastern Hararghe	Deder	1900	55	35
		1920	65	50
		1950	65	50
		2250	75	50
		2400	80	70
		2200	70	75
		2000	70	58
		2250	75	50
	Mean		69.38	54.75
	Chelenko	1900	35	25
		2050	40	30
		2350	85	75
		2250	80	75
		2000	70	60
		2000	50	35
		1860	45	25
		1960	45	25
		2125	55	25
		2100	55	20
		1700	35	15
	Mean		74.38	51.25

Danson *et al*. (2008) reported that increased incidence of common rust of maize in Africa was associated with weather variables, cropping systems, cultural practices such as reduced tillage, continuous cultivation of maize, and use of susceptible maize cultivars. According to the authors, conservation tillage leaves infested residue from previous crop on the soil surface that increases initial inoculums of the disease attached to the green bridge which serve as the over wintering of the parasite (obligate fungi). Moreover, increasing crop residue on the soil proportionally increases the amount of primary inoculum sources of the pathogen (Dey *et al*., 2012).

Fig 2. Infested Maize Fields with Common Rust of Maize (*Puccinia sorghi*) at Chiro, West Hararghe, Photo taken by the Author, 2013.

Fig 3: Infested Maize Fields with Common Rust of Maize (*Puccinia sorghi*) at Tullo, West Hararghe Zone, Photo taken by the Author, 2013.

Fig 4. Infected Maize Fields with Common Rust of Maize (*Puccinia sorghi*) at Deder east Hararghe Zone, Photo taken by the Author, 2014

Statistically there was also a significant ($p<0.001$) difference in severity of the disease between the two zones. The mean severity of common rust of maize in the zones ranged from 35 to 75% (Table 3). Severity of common rust of maize was also higher at Boke (75%) and Tullo (67%) followed by Chiro (52%) districts whereas the lowest severity was recorded for Komobolch (25%), in 2013. This result revealed that higher variations in disease incidence and severity were recorded for the two zones (Table 3). This suggests that variation in existing weather condition, cultural practices, lack of crop rotation and difference in genetic background of maize genotype planted by farmers in the zones contributed for the variation in the development of the fungus and the disease, respectively.

Therefore, farmers can have different options to manage this disease based on the variation in incidence and severity of common rust of maize by choosing from a number of management techniques including cultural practices, which include crop rotations, soil cultivation, intercropping with common bean, resistant host genotypes, use of short-season maize varieties, regulating planting time and plant density and use of fungicides.

3.3. Incidence and Severity of Common Rust of Maize Across Districts within Zones

The survey result on the prevalence, intensity and importance of common rust of maize in maize growing districts of separate zones of eastern Ethiopia were presented in Table 3. Common rust of maize was prevalent in all the assessed areas of the two zones. Both incidence of the disease varied significantly across the districts within two zones of different agro-ecological at Chiro (Fig. 2) and Tullo (Fig. 3) and at Deder (Fig. 4) East Hararghe Zone; and the severity of the disease conditions were shown in Tables 4. The mean incidence of common rust of maize in the different districts ranged from 55% to 100%. Statistically, there was highly significant ($p < 0.001$) difference among districts in terms of common rust of maize incidence and severity (Tables 3). The seriousness of common rust of maize was elucidated by the damage (severity) demonstrated on the plant.

Similarly, a survey conducted by Fininsa and Yuen (2001) in 280 farmers' fields in 10 districts of different cropping systems in the Hararghe highlands including sole maize, maize-bean, maize-bean-sorghum and maize-bean-other has shown the difference in occurrence and distribution of common maize rust of maize in studied geographical area. In their conclusion they reported mean rust incidences of 69–75% and severities of 48–57% in all the surveyed cropping systems. This is in agreement with the present finding, which depicted higher values of common rust incidence and severity in this investigation (Table 4).

Table 4. Distribution of common rust of maize in eastern Hararghe zone (mean values).

Distribution level	Deder		Chelenko		Haramaya		χ2 test
	No.	%	No.	%	No.	%	
High	72	82.75	85	100	92	93.9	
Medium	15	17.24	0	0	6	6.1	12.50*
Low	0	0	0	0	0	0	
Over all sample	87	99.9	85	100	98	100	

Generally, the overall severity of the disease was 65% (Table 4). The highest frequency of epidemic occurrences of this disease was more associated with areas which have predominant and intermediate relative humidity (Tullo, Kuni and Oda Roba ($\chi2=23.5$, df=4)) followed by areas which have an intermediate annual rainfall amounts and warmer temperatures. The prevalence and intensity of the disease was also associated with the existing cropping systems, weather variables and varieties used during the survey time (*r=0.55; r=0.45; r=0.25* and *r= 0.50*), respectively. From this study, it was also observed that the maize common rust is the most widely distributed and important foliar disease of maize in the Hararghe highlands significantly limiting maize yield. In view of the fact that, all of the surveyed areas, common rust of maize was recorded in all districts, thus common rust of maize was present in all areas of the assessed districts. Earlier results of various surveys conducted in most maize growing regions of Ethiopia indicated that the disease has a wide distribution and significant impact on maize yield reduction on both local and improved varieties (Tewabech *et al*., 2012; Fininsa, 2001).

According to Worku *et al.* (2012), some of the released hybrid maize varieties, BH-660, BH-661 and PHB-30H83 were found to be relatively tolerant to common rust of maize. This disease has also been observed in maize seed multiplication sites at eastern Shewa, Jimma, east Wollega and Sidama zones where monocropping is practiced using the recently released maize varieties. Several reports, from the U.S.A. (Iowa), Brazil, Kenya, Ethiopia showed the epidemics of common rust of maize is severe under monoculture (sole maize), with no rotation practices and minimum tillage practices (Fininsa and Yuen, 2001; Doyel *et al*., 2012). It was apparent that maize is grown over a large area of eastern and southeastern parts of Ethiopia where this disease dominantly exists.

3.4. Relationship between Weather Variables, Common Rust Incidence and Severity

The relationship between disease development and weather variables was established using correlation analysis to look for the effect of individual variable on disease development. Correlations between weather variables and common rust of maize (CRM) incidence and severity were determined (Table 5). The result revealed that common rust of maize incidence and severity had negative and insignificant correlation with altitude (r = 0.55 and r = -0.850, respectively). There was strong positive correlation between rainfall and mean common rust of maize incidence and severity (r = 0.25 and r = 0.55, respectively).

Rainfall during the actual maize production seasons of each surveyed area in 2013 and 2014 was also strongly correlated but insignificantly with both common rust of maize incidence and severity. On the other hand, temperature had insignificant correlation with both disease incidence and severity. This indicated the strong influence of weather condition particularly that of rainfall on common rust of maize development. A strong positive and highly significant correlation (r = 0.85) was also found between disease incidence and severity.

In the present survey, conducted in Hararghe highlands, eastern Ethiopia greater variation in common rusts of maize prevalence, intensity and importance, were observed ranging from mild to severe infections. In this study, all of the surveyed areas showed moderate to severe common rust of maize infection, which usually have, humid or warm temperature and high rainfall. Cropping systems such as inter-cropping and use of cultivar mixture are also recognized in reducing disease pressure in positive or negative ways (Fininsa and Yuen, 2001; Jeger, 2004). From the present investigation it was observed that farmers in surveyed region do not apply any specific management practice to control common rust of maize at least intentionally.

Disease assessment is one of the most challenging tasks in working with plant diseases (Madden *et al*., 2007). A diseased plant or group of diseased plants is often recognized easily once symptoms or signs become visible; however, it is the quantification of the disease that presents the challenge. The assessment of disease incidence (i.e., the number or proportion of diseased plants in a population) is an apparently simple counting task, but is subject to the usual limitations of interpretation related to sample size. The accurate and precise estimation or measurement of disease severity (i.e., the area or proportion of plant tissue that is symptomatic) can be a formidable task because of visual and measurement errors and the need for samples to be representative of the area considered and to be of adequate number (Danson *et al*., 2006; Delaney *et al*., 1998; Madden *et al*., 2007; Siniya *et al*., 2013; Bekeko*et al*., 2013). Understanding disease epidemiology as it is affected by different variables is also useful to design ecologically sustainable disease management tactics and strategies. Management practices aimed at a reduction of initial inoculum are effective against polycyclic diseases and/or diseases with longer latent periods, especially diseases having multiple hosts (Zadoks and Schein, 1979). Therefore the present study helps in managing this disease in the study area.

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Table 5. Correlation values of common rust of maize incidence and severity with environmental variables in 2013 and 2014 main cropping seasons.

Variables	Altitude (m.a.s.l)	Rainfall(mm)	Cropping system	Variety	Incidence (%)	Severity (%)
Altitude (m.a.s.l)	1					
Rainfall(mm)	0.830	1				
Cropping system	0.752	0.875	1			
Variety	0.750	0.550	0.645	1		
Incidence (%)	0.255	-0.725	-0.540	-0.750	1	
Severity (%)	-0.680	-0.760	-0.565	-0.850	0.975	1

Note: m.a.s.l = meters above sea level

5. Conclusion

The results of this study demonstrated that common rust of maize occurred in all assessed districts of both eastern and western Hararghe zones having different agro-ecologies. The highest mean common rust incidence (75.57%) and severity value of (355%) were recorded for Boke, Chiro, Oda Bultum and Tullo districts in the western Hararghe zone whilst Deder, Chelenko, Haramaya and Kombolcha districts of the eastern Hararghe zone had the lowest mean incidence (45%) and severity (25%) scores, respectively. It is, thus, concluded, that common rust (*Puccinia sorghi* Schw.) is the most widely distributed and important foliar disease of maize in Hararghe highlands.

Hence, the information generated from this study may help in understanding and planning the type of management decision to be used in managing the disease in the study area. Therefore, it is recommended that use of tolerant and/or resistant varieties and designing an efficient, inexpensive and sustainable management approaches such as intercropping with food legumes, plant density adjustment and use of improved soil fertility management practices against this pathogen is very crucial for sustainable management of the disease in Hararghe highlands.

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