International Journal of Agricultural Research and Review: ISSN-2360-7971, Vol. 7(1): pp 729-736, January, 2019.

Full Length Research

Status of Wheat Stem Rust (*Puccinia graminis* f.sp. *tritici*) in Hararghe Highlands, Ethiopia

Arif Abrahim[1*], Ayele Badebo[2] and Issa Eibrahim[3]

[1,3]Wolkite University College of Agriculture and Natural Resource Department of Horticulture, P.O.BOX O7, Wolkite, Ethiopia
[2]Ethiopian Institute of Agricultural Research Debra Zeit Agricultural Research Center, Debra zeit, Ethiopia

Corresponding Author: Arif Abrahim: e-mail: rfabrahim@gmail.com
Ayele Badebo: ayele88@yahoo.com
Issa Eibrahim: issa.eibrahimps@gmail.com

Accepted 6th January, 2019

Wheat is one of the important cereal crops of Ethiopia. It ranks third in land coverage and total production after tef and maize and in productivity after maize and sorghum. Hararghe highlands are also considered to be suitable for wheat cultivation in the country. However, the production of wheat in this region is threatened by the stem rust disease. This study was conducted with the following objectives: to determine distribution, incidence and severity of wheat stem rust Puccinia graminis f.sp. tritici in Hararghe highlands. Field surveys were carried out in eight districts of east and west Haraghe zones. A total of 200 fields were surveyed. Stem rust occurred in 80% and 74% of the fields surveyed in East and West Hararghe zones, respectively. Its incidence was 38.32% and 30.43% in East and West Hararghe areas, respectively. There was significance difference among the zones, districts and peasant associations (P< 0.05). The highest mean severity (35.36%) was recorded in Meta followed by Anchar (12.4%) and Melkabalo (12.00%). The disease severity was highly significanct among the zones, districts and peasant associations (P< 0.05). All the varieties grown in the two zones were attacked by the disease in one area or the other, though the degree of incidence and severity varied. Varieties such as Kubsa, Wabe, Abola and Pavon76 were found to be severely affected in East and West Hararghe zones. During the main crop season, the disease was more severe in Meta district and Anchar district of East and West Hararghe zones, respectively. The wheat rust trap nursery planted at Haramaya indicated maximum severity of 100%. But, in Hirna it indicated maximum severity of 40%. Differential lines such as PBW343, BARLETA BENVENUTO, CNS SR32AS, W2691SR9B, W2691SR10 and SWSR22T.B, BT/WLD and H44 DERIV have high infection at Haramaya whereas they had less infection at Hirna. This indicated that the disease intensity at Haramaya was very high than Hirna. Inoculation of quick-test in the greenhouse indicates susceptible reaction with bulked isolates of Puccinia graminis f. sp. tritici collected from East and West Hararghe zones.

Keywords: Stem rust, incidence, severity, Puccinia graminis f. sp. tritici, East and West Hararghe

1. INTRODUCTION

Wheat is highly grown and most important food security crops in Ethiopia (Hailu *et al*., 1991; Bekele *et al*., 1999). The order of production status and ranks in yield of wheat in Ethiopia is third after maize and sorghum (CSA, 2001). From the sub-saharan Africa wheat is highly produced in Ethiopia (Hailu *et al*., 1991), with 1,025,310 hectares (CSA, 2001). It is grown in diversified ecological conditions with different types of crop husbandery (Belay and Tanner, 1999). The altitude range of 1900-2700 m.a.s.l. is suitable for the production of wheat (Hailu *et al*., 1991). Wheat requires optimum amount of rainfall with fair distribution during the growth period. In the highlands, rainfall distribution is bimodal, main rainy season (*meher*) falling from June to September and short rainy season (*belg)* falling

from February to April and the amount ranges between 600-2000 mm per annum (Hailu *et al*., 1991). The crop is cultivated in both seasons though the main crop is in *meher.* Though the seasons differ, the crop growth stage overlaps in most cases. This creates favorable condition for the carryover of stem rust urediospores from one season to other and leads to the development of epidemics in wheat growing areas (Mamluk *et al*., 2000). Hararghe highlands are considered to be suitable areas for wheat cultivation in the country where it is produced on a total of 50,297 ha and the average productivity is 1,214 kg/ha which is lower than the average yield (1800kg/ha) of the other wheat producing regions of Ethiopia (FAO/WFP, 2009). Varieties grown in East and West Hararghe zones include: Kubsa (HAR1685), Wabe (HAR710), Abola (HAR1522), ET13-A2, Pavon76 and local cultivars (MoARD, 2009).

Even though, there were a large area under wheat production in Ethiopia, there were low national average yields of about 2t/ha (FAO/WFP, 2009), which is below the average of different African countries and the world average as a general. The same is true for Hararghe Highlands. The major factors for the low yielding of wheat are low and uneven distribution of rainfall, cultivation of low yielding varieties, poor agronomic practices and serious diseases like rusts, septoria leaf and glume blotch, (Aykroyd and Doughty, 1971; Dereje and Yaynu, 2000). In Hararghe highlands rusts occur annually depending on weather conditions. At higher altitude areas (2400-2700 m.a.s.l) yellow rusts commonly occur every year and stem rusts mainly occur at medium altitude (1900-2400m.a.s.l) (MoARD, 2009).

According to (Temam *et al*., 1985; Roelfs *et al*., 1987; Masresha, 1996; and McVey *et al*., 1997) the Stem rust of wheat caused by *P.graminis* Pers. has been a major disease of many small grain cereals and forage grasses worldwide. The warmer environmental conditions with high relative humidity can causes severe disease and addresses great losses (Haldore *et al*., 1982; Roelfs *et al*., 1992). 100% yield Losses have been occurred in susceptible local wheat cultivars. According to (Eshetu, 1985, and Dereje and Yaynu, 2000) wheat yield losses due to stem rust pathogen have been 52% in Ethiopia.

Due to the arrival of new pathogen races from time to time, the resistant cultivars with new R-genes are continuously being developed to prevent such epidemics. But, these R-genes become susceptible to new pathogenic races sooner or later. Different types of physiologic races are known in a pathogen of *P. graminis* f.sp. *tritici* (Knott, 1989). High infestation of wheat stem rust disease was occurred in 1972, in Ethiopia, due to the breakdown of resistance gene in cultivar Lakech, which was grown on large areas of the countries. As the same time, the cultivar Enkoy left out of production in the country after the epidemics in 1992. Currently cultivar Kubsa has become highly susceptible to the newly evolved stem rust pathogen. Thus monitoring of the pathogen races in reaction with the response of cultivars under production and their virulence is important part of rust management strategy to avoid crop losses (Roelfs *et al*., 1987; Roelfs, 1988; Park and Welling, 1992). There are limited reports on the distribution of stem rust races in some parts of Ethiopia (Serbessa, 2003; Belayneh Admassu *et al.*, 2008). So, knowing the status of resistance for the cultivars under production and disease population is very important. Although Hararghe is one of the wheat production areas in the country, there is no enough information on the distribution, incidence, and severity of wheat stem rust disease. Therefore, this study was conducted with the following objectives:

- To determine distribution, incidence and severity of wheat stem rust in Hararghe highlands

2. MATERIAL AND METHODS

2.1. Description of the study area

The study was conducted in major wheat producing areas of East and West Hararghe zones. Hararghe is located in the eastern parts of the Oromia Regional State and characterized by various agro-ecological zones. East Hararghe zones are characterized by different agro-climatic zones consisting of *dega* (7.67%), *woinadega* (24.54%) and *kolla* (67.76%). It is located at 41^0 12'- 42^0 53' East longitude and between 7^0 32'- 9^0 44' North latitude, at minimum and maximum elevation of 500 and 3405 m.a.s.l. respectively. The average annual minimum and maximum rainfall is 400 and 1200 mm, respectively. Its minimum and maximum temperatures are 13^0C and 28^0C respectively. The agro – climatic zones of West Hararghe consist of *dega (*10%), *woinadega* (38%) and *kolla (*52%). It is located at 7^0 32' - 9^0 47' North latitude and between 41^0 24' - 43^0 48' East longitude, at minimum and maximum altitude of 1200 – 3600 m.a.s.l, respectively. The average mean minimum and maximum annual rainfall is 650 – 2000mm with the temperature of between 20.5^0C – 24^0C (MoARD, 2009).

Haramaya is located $9^0$26'N, $42^0$3'E, 1980 meters above sea level, Eastern Hararghe. The site has a bimodal rainfall distribution pattern and is representative of a sub-humid, mid-altitude agro-climatic zone. The average annual rainfall is of 60mm and the mean annual temperature is 17^0C with a range of 14^0C to 18^0C. Hirna is located at 41^0 4' E, $9^0$12' N at an altitude of 1870 meter above sea level in western Hararghe. The site receives a mean annual rain fall of 990-1010mm with average temperature of 240c (ALARC, 1997).

2.2. Determination of the distribution of wheat stem rust in East and West Hararghe zones.

A survey was conducted for stem rust of wheat in Hararghe Highlands during the 2016 main cropping season. Two basic systems of surveys were employed. The first involved the use of mobile units (observers travelling between large numbers of sites in the farmer fields). The second, methodology made use of static units mainly by using Ethiopian Wheat Rust Trap Nursery (EWRTN) which was planted at two stem rust hot spot areas, Haramaya and Hirna. Field surveys were carried out from mid-September to mid-October 2016 during which stem rust was expected to reach its maximum severity level (Serbessa, 2003). It was carried out in a total of eight districts of east and west Hararghe zones. Four districts from East Hararghe (Meta, Deder, Gurawa and Melkabalo) and four from West Hararghe (Masala, Tullo, Hancar and Gemachis) were considered. Five peasant associations (PAs) were selected per district based on their potential of wheat production. From each PA five farmers' fields were selected and a total of 200 farmers' fields were assessed.

The wheat stem rust trap nursery consisting of 115 commercial cultivars and 40 stem rust differentials and the universally susceptible wheat variety, "Morocco". The nursery were obtained from Kulumsa Agricultural Research Center and a resistant variety, ''Qulqulu'' (ETBW4621) was obtained from Haramaya University. The nursery was planted at Hirna and Haramaya which are stem rust hot spot areas in Hararghe. Each entry was planted in un-replicated plots of 1m long with 2 rows and 20 cm spacing between rows using the recommended seed rate of 150kg/ha. Fertilizers and other cultural practices were applied as per recommendations for the areas.

2.3. Determination of disease incidence

During the field survey, disease assessment was made by moving in an "X" fashion or diagonally in each field and observing 10 plants and recording them as diseased or healthy. The number of diseased plants was expressed as a percentage of the total number of plants assessed giving information on disease incidence. Incidence was expressed in percent according to the following formula.

$$\text{Disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total plants assessed}} \times 100$$

2.4. Determination of disease severity

In each field disease severity (percentage of plant tissue covered by the disease) was determined by using the modified Cobb's scale (Roelfs *et al*., 1992). Disease severity was scored on 10 plants per field (Peterson, *et al*., 1948). In the disease trap nursery disease severity was assessed three times starting from the onset of the diseases on the susceptible check, Morocco.

2.5. Evaluation of level of stem rust infection for wheat cultivars grown in East and West Hararghe Zones

The assessment of stem rust disease was carried out on subsistence wheat fields of East and West Hararghe zones. The wheat fields along the road sides were observed to see the status of stem rust on the cultivars under production. The level of infection was determined by considering the intensity of the disease for cultivar inspected in the fields. Ten (10) plants per field were inspected for recording disease incidence. The disease severity of respective cultivars was assessed on 10 randomly selected plants in each field. The Coefficient of Infection (C.I.) was calculated using the methods outlined by Roelfs *et al*. (1992) in which the values of severity were multiplied by constant number of host response given, i.e., immunity = 0, R= 0.2, MR = 0.4, MS = 0.8 and S = 1. This is used to determine the level of infection of plant tissues or diseased area infected with the stem rust pathogen.

2.6 Data collected

The following data were collected during field survey:

Disease incidence: percent of infected plants based on the total number of plants observed for wheat stem rust.

Disease severity: The severity of the disease was recorded on 10 randomly selected plants by estimating the percentage of leaf area affected by the disease from each plants assessed and competing average of the plants.

Disease prevalence: it was computed as the proportion (%) of fields showing disease symptom observed out of the total fields assessed.

2.7 Data analysis for disease survey

The mean disease incidence and severity of stem rust were calculated for each district, peasant association and field. Data were subjected to nested random effects analysis of variance (Steel and Torrie, 1980; Kiros, 1993). The Statistical Analysis System (SAS) Version 9.2 software (SAS, 2009) was used.

3. RESULTS AND DISCUSSION

3.1. Distribution of wheat stem rust in East and West Hararghe Zones

During the study a total of 200 farmers' fields were surveyed in both East and West Hararghe zones. The crop growth stage during field assessment varied from 7 to 9 according to Zadok's growth scale. Old varieties as well as recently released varieties were found in the zones. Relatively recently released cultivars like Kubsa (HAR1685), Abola (HAR1522), Wabe (HAR710), Galema (HAR-604), Pavon76, ET13-A2 and local varieties were found growing in these zones. The cultivars Kubsa was the most widely cultivated following by ET13-A2, Abola and Wabe. The local cultivars were also highly cultivated in these areas.

In East Hararghe zone, a total of 100 farmers' fields were surveyed in which stem rust occurred in 80 fields indicating 80% prevalence of the disease in the zone. In West Hararghe zone also a total of 100 farmer's fields were surveyed in which stem rust occurred in 74 fields indicating 74% prevalence of the disease in the zone. The disease occurred on all the varieties grown in one field or the others.

The survey reports of earlier years of Ethiopia revealed that stem rust of wheat was commonly found in all wheat growing regions. Getaneh (1996) reported high incidence and severity of stem rust in Arsi, Bale, Shewa, Hararghe, Sidamo, Wellegga and Gojam. The survey also conducted by staff of the Institute of Agricultural Research in the year 1995/96 revealed that there was trace to 80% severity of stem rust in the survey period. Some report have been showed that the occurrence of the disease was high except for some years where adverse climatic conditions prevail (Temam *et al*., 1985; Temesgen *et al*., 1996, Getaneh, 1996).

The nursery data at Haramaya and Hirna were recorded from 116 commercial varieties including 'ETBW4621' (Qulqulu). The disease severity on the universally susceptible cultivar Morocco ranged between 90S-100S at Haramaya and Tr-50S at Hirna.

Forty seven percent (47%) of the commercial cultivars planted at Haramaya indicated rust severity of about 60% with susceptible host reactions. Twenty five percent of these varieties exhibited rust severity between 20% and 60% with moderately susceptible host response whereas the rest of the cultivars (28%) showed resistant and moderately types of resistant reactions. On the other hand, 97% of the commercial cultivars planted at Hirna showed resistant reaction. This indicates that the prevailing environmental conditions during the 2016 were not conducive for the occurrence of stem rust at Hirna. Earlier reports (Getaneh, 1996) indicated that the geographical location, crop management practices, types of cultivars grown or spore load in the atmosphere make difference the intensity of stem rust disease from one area the other.

The stem rust differential lines planted at Haramaya and Hirna showed that disease incidence was about 100% on susceptible cultivars at Haramaya and 40% at Hirna. This indicates that the environmental conditions were very suitable for disease occurrence in Haramaya than Hirna areas. Maximum disease severity at Haramaya was obtained from differentials such as PBW343 (Sr31), BARLETA BENVENUTO, CNS SR32AS (Sr32), W2691SR9B (Sr9b), W2691SR10 (Sr10) and SWSR22T.B (Sr22), BT/WLD and H44 DERIV.

3.2. Incidence of wheat stem rust

A total of 40 peasant associations (PAs) and 200 farmer fields were surveyed in eight districts of Hararghe highlands. The incidence of wheat stem rust was computed for zones, districts, peasant associations and farms. There was significant difference ($P< 0.05$) among the zones, districts and peasant associations. The highest disease incidence (60.6%) was obtained from Meta district followed by Anchar (39.8%) and Melkabalo (37.8%). The least disease incidence (17.3%) was recorded from Tullo district (Table 1).

Table 1: The Mean incidence of wheat stem rust in surveyed regions during the 2016 main cropping season.

Zones	Districts	Disease Incidence (%) within PAs						
		1	2	3	4	5	Mean	Std. error of mean
East Hararghe	Gurawa	30.00	34.00	12.00	20.00	58.00	30.80	5.71
	Meta	64.00	61.00	56.00	57.00	65.00	60.60	4.77
	Dedar	22.20	20.00	23.00	36.00	19.00	24.04	3.38
	Melkabalo	46.00	26.00	31.20	21.00	65.00	37.84	4.98
Total							38.32	
West Hararghe	Masala	41.60	45.00	33.60	42.00	24.00	37.24	4.17
	Tullo	25.00	17.00	27.40	5.00	12.00	17.28	2.98
	Gemachis	52.00	25.00	23.20	24.60	12.00	27.36	4.83
	Anchar	49.20	64.00	26.00	26.00	34.00	39.84	6.61
Total							30.43	

PAs = Peasant associations

3.3. Severity of wheat stem rust

Like disease incidence, severity of stem rust was computed for zones, districts, peasant associations and fields. There was significant difference ($P < 0.05$) among the surveyed zones and highly significant difference among the districts and peasant associations (PAs). The highest mean severity (35.36%) was recorded in Meta followed by Anchar (12.40%) and Melkabalo (12.00%) (Table 2). This might be due to their difference in geographical location, crop management practices and type of cultivars grown. The lowest disease severity (4.72%) was recorded in Tullo district followed by Dedar (6.16%).

There were high disease incidence and severity with wide range average diseases recorded in this study. According to (Getaneh and Temesgen, 1995; Mamluk *et al*., 2000) such types of disease occurrence and range may be due to the conduciveness of the environmental conditions, cultivation of susceptible cultivars and possibly occurrence of high spore load in the atmosphere for the specific year in the surveyed regions.

Table 2: The Mean disease severity of wheat stem rust in the surveyed regions.

Zones	Districts	Disease Severity (%) within PAs						
		1	2	3	4	5	Mean	Std. error of mean
East Hararghe	Gurawa	6.80	8.00	2.40	3.60	12.40	6.64	1.29
	Meta	36.40	28.00	36.80	35.20	40.40	35.36	3.59
	Dedar	6.00	4.40	6.00	10.80	3.60	6.16	0.86
	Melkabalo	13.60	9.20	8.40	6.40	22.40	12.00	1.62
Total							15.04	
West Hararghe	Masala	14.80	14.00	9.60	11.20	4.40	10.80	1.52
	Tullo	6.80	2.80	9.20	1.60	3.20	4.72	0.79
	Gemachis	22.80	8.40	6.00	5.20	2.80	9.04	2.18
	Anchar	17.60	22.80	6.40	6.40	8.80	12.40	2.37
Total							9.24	

PAs = Peasant associations

3.4. Wheat cultivars grown and their level of infection by stem rust in East and West Hararghe Zones.

In East Hararghe zone the highest disease incidence (70%) was recorded on cultivar Kubsa followed by the cultivar Pavon76 (60%) and local cultivars (59%) whereas the least disease incidence was obtained from cultivar ET-13A2 and Abola (Table 3). The highest disease severity (23S) and reaction was recorded from the cultivar Kubsa whereas the least disease severity (TrR-3MR) and reaction was obtained from cultivar Wabe (Table 4).

In West Hararghe zone the highest mean incidence was obtained from cultivar Abola (54%) and the least was also obtained from cultivar Pavon76. The mean disease severity and reactions were high on local cultivars (9S) and cultivar Kubsa (7S). In spite of the wide spread occurrence of the disease, cultivars like ET-13A2, Abola and the locals in East Hararghe and Wabe, Pavon76 and ET-13A2 in West Hararghe revealed low disease infection.

Table 3: Disease Incidence on Different Cultivars in East and West Hararghe Zones**.**

Zones	Districts	Cultivars					
		Kubsa	Abola	Wabe	ET-13A2	Pavon76	Local
East Hararghe	Gurawa	36	0	30	-[a]	60	45
	Meta	70	30	40	-	60	59
	Dedar	21	10	-	22	-	41
	Melkabalo	39	45	-	10	45	33
Mean Incidence		41.5	21.25	35	16	55	44.5
West Hararghe	Masala	36	60	53	48	-	17
	Tullo	18	0	-	32	10	17
	Gemachis	29	53	-	15	-	34
	Anchar	21	85	55	35	-	43
Mean Incidence		26	49.5	54	32.5	10	27.75

[a] Farms for which the respective cultivars have not been encountered

Table 4. Severity and Coefficient of Infection of Stem Rust of Wheat on Different Cultivars in East and West Hararghe Zones**.**

Zones	Districts	Cultivars						Mean C.I[b]
		Kubsa	Abola	Wabe	ET-13A2	Pavon76	Local	
East Hararghe	Gurawa	5MR	0	TrR[a]	-[c]	TrR	1R	0.088
	Meta	23S	4MS	3MR	-	18MS	11S	2.16
	Dedar	2R	TrR	-	3R	-	5MR	0.12
	Melkabalo	6MS	5R	-	5R	9MR	5MS	0.576
Mean C.I		7.55	1.93	2.4	0.8	9	4.3	
West Hararghe	Masala	8MS	11MR	6MR	8MS	-	5MS	0.944
	Tullo	4MR	0	-	5R	TrR	4MS	0.232
	Gemachis	7S	5R	-	TrR	-	4MS	0.448
	Anchar	3MR	13MS	11MS	8MR	-	9S	1.432
Mean C.I		4.05	3.95	5.6	3.35		4.85	

[a] Trace level of disease infection with resistance reaction
[b] Coefficient of Infection
[c] Farms for which the respective cultivars have not been encountered

4. SUMMERY AND CONCLUSSION

Stem rust of wheat caused by the fungus *Puccinia graminis* f. sp. *tritici* was found to be prevalent in East and West zones during the main growing season of 2016 with slightly higher prevalence (80%) in East Hararghe than in West Hararghe zone (74%).

The incidence of the disease was low (38.32% and 30.43% in East and West Hararghe zones, respectively) in the survey areas as compared to other survey years of earlier works where 70-100% incidence was recorded. The Highest disease incidence was recorded on the cultivar Kubsa that was grown on large areas in the two zones. The incidence was highest in Meta district of East Hararghe zone and the lowest was recorded in Tullo district of West Hararghe zone. The severity of stem rust was highest in Meta district of East Hararghe zone followed by Anchar district of West Hararghe zone. The highest severity was recorded on the cultivar Kubsa in both zones.

In view of the high incidence and severity of stem rust on the cultivar Kubsa that covers 95% of the area under production in the surveyed areas, it appears that there is a need for replacement of this cultivar by other more resistant new cultivars in the production system in both zones. Since all the cultivars assessed were found to be attacked by the disease, a thorough, season based regular monitoring of the pathogen is required for the areas not covered in this survey in the main wheat growing areas in East and West Hararghe zones.

The commercial cultivars planted at Haramaya indicated that maximum disease incidence of 90% was recorded. But, in Hirna it indicated maximum incidence of 10%. Here, most cultivars revealed resistance type reactions. Therefore, these conclude that the disease occurrence at Haramaya area is very high and most of the commercial cultivars were susceptible to the disease. This is due to the favorable environmental conditions for wheat stem rust disease occurrence at Haramaya than Hirna.

5. RECOMMENDATIONS

The area under wheat in Ethiopia has dramatically increased over the years. The level of the disease has also increased. Due to the impact induced by stem rust and other diseases the productivity of the crop has remained low and this needs greater attention if national goal for food self-sufficiency is to be attained. The majority of wheat in Ethiopia is grown by subsistence farmers, for whom the use of chemical fungicides against stem rust is uneconomical.

Hence, farmers need to be continuously supplied with resistant varieties to avoid epidemics of stem rust, especially in the light of the wide distribution of race Ug99 and other newly developed variants of Pgt. It is also evident that Pgt populations in Ethiopia are highly variable. Therefore, it is imperative for the national agricultural research system to monitor pathogen populations over time to track further virulence evolution and to ensure that currently effective resistance genes are applied within a system of resistance-gene management.

6. ACKNOWLEDGEMENTS

The author's would like to express his special and deepest gratitude to Haramaya University for their permission to conduct research on their research sites and to Wolkite University. The authors also wants to thanks the Debra Zeit Agricultural Research Center for their contributions in giving seeds of wheat trap nursery.
The assistance of East and West Hararghe Zone Agricultural and Rural Development Office in providing the necessary information for survey work is gratefully acknowledged.

7. REFERENCES

ALARC (Alemaya University Research Center), (1997): Proceedings of the 13th Annual Research and Extension Review Meeting. February, 26-28, 1996.

Aykroyed, W.R., and Doughty, J., (1971): Wheat in human nutrition. Food and Agriculture organization of the United Nations. Rome, Italy.

Bekele Hunde Kotu, Verkiuji, H. and Mwangi, W., (1999): Adoption of improved wheat technologies in Adaba and Dodola woredas of Bale highlands. Pp. 89-93. *In*: proceedings of the tenth Regional Wheat workshop of Eastern, central and southern Africa. Addis Ababa, Ethiopia.

Belay Sime and Tanner D.G. (1999): Yield potential and weather risks associated with wheat production in Ethiopia. Proceedings of the Tenth Regional wheat Workshop of Eastern, Centeral and southern Africa. Addis Ababa, Ethiopia, pp 316-324.

Belayneh A, Lind V, Friedt W, Ordon F **(**2008): Virulence analysis of *Pucciniagraminis* f.sp. *tritici* populations in Ethiopia with special consideration of Ug99.

CSA, (2001): Statistical Abstracts 2000. Federal public of Ethiopia, central statistical Authority. A. A, Ethiopia.

Dereje Gorfu and Yaynu Hiskias, (2000): Yield losses of crops due to disease in Ethiopia. *Pest management Journal of Ethiopia*. 5:55-67.

Eshetu Bekele (1985): A Review of Research on Disease of Barley, Tef and Wheat in Ethiopia. *In*: Tsedeke Abate (eds)." A Review of crop protection Research in Ethiopia. "Addis Ababa, Ethiopia, Pp 79-148.

FAO/WFP, (2009): Crop and Food Security Assessment Mission to Ethiopia. Addis Ababa, Ethiopia.

Getaneh Woldeab and Temesgen Belayneh, (1995): Preliminary study on atmospheric spore load of wheat rust at Ambo. Crop protection society of Ethiopia. Proceedings of the second Annual conference April 26-27, 1994. Addis Ababa. Ethiopia, p35.

Getaneh Woldeab. (1996): Studies on fungal diseases of wheat at Plant Protection Research Center, 1974-1994. pp 177-182. In: Eshetu Bekele, Abdurahman Abdulahi and Aynekulu Yemane (eds). Proceedings of the Third Annual Conference of the Crop Protection Society of Ethiopia. May 18-19, 1995. Addis Ababa, Ethiopia.

Hailu Gebre-mariam, Tanner, D.G., and Mangistu Hulluka, (1991): Wheat Research in Ethiopia: A historical perspective. Addis Ababa. IAR/CIMMYT.

Haldore H., Borlang, N.E. and Anderson, R.G. (1982): Wheat in the third world. West view press. Boulders Colorado. intensity on leaves and stems of cereals. Canad. J. Res. C-26: 496-500.

Kiros Meles, (1993): Studies on barley scald (Rhynchosporium secalis (OUD) Davis) and evaluation of barley lines for resistance to disease in Ethiopia. M.Sc. Thesis Presented to the School of Graduate Studies, Alemaya University of Agriculture.

Knott, D.R. (1989): The wheat-Rusts Breeding for Resistance. Springer, Verlag. Berlin Heidberg, Germany.201p.

Mamluk, O.F., El. Daoudi, Y.H., Bekele, E., Solh, M.B., Ahmed, M.S., Mahir, M. A. and Bahamish**,** H.S. (2000): Wheat leaf and Stem Rusts in the Nile Valley and Read Sea Region. ICARDA/NVRSRP, Cairo, Egypt, 75p.

Masresha Aklilu. (1996): Wheat rust races identified in virulence surveys in Ethiopia. In: Tanner, D. G., Payer, T. S., and Abdella, O. S. (eds). Proceedings of the Ninth Regional Wheat Workshop of Eastern, Central and Southern Africa. Addis Ababa, Ethiopia, pp 458-461.

McVey,D.V.,Long,D.L. and Roberts, J.J. (1997): Races of *puccinia graminis* in the United States during 1995. Plant Dis. 81:306-310.

MOARD (Ministry of Agriculture and Rural Development), (2009): Crop Development Department. East and West Hararghe Rural Development and Agricultural Office. The 2009 Meher Post Harvest Assessment Result. Addis Ababa, Ethiopia.

Park RF and Wellings CR, (1992): Pathogenic specialization of wheat rusts in Australia and New Zealand in 1988 and 1989. *Australasian Plant Pathology* **21**, 61–9.

Peterson, R.F., A.B. Campbell and A.E. Hannah. (1948): A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. Canad. J. Res. C-26: 496-500.

Roelfs, A. P., Singh, R. P., and Saari, E. E. **(**1992): ‘‘Rust Diseases of Wheat: Concepts and Methods of Disease Management.’’ CIMMYT, Mexico, D.F.

Roelfs, A.P and Martens, J.W. (1988): An international system of nomenclature for *Puccinia graminis f.sp. tritici*. *Phytopathology* 78: 526-533.

Roelfs, A.P., Casper, D. H., Long, D.L. and Roberts, J. J., (1987): Races of *Puccinia graminis* f.sp. *tritici*. *Phytopathology* **74**: 526-533.

SAS (Statistical Analysis System) software, (2009): Version 9.2. Inc. Carry, North California, USA.

Serbessa Negera. **(**2003): Wheat stem Rust (*puccinia graminis f.sp.tritici*). Intensity and Pathogenic variability study in Arsi and Bale zones. MS.c Thesis, AU.

Steel, R.G.D. and J.H. Torrie, (1980): Principles ana Procedures of Statistics: A Biometrical Approach. McGraw-Hill, New York.

Temam Hussein, Solomatin, D.A. and Masresha Aklilu (1985): Races of *puccinia graminis f.sp. tritici* in Ethiopia. In: Tsedeke Abate. (eds). A review of crop protection Research in Ethiopia. I.A.R., Addis Ababa.

Temesgen Kebede, Ayele Badebo and Bekele Geleta. (1996): The current status of rust virulence and utilization of bread wheat resistance in Ethiopia. *In* Tanner, D.G., Payne, T.S., and Abdella, O.S. (eds). The Ninth Regional wheat workshop for Eastern, central and south Africa. Addis Ababa .Ethiopia, CIMMYT, Pp494-499.