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Research Article

Assessment of Wheat Fusarium Head Blight and Associated Fusarium Species in West Shewa, Ethiopia

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ABSTRACT

Wheat (*Triticum* spp) is one of the most food security crop in Ethiopia and produced in mid and highland areas of the country. Fusarium head blight (scab) which is incited by *Fusarium* species is among the biotic stresses that causes a significant reduction in wheat grain yield and quality in the country. However, in West Shewa zone of Ethiopia the distribution and intensity of the disease is not well studied. Therefore, the study was conducted during 2019 cropping season when wheat was at dough growth stage to determine the status and distribution of FHB in the zone. Eighty wheat fields planted to local and improved cultivars were assessed by following "W" fashion using ($0.5*0.5m^2$) quadrats. The disease prevalence in the area was 88.75%. However, the disease incidence and percent of severity index varied significantly ($p<0.05$) across the districts. Generally, the mean disease incidence and percent of severity index were 43.7% and 76.3%, respectively. Four *Fusarium* species, viz. *F. graminearum, F. poae, F. avenaceum and F. culmorum* were isolated and identified from the infected wheat ear samples collected during field assessment. Hence the study concludes that wheat production in the area is severely threatened by FHB due epidemic occurrence of the disease. So, intensive and extensive surveillance should be carried out across wheat growing agro ecologies in the country. Farmers should also trained on identification, importance and management of the disease. Integrated disease management is needed as the frontline to reduce the disease problem.

Key words: Fusarium head blight, Fusarium graminearum, Wheat, Disease intensity, Ethiopia

INTRODUCTION

Wheat (*Triticum* spp) is one of the most widely cultivated cereal crop in the world and cultivated annually on about 220 million hectares (MH) of land. In Sub Saharan Africa more than 7.5 million tons (MT) of wheat is produced annually on more than 2.5MH of land (FAO, 2017). In Ethiopia it is grown on more than 1.74 million hectares of land which is covered 13.78% of the total grain crop production and more than 4.2 million households relying on it (CSA, 2018). Both durum (*Triticum turgidum* L. var durum) and bread wheat (*Triticum aestivum* L.) species are widely cultivated in Ethiopia although other wheat species are cultivated to a lesser extent. It ranks second after maize contributing 15.17% of the total annual cereal production and fourth after tef, maize, and sorghum in area coverage (CSA, 2019). It serves as an important source of protein and calories for more than one-third of the world population (Hussain et al., 2002). It also used as staple food in deities of many Ethiopians and provided 12% of the daily per capital caloric intake for more than 90 million population of the country (FAO, 2017).

West Shewa zone is among wheat potential areas of Ethiopia. Although wheat is potential and the productivity of the crop has increased in the last few years, the annual average productivity is estimated at 2.7tons/ha (CSA, 2019), which is quite low when compared to what is commonly obtained by research in the country. This is due to various biotic, abiotic and socioeconomic factors. Fusarium head blight (FHB) which is incited by complex *Fusarium* spp. is among biotic factors that causes both quantity and quality losses in major wheat growing areas. The disease is characterized by early mature bleaching of infected spikelets and formation of orange sporodochia at the base of glumes (Bilikova and Hudec, 2013). Surveys conducted earlier in Ethiopia revealed that the disease has been found to be the major biotic constraint in Ethiopia (Bekele, 1990; Misgana and Yesuf, 2016; Kebede *et al.*, 2020). International Maize and Wheat Improvement Center (CIMMYT) has listed the disease as a major threat to wheat production throughout the world (Goswami and Kistler, 2004). Despite frequent occurrence and severe epidemics of the disease in the country, there is no adequate information on the distribution and intensity of

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the disease in the West Shewa zones of the Oromia region as of today. Therefore, this study was undertaken to determine the distribution and intensity of FHB in Western Shewa Zone, Oromia Regional state of Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

Survey was carried out in major wheat growing districts of West Shewa zone of Ethiopia from Mid-September to November, 2019 main cropping season when the crop was at milk to dough growth stages. West Shewa zone is located at 8º 17'- 8º 57'N latitude and 37º 08'- 38º 07'E longitude, with altitudes ranging from 1380-3300 m.a.s.l. The survey districts and locations in the zone were selected based on wheat area coverage. They were namely Dandi, Ejersa lefo, Ejere, Ambo, Toke kutaye, Liban jawi, Chaliya and Mida kegn. The hierarchical sampling structure was used to collect wheat head samples infected by FHB from inspected fields in selected areas. Two Peasant Associations (PAs) from the selected districts and five wheat fields from each PA were assessed. Global Positioning System (GPS) reading was taken at each sampling point and the coordinates were used to generate maps using the Geographic Information System (GIS) software Arc Map10.3.

Disease assessment

Disease assessments were made diagonally along each field using 0.5m x 0.5m quadrat at five spots. Disease data (incidence, severity and prevalence) were collected according to Miedaner *et al.* (1996).

Disease Prevalence (DP): Disease prevalence was also expressed as percentage of diseased fields over the total fields inspected.

$$\text{DP}(\%) = \frac{\text{Number of infected field}}{\text{Total number of assessed field}} * 100$$

Disease Incidence (DI): Disease incidence were determined as proportion of infected plants showing blighted symptoms in the field.

$$\text{DI}(\%) = \frac{\text{Number of Diseased plants}}{\text{Total number of plants observed}} * 100$$

Disease Severity (DS): was determined as the proportion of bleached spiklets with in randomly thrown quadrats. In each field severity was rated on a scale of 1 – 9, where: 1 = no symptoms, 2 = <5%, 3 = 5-15%, 4 = 16-25%, 5 = 26-45%, 6 = 46-65%, 7 = 66-85%, 8 = 86-95%, 9 = 96-100%. Miedaner *et al.*, (1996). Severity scores were converted to percent of disease severity index, (PSI) using the formula suggested by Wheeler (1969) and Kumar *et al.* (2011) as described below.

$$\text{PSI}(\%) = \frac{\text{Sum of numerical rating}}{\text{Total number of plant observed x maximum rating}} * 100$$

Samples which showed typical FHB symptoms were collected from infected fields and brought to laboratory for further identification. Infected kernels and glumes from each sample were surface sterilized using 5% sodium hypochlorite solution for 3 minutes and rinsed three times in distilled water for 3 min. They were subsequently plated and purified on low strength Potato Dextrose Agar (PDA) that amended with mineral salts (Muthomi, 2001) and characterized as described in the "Fusarium Laboratory Manual" (Leslie *et al.*, 2006). Samples were incubated at room temperature under 12hr photoperiod of fluorescent light. After 5 days, Fusarium species were identified to species level based on their morphological and microscopic identifications according to Nelson *et al.* (1983) and Leslie and Summerell (2006).

Data Analysis

The collected survey data were arranged for two stage nested design and analysed using SAS (9.4) version. Duncan multiple range test (DMRT) was used to compare means for each parameter measured at (α = 0.05). Disease distribution map was also generated using the GIS software Arc Map 10.3. Correlation analysis were also performed to correlate disease intensity with weather conditions.

RESULTS AND DISCUSSION

Prevalence and Distribution of Head Blight

The survey covered a total of 80 wheat fields planted to local and 10 different released Ethiopian wheat varieties across selected districts and farmers associations in the zone. Among these, 72 (90%) wheat fields were covered by improved varieties and only 8 (10%) fields were covered by local cultivars. The survey results revealed that the disease prevalence and distribution were high and it is getting increasingly important in all assessed areas. The disease prevalence in the zone were ranged from 70% to 100% across the inspected districts and 25% to 100% across wheat cultivars under production. The disease was more prevalent in Ambo, Dandi and Toke kutaye districts with 100% prevalence. In contrast, the disease was relatively less prevalent (70%) in Liban jawi and Mida kegn districts (Table 1). As a whole, of assessed fields, 71 (88.75%) fields were infected by the disease.

The most dominated cultivars in the study areas were Kakaba (20%), Danda'a (18.75%), Digelu (12.5%), Kubsa (12.5%) and local (10%) varieties were highly infected by the disease in all assessed fields with 100%, 100%, 90%, 90% and 87.5% disease prevalence (Table 2). Of the 71 (88.75%) infected fields, 64 (80%) were sown with improved varieties and 7 (8.75%) were covered by the local cultivars. This high distribution and prevalence of the disease across districts and most dominant cultivars in the area showed as the disease becoming major wheat production constraint. This might be due to conducive environmental conditions happened in the area during the season and the widely cultivated varieties also exhibited susceptible reaction. The sporadic nature of the disease also makes the disease more difficult to control it on time before it causes huge damage, because it is caused by complex *Fusarium* species and its distribution is highly determined by the environmental factors (Parry et al., 1995; Martinez *et al.*, 2012).

Even though the disease is important and widely distributed in area, majority of the growers didn't take any action against the disease because of their insufficient knowledge about the disease. Out of the interviewed respondents, only 8 (10%) of them knows about the disease. Majority (55%) of the farmers thought that it was frost damage or cold effect and they locally named the disease "*ofiin gogii*"(in Afan Oromo), which means "blighted by itself". Others, 26.25% of growers considered it as another disease symptom which like rust and 8.75% thought as it is forced maturity due to lack of enough rains. This lack of disease recognition or being ignorant about the disease by most farmers lagged them behind in applying appropriate and timely control measures.

Disease Incidence and Severity Index

Even though FHB prevalent in most of the surveyed areas, the disease incidence and severity varied markedly among districts and varieties currently under production. There were significant (P<0.05) differences in FHB

Table 1: Prevalence, Incidence and PSI of FHB in West Shewa zone of Ethiopia in 2019 main cropping season

Districts	NAF	NIF	Prevalence	Altitude range	Incidence	PSI
Dandi	10	10	100	2119-2329	57.0a	90.4a
Toke kutaye	10	10	100	2039-2304	49.0ab	86.0a
Ejersa lafo	10	9	90	2076-2198	45.5ab	77.2ab
Chaliya	10	9	90	2502-2608	41.0ab	77.6ab
Ambo	10	10	100	2188-2303	41.0ab	86.1a
Liban jawi	10	7	70	2251-2466	40.8ab	61.1bc
Ejere	10	9	90	2154-2314	40.3ab	78.9 ab
Mida kegn	10	7	70	2552-2899	35.0b	52.8c
Mean			88.75	2039-2899	43.7	76.3
CV (%)					17.2	6.6

Where: NAF: Number of Assessed fields; NIF: Number of infected fields; CV: Coefficient of Variation; PSI: Percent of Severity Index; Means with the same letter are not significantly different (Duncan grouping at P=0.05).

Table 2: Prevalence and intensity of FHB on various wheat varieties grown in West Shewa zone in 2019 main cropping season.

Varieties	Altitude range	NAF	NIF	Prevalence (%)	Incidence	PSI
Danda'a	2105-2774	15	15	100	57.0	87.4
Kakaba	2039-2603	16	16	100	52.8	86.5
Kubsa	2055-2899	10	9	90	45.0	76.5
King bird	2094-2502	3	3	100	43.3	88.6
Digelu	2083-2766	10	9	90	43.3	76.3b
Dashen	2466-2881	3	3	100	39.3	76.3b
Local	2109-2870	8	7	87.5	37.5	75.9
Hidase	2158-2774	5	4	80	31.0	69.7
Ogolchu	2162-2387	4	3	75	30.0	62.2
Wane	2085-2303	2	1	50	22.5	41.5
Huluka	2273-2650	4	1	25	11.3	24.2
Mean/Range	2039-2899			88.75	43.7	76.2

Table 3: Composition of identified *Fusarium* species from infected wheat heads in West Shewa zone, during 2019 main cropping season

Fusarium Species	Field location	Variety	Total fields	Percent (%) Frequency
F.gramenearum	Toke kutaye, Ejere, Dandi, Ambo, Liban jawi	Danda'a, Ogolchu, Kubsa, Kakaba, Kingbird	18	42.9
F.culmorum	Ejere, Ejersa lafo, Ambo, Mida kegn	Danda'a, Kubsa, Digelu, Kakaba	11	26.2
F. avenaceum	Dandi, Chaliya, Ambo	Danda'a, Dashen, Kakaba, Hidase	8	19.3
F.poae	Ambo, Ejere	Kubsa, Danda'a, Hidase, Kubsa	5	11.9

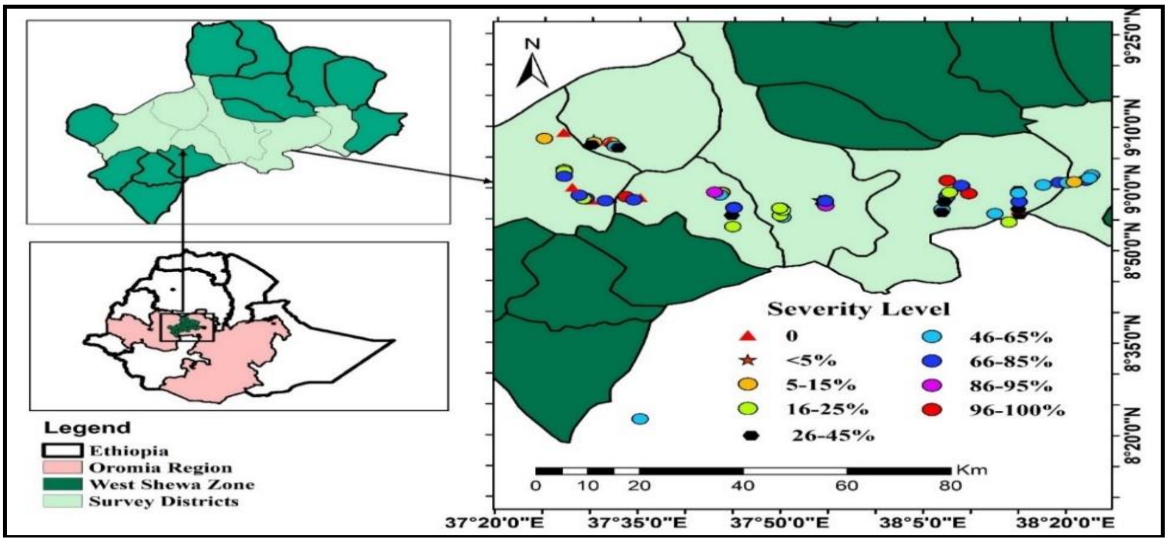

Fig. 1: Distribution and severity of FHB in West Shewa zone survey areas during 2019.

incidence and PSI among the assessed districts (Table1). Significantly higher FHB incidence was recorded in Dandi (57.0%) district, and it is followed by Toke kutaye (49.0%), Ejersa lafo (45.5%) and Chaliya (41.0%) districts. Whereas, the lowest FHB incidence was recorded in Mida kegn (35.0%) district.

Similarly, significantly higher FHB severity index was recorded in Dandi (90.4%), followed by Ambo (86.1%) and Toke kutaye (86.0%) districts. And the lower FHB severity index was recorded in Mida kegn (52.8%) (Fig. 1, Table 1). Generally, the mean FHB incidence and severity index across assessed districts were 43.7% and 76.3%, respectively.The mean disease incidence across the varieties currently under production in assessed locations was ranged from 11.3% to 57.0% in fields planted to Huluka and Danda'a varieties, respectively. And the mean disease severity index was also ranged from 24.2% (on Huluka) to 88.6% (on Kingbird) varieties (Table 2). The variability of the disease incidence and severity from location to location and variety to variety might be due to various environmental, agronomic and genetic factors in the production area. Xu *et al* (2008) stated the variability of FHB among geographical locations and years is might be due to variations in weather and climatic conditions and cropping systems practiced by growers.

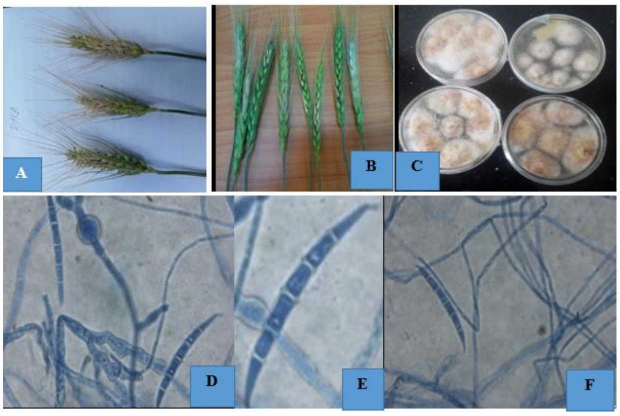

Fig. 2: Isolation and identification of *Fusarium species* that causes FHB at AmARC, Ethiopia: (A&B) Infected wheat head samples collected during survey Isolated *Fusarium species* on PDA, (C) Isolated fungal pathogens on PDA media from infected wheat heads (D, E &F) Morphological and Microscopic identification of isolated species

Most of the wheat cultivars currently under production in the area showed susceptible reaction to the disease with significant yield and quality losses. None of the varieties were showing resistant to the disease. This suggests that the disease could pose a major threat to wheat production in the zone. Mamluk *et al*. (2000) stated majority of the wheat cultivars grown by Ethiopian farmers are susceptible to the major wheat diseases. Bekele (1990) also reported except some varieties, most of the wheat cultivars in Ethiopia are susceptible to FHB disease. However, the disease extent was vary among wheat cultivars. This variation could be attributed to the natural interplay between the cultivars, pathogen and the environment that providing a conducive atmosphere for disease expression (Stevens, 1960).

The farmers incurred a serious FHB epidemic in the zone especially, in Dandi district during the season. This might be due to continuous rainfall until wheat dough growth stage as the disease highly depends on environmental factors. In line with this finding, Xu (2013) and Osborne and Stein (2007) reported frequent rains and optimum temperature prevailed during and post wheat anthesis growth stage makes conducive condition for the outbreak and spread of FHB. Burlakoti *et al*. (2010) also stated that FHB is a sporadic disease and the disease distribution and intensity is largely dependent on the existing environmental and agronomic factors. FHB is polygenic disease and the intensity of the disease highly depends on the environmental conditions (Chrpova *et al.*, 2010).

Majority (>85%) of the interviewed farmers in the area practiced mono-cropping system. They planted tef, barley, maize and wheat itself before and after wheat crop due to the shortage of the farm land. They left wheat residues on fields as standing hay for livestock consumption until the next wheat cropping season might also contributes for the overwintering of pathogen. The livestock could distribute the residues in the field with their legs. This condition also could be increase the disease problem by increasing the disease inoculum in the field. The disease overwinter on/in the crop residues and dispatched to the field. Dill-Macky and Jones (2000) stated the residues of the host crops are used as inoculum source and causes FHB outbreak if wheat is sown in infected fields by the disease. Barley, oat, tef and maize are reported as host ranges for the disease. If either of these crops planted before and after the wheat they make conducive condition for the continuous occurrence and the spread of pathogens in the field and it increases the disease problem in the subsequent season (Goswami and Kistler, 2004; McMullen *et al.*, 2012).

In contrast, the lowest FHB was noted at Mida kegn which had a relatively higher elevation and colder temperature during the wheat anthesis and milk stage than others. This implies that elevation and temperature could have determine the disease occurrence and extent. Most of the farmers in that area produced other crops like faba bean, rapeseed, linseed, field pea and need. This might decrease the disease distribution and extent.

The source of wheat cultivars used for production also have crucial role for the epidemics of the disease. Approximately half of the respondents (47.5%) got the seed formally from the government through agricultural offices and farmers associations and 17.5% of the growers got it from Agricultural Research Institutions and non-government organizations. The rest 35% got informally from market, neighbours and used their own saved wheat seeds. Most (89.3%) wheat fields grown from informal seed sources were infected by the disease. This indicated that source of wheat cultivars could also has contributed its own role in increasing the disease. The use of farmers own saved seed possibly increases the spread of FHB, provided that the previous harvested seeds are infected, and result to low germinability, seedling blight and low seedling vigor which in turn predispose the crop to severe disease development and consequently high yield losses. Mobasser *et al.* (2012) stated informal sources of the seed increase the FHB extent in wheat growing areas of Iran by contributing as inoculum sources for the disease.

Various studies demonstrated that distribution and extent of wheat FHB highly depend on environmental, agronomic and socio-economic factors. High humidity during wheat anthesis stage (Parry *et al.*, 1995; Osborne and Stein 2007; Bernhoft *et al.*, 2012), mono-cropping system (Fernando *et al.,* 2000). Unavailability of registered fully-resistant or tolerant varieties for the disease is another factors that increases the disease. Even though source of resistance in bread wheat is available, no promising resistant variety released for FHB in the country. Steiner *et al.* (2018) stated that unlike to durum wheat, large range of resistance sources are known in bread wheat types. Hailu (1991) also reported bread wheat is exotic crop to Ethiopia, and resistant cultivars to the wheat disease are developed through selection and crossing using genetic materials introduced from abroad, mainly from CIMMYT. It is therefore speculated that wheat production in Ethiopia threatened by the FHB epidemics.

Isolation of *Fusarium* species associated to wheat head blight

From 71 infected wheat fields more than 135 diseased wheat head samples were collected during the survey and the pathogens were isolated under aseptic conditions. Of this only 42 viable and well grown isolates were subjected for identification to species level based on their morphological and microscopic characteristics according to Nelson *et al.* (1983) and Leslie and Summerell (2006) identification keys. Four different *Fusarium* species viz. *F. graminearum, F. avenaceum, F. poae,* and *F.culmorum* that commonly found associated with wheat fields infected by FHB in the area as detailed in fig. 2 and table 3. Among these, *F. graminearum (42.9%)* is the most dominant species. This is followed by *F.culmorum (26.2%)* and *F. avenaceum* (19.3%) in the inspected areas. However, *F. poae* found in lesser frequency.

These were among the *Fusarium* species reported previously by Bekele (1990) during 1988 in major wheat growing areas of Shewa, Arsi, Bale and Gojam of Ethiopia. Kebede *et al.* (2020) also reported as these species commonly associated in Southwest part of Ethiopia during 2017 growing season and also reported as *F.graminearum* is the most dominant species in the area. Parry *et al.,* (1995) stated F. graminearum, F.culmorum are F. avenaceaum and F. poae, the major FHB causing species in the world. Many research reports showed *F.graminearum* is a prevalent species causing wheat FHB in the world (Goswami and Kistler, 2004; Osborne and Stein, 2007). Saharan *et al.* (2003) also stated as *F.graminearum* is the principal pathogen responsible for FHB in the world.

Conclusion and Recommendations

Fusarium head blight is a destructive disease that could pose major threat to wheat production by causing both quantitative and qualitative losses in West Shewa zone of Ethiopia. The frequent rainfall and optimum temperature during the wheat flowering stage in the area during 2019 main cropping season might provide conducive conditions for the epidemics to occur. The sporadic nature of the disease, mono-cropping system mostly practiced by farmers, informal distribution of seed, lack of awareness of farmers about the disease, lack of resistant/tolerant varieties to FHB are among factors that increase the disease epidemics in the area. Most the wheat cultivars currently under production in the zone exhibited susceptible reaction to the disease. Due to this the disease could pose threat to wheat production in the area. Therefore, intensive and extensive surveillance should be carried out across the major wheat growing agro ecologies in the country to develop disease distribution map and generate clear picture of the disease status and magnitude of losses; farmers should grow non-cereal crops before and after wheat and they should be trained on identification, importance and management of the disease. Integrated disease approach should be implemented as the frontline to reduce the disease problem.

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