academicresearchJournals

Vol. 7(2), pp. 63-74, March 2019
DOI: 10.14662/ARJASR2019.005

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Effects of climate variability on development of wheat rust diseases (Puccinia spp.) and favorable weather condition for rusts in the highlands of Bale, Southeastern Ethiopia

Zerihun Dibaba Tufa[1]*

[1]Sinana Agricultural Research Center, Bale Robe, Ethiopia. Corresponding author*: zerihun.dibaba@gmail.com

Accepted 27 February 2019

Rainfall, temperature and relative humidity are the most important climatic parameters for agricultural practices and more conducive for disease and insect developments. In this study, effects of climate variability on development wheat rust diseases and favorable weather condition for rust were analyzed. Cropping season weather data obtained from nearby stations were used to analysis impacts on rust disease occurrence. The result of historical data analysis suggested that, annual rainfall amount was increased by 9.1 mm/yr and 2.8 mm/yr at Sinana and Robe respectively. On the other hand, the seasonal kiremt rain was increased by 6.1 mm/yr at Sinana station and 2.9 mm/yr at Robe station. The study results revealed that climate variability has played a great role in agricultural practices, which in turn influences crop diseases occurrence. In particular, it has induced wheat rust diseases over the study areas that significantly affect the quality and quantity of the yield. The correlation between monthly rainfalls and disease severity about -0.86, while for relative humidity and diseases severity reached 0.74 at (p= 0.05). This condition was also true for maximum and minimum temperature with rust diseases, the correlation analysis indicated 0.61 and 0.79 respectively (p=0.05). From weekly analysis during cropping season, the climatic condition conducive for rust diseases occurrence were identified. Therefore, the development and spread of rust is highly enhanced with maximum temperature and minimum temperature ranges 20.8 ^{o}C to 28 ^{o}C and 8.2 ^{o}C to 11.7 ^{o}C , while relative humidity was more than 70 % across the highland regions. In view of this condition, early warning can be well practiced by acquiring appropriate lead-time climate-based forecasting of on the possible occurrence of both climates and diseases on varieties of wheat crops across the Bale highlands.

Key words: Climate variability, wheat rust, disease, variety.

Cite this article as: Zerihun, D.T. (2019). Effects of climate variability on development of wheat rust diseases (Puccinia spp.) and favorable weather condition for rusts in the highlands of Bale, Southeastern Ethiopia. Acad. Res. J. Agri. Sci. Res. 7(2): 63-74

Back ground and justification

Ethiopia located between 30N-150N and 330E-480E within the tropical region of horn Africa. The annual rainfall distribution in the western part of the country has one maximum during July or August. In Ethiopia there are some regions which experiences three seasons with two rainfall peak (one peak is more dominant than the other), while some regions have four seasons with two distinct rainfall peaks (Bimodal type), there are still some regions with two seasons having single rainfall peak (mono modal type). The area has bimodal rainfall pattern with the first rainy season starting in March and taper off in July; it is locally named “Ganna” while the second rains falls between August and December, locally known as “Bona” (Olkeba, 2011). According to Degefu (1987), 85 to 95% of the food crop of the Ethiopia is produced during June to September period. kiremt rain, that falls during June–September months (JJAS) accounts for 50%–80% (Sisay, 2009). Thus, the most severe droughts are usually related to a failure of the JJAS rainfall to meet Ethiopia’s agricultural and water resources needs, (Korecha and Barnston, 2007). In Ethiopia, climate variability and change form a serious concern because the country’s economy is almost totally dependent on rain fed agriculture which is the most vulnerable agricultural sector (Tufa and Getnet, 2018).

Agriculture is the most vulnerable and sensitive sector that is seriously affected by the impact of climate variability and change (Gizachew, 2012). Due to climate variability, most of Ethiopian economies varied from year-to-year (Sisay, 2009). The impacts of climate change on crop yields occurring more in developing countries, compared to developed countries (World Bank 2012).The impacts of increased temperature and changes in rainfall patterns resulting to reduce agricultural production (Valizadeh *et al.,* 2013).Weather are one of the key components that control agricultural production. In some cases, it has been stated that as much as 80% of the variability of agricultural production is due to the variability in weather conditions, especially for rain fed production systems (Petr, 1991; Fageria, 1992). Weather has a major impact on plants as well as pests and diseases. In Ethiopia, wheat has been among the major cereals of choice dominating the food habit and known to be a major source of energy and protein for the highland population (Dereje and Chemeda, 2007). According to Geletu *et al*., (2012) Ethiopia is the second largest wheat producer in Sub-Saharan Africa and has good wheat growing conditions. However, In addition to moisture stress, heat stress, frost, and salinity, wheat production is hindered by three different types of rust diseases (EATA Group, 2012). The stem rust reduce the wheat yield up to 100%.Yellow rust can losses the wheat yield by 50-100%.whereas Leaf rust reduce <10% (ICARDA,2011). Wheat diseases not only reduce yield but also affect the qualities of grains (Dereje and Chemeda, 2007).

Using information on the effect of weather and climatic factors on agricultural productivity can not only reduce the damage but can also make it possible to enhance agricultural productivity (Gizachew,2012).The most important climatic parameters influencing agriculture are: Seasonal rainfall (onset, end date…), temperature ,relative humidity and sunshine. But, apart suffering from climatic variability, there is no attention and/or efforts to solve the rising problems due to climate variability particularly in our study area. However, in this paper I was analyzed meteorological data for Bale highlands to quantify climatic conditions that influence the development and spreading of rusts on wheat varieties. Therefore this study is initiated to fill the knowledge gap between problems of climatic variability and professionals so that attention could be given to alleviate this problem.

OBJECTIVES

- To analysis climate variability of study areas
- To evaluate and identify the most climatic conditions suitable for wheat rust

MATERIALS AND METHODS

Description of the Study Area

Experiment was conducted at Sinana Agricultural Research Center (SARC) on-station Adaba, Robe area and Agarfa sub-site Bona season in 2013/14 – 2015/16. SARC is located at 07^o 06’ 12’’ to 07^o 07’ 29’’ N and 40^o 12’ 40’’ to 40^o 13’ 52’’ E with altitude 2400 meter asl. The area receives annual rainfall of 750 to 1100 mm. The monthly average values of maximum and minimum temperatures are 21ºC and 9 ºC respectively. Whereas, Agarfa is located 07^o 26’N and 39^o 87’E with altitude 2514 meter asl. Its annual rainfall ranges from 1000 to 1100mm.The monthly average values of maximum and minimum temperatures are 22.8 ºC and 7.3ºC, respectively. Adaba is located 07^o 01’N and 39^o 24’ E with altitude 2365 meter asl. The mean annual rain fall range from 600mm to 750mm and it has a mean monthly temperature varying from 7.05 ^{o}C for the min temperature and 24.5 ^{o}C for the maximum temperature. Robe is located 7^o 06’44’’N and 40^o 01’33’’E with altitude 2464 meter asl. The average annual maximum and minimum temperature is 25.9 ^{o}C and -1.21 ^{o}C respectively.

Data Collection

Meteorological data

Daily, monthly and decadal meteorological data such as rainfall in (mm), relative humidity in (%) and temperature (^{o}C) which were obtained from Sinana and Robe stations.

Observed rainfall

Thirty three years of rainfall data were used to characterize the seasonal and annual rainfall variability and trends using time series data for which stations had long term data.

Mann-Kendall's test: Mann- Kendall trend test was employed to detect the trend of climate variability. The Mann-Kendall's test statistic was given as:

$$s = \sum_{i=1}^{N-1} \sum_{j=1+i}^{N} sgn(xj - xi)$$

Where S is the Mann-Kendal's test statistics; x_i and x_j are the sequential data values of the time series in the years i and j (j> i) and N is the length of the time series. A positive S value indicates an increasing trend and a negative value indicates a decreasing trend in the data series. The sign function is given as:

$$sgn(xj - xi) = \begin{cases} +1 \; if(xj - x_i) > 01 \\ 0 \; if(xj - x_i) = 0 \\ -1 \; if(xj - x_i) < 0 \end{cases}$$

For n larger than 10, ZMK approximates the standard normal distribution was computed as follows:

$$ZMK = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} if \; S > 0 \\ 0 \; if \; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \; if \; S < 0 \end{cases}$$

Where, S is variance and the presence of a statistically significant trend is evaluated using the ZMK value.

The Sen's estimator of slope: This test was applied when the trend supposes to be linear, describing the quantification of changes per unit time. The slope (change per unit time) was estimated above procedure of Sen (1968).
The coefficient of variation of seasonal rainfall variability was analyzed by:

$CV = (\frac{SD}{\bar{x}})$*100, Where$\bar{x} = \sum \frac{xi}{N}$ and $SD = \sqrt{\frac{(xi - \bar{x})^2}{N-1}}$

And seasonal rainfall anomaly during kiremt season can be analyzed by:

$$Rainfall\ Anomally\ Index(RAI) = \frac{xi - \bar{x}}{SD}$$

Where $\bar{x}$ is long year mean and N is total number of year during observations were held for specific site, SD is standard deviation, X_i is rainfall of each month and RAI is rainfall anomaly of each month. If RAI is more than 0.5, between -0.5 and 0.5, less than -0.5 is meteorologically the month is wet, normal and dry respectively.

Treatments and Experimental Design

Six bread wheat varieties (Madda Walabu, Digalu, Sofumar, Kubsa, Danda'a and Tussie) and two bread wheat differential cultivars (Morocco and PBW343) were arranged in RCBD with three replications. The plot size was plots of 1.2m x 2m having total experimental area of 16.6m x 9m with between row, plot and block spacing of 0.2m, 1 m and 1.5 m, respectively. All cultural practices were done as per the agronomic recommendation for the crop.

Disease data

Disease data were collected with 7-9 days starting from sign observed at SARC wheat experiments and which were documented as progress report was used. Relationships of each weather factor with three rust diseases were determined through correlation analysis.

Agronomic data

The agronomic data collected from experimental stations including planting date, planting density, plant height, no. of productive tiller, seed/spike, no. of spikelet, biomass, sample grain yield and rust disease severity/ reaction were collected throughout the cropping season and used for the yield losses analysis. At crop maturity, the four middle rows were harvested for the determination of grain yield.

Data Management and Statistical Analysis: All collected data were subjected to the analysis of Stata and Instat plus software respectively. A simple correlation and regression analysis was employed to test the relationship between weather observations and rust diseases occurrence.

RESULTS AND DISCUSSION

Characterization of Climate Variability under Bale highlands

The analysis of temperature and precipitation revealed changes in extreme values during 1984–2016 in the study area. The analysis of past rainfall variability and trend was conducted after the quality control was done, missed data was filled.

Start of rainy Seasons

Start of rainy season in minimum on average during the February for belg season at Sinana and Robe. The start of the kiremt season also depicted that the rain begun raining at least in the 2nd decade of July at Sinana while 2nd decade of June at Robe. Earlier planting before 3rddecades of July were possible in Sinana and Robe in one out of four years for kiremt season. Also, planting before 1st decades of August at Sinana and 3rd decades of July at Robe were possible in three out of four years' time of the kiremt. The start of the kiremt season CV was 5.3 % for Sinana and 10.2 % for Robe area. From this point of view, the start of kiremt season was less predictable at Robe, thus, decisions pertaining to crop sowing activities would be with risk. The standard deviation for mean start of the season showed high deviations about 11.2 days and 20.2 days at Sinana and Robe respectively.

End of Seasons

The end of belg season could be extended to a maximum of 1st decades of May for Sinana and 2nd decades of May for Robe, while for the kiremt season ranged between 1st decade of October to 1st decade of November at Sinana and 1st decades of October to 2nd decades of October at Robe. There was 75% probability to end before 1st decades of November at Sinana while there was 75% probability that the end of season before 2nd decades of October at Robe. The end of the season CV was 5.9% for Sinana area while end of the season CV was 4.6 % at Robe area.

Length of Growing Seasons (LGS)

The length of growing season in belg season ranged from 2nd decades of February to 1st decades of May for Sinana and 3rd decade of February to 2nd decades of May for Robe whereas the length of growing season for kiremt season ranged from 40 days to 132 days at Sinana and 29 days to 131days at Robe area. The probability that the area could be supported a variety with LGS greater than 73 days was 25% at Sinana and 58 days was 25% at Robe while the probability that the area had recorded LGS less than 99 days was 75% at Sinana and 84 days was 75% at Robe for kiremt season. Hence crops that require LGS of up to 132 days and 131 days could be produced with less risk of water shortage in Sinana and Robe areas respectively in kiremt season. The issue of LGS requires further due attention in that one needs to know the type and level of risks of yield loss associated with cultivars of different maturity categories, requiring different amounts of water during a sequence of growth stages. The LGS of the season CV was 25.1 % for Sinana and 28.9 % for Robe areas. Therefore, the LGS in the area had high variability at Robe.

Number of Rainy Days

The average numbers of kiremt rainy days were 136 days and 114 days with CV value of 18.4 % and 10.6 % at Sinana and Robe stations respectively (Table 1). The standard deviation of rainy days was 25.1 days and 12.1 days at Sinana and Robe stations respectively. The study also depicted that the number of rainy days was less than 119 days and 109 days once in four years, less than 156 days and 121 days for three times in four years, it was less than 127 days and 115 days twice in four years at Sinana and Robe station respectively. The minimum and maximum number of rainy days was 90 days and 189 days for Sinana station and 81 days and 135 days for Robe station. This indicates that the amount of rainfall achieved depend on the number of rainy days that could be available to plants which in turn depends on the rainy season's onset, length, temporal distribution and cessation and can indirectly indicate the climatic suitability of the crop and its success or failure in a season (Ngetich *et al.,*2008).

Additionally, the Mann–Kendall trend test showed a decreasing trend of start of season, end of season and annual number of rainy days at Sinana and end of season and length of growing season at Robe stations; however, it is not statistically significant (Table 2).

Probability of Maximum Dry Spells Length

Probability of dry spells exceeding 5,7,10 and 15 days length at two stations in the Sinana district during 1984-2016 was depicted in Figure 3. The graphs in Figure 3 also demonstrate how the probability of 15 days of dry spell curves stays at their maximum value of near to 80% during the earlier and later months relative to the growing seasons. When looked in to the probability of dry spell occurrence of 5 days length, it was at more than 95% over Sinana and 80% over Robe areas for kiremt season.

The probability of occurrence of dry spells greater than 5 and 7 days length were observed being near to 0% at Robe and Sinana for kiremt season (Figure 1).There was no chance for the occurrence of dry spell at greater than 7, 10 and 15 days lengths during the peak months of kiremt season for Sinana and Robe areas. As the length of dry spell threshold becomes short, the probability of dry spells occurrence increases and conversely, as the dry spells threshold becomes longer, the probability of dry spells occurrence decreases with-in the growing seasons in both locations.

Generally, at both locations, curves of probability of dry spells attain minimum during months of peak rainfall periods and turn upward again from the 2nd decades of

Table 1.Descriptive statistics of kiremt season rainfall characteristics from 1984-2016

Sinana station								
Rainfall features	Min	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Max	Mean	StdDev(±)	CV (%)
SOS(DOY)	195	199	208	219	235	210	11.2	5.3
EOS(DOY)	275	276	287	305	334	293	17.26	5.9
LGS(Days)	40	72.5	79	99	132	83.3	20.9	25.1
NRD(days)	90	119	127	156	189	136	25.06	18.4
TKRF(mm)	194.9	284.3	355	488.2	819	402.5	158.4	39.4
Robe station								
SOS(DOY)	167	197	201	206	246	196.5	20.1	10.2
EOS(DOY)	275	275	281	289	321	285.3	13	4.6
LGS(Days)	29	58	73	84	131	74	21.4	28.9
NRD(days)	81	109	115	121	135	113.7	12.1	10.6
TKRF(mm)	214.3	296.6	377.9	422.9	538.2	367.3	83.2	22.7

Note: SOS, start of season; EOS, end of season; LGS, length of growing Season; NRD, number of rainy days; TKRF, Total Kiremt season rainfall; SD, standard deviation; CV, coefficient of variation.

Table 2.Trend analysis of rainfall features for Sinana and Robe areas (1984-2016)

Station	SOS			EOS			LGS			NRD		
	ZMK	p.	S	ZMK	p.	S	ZMK	p.	S	ZMK	p.	S
Sinana	-0.43	0.67	-0.1	-0.35	0.73	-0.1	0.78	0.44	0.1	-0.15	0.88	-0.2
Robe	0.75	0.45	0.3	-0.21	0.84	-0.2	-1.43	0.15	-0.5	0.76	0.44	0.3

ZMK, Mann–Kendall trend test, S: Sen"s slope, P: p-value

November, signaling end of the growing season. This suggests that as the probability of dry spell increased, the standing crops faced with risk of water shortage.

Trends and Relationship between Rainfall Features

Total annual and Kiremt seasonal rainfall data for the period 1984 to 2016 in Sinana district was presented in figure 2. Total annual and seasonal time series for Sinana and Robe stations revealed increasing trends after the year of 2006 while more increment was shown at Sinana in near decade figures 2. There was an observed slightly variability trends of seasons before a decade at Sinana and Robe stations. Total annual rainfall had shown upward slope which indicated increasing for historical in trend at Sinana and Robe stations. The result of historical data analysis suggested that, annual rainfall amount was increased by 9.1 mm/yr and 2.8 mm/yr at Sinana and Robe respectively. On the other hand, the seasonal kiremt rain was increased by 6.1 mm/yr at Sinana station and 2.9 mm/yr at Robe station.

From this point of view, it was possible to confidentially advise the farmers of the area in a way that they could have information like when to plant and the variety to be used in agriculture practices.

Annual and seasonal rainfall totals

Trends of annual and seasonal rainfall amount at Sinana and Robe are presented in Table 3. The result indicated that rainfall total of the rainy and dry seasons as well as the annual totals increased slightly, but trends were not statistically significant for the period 1984-2016. During the study period, the area received considerable amount of annual rainfall that ranged from 538 mm to 1586 mm at Sinana and 506.2 mm to 1101 mm at Robe (Table 3).

The kiremt season contributed more annual rainfall totals compared to another seasons for both stations. The coefficient of variation also showed that more variable at Sinana and less variable at Robe when compared all seasonal rainfall (Table 3). Furthermore, the results of seasonal climate data analysis revealed that the mean of the main rainy (kiremt season) season was 367.3 mm with CV value of 22.7 % which was the least as compared to the CV values of small rainy season (Belg season) 36.1 % at Sinana and 34.1 % at Robe while dry period (bega season) 41.2 % at Sinana and 43.7 % at Robe. This indicates that belg rain was less variable than kiremt and bega rains at Sinana while kiremt rain was less variable than belg and bega rains at Robe.

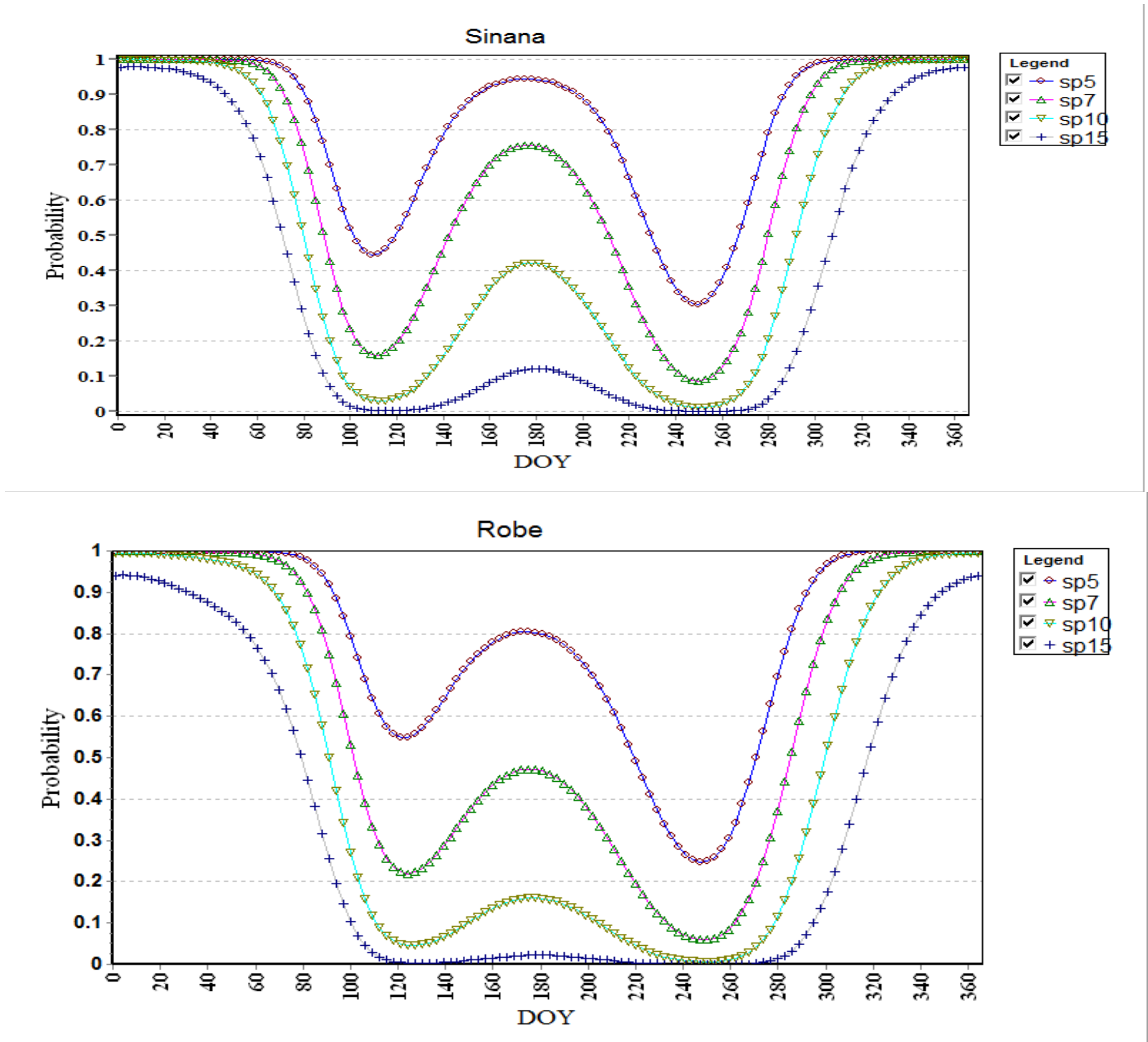

Figure 1. Probabilities of maximum dry spells exceeding 5, 7, 10 and 15 days length within 30 days after starting date at two stations in Sinana district during 1984-2016

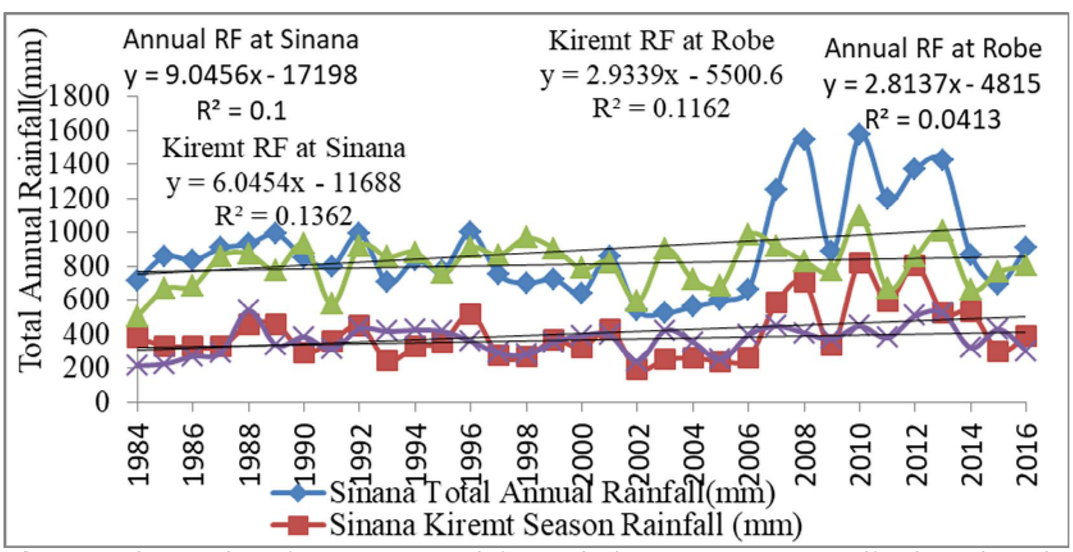

Figure 2. Time series of total annual rainfall and Kiremt season total raifall based on the data of 1984-2016 at Sinana and Robe

Table 3. Descriptive statistics of rainfall of annual and seasonal rainfall totals of Sinana and Robe areas during the period of 1984-2016

	Sinana station								
	Descriptive statistics					Trends			
Parameters	Mean	Min	Max	Media	SDE	CV (%)	ZMK	p-values	Slope
Annual RF	905.1	537.9	1586.3	863.9	277.6	30.67	0.92	0.356	9.05
Kiremt RF	402.5	194.9	819	355	158.4	39.35	1.36	0.169	6.05
Belg RF	339	160	716.2	337.4	122.5	36.14	-0.20	0.843	1.10
Bega RF	163.7	51.1	383.8	156.6	67.7	41.36	1.47	0.140	2.0
				Robe station					
Annual RF	812.4	506.2	1101	830.5	133.8	16.47	0.60	0.549	2.8
Kiremt RF	367.3	214.3	538.2	377.9	83.22	22.66	1.91	0.056	2.9
Belg RF	259.1	140.6	545.1	232.7	88.38	34.11	-1.04	0.298	-1.03
Bega RF	186	36.4	454.4	199.6	81.34	43.73	0.72	0.470	0.91

ZMK Mann–Kendall trend test, Slope: Sen"s slope

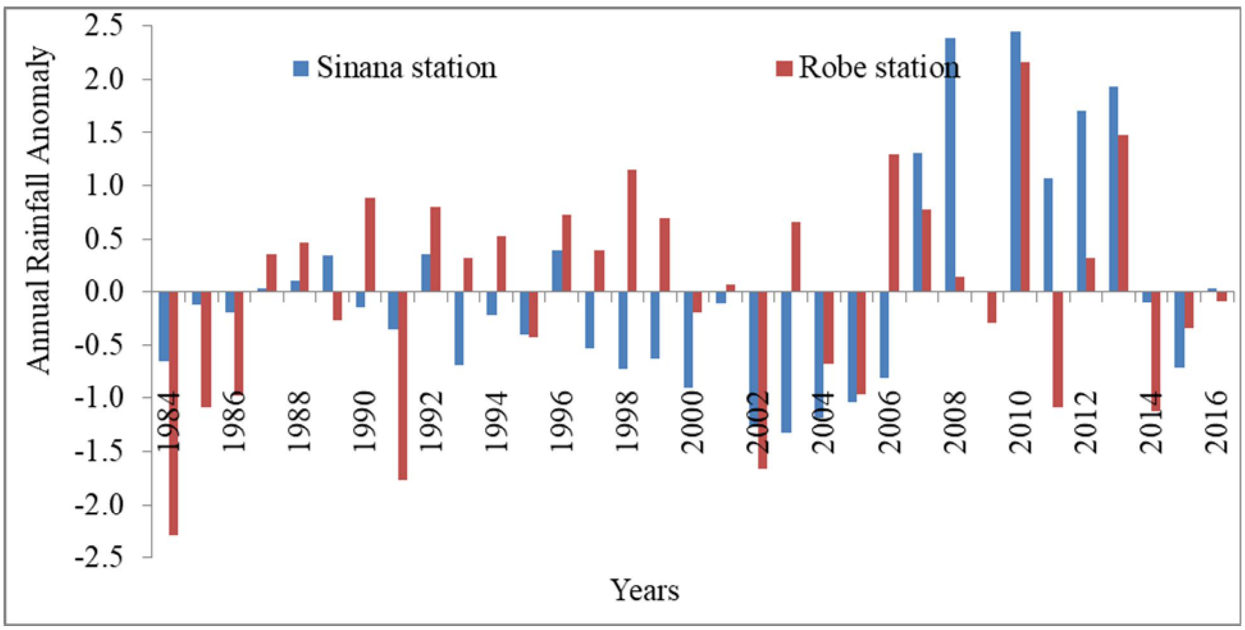

Figure 3. Annual rainfall anomalies for Sinana and Robe areas for the period (1984-2016)

Annual and seasonal rainfall anomalies

There was high seasonal and annual rainfall variability in the study area over 1984-2016. There were wet (0 to +0.5) and dry (0 to -0.5) periods over the study area for both annual and seasonal rainfall. Similarly, annual rainfall anomalies wet (above +0.5) and dry periods (above -0.5) were observed in certain years. The years of 2007, 2008, 2010, 2011, 2012 and 2013 experienced extreme wet condition, while the years 2000, 2002, 2003, 2004, 2005and 2006 were extreme dry at Sinana station. Similarly, extreme wet condition showed in the years of 1998, 2006, 2010 and 2013 while the years of 1984, 1985, 1991, 2002, 2011 and2014 extreme dry period at Robe station. The main rainy (kiremt) season for the years 2007, 2008, 2010, 2011 and 2012 at Sinana station and the years 1988, 2012 and 2013 at Robe station were experienced extreme wet condition and the other years 1993, 2002and 2005 at Sinana and the years 1984, 1985, 2002 and 2005 were extreme dry period at Robe. This result implies that the production of crops could be affected severely in these periods either due to deficit or excess of rainfall required for agricultural activities at Sinana and Robe areas (Figures 3-4).The influence of rainfall on wheat production can be related to its total seasonal/intra-seasonal amount distribution. However, the effect of rainfall variability on wheat production varies with types of varies with types of varieties grown, types and properties of soils and climatic conditions of a given area (Badege *et al.,* 2013).

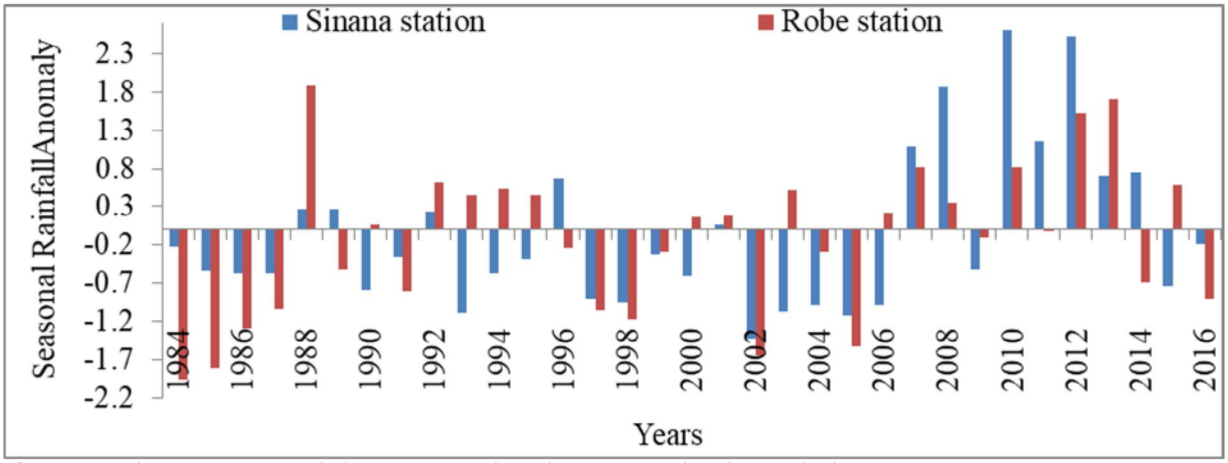

Figure 4. Kiremt season rainfall anomaly for Sinana area for the period 1984-2016

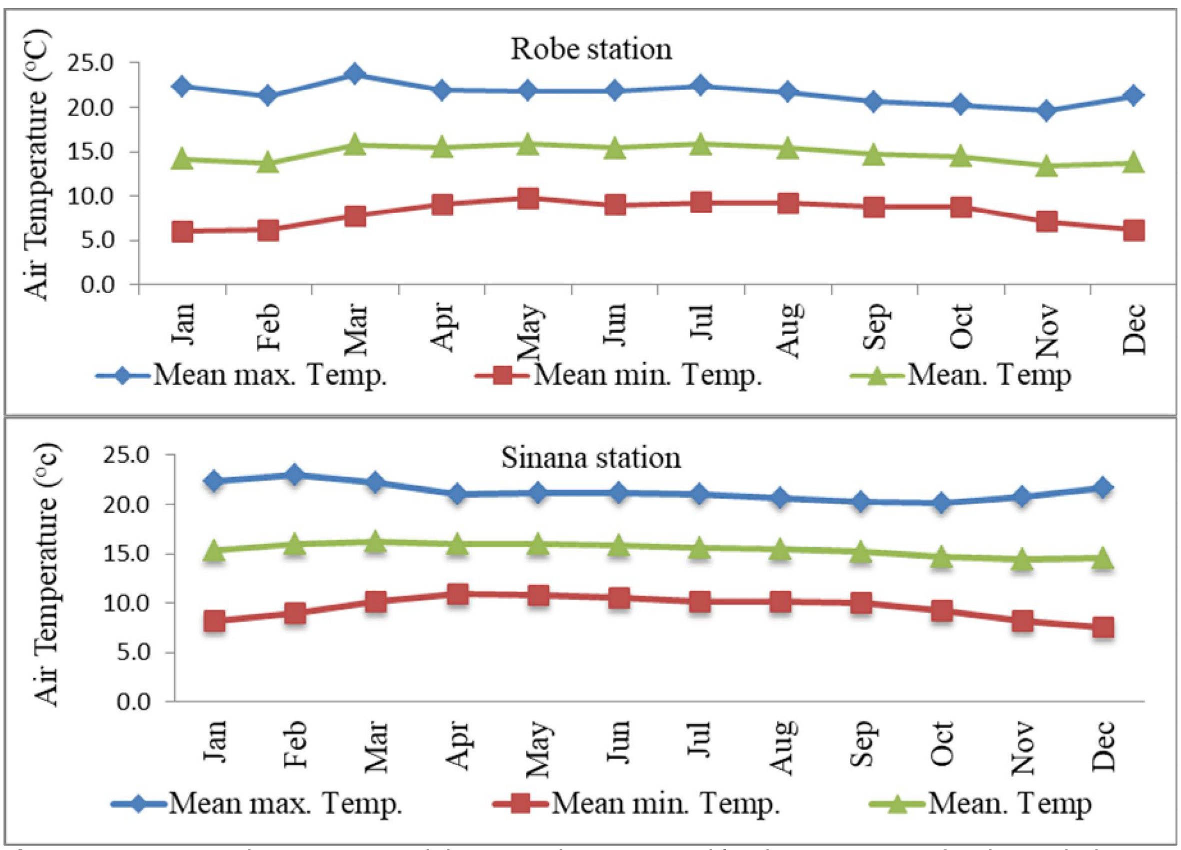

Figure 5. Mean maximum, mean minimum and mean monthly air temperature for the period 1984-2016 at Sinana and Robe station

Trend analysis of annual maximum and minimum temperature

The temporal variability of average maximum and minimum temperatures had been examined at inter annual time scale for the period 1984-2016 at Sinana and Robe. The result indicated that annual maximum temperature had decreased by -0.15°C while annual minimum temperature has increased 1.5°C at Sinana respectively in the last three decades. Similarly, annual maximum and minimum temperature had increased trend 0.28 °C and 0.41 °C respectively in the last three

Table 4. Trends of annual Max. and Min. temperature in Sinana and Robe areas for 1984-2016

Stations	Minimum Temperature				Maximum Temperature			
	Mean	ZMK	P-value	S(^{o}C/yr)	Mean	ZMK	P-value	S(^{o}C/yr)
Sinana	9.6	5.11**	0.000	0.15	20.2	-1.82	0.069	-0.02
Robe	8.1	4.21**	0.000	0.04	21.6	3.54**	0.000	0.03

Note: ZMK: Mann–Kendall trend test, S: Slope (Sen‟s slope) is the change (^{0}C/year) ** indicates significant trend at less than 1% p-values

Table 5. Reaction of Bale highland wheat crop to yellow, leaf and stem rust diseases based on modified Cobb scale (Peterson et al. 1948)

	Degree of infection (reaction) to			Yield loss (%) due to		
Variety	yellow rust	stem rust	leaf rust	yellow rust	stem rust	leaf rust
PBW343	S	S	S	31.6	21.6	21.5
Maddawalabu	R	MS	R	1.7	2.9	2.2
Morocco	S	S	S	32.1	26.1	27.9
Kubsa	S	S	MS	25.0	20.7	16.6
Sofumer	S	MS	R	11.0	8.7	8.8
Digalu	R	S	R	15.0	25.9	10.2
Tussie	S	S	MR	12.8	10.8	8.2
Danda'a	R	MS	R	10.4	16.6	9.4

S= Susceptible, MS= Moderately Susceptible, MR= moderately resistant and R= Resistance.

decades at Robe. This was due to high variability of climate aspects in the southeastern highland of the country. The probability of occurrence of dry spell caused due to high heat stress the study area was increased the impact of temperature variability on agricultural activities would be with high risk. Mean annual trends of maximum and minimum temperatures at Sinana and Robe stations for the historical was indicated in (Table 4). The result showed that annual maximum and minimum temperature at Robe and minimum temperature at Sinana was increased and statistically significant in the last three decades for ($p<0.01$). On the other hand, decreasing annual maximum temperature at Sinana was not statistically significant ($p<0.05$).

Mean monthly temperature clearly showed that the area experience the highest mean recorded in March, while the month of November showed that the lowest air temperature was observed which could reach up to 16.2 ^{0}C and 14.5 ^{0}C respectively showed the mean monthly maximum and minimum temperature at Sinana area for the period 1984-2016 (Figure 5). Similarly, the highest mean monthly temperature was recorded in May and July up to 15.8 ^{0}C, while the month of November showed that the lowest air temperature was observed which could reach up to 13.4 ^{0}C at Robe station. As the result showed that, the highest mean maximum temperature was recorded in March at Sinana station and in May and July at Robe station, while in the month of November mean minimum temperature was received for both areas.

Wheat rust severity and average yield loss values for 6-wheat cultivar's and 2-local check

Rust disease severity data was collected from all succeed sites and patch into Excel in the order of recorded time and its reaction with all varieties trials. Diseases severity and host response data are combined into a single value called coefficient of infection. The coefficient of infection is calculated by multiplying the severity times a constant for host response (i.e. R=0.2, MR =0.4, MS =0.8 and S =1). The yield loss due to diseases severity calculated by Cobb scale (i.e. 1% terminal severity is equivalent to a 0.54 % loss in yield). Some of the cultivars such as Madda walabu, Digalu and Danda'a were resistance for yellow and leaf rust, while moderately susceptible to stem rust. Kubsa was moderately susceptible for leaf and susceptible to yellow and stem rust disease. Tussie and Sofumer were susceptible for this climatic condition during the study periods. (Table 5)

Wheat rust disease over study area in relation to some climate parameters

During study years, a wheat rust disease requires optimum climate variability for its development and infection. However, over Bale Highlands the favoring for its development minimum temperature between 4.5^{o}C to 15.6^{o}C while require maximum temperature 20^{o}C to 28^{o}C for its infection during the main cropping season. The results have shown that the correlation value between monthly rainfall totals with leaf rust, yellow rust and stem rust were indicated -0.76, -0.94 and -0.57 while positively correlated with relative humidity and temperature, which is statistically good and so facilitates its development and infection on main cropping season. Therefore, yellow rust diseases has decreased and

Table 6.Correlation between climatic parameters with stem rust, yellow and leaf rust intensity over Bale highlands.

Parameter	Correlation coefficient (r)		
	Leaf Rust	Yellow Rust	Stem Rust
Seasonal rainfall	-0.76*	-0.94**	-0.57*
Relative Humidity	0.88*	0.72*	0.63*
Minimum temperature	0.66*	0.84*	0.89*
Maximum temperature	0.69*	0.59*	0.57*

Note **= highly significant,*=significant and ns=non-significant', (p =*0.05)*

Table 7. Correlation between climatic parameters and rust wheat rust diseases intensity

Parameters	Correlation coefficient (r)
Seasonal rainfall	-0.86
Relative humidity	0.74
Maximum temperature	0.61
Minimum temperature	0.79

favored by high amount of rainfall for spore germination (development) with a correlation value (i.e. yellow rust and seasonal rain -0.94) given on table 6. This is because the condition is not favorable for the spreading of yellow rust over wheat fields during the cropping season. The negative impact of climate change was expected in future climate scenarios on bread wheat productivity (Zerihun *et al.,*2018)

The correlation between minimum temperature and stem rust diseases was indicated 0.89, which is statistically significant. In fact, the correlation values between maximum temperature and yellow rust is 0.59, which is not good. This study has shown that whenever the climatic conditions are favorable, wheat crop is highly affected by climate related disease. The stem rust diseases mostly affected when it reaches vegetative and flowering stages. From the analysis indicated that, the correlation between minimum temperature and stem rust is 0.89 and statistically significant. The most disastrous rust diseases occurred due to climate variability over Bale highlands as it seen from simple correlation table 6. For instance, the correlation values existed between relative humidity and leaf rust diseases development in the main cropping season over the wheat fields revealed 0.88 was extremely high, which is statistically good. The series of annual diseases severity in the four locations of Bale highlands showed strong inter-annual fluctuation, without visually apparent association with climate variability as shown in table 6. This analysis showed that there was a climate impact on wheat rust diseases occurrence. This indicated that the development of rust diseases mostly depends on temperatures, rainfall and relative humidity for development and spreading. Negative impact of climate change was expected in future climate scenarios on bread wheat productivity in the Bale highlands (Zerihun *et al* 2018)

Severity of rust disease versus mean local climate patterns over Bale highlands

The computed correlation values for cropping season rainfall and diseases severity showed strong associations among the parameters. For instance, the correlation between monthly rainfalls and yellow, stem and leaf average rust disease severity about -0.86, while for relative humidity and yellow, stem and leaf average rust diseases severity reached 0.74. This condition was also true for maximum and minimum temperature with yellow, stem and leaf average rust diseases, the correlation analysis indicated 0.61 and 0.79 respectively. The results hence revealed that the rust diseases severity is highly favored by cropping season rainfall than the relative humidity as shown in table 7. It is found that cropping season rainfall and wheat rust diseases had indirect relation, while maximum temperature, minimum temperature and relative humidity had direct relation with wheat rust diseases as table 7. Generally, wheat rust development and severity follows climate parameters such as rainfall, relative humidity and temperature.

Generally, wheat rust development and severity follows local climate variability, since the relationship between the yellow, stem and leaf rusts, relative humidity and temperature are directly related to the rust diseases as shown in table 7. From weekly analysis during cropping season, the climatic condition conducive for rust diseases occurrence were identified. Therefore, the development and spread of rust is highly enhanced with maximum temperature and minimum temperature ranges 20.8^{o}C to 28^{o}C and 8.2^{o}C to 11.7^{o}C, while relative humidity was more than 70 % across the highland regions. For long period, warm and humid climate the rust was development and infection was severe and requires long period dew point (RH) at least 6 to 8 hrs.

Moreover, the effects of local climatic parameters on rust diseases over Bale highlands during development

Table 8.The effect of local climatic on wheat rust diseases based on Pearson's correlation value

Met-parameters	Effect of climate variability on rust diseases of wheat
Rainfall	During rainfall increased, it decreases spore development by cleaning the spores from the leaf and stem with wheat. If cropping season rainfall amount increases, the infection decreases by scrubbing the spores from the plant and increases RH.
Maximum temperature	An average ranges between 20.8 ^{o}C to 28 ^{o}C of maximum temperature, it increases spreading during cropping season and favors for spore development in the main season.
Minimum temperature	An average ranges between 8.2 ^{o}C to 11.7 ^{o}C minimum temperature has positive effect on spore development and below 8.2 ^{o}C eliminates rust injuries.
RH(moisture)	A function of moisture in the cropping season used to spread wheat rust on field, initiate germination within 1 to 3hrs of contact with moisture, health of the spores rapidly increases at moisture contents more than 70%.

and spreading periods summarized in the table 8. As we conclude from table 8, the three extreme events of climate parameters influence directly or indirectly to occurred wheat rust diseases in the area. Attain maximum infection at 8 to 12 hrs of dew at average temperature about 18^{o}C with moisture contents more than 70% and lack of enough rainfall respectively.

CONCLUSION AND RECOMMENDATION

Climate variability was believed to cause the most damaging impacts on agricultural practices in developing countries like Ethiopia. The study tried to investigate the impact of climate variability on wheat rust disease development. The results of this study showed that wheat yield variability over Bale highland determined by fluctuation of rainfall, temperature and relative humidity for developing and spreading of rust diseases mainly during main season. Results from the analysis of average wheat yield loss showed that the current levels of 6-cultivers and two check of wheat yield widely responding to yellow, leaf and stem rust diseases. The studies made on the relationship between short-term meteorological variations and diseases development and their spatial spread across the Bale highland has not yet well assessed. Such studies could be used for predicting wheat rust diseases development and infection during the main seasons. The potential impacts of local climate variability on the rust diseases and wheat production were also investigated using various statistical techniques.

Moreover, the average relative humidity, rainfall and temperature observed during cropping season created conducive conditions for the rust infection on wheat crop across the Bale highlands. Being rust diseases are one of the most natural factors that affect wheat crops; they reach maximum infection stage in main season. Generally, rust disease directly relied on the level of climatic conducive prevailing during main season to temperature, relative humidity and rainfall. The overall results as generated based on local climatic factors and rust diseases as well as wheat yields can be utilized in the provision of optimizing climatic information for monitoring wheat crop performances over Bale highlands and demonstrate these techniques over regions having similar climatic conditions.

As stated above, we identified some climatic factors as precursor indicators for the severity of rust diseases and wheat yield losses over the highland of Bale. This is due to the fact that farmers are always operate under uncertainty by avoiding some external inputs such as weather forecasts for their early planning. Therefore, there is a need to establish a system that enables to use available climatic information towards the optimization of wheat productivity across the Bale highlands. This in fact requires coordinated efforts among the meteorological institutes, agricultural research institutes and farmers training centers. Finally, there is a need to design and expand multi-sectors researches particularly focusing on microclimates and rust diseases, frosts, and insect's pests that are responsible for year-to-year crop yield variations.

ACKNOWLEDGEMENTS

The author express his gratitude to the Oromia Agricultural Research Institute for its financial support and staff of Agroforestry and cereal research teams of Sinana Agricultural Research Center for their follow-upand data collection timely during the trial on the field.

REFERENCES

Badege Bishaw, Henry Neufeldt, Jeremias Mowo, Abdu Abdelkadir, Jonathan Muriuki, Gemedo Dalle, Tewodros Assefa, Kathleen Guillozet, Habtemariam Kassa, Ian K. Dawson, Eike Luedeling, and Cheikh Mbow.2013. Farmers' Strategies for Adapting to and

Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya. edited by Caryn M. Davis, Bryan Bernart, and Aleksandra Dmitriev. Forestry Communications Group, Oregon State University, Corvallis, Oregon.

Dereje Hailu and Chemeda Fininsa, 2007. Relationship between stripe rust (Puccinia striiformis) and grain quality of bread wheat (Triticum aestivum) in the highlands of Bale, southeastern Ethiopia.

Diriba Korecha and Tony Barnston, 2007. Predictability of June–September Rainfall in Ethiopia, National Meteorological Agency of Ethiopia, Addis Ababa, Ethiopia and International Research Institute for Climate and Society, Palisades, New York.

EATA Group, 2012. Discussion on Establishment of Early Warning System through Rust Trap Nurseries for the Prevention Rust Wheat Diseases Outbreaks.

Fageria, N.K., 1992. Maximizing Crop Yields. Marcel Dekker,New York.

Geletu Bejiga, Firdissa Eticha, Abebe Atilaw, Zewdie Bishaw, Asnake Fikre and Lijalem Korbu, 2012. Progress report of the project entitled ”Rapid deployment of high yielding and rust resistant wheat varieties for achieving food security in Ethiopia“ - financed by USAID and implemented by EIAR and ICARDA.

Gizachew Legesse, 2012. Application of best-bet agronomic practices in response to seasonal weather forecast.

ICARDA ,2012. Synthesis of a dialog between policy makers and scientists from 31 countries at:International Wheat Stripe Rust Symposium, Aleppo, Syria, April 2011.

Ngetich, K.F., Mugwe, J.N., Mucheru-Muna, M., Shisanya, C.A., Diels, J. and Mugendi, D.N. 2008. Determination of seasonal length and rainfall onset and cessation dates in the Kenyan highlands. Kenyatta University. Nairobi, Kenya. p11.

Olkeba Birru, 2011. Efects of surface management practices on soil, water & Nutrient conservation & Yield of Whea t(Triticum aestivum L.) at Bale Highlands, Southeastern Ethiopia.

Petr, J., 1991. Weather and Yield. Elsevier, Amsterdam,Netherlands

Sisay Eshetu, 2009. Assessing &Modeling the impact of climate variability on severity of rust diseases & Wheat production over Arsi Highlands, Ethiopia.

Tufa ZD, Getnet M.2018. Analysis of climate change under future climate scenarios in Bale highlands, Southeastern Ethiopia. Acad. J.Environ. Sci. 6(7): 174-183.

Valizadeh, J., Ziaei, S.M. and Mazloumzadeh,S.M. 2013. Assessing climate change impacts on wheat production (a case study). *Journal of the Saudi Society of Agricultural Sciences, Vol. 13 (2) pp: 107-115.*

World Bank. 2012. Turn down the Heat, why a 4 .C warmer world must be avoided. A report for the world bank by the Potsdam Institute for Climate Impact Research and World scientists' warning to Humanity. Washington, DC: World Bank.

Workneh Degefu, 1987. Some aspects of Meteorological Drought in Ethiopia. Drought and Hunger in Africa, Edited by Michael H. Glartz Cambridge University, press, London, pp 21- 36.

Zerihun Dibaba Tufa, Mezegebu Getnet, Lisanework Nigatu, 2018: Modeling Impacts of Climate Change on Bread Wheat (Triticum Aestivum l.) Productivity in Bale Highlands, South Eastern Ethiopia: Case of Robe Area (29-40). *Asian Journal of Applied Science and Engineering, Volume 7, No 1*