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Preliminary survey of foliar maize diseases in North Western Ethiopia

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In Ethiopia, maize is the staple food and one of the main sources of calories particularly in the major maize producing-regions of the country. Survey was conducted to determine the prevalence, incidence and severity of foliar maize diseases in North Gondar Zone. A total of 150 farmers’ fields were randomly sampled from five districts (Chilga, Gondar zuria, Takussa, Metema and Dembia) in North Gondar Zone of Amhara Region during cropping seasons of 2015 and 2016 years. Five quadrants were examined per farmers’ field for estimation of maize foliar disease incidence and severity infestation. This was done followed by pathogen isolation and disease identification laboratory procedures. Both of two years surveyed data were collected, analyzed and expressed using simple percentage. Results indicated that the dominant maize diseases were caused by Exserohilum turcicum, Puccinia sorghi and Cercospora zeae-maydis patogen. Maize disease incidence of E. turcicum ranged from 50 to 80%, P. sorghi 19 to 62% whereas that of C. zeae-maydis reached 42% on foliar maize disease. In addition 3-19% of disease incidence of maize streak virus was recorded from seemingly healthy maize plants. Among four identified diseases Turcicum leaf blight (TLB), Common leaf rust (CLR) and Gray leaf spot (GLS) were recorded as major disease, while maize streak virus (MSV) was as minor disease. The present study provides an indication of the incidence and severity of foliar diseases of maize on which management strategies could be derived to improve the maize production in the surveyed areas.

Key words: Disease, foliar, incidence, maize, prevalence, severity.

INTRODUCTION

Maize (Zea mays L.) is one of the popular crops grown in the world, ranking second to wheat and used as a staple food in the tropics and is a valuable source of raw material for many industrial products (Vasal, 2000; FAOSTAT, 2012). Maize is the most versatile crop, adapted to different agro-ecological and climatic conditions. Maize is among the leading cereal crops selected to achieve food self-sufficiency in Ethiopia (Benti and Ransom, 1993). Maize is widely grown in Ethiopia and ranks first in total production and yield per hectare, and next to teff in the area coverage of 1.77 ml ha with a production of 39 ml Qt (CSA, 2010). The major

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constraints to maize production in the country include both abiotic and biotic factors, such as a drought, nutrient deficiencies, weeds, diseases and insect pests (Ransom et al., 1993). Among the biotic stresses, diseases are one of the most important limiting factors in maize production. Diseases are one of the major constraints in realizing the potential yield of this crop. It suffers from a number of diseases but Turcicum leaf blight (Exserohilum turcicum), Southern rust (Puccinia polysora), are the important constraints ones in globe responsible for yield losses. Gray leaf spot (Cercospora zeae-maydis) disease causes yield losses from 5 up to 30% (Ward et al., 1999; Misgana, 2014).

Forty seven different types of diseases were found to affect maize production in Ethiopia (Assefa and Tewabech, 1993). The incidence of maize diseases may vary considerably with geographical location. The influence of agro-ecological zones on the severity of foliar diseases has also been suggested in Ethiopia, while severe systemic infection of maize in western Ethiopia, high incidence and severity of turcicum leaf blight (E. turcicum) were recorded at Omo Nada, Chenia, Nedjo and Bure with 70-100% incidence for all localities and 50, 45, 35 and 32% severity, respectively an area characterized by diverse climate, physical geography, edaphic factors, and farming practices (Tewabech et al., 2001; Tilahun et al., 2001; Keno et al., 2018).

Although quantified data on yield losses due to disease are not available for the country, the importance of disease in maize production has been given due attention (Tewabech et al., 2001). Preliminary studies, which listed the constraints to maize production in North Gondar and subsequent reviews on maize diseases in the Amhara region, do not provide quantitative values of disease prevalence, incidence or severity, nor have any studies hitherto examined the relationship between disease severity and the agro-ecological location of the fields. Such knowledge gaps have hindered efforts to assess the true economic importance of diseases in maize production in Amhara region. Indeed, few reports of estimated yield losses from diseases in Amhara region are based on visual estimates of individual diseases in spite of the fact that more than one disease is commonly observed in maize fields. These factors probably influence the distribution and severity of maize diseases, but detailed information on these effects is lacking. Obtaining of the data is a prerequisite for developing a reliable quantitative assessment of the economic impact of the diseases, which are most models are related to the yield of incorporating information on disease incidence and severity. Such information can be obtained on a District level through disease surveys (Benti and Ransom, 1993). Assessment of the prevalence and severity of foliar maize diseases is important to map the geographic distribution and determine the status of the disease in addition to providing baseline data to prioritize research problems (Rusuka et al., 1997). The aims of this study were to determine the prevalence, incidence, severity, and identification of major and minor maize foliar diseases in maize growing districts of Northern Gondar Zone, Ethiopia.

**METHODOLOGY**

**Description of the field survey areas:**

Foliar maize diseases were surveyed on five districts (Chilga, Gondar zuria, Takuska, Metema and Dembia) in the Northern Gondar Zone (Figure 1). Two surveys were carried out in during 2015 and 2016 cropping main seasons on farmer maize fields. The total fields at an altitude ranging from 580 to 2700 masl were assessed from all visited districts (BFED, 2013).

**Survey and sample collection**

Foliar disease prevalence, incidence and severity were recorded for maize crop. Maize fields were randomly selected at intervals of 5-10 km along the main and accessible rural roads except when there is no suitable field available, and then the next maize field was sampled. Within selected fields, five quadrants (2 x 3 m) diagonally spaced about 10 m apart were sampled. At each field site, a W-pattern was used to cover the whole field, making five stops and evaluated for incidence and severity of maize foliar diseases. Disease infected plants in each quadrant were collected for diagnostic use. A total of 150 fields were surveyed between silking and milking stage of the crop for both main cropping seasons. Eighty and seventy fields were assessed along the same route during the cropping seasons of 2015 and 2016 years, respectively. The survey transect was approximately 3120 km long both years and cover five different agro-ecological district fields. All sample fields belonged to small-holder farmers (Chemed and Jonathan, 2001; Alemu et al., 2016).

**Maize foliar disease identification**

The maize disease infected leaves samples were collected from farmers’ fields of five districts. The collected samples were taken for laboratory identification, using different media culture, microscopic observation and literature (Bock, 1974, Angelique et al., 2008). The leaf tissues obtained during the field survey were being used for isolation of pathogens to confirm those pathogens associated with symptoms observed in the field. The isolates obtained have been added to the collections of pathogens in each state. Each state has undertaken isolation and identification of fungal pathogens associated with foliar diseases. Semi-selective media were utilized to recover pathogens growth either present or maybe not. PDA media amended with streptomycin can be used to isolate fungal pathogens. The morphological and cultural characters were critically studied both visually and under high power magnification (40 X) from 15 days old pure cultures. Diagnosis is based on visual examination for symptoms and culturing onto artificial media. The diseases also identified based on CIMMYT monograph on guide for identification of maize diseases edited by Carlos L (1984) and Singh et al. (2004).

**Disease assessment**

Disease severity, area of plant tissue disease was rated on 10 randomly selected plants using standard scales of 1-9 (CIAT, 1987) where 1 is no visible disease symptom and 9 is disease covering more than 25% of the foliar tissue. The severity grades were
Maize foliar disease incidence in each field was assessed as the proportion of plants showing symptoms in a field. In each field of 20 plants in the middle of each 1 m² area were randomly selected and the number of plants having foliar disease symptoms on a whole plant basis counted and expressed as a percentage of the plant population. Any unknown disease samples were collected and put in paper bags for further inspection in the laboratory. To determine the incidence of maize disease at different farm fields used the following formula (Alemu et al., 2016).

\[
\text{Disease incidence} \% = \frac{\text{Number of diseased plants observed}}{\text{Total number of plants examined}} \times 100
\]

Disease prevalence was assessed by determining the number of fields where foliar maize diseases were recorded in relation to the number of fields sampled in surveyed districts.

**Data collection**

The mean rating for 50 plants of foliar disease was calculated for each field. Additional information was also collected on each assessed field, relative location; altitude (m), type of cropping system was noted. Altitudes were recorded using a barometric altimeter. The plant population in each quadrant was counted and the mean plant population density was obtained by averaging the plant population in five quadrants farmers (Chemeda and Jonathan, 2001).

**Data analysis**

For each disease, prevalence and incidence or severity data was summarized. To obtain the variation between the surveyed diseases, descriptive statistics were used. The number of fields was in each severity category is expressed as a percentage of the total number of fields surveyed to obtain severity frequency distribution. In order to assess the relationship between agro-ecological zones and disease incidence, curves illustrating the frequency of fields with a given disease severity rating in each district were calculated. All statistical computing was used SAS software (SAS, 2002).

**RESULTS**

The present article reveals up to date information on maize diseases situation in North Gondar Zone districts. A total of 150 maize fields in North Gondar Zone were surveyed during 2015 and 2016 cropping seasons. Prevalence of most leaf diseases varies from field to field and year to year, depending on environmental conditions, tillage practices, cropping sequence, and hybrid susceptibility. Moderate temperatures and moisture in the form of rain and heavy dew usually favor development of foliar diseases and more than one type can be present on the individual plant. Four foliar diseases and their causal agents diagnosed on maize crop in five districts (Chilga, Dembia, Takussa, Gondar zuria and Metema) with an altitude ranged from 580 to 2700 masl are presented in Table 1. The incidence, severity and prevalence of diseases in maize were investigated during the 2015 and 2016 cropping season following a planned two time...
surveys across five districts in the North Gondar Zone. Totally the occurrence of the maize diseases was investigated in five districts of 80 and 70 farmers’ fields, which were from the first and second year surveys respectively. The survey was carried out in major maize growing areas of Northern Gondar Zone by adopting roving survey methodology as mentioned in materials and methods. The present work was initiated with a survey to know the incidence, severity and distribution of foliar maize diseases in the surveyed districts. The survey was indicated that Turcicum leaf blight (E. turcicum), Common leaf rust (CLR) (P. sorghi) and Gray leaf spot (C. zeae-maydis) are major prevalent diseases in five districts of North Gondar zone with high severity and incidence. Maize streak virus is less important in areas with minor prevalent diseases (Table 1).

Foliage maize disease prevalence

A total of 150 maize fields were surveyed across five districts during 2015 and 2016 to document the occurrence and number of affected plants of foliar maize diseases. Turcicum leaf blight (E. turcicum) maize disease was the most widespread common foliar maize disease in the North Gondar surveyed districts. In both cropping seasons, the disease was detected in 150 (69%) of sampled fields. Turcicum leaf blight (TLB) was the most common disease and found from 104 fields out of 150 totals sampled maize fields on both surveyed years. The disease prevalence in two surveyed cropping seasons were found in major maize fields sampled in Chilga 82.86% and Dembia 70.37% compared to other districts (Table 2). During surveyed both cropping seasons TLB occurred less mean disease prevalent 60 and 64% in Metema followed by Takussa district respectively.

CLR of maize caused by P. sorghi was widely distributed throughout the surveyed major maize growing districts of North Gondar Zone. The occurrence was the second major disease found to be very high prevalence in North Gondar Zone, data indicated that higher prevalence 67.86 and 63.33% disease distribution occurred at Takussa and Metema districts respectively during two surveyed years (Table 2). However, the survey data indicated that the lowest prevalence was recorded on Chilga 42.86% followed by Gondar zuria with 43.33% CLR disease distribution on maize grown fields. The disease often appears relatively late in the growing season and seldom causes much loss in grain yield (Table 2). CLR disease in previous researcher was also indicated that one of the major diseases of maize growing areas in Ethiopia (Mengistu, 1982; Tarr, 1962).

Gray leaf spot caused by C. zeae-maydis was one of the

### Table 1. Major and minor of maize foliar diseases on five surveyed districts and its’ diagnosed causal agents.

| S/N | Maize foliar disease                  | Chilga (1850-2400 masl) | Dembia (1750-1900 masl) | Takussa (1600-1800 masl) | G/Zuria (1933-2700 masl) | Metema (580-1500 masl) | Total |
|-----|--------------------------------------|-------------------------|-------------------------|--------------------------|--------------------------|-------------------------|-------|
| 1   | Turcicum leaf blight (Exserohilum turcicum) | **                      | **                      | **                       | **                       | **                      | **    |
| 2   | Common leaf rust (Puccinia sorghi)    | *                       | *                       | *                        | *                        | *                       | *     |
| 3   | Gray leaf spot (Cercospora zeae-maydis) | *                       | *                       | *                        | *                        | *                       | *     |
| 4   | Maize Streak Virus                   | *                       | *                       | *                        | *                        | *                       | *     |

*=Major (>25%); *=Minor (<25%); D.I. =Disease Incidence

Numbers with bracket is altitude (masl=meter above sea level).

### Table 2. Mean prevalence of maize foliar diseases for five districts during a survey of two cropping main seasons.

| Maize foliar diseases | Chilga | Dembia | Takussa | G/Zuria | Metema | Total |
|-----------------------|--------|--------|---------|---------|--------|-------|
|                       | N.F % | N.F % | N.F %  | N.F %  | N.F % | N.F % |
| Turcicum leaf blight  | 29     | 82.86 | 19      | 70.37  | 18     | 64.28 | 20     | 66.67  | 18     | 60.00  | 104   | 69.33 |
| Common leaf rust      | 15     | 42.86 | 17      | 62.96  | 19     | 67.86 | 13     | 43.33  | 19     | 63.33  | 83    | 55.33 |
| Gray leaf spot        | 11     | 31.43 | 9       | 33.33  | 6      | 32.14 | 7      | 23.33  | 9      | 30.00  | 45    | 30.00 |
| Maize Streak Virus    | 4      | 11.43 | 5       | 18.52  | 6      | 21.43 | 4      | 13.33  | 7      | 23.33  | 26    | 17.33 |
| Total assessed fields | 35     | 27     | 28      | 30      | 30     | 150   |

N.F. = Number of fields, where the disease samples were collected

% = Percentage of the disease that occurred from total sampled fields.
important foliar maize diseases that occurred on five surveyed districts of North Gondar Zone. In two cropping season, the highest mean prevalence Gray leaf spot (GLS) maize disease was recorded from Dembia 33.33% followed by Takussa district 32.14%, while the lowest prevalence was occurred at Gondar zuria 23.33%. But the two years data mean prevalence of Gray leaf spot disease on maize field indicated that the disease occurrence from Dembia was higher than the Gondar zuria maize disease prevalence (Table 2). Foliar maize disease Maize streak virus (MSV) distribution has occurred in all surveyed districts, however the disease moderately prevalent than the rest of recorded foliar disease. In two years field survey mean data indicated that the highest MSV prevalence was recorded on lowlands of Metema followed by Takussa districts. But the lowest MSV prevalence was occurred at high land area of Chilga followed by Gondar zuria district. The disease prevalence during both cropping seasons was high in lowlands compared to the highlands. The overall sampled fields showed that the least mean prevalence disease 17.33% sample was recorded from MSV disease compared to other foliar maize disease (Table 2).

### Disease incidence

The average percent diseases incidence was worked out based on the field observations. North Gondar Zone higher disease incidence of Turcicum leaf blight (*E. turcicum*) was recorded in all of the five surveyed districts. The result of survey conducted for 2015 year showed that Turcicum leaf blight (TLB) was widely distributed and caused greater disease incidence damage by 70% in Chilga and followed by 65% both in Gondar zuria and Dembia district on farmer maize fields, while the minimum disease incidence 50% was recorded on Metema district, where the lowest altitude was recorded. In 2016 cropping season the disease survey revealed that TLB was prevalent in major maize growing areas of the Northern Gondar Zone in low to severe form with the incidence of ranging from 54 to 80%, where the highest percent disease incidence was recorded from Chilga 80% and the minimum one was noticed in Metema district by 54% disease incidence (Table 3). The TLB disease incidence infestation level across surveyed districts indicated that the maximum mean incidence 75% was recorded from Chilga where the altitude occurred more than 2000 m.a.s.l. But the minimum disease incidence 52% was recorded from Metema district, where less than 1500 m.a.s.l. altitude range area was occurred (Figure 2).

The maximum Common leaf rust (*P. sorghii*) disease incidence was recorded from Takussa 54% followed by Dembia 44%, while the minimum incidence of 19% in the Chilga district during 2015 maize growing season. In the second year cropping season, the maximum incidence 62% was also observed in the same surveyed district from Takussa and followed by Dembia with a 50% incidence (Table 3). (CLR) maize foliar disease in the different districts ranged from 21 to 58% mean incidence. To the period of 2015 cropping season the disease survey revealed that Gray leaf spot of maize was prevalent in all the maize growing surveyed districts in low to high form with the incidence ranging from 15 to 42%. Among the five districts in the first year survey, the maximum disease incidence was observed in Metema 42%, followed by Takussa 31% and the lower disease incidence by 15% in Chilga district. Survey in the second year indicated that the highest GLS incidence disease was observed in Takussa 37% followed by 34% in Metema district. However, the disease incidence was lower in Chilga than Gondar zuria district (Table 3). During both main cropping seasons the Maize streak virus has occurred in five districts and recorded with a low incidence. Maximum disease incidence value was recorded from Takussa 17% followed by Metema 15% among surveyed districts of North Gondar Zone. But the minimum MSV incidence was obtained from Chilga and Gondar zuria assessed maize fields on the first surveyed year. The second year data indicated that the maximum disease incidence 19% followed by 13% was showed in Metema and Takussa district respectively (Table 3). The lowest TLB mean disease incidence 52% was obtained in Metema district, while the highest mean incidence 75% was recorded in higher altitude of Chilga district.

However, CLR foliar disease lowest mean incidence 21 and 24% was recorded in Chilga followed by the highest

### Table 3. Maize foliar disease incidence in North Gondar Zone during 2015 and 2016 main cropping season.

| Maize foliar disease          | Chilga (D.I. %) | Dembia (D.I. %) | Takussa (D.I. %) | G/Zuria (D.I. %) | Metema (D.I. %) |
|------------------------------|----------------|----------------|----------------|----------------|---------------|
|                              | 2015 2016      | 2015 2016      | 2015 2016      | 2015 2016      | 2015 2016     |
| Turcicum leaf blight         | 70 80          | 65 63          | 60 70          | 65 73          | 50 54         |
| Common leaf rust             | 19 23          | 44 50          | 54 62          | 23 25          | 40 38         |
| Gray leaf spot               | 15 21          | 22 28          | 31 37          | 19 21          | 42 34         |
| Maize Streak Virus           | 3 7            | 9 11           | 17 13          | 6 10           | 15 19         |

D.I. % = Disease Incidence percentage; G/Zuria = Gondar zuria.
altitude of Gondar zuria district respectively. The highest CLR mean incidence 58% was recorded in Takussa district where the lower altitude occurred. The overall mean incidence of the CLR disease was very high in the first and second of surveyed years and also the disease was more prevalent at flowering and grain filling stage in most of the surveyed areas. Two years foliar mean disease incidence showed that the lowest altitude of Metema district with the highest mean incidence 38% was recorded from GLS followed by MSV foliar disease incidence 17%, while the lowest incidence 18 and 5% was recorded on GLS and MSV foliar disease from higher altitude of Chilga district respectively (Figure 2).

Maize foliar disease severity

Survey on farmers’ fields in major maize growing areas of Northern Gondar Zone revealed that, TLB severity varied from one locality to another, due to varied environmental conditions prevailing, cropping pattern and inoculums sources. During the 2015 cropping season among surveyed areas, the most affected fields were found in Gondar zuria with 28% disease severity, followed by Chilga district of 25% severity, but the minimum severity was noticed in Metema by 17%. In 2016 cropping season the disease survey revealed that TLB of maize was prevalent in major maize growing districts of the North Gondar Zone in low to severe form with the severity ranging from 17 to 35%,and the maximum disease severity 35% was observed in Chilga district with highland altitude areas of maize farm lands. But the minimum severity 17% was recorded from Takussa district (Table 4).

Among identified foliar maize disease Common leaf rust was the second widely distributed type of maize foliar disease, which documented severity next to TLB disease. The maximum CLR disease severity was observed in Metema 31% followed by Takussa 28% and the minimum severity was noticed in Gondar zuria by 16% during the first surveyed year. The disease severity in affected fields of Dembia and Chilga districts was 23 and 19% respectively during 2015 cropping year. CLR is one of the major foliar maize diseases having high disease severity that has been recorded in the surveyed districts. The infection was more serious during the second main cropping season in predominantly lowland areas were indicated the highest severity 33% in Metema and followed by 32% in Takussa district, and likewise in previous year the lowest severity 20% was recorded from Gondar zuria district (Table 4).

Gray leaf spot was also widely distributed throughout the major maize growing districts of North Gondar Zone. In the first cropping season, the occurrence of the
Disease was found to be very high severity ratings of 32, 21 and 16% at Metema, Takussa and Dembia districts respectively. To the period of 2015 cropping season the disease survey revealed that Gray leaf spot of maize was prevalent in all the maize growing surveyed districts in low to severe form with the severity ranging from 10 to 32%. The minimum severity 10% was noticed in Gondar zuria maize fields. During the second year, the highest severity 27% was indicated on Takussa and followed by severity of 24% on Metema district. Gray leaf spot maize was the third major maize disease of Northern Gondar Zone, which ranging from 12 to 27% severity (Table 4).

Among the five surveyed districts, the maximum MSV disease severity was observed in Metema 9%, followed by both Takussa and Gondar zuria districts having with the same value of 7%, however the minimum disease severity 3% was recorded from Chilga during the first cropping season. In the second surveyed year greater severity ratings were recorded by 13, 11 and 7% at Metema, Takussa and Dembia districts respectively. However, the occurrence of the disease was found to be very sporadic. The occurrence of maize streak virus foliar disease was observed in all surveyed districts with low infestation level ranging from 3 up to 13 percentages of severity index in both cropping season (Table 4).

Two years mean percentage disease severity indicated that the maximum TLB mean PSI 30% was observed in Chilga followed by 25% PSI in Gondar zuria district. But minimum PSI 19% value was showed by both Metema and Takussa lower altitude districts. In general TLB highest mean PSI was recorded on the higher altitude surveyed farm fields, while the lowest mean PSI was obtained from the lowest altitude district (Figure 3). In both cropping seasons 41 of 104 fields with TLB severity ratings ≥20% were recorded in the surveyed districts. Recently the area under maize was expanded in the improved varieties by replacing of the local varieties. The relation between the altitude and the mean maize foliar severity indicated that two years mean higher severity value of CLR, GLS and MSV foliar diseases were recorded in lowland areas of lower altitude districts, while the lowest severity of TLB foliar diseases was obtained from the same districts. It is apparent that among the surveyed districts the highest mean CLR mean PSI 32% was recorded from Metema, while the lowest was from G/zuria with 18% PSI, where the highest altitude occurred. The highest GLS mean PSI was recorded in Metema 28% followed by Takussa 24%, while the lowest in the Chilga district with 12% of PSI. The mean severity of MSV was ranged from 4 to 11%, the highest MSV mean PSI 11% was recorded from Metema, while the lowest PSI 4% was obtained from Chilga where the higher altitude range was recorded (Figure 3).

**DISCUSSION**

In addition to surveying for the occurrence and incidence of the above diseases, greater focused was placed on maize major leaf diseases of Turcicum leaf blight, Common leaf rust and Gray leaf spot and as a minor leaf disease of maize streak virus diseases were recorded in all five surveyed districts. The data indicated that the fields planted with local cultivar developed higher levels of TLB disease, while for improved cultivar was mainly affected with CLR disease. However, MSV diseases with lower incidence and severity infestation were observed in surveyed fields. Differences in disease severity in different fields planted with the same cultivar may have been caused by variations in levels of inoculum, plant maturity, nutritional status, local environmental conditions, and production methods. Several diseases attack maize crop during its growth stage. In Ethiopia 47 different types of diseases were recorded on maize, foliar and flower diseases being the most important once, which were mainly fungal diseases and among these the major foliar diseases were Turcicum leaf blight, Common leaf rust and Maize streak virus diseases (Tewabech et al., 2001).

The results of surveys conducted for two years showed that TLB was widely distributed and caused severe damage in Metema, Chilga, Gondar zuria, Dembia and Takussa districts. The highest incidence and percentage severity index of Turcicum leaf blight disease was recorded in Chilga and it might be attributed by favorable climatic conditions, high altitude, susceptible maize varieties grown and possibly disease pressure from the available patho-types of the pathogen. TLB disease has been reported throughout the world wherever maize is widespread.

### Table 4. Foliar maize disease percentage severity index in the surveyed districts during 2015 and 2016 main cropping season.

| Maize disease       | Chilga (PSI %) 2015 | Chilga (PSI %) 2016 | Dembia (PSI %) 2015 | Dembia (PSI %) 2016 | Takussa (PSI %) 2015 | Takussa (PSI %) 2016 | G/Zuria (PSI %) 2015 | G/Zuria (PSI %) 2016 | Metema (PSI %) 2015 | Metema (PSI %) 2016 |
|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Turcicum leaf blight| 25                  | 35                  | 18                  | 22                  | 21                  | 17                  | 28                  | 22                  | 17                  | 21                  |
| Common leaf rust    | 19                  | 23                  | 23                  | 25                  | 28                  | 32                  | 16                  | 20                  | 31                  | 33                  |
| Gray leaf spot      | 12                  | 12                  | 16                  | 22                  | 21                  | 27                  | 10                  | 18                  | 32                  | 24                  |
| Maize Streak Virus  | 3                   | 5                   | 5                   | 7                   | 7                   | 11                  | 7                   | 3                   | 9                   | 13                  |

PSI = percentage severity index; G/Zuria = Gondar zuria.
cultivated (Leonard et al., 1985; Adipala et al., 1993; Shiferaw et al., 2011). The high disease incidence and severity index in the highlands were obtained due to conducive climatic conditions. This result coincided with Nwanoike (2015) and showed that TLB disease incidence in highland district was significantly higher. Assefa (1999) also indicated that TLB infection is more serious during the main season in predominantly wet and humid areas. Generally TLB disease incidence and severity were severely affected the maize crop in the highlands as compared to relatively dry lowland districts. Similarly Adipala et al., (1993) and Ramathani et al (2011) reported that the prevalence of TLB in highlands and wetter areas of Kenya and Uganda was severely occurred. Previous reports showed that TLB is a serious disease in the highlands associated with cool, high relative humidity, mid-altitudes and cloudy weather conditions (Muriithi and Mutinda, 2001, Levic et al., 2008). Among surveyed districts the result indicated that Chilga was a hotspot area for TLB disease on maize crop. Particularly the disease incidence and severity were recorded on local and improved varieties, however the local variety was found to be lower incidence compared to the improved variety. TLB disease distribution indicated that the maximum mean disease incidence was recorded above 2000masl in Chilga followed by Gondar Zuria district. But the minimum disease incidence was observed at 1825masl in Dembia district, where the relative humidity was not too much compared to the highlands. This disease is one of the major maize diseases having wide distribution and high economic importance in North Gondar zone districts. Two years surveyed data indicated that among foliar diseases the maximum mean disease incidence 75% was recorded on Turcicum leaf blight maize disease. This mean data was agreed with the previous study of Berhanu (2015) 100% incidence for all surveyed districts. The current survey study revealed TLB pressure in maize farms of Northwestern Ethiopia and needs to be designed in an efficient, inexpensive and sustainable management approaches against this disease. Tewabech et al. (2001) described that TLB is one of the major maize diseases

Figure 3. Two years mean maize foliar disease PSI in the surveyed. Districts across different altitude range (Mean = Two years severity average data, PSI = Percent severity index).
having wider distribution and high economic importance in Ethiopia and the infection appears more during the main season in constantly wet and humid areas. Severe grain yield losses as high as 28 to 91% due to TLB have been reported in several parts of the world (Gowda et al., 1992; Harlapur et al., 2000; Keno et al., 2018).

The second most important Common leaf rust disease was recorded in all surveyed districts and caused more intense damage in mid altitude areas of all improved varieties in both cropping seasons with higher mean disease incidence and percentage of severity index infestation level. The infection was more serious during the main season in predominantly wet and humid areas were indicated the incidence with very high severity. Keno et al. (2018) indicated that CLR is an important disease of maize in Ethiopia and widely distributed throughout the major maize growing regions of the country. However, the importance varies from place to place particularly during the survey it was more severe in mid-altitude than highland maize growing areas. CLR disease usually appears at the Knee-high stage or at tasseling. The survey results for both cropping seasons showed that CLR was widely distributed and caused more severe damage in Metema and Takussa with higher conducive temperature and sufficient rainfall conditions compared to other surveyed districts. Higher infestation incidence of 58% Common leaf rust in the surveyed area was due to the cultivation of improved susceptible variety and environmental condition. This study was coinciding with Chemeda and Jonathan (2001) previous work indicated that higher temperature and better rainfall during the survey seasons are often conducive factors for a rust epidemic and the hybrid maize varieties were highly susceptible to rust under Hararghe conditions compared to local adapted ones with the mean incidence ranged from 49-84%. In previous research work CLR on a susceptible cultivar was reduced grain yields by 23% from the western region of Ethiopia (Assefa and Tawabech, 1993).

Gray leaf spot caused by *C. zeae-maydis* was also an important major foliar disease, and widely distributed throughout the surveyed maize growing areas of North Gondar zone. Currently the disease is known to have widespread throughout the maize production areas of worldwide, including South America (Pozar et al., 2009), China (Zhang et al., 2012) and Ethiopia (Wegary et al., 2001). According to the report, GLS has become the principal maize disease since 1998 in Ethiopia. Recent survey in the country showed that GLS has increased in prevalence and severity in the major maize producing regions of western, southern and northwestern parts of Ethiopia (Alemu et al., 2016; Dagne et al., 2001). GLS is evident on plants as small spots first on lower leaves of plants at tassel initiation. The disease moves upwards and spots change into long characteristics lesions within a month turning plants into a diseased field. The disease is significant since it rapidly destroys foliage when the plant is near at grain maturity (Manandhar et al., 2011). Observations showed that Gray leaf spot disease infestation was severe foliar disease in the surveyed districts. Although the disease intensity on maize production areas was varied due to weather, tillage system, and altitude range. It was occurred higher incidence and severity during the main season in predominantly warm temperature and high humidity maize production areas of low and mid altitude of Metema and Takussa districts. The study was agreed with Aschalew et al. (2012) previous work indicated that GLS disease is favored by humid and warm condition for its' development. Particularly in favorable climatic condition maize Grey leaf spot disease in South Africa is capable of reducing grain yields by 20-60% (Ward et al., 1997). To date, the disease is one of the most important threats to maize production in Ethiopia, causing yield losses as high as 29.10% and considerable yield loss in most maize growing areas of the country (Assefa, 1999; Wegary et al., 2004; Keno et al., 2018).

Maize foliar Maize streak virus disease observed from all surveyed districts, however this disease has occurred as a minor disease and the result was closer with Alemu et al. (1997) data at Bako maize planted in the off season was infected by MSV disease 15-20%. This study indicated that the maximum mean MSV foliar disease incidence was obtained from the lowest altitude Metema district, while the minimum incidence was recorded from the higher altitude of Chilga district. In Ethiopia, MSV is the most dominant viral disease of maize. Currently, MSV infestation has spread to the low, mid and highland areas of the country. But in recent years, the disease is becoming very important in the mid-altitude agroecology of Ethiopia and posing a significant threat to maize production in the country (Assefa, 1999; Keno et al., 2018). In Ethiopia condition, the main inoculums source of MSV disease was from grass family like *Digitaria sp.*, *Eleusine indica* and *Panicum* species were found to serve as hosts to carry the disease over from season to season and further transmitted by several aphid species to maize crop (Alemu et al., 1997).

**Conclusion**

All the above identified diseases were destructive to maize production in North Gondar Zone, due to the fact that they occurred widespread in maize producing areas. From this study detected that foliar diseases are among the major production constraint that contributed yield losses in maize producing districts. During the survey maize growth period was also affected by drought, water logged and hail are highly observed as abiotic stresses that caused yield loss. Four important foliar maize diseases, three of them are as major and one is as minor diseases were identified and based on this study further the maize diseases management should be investigated.
It is anticipated that the disease will continue to threaten maize production until appropriate control methods are developed. Therefore it could be used for screening of germplasms for resistance against the diseases and urgent control measure should be taken especially on TLB. Common leaf rust and other foliar disease to save the crop. In general farmers do not use improved technologies. Hence, there is a need to introduce improved disease management techniques such as using resistant varieties, cultural and chemicals to be incorporated as integrated disease management practices.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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