Status of Fusarium Head Blight on Wheat Fields in Southwestern Ethiopia

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Abstract

The status of Fusarium Head Blight (FHB) was thoroughly assessed on 52 wheat fields from 5 districts within 3 zones of Oromia. The results showed that FHB was 93.9% prevalent with significantly varied incidences (among zones) and severity (among districts and zones). The highest incidence of 38.7 and 26.0% had been recorded in Buno-Bedele and Jimma zones. Correspondingly, the highest field-severity and FHB-index of 28.2 and 13.9% had been recorded in Buno-Bedele. Besides, the 2 mostly grown Danda'a and Digalu varieties were vulnerable to FHB sustaining 32.3 and 30.5% incidence, 21.8% and 21.7% field-severity, and 10.5% and 8.8% FHB-index. The variation in FHB intensity had influenced mainly by altitude, tillage frequency before sowing, and rainfall received during flowering to hard-dough stages. This study reveals evidence that FHB is becoming a potential disease to wheat in Southwestern Ethiopia (SWE). Thus, it demands an intervention to reduce its possible risk to wheat across SWE.

Key words – Fusarium head blight (FHB) – *Fusarium* spp. – *Triticum aestivum*

Introduction

Wheat (*Triticum* spp.) is the second most cultivated cereal crop in the globe, next to rice (FAO 2018). Ethiopia is the second-largest wheat producer next to Egypt in Africa (FAO 2018), with a total of 4.54 million tons produced on 1.70 million hectares of land with a national average yield of 2.68 t ha^{-1} (CSA 2017), below the global yield of 3.65 t ha^{-1} (FAO 2018). These are due to numerous factors, including biotic (pests), abiotic, technical and socio-economic, and climatic factors (Barron et al. 2003, Liu et al. 2008, Hailu et al. 2011, Mann & Warner 2015). Pests were the main constraints that caused crop losses in East Africa (Oerke 2006). Among them, fungal diseases like *Puccinia* spp., *Septoria* spp., and *Fusarium* spp. are the main constraints to wheat production in Ethiopia (Hailu et al. 2011). *Fusarium* head blight (FHB) of wheat was one of the biotic stresses that obtained the biggest concern (Tesfaye & Pim 2016).

Fusarium head blight is the most destructive fungal disease of wheat worldwide, particularly in humid and semi-humid wheat-growing areas (Martinez-espinoza et al. 2014, Lenc 2015). The disease is caused by up to 19 species (Liddell 2003). FHB pathogens infect several cereal crops, including wheat, barley, oats, rye, corn, canary seed, and forage grasses, but wheat, barley, and maize are the most affected crops (Clear & Patrick 2003, Kosová et al. 2009). Globally, the FHB of

wheat has emerged as a major threat to global food security (Goswami & Kistler 2004, McMullen et al. 2012). Infection of wheat kernels by FHB pathogens contributed to losses in grain yield and quality that includes poor seed germination (or blighted seedlings), shriveled kernels, reduced number of kernels per spike, low protein content in kernels, and low baking quality of wheat grains (Gärtner et al. 2008). In addition to crop losses, several *Fusarium* species can produce a range of mycotoxins in infected grains, making them unsuitable for animal and human consumption (Grabowski et al. 2012, Darwish et al. 2014).

In sub-Saharan Africa (SSA), there is a lack of information regarding the FHB epidemics and economic losses on wheat because of the underdeveloped research on the disease (Dweba et al. 2017). Particularly in Ethiopia, there is little information on FHB of wheat that reported the disease as one of the major wheat diseases at high altitude areas (Bekele 1985) and the 1988 cropping season as a scabby season with an incidence of 85% and severity of 5–80% (Bekele 1990). Besides, the disease was reported to cause yield losses of 60% and above under experimental conditions in the 1989 cropping season of Ethiopia (Snijders 1989). Less concern was given to the FHB of wheat in Ethiopia since then. In addition, the past efforts made on FHB do not enclose southwestern Ethiopia (SWE) (particularly Jimma, Buno-Bedele, and West-Wollega zones), where wheat is grown as one of the staple food crops. These three zones donated 4.89% of hectares and 3.52% of tonnes to the total wheat production of the Oromia region, Ethiopia (CSA 2017). Therefore, this study was aimed to assess the occurrence and extent of FHB on wheat fields across SWE.

Materials & Methods

Description of study areas

This study was conducted across SWE, namely in Dedo and Seka-Chekorssa districts of Jimma zone, Bedele and Gechi districts of Buno-Bedele zone, and Begi district of West-Wollega zone as shown in Fig. 1.
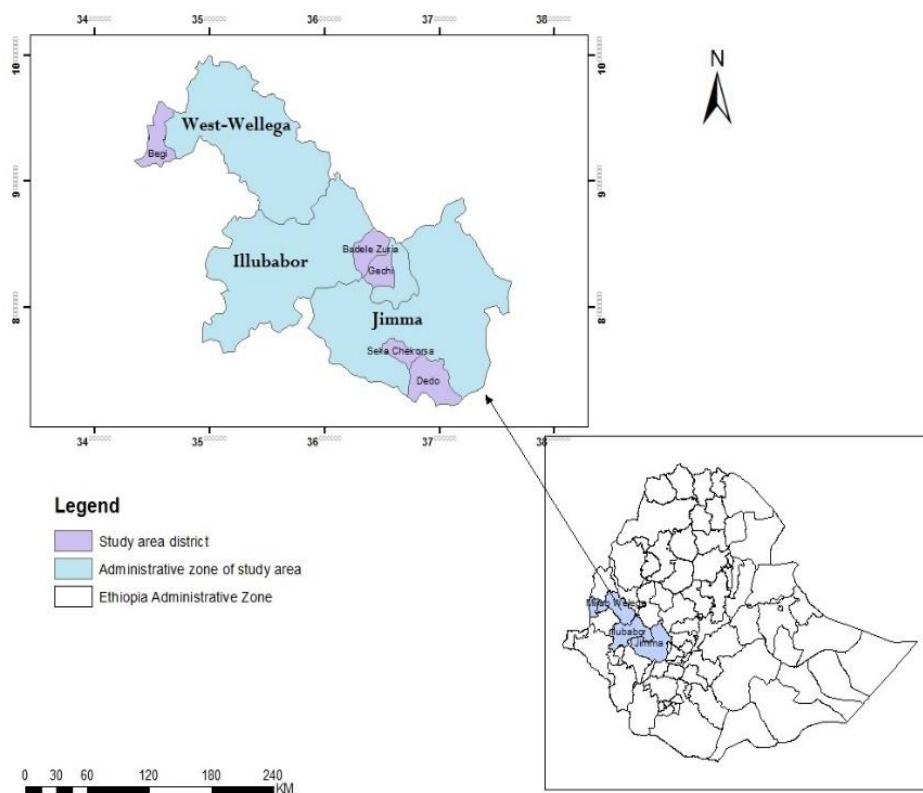

Fig. 1 – Surveyed zones and districts for FHB of wheat in SWE during 2017 cropping season.

Sampling method and assessment of FHB disease

The purposive multistage sampling method had used to choose wheat-producing zones, districts within zones, and *Kebeles* within districts. Random sampling was applied to select wheat fields in each *Kebeles*. In particular, potential wheat-growing districts and *Kebeles* had decided by consulting zonal agricultural bureaus and the district's agricultural and natural resource offices, respectively.

A field survey of FHB had carried out in 2017 during early milk to the hard dough wheat growth stages (Zadoks et al. 1974). Within the fields, disease assessment had made in four spots (each having 30 cm x 30 cm quadrat) along the diagonal of the field at random. All wheat spikes within the quadrat had been counted and visually examined for the presence or absence of FHB symptoms. Spikes had noted as diseased when a single spikelet had shown typical FHB symptoms (Fig. 2).
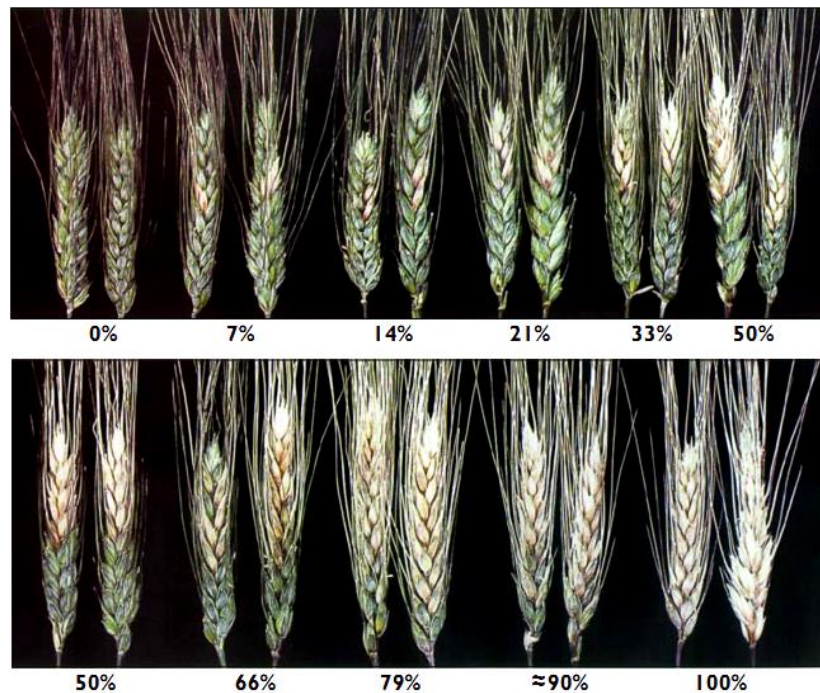
Fig. 2 – A visual FHB severity rating scale in wheat expressed in %.

Collected data

The incidence of FHB was recorded as the percentage of infected wheat spikes (Wegulo et al. 2008) per quadrat. Also, the severity of FHB had recorded on ten randomly chosen spikes per quadrat following the modified Horsfall-Barrett's scale (Stack & McMullen 2011). The severity had then partitioned to field severity (the average score of all assessed wheat spikes per field) and infected head severity (the average score of only infected wheat spikes per field) (Stack & McMullen 2011). Moreover, the FHB index (an estimate of overall disease intensity) was determined from the product of FHB incidence and field severity, divided by 100 (Wegulo et al. 2008). Finally, the prevalence of FHB across SWE had determined as a proportion of wheat fields with FHB infection out of all assessed wheat fields per district.

Agronomic practices such as previous crops, altitude, fertilizer applied, weed infestation level, source of seeds, wheat variety, planting pattern, and tillage frequency were recorded from each farm to determine the relationship with incidence and severity of FHB of wheat.

Data analysis

The three-stage nested design procedure in SAS 9.3 statistical software (SAS 2010) was used for the analysis of FHB Incidence, field severity, infected head severity, and FHB index data.

Means were separated using the LSD test at significance levels of 0.05. The associations of disease intensity with altitude and previous crop were computed using the CORR procedure of SAS 9.3 statistical software (SAS 2010). The relationship of FHB incidence and field severity (dependent variables) with independent variables was assessed using multiple regression of SAS 9.3 (SAS 2010). The three-stage nested model used in analyzing the data was described as follows:

$$y_{ijk} = \mu + \tau_i + \beta_{j(i)} + \gamma_{k(ij)} + \varepsilon_{l(ijk)}$$

Where: y_{ijk} is the FHB disease intensity where *"Kebeles"* k is nested within district J nested within zone i, μ is the overall mean, τ_i is the effect of the ith zone, $\beta_{j(i)}$ is the effect of the jth district within the ith zone, and $\gamma_{k(ij)}$ is the effect of the kth *"Kebeles"* within the jth district and i^{th} zone, and $\varepsilon_{l(ijk)}$ is the error term.

Results and discussion

Occurrences and extent of FHB across SWE

Fusarium head blight disease of wheat was found widespread across all inspected districts in SWE with an overall prevalence of 93.88%. At the district level, the disease was 100% prevalent in Seka-Chekorssa, Bedele, and Gechi, 91.70% in Dedo, and 80 % in Begi (Table 2). Analysis of variance showed that field severity and infected head severity of FHB had significantly differed (at $p < 0.01$) among zones, districts within zones, and *Kebeles* within districts and zones. In the same way, incidence and FHB index had shown a varying difference (at $p < 0.01$) among zones and *Kebeles* within districts and zones (Table 2).

The results indicated that FHB had observed varying incidences ranging from 0–100% in Jimma, 11.3–84.6% in Buno-Bedele, and 0–53.2% in West-Wollega zones during the 2017 main cropping season of Ethiopia (Table 2). The average FHB incidence in wheat fields was 38.69%, 26.00%, and 13.82% in Buno-Bedele, Jimma, and West-Wollega zones of the Oromia region, respectively (Fig. 3). At the district level, the higher FHB incidences of 38.7% in Gechi, and 38.6% in Bedele districts of the Buno-Bedele zone were recorded, followed by Dedo (26.6%) and Seka-Chekorssa (25.2%) districts of Jimma zone. In contrast, the lowest incidence had recorded from the Begi (13.8%) district of the West-Wollega zone (Table 2).
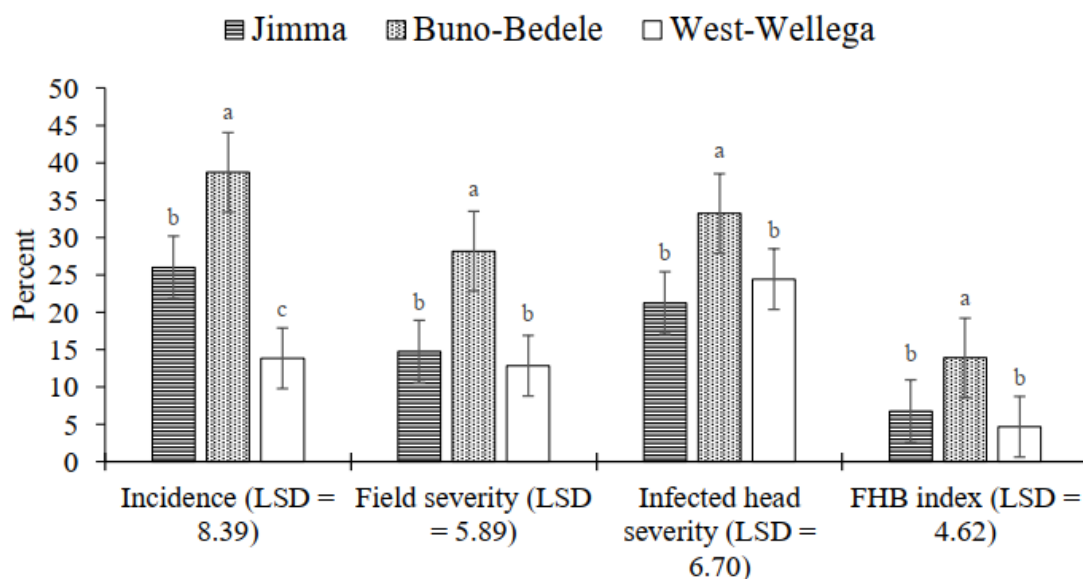
Fig. 3 – In three zones across SWE, the mean incidence, field severity, and infected head severity of FHB during 2017. Bars with a different letter for respective disease parameters are significantly different at $p < 0.0001$. LSD is the least significant difference; FHB is Fusarium head blight.

According to a survey conducted in 1988 cropping season of Ethiopia, FHB incidence of 0 to 35% was reported at farmer's fields in Holeta and Kulumsa areas, 0 to 56% at experiment stations, 0 to 57% at seed production fields, and 0 to 84% at state farms (Bekele & Karr 1997). Almost after 25 years, FHB disease of wheat had reported with an incidence of 10 to 47% at farmer's fields during 2014 main cropping season in Ari district of South Omo Zone, SNNPR, Ethiopia (Mitiku & Eshete 2016). These showed an increasing trend in FHB incidence over time in Ethiopia.

As illustrated in Fig. 3, the highest severities of FHB had recorded in the Buno-Bedele zone with field severity of 28.2%, infected head severity of 33.2%, and FHB index of 13.9%. These revealed that FHB was severe in the Buno-Bedele zone than Jimma and West-Wollega zones. On the other hand, statistically similar field severity, infected head severity, and FHB index had recorded in Jimma, and West-Wollega zones (Fig. 3). At district levels, the severity of FHB on wheat fields was high in the Bedele and Gechi districts of the Buno-Bedele zone. The average field severity was 30.1% in Bedele and 26.9% in Gechi districts of the Buno-Bedele zone. Also, higher severity of infected heads had observed on wheat crops grown in Bedele and Gechi districts (Table 2).

On the other hand, lower and statistically similar FHB field severities had been recorded in the Seka-Chekorssa, and Dedo districts of the Jimma zone, and in the Begi district of the West-Wollega zone (Table 2). Moreover, the FHB index ranging from 4.7% to 14.7% had been recorded on wheat fields across SWE (Table 2). The disease was severe in the Gechi and Bedele districts of Buno-Bedele, where the FHB index had been recorded with a magnitude of 14.7% and 12.6%, respectively (Table 2). The use of fungicide application was suggested in North America when FHB severity is above 10% (De-Wolf et al. 2003). Also, in Brazil, a 7% severity in a group of spikes at the dough stage has significantly reduced kernel weight per spike, 1000 seed weight, and kernel infection (Casa et al. 2004). In the current study, the average field severity of 12.8 to 30.1% at district levels (Table 2) indicated that FHB disease of wheat is high in all the assessed zones that need an intervention to minimize its probable risk on wheat in SWE.

Influence of agronomic practices on FHB of wheat in SWE

Results showed that FHB incidence was highly affected by the previous crop sown in the field, tillage frequency before sowing the wheat crop, and the wheat varieties cultivated in the study area (Table 3). In the same way, FHB field severities and infected head severities were also significantly influenced by the previous crop sown in the field, tillage frequency before sowing the wheat crop, the grown wheat varieties, and altitudes (agro-ecologies). Also, weed infestation levels and sowing pattern affected FHB field severity and infected head severity, respectively (Table 3).

As indicated in Table 3, seed sources such as AGP-II, Cascape project, local co-operative association, and agricultural offices were found to contribute more to the occurrence and severity of FHB disease of wheat across the three zones in SWE. The higher incidences had been obtained from wheat fields sown by seed provided by AGP-II (47.7%), Cascape project (40.9%), and local co-operative association (36.2%). Higher FHB field severity and infected head severity were obtained from wheat fields sown by seeds provided by AGP-II (36.4%) and the Cascape project (27.9%). Also, wheat seeds provided by agricultural offices had attributed to higher infected head severity in the study area (Table 3).

These might indicate the existence of varied infection levels of seed by FHB pathogens. Seed-Borne pathogens cause enormous crop losses by attacking seedlings and kernel infection (Kubiak & Korbas 1999, Gärtner et al. 2008). Therefore, the use of *Fusarium*-free wheat seeds as a seed source prevents the entry of *Fusarium* inoculum into the wheat field.

This study revealed that the preceding crops such as finger millet, wheat, maize, tef, and soybean had highly attributed to the occurrence and severity of FHB disease of wheat in Jimma, Buno-Bedele, and West-Wollega zones of Oromia region, Ethiopia. The higher incidences had recorded from wheat fields previously planted by finger millet (53.2%), wheat (36.2%), and maize (35.7%), followed by tef (29.1%), potato (24.01%), and soybean (14.2%). Also, higher field and infected head severities had been recorded on wheat fields previously cultivated by finger millet,

wheat, and maize with a magnitude of 40.2% and 48.7%, 36.8% and 44.6%, and 26.3% and 34.1%, respectively (Table 3). Several studies in other countries indicated that agronomic practices in the field such as preceding crops, crop variety, and tillage have an impact on the diversity and spread of *Fusarium* pathogens that caused FHB on wheat (Dill-Macky 2008, Fernandez et al. 2008, Katz 2008, Wegulo et al. 2015).

Table 1 Nested ANOVA table for mean squares incidence and severity of FHB

Source	Degree of freedom	FHB incidence	Field Severity	Infected head severity	FHB index
Model	47	2017.25**	1059.23**	1088.22**	580.06**
Zones	2	8645.28**	5460.81**	3857.87**	1703.43**
Districts (Zones)	2	55.41ns	662.33**	2012.06**	37.28ns
Error	175	166.9	85.10	165.70	44.05
Mean		**28.47**	**19.41**	**26.32**	**9.04**
CV (%)		**45.37**	**47.53**	**48.91**	**76.42**

[ns]not significant at p<0.05; ** significant at p < 0.01, FHB = Fusarium head blight, ANOVA = Analysis of variance

Table 2 Altitude ranges, prevalence (%), mean incidence (%) and severities (%) of wheat scab by districts in SWE (2017)

Districts	The altitude range of assessed fields	Prevalence	FHB incidence		Field severity		Infected head severity		FHB index	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
Dedo	2328–2613	91.7	0–100	26.6[b]	0.0–59.7	12.3[b]	0.0–59.7	16.7[c]	0–59.7	7.5[ab]
Seka-Chekorssa	2051–2462	100	7.6–44.2	25.2[b]	3.8–36.8	18.0[b]	10.7–44.6	27.3[b]	0.5–13.3	5.9[c]
Sub[Jimma]	**2051–2613**	**95.8**	**0–100**	**26.0**	**0.0–59.7**	**14.7**	**0.0–59.7**	**21.2**	**0.0–59.7**	**6.8**
Bedele	1949–2009	100	18–69.8	38.6[a]	17.4–45.4	30.1[a]	22.4–50.4	37.3[a]	3.9–22.5	12.6[ab]
Gechi	2140–2269	100	11.3–84.6	38.7[a]	3.9–48.3	26.9[a]	9.6–49.0	30.6[ab]	0.4–38.2	14.7[a]
Sub[Buno-Bedele]	**1949–2269**	**100**	**11.3–84.6**	**38.7**	**3.9–48.3**	**28.2**	**9.6–50.4**	**33.2**	**0.4–38.2**	**13.9**
Begi	1711–1951	80	0–53.2	13.8[c]	0.0–41.6	12.8[b]	0.0–53.7	24.4[bc]	0–21.3	4.7[c]
Overall	**1711–2613**	**93.9**	**0–100**	**28.5**		**19.4**		**26.3**		**9.0**
LSD				**10.3**		**7.2**		**8.2**		**5.7**

Mean values in a column with different letters are significant at p ≤ 0.05, LSD = least significant difference, FHB = *Fusarium* head blight, CV = coefficient of variation

Wheat and maize are the main hosts for *Fusarium* spp. that cause FHB in wheat (Kuhnem et al. 2015). Also, *Fusarium* spp. such as *F. graminearum*, *F. culmorum*, *F. moniliforme*, *F. sporotrichoides*, *F. oxysporum,* and *F. solani* were reported as seed-borne pathogens of finger millet in India verifies finger millet as a host for FHB pathogens (Penugonda et al. 2010, Sobha-Rani & Dorcas 2016). Besides, the soil-borne *Fusarium* spp. (*F. poae*, and other 21 *Fusarium* spp.) were also caused by a pathogenic effect on finger millet seedlings in Nigeria (Akanmu et al. 2013). Based on

these, the pathogenic *Fusarium* species responsible for FHB on wheat across the study area can survive saprophytically on finger millet residues. It might be because of this reason that higher FHB infection had been recorded on wheat fields previously planted by finger millet in the study area.

Maize (corn) as preceding crop, cereal rich rotation, and zero or minimal soil tillage were reported in favoring the spread of *Fusarium* infection on cereals (Fernandez et al. 2008, Wegulo et al. 2015). A greater FHB severity had been reported in wheat fields directly sown into corn residues when compared to those planted into soybean residue (Dill-Macky & Jones 2000). These implied the fact that preceding crops play a great role in promoting FHB severity on the succeeding wheat crop either by being a suitable host which increasing the inoculum levels within the field or by producing bulky crop debris suitable for the saprophytic survival (Dill-Macky & Jones 2000, Beyer et al. 2007).

According to the study conducted in Uruguay, higher colonization of *Fusarium* species had been observed on residues of wheat and barley than maize, but maize residues can be a source of primary inoculum for three years (Pereyra & Dill-Macky 2008). Remarkably, all the *Fusarium* species that cause FHB disease are capable of surviving as saprophytes (Parry et al. 1995) on a range of crop residues including corn, small grain cereals, and numerous other grass species and become a primary source of inoculum for FHB disease of Wheat (Keller et al. 2003, Dill-Macky 2008, Pereyra & Dill-Macky 2008).

A study on the effect of crop rotation on FHB development had reported a higher FHB incidence of 23.8% in soft winter wheat planted following corn-soybean rotation, whereas the lower incidence of 0.9–6.0% from soft winter wheat planted next to corn-pea rotation (Del-Ponte et al. 2003). Here we can observe that the FHB pathogen (*F. graminearum*) had also the capacity to survive on stubbles of field pea that would likely become a potential inoculum source reservoir for a wheat crop growing in the following year (Chongo et al. 2001).

Besides, viable spores originated from windblown infected residues of wheat or other hosts from one cereal field to the next (Phalip et al. 2006), transportation of infected crop residues and seeds to new areas (Government-of-Alberta 2018), and windblown viable aerial ascospores at lower atmosphere up to 182.88 m above ground from distant (over kilometers) that can settle through precipitation or gravitation (Maldonado-Ramirez et al. 2005) may act as a primary source of inoculum for wheat infection (Keller et al. 2014). As a result, wheat plants in fields without cereal residue may also develop FHB disease.

This study found that wheat variety Kubsa was highly infected by FHB, with a mean incidence, infected head severity, field severity, and FHB index of 43.1%, 39.0%, 32.7%, and 14.0%, respectively. Following Kubsa, variety Kakaba had shown higher infected head severity of 36.2%, but it had a moderate field severity of 18.0% (Table 3). Digalu and Danda'a varieties had FHB infections of 32.3% and 30.5% incidence, 21.8% and 21.7% field severities, 28.9% and 30.6% infected head severities, and 10.5% and 8.8% FHB index, respectively (Table 3). Similarly, higher severity of 40.1 % had previously been reported on Danda'a variety in the South Omo zone, SNNP, Ethiopia (Mitiku & Eshete 2016).

This investigation found that all the released bread wheat varieties grown in SWE have sustained FHB index ranged from 5.0% to 14.0% (Table 3), while the highest and statistically the same FHB index of 14.0%, 10.49%, and 8.8% had recorded on Kubsa, Digalu, and Danda'a varieties, respectively (Table 3). These indicated that the 2 most popularly grown wheat varieties (Danda'a and Digalu) were vulnerable to FHB disease of wheat like that of Kubsa variety. These suggest that FHB could pose a major threat to wheat production across SWE in case an epidemic of FHB could occur. Therefore, the need to search for resistant wheat varieties from all available wheat genotypes for Ethiopia to intervene in the probable risk of FHB in the country is of great importance.

In contrast, lower mean incidence (14.2%), field severity (4.3%), infected head severity (9.3%), and FHB index (0.8%) had been recorded on *Triticale* cultivar across SWE (Table 3). *Triticale* cultivars found across SWE can grow more than 150 cm tall. According to the study

conducted during 2013 and 2014 in Ottawa, Ontario, Canada, taller eastern spring wheat varieties were showed a strong negative relationship with the FHB index, meaning that the spikes of the taller plants were less prone to FHB propagules. Also, the microclimate of taller plants is less favorable to FHB disease due to lower relative humidity (Moidu et al. 2015). It might be because of this that the *Triticale* is less vulnerable to FHB infection in SWE. These demand an additional investigation to confirm whether plant height or other traits had been attributed to less FHB infection on *Triticale*.

Table 3 The effect of altitude and agronomic practices on the mean intensity of FHB during 2017 on wheat fields in SWE

Agronomic practices	Class	Proportion of fields (%)	DI[a] (%)	FS[b] (%)	IHS[c] (%)	Agronomic practices	Class	Proportion of fields (%)	DI (%)	FS (%)	IHS (%)
Previous crop	Barley	5.8	5.9[cd]	2.1[d]	7.6[e]	Altitude ranges of assessed fields	1711 – 2269	73.1	29.6	22.8[a]	32.2[a]
	Faba bean	5.8	11.0[cd]	6.2[cd]	12.3[de]		2328-2613	26.9	25.5	11.8[b]	17.6[b]
	Finger millet	7.7	53.2[a]	40.2[a]	48.7[a]		**LSD**		**NS**	**8.9**	**9.7**
	Field pea	3.9	12.6[cd]	9.2[cd]	16.7[cde]	Planting date	July	48.1	31.0	17.7	24.6
	Maize	19.2	36.9[ab]	26.9[ab]	34.3[a-c]		August	51.9	22.9	19.5	29.2
	Potato	3.9	24.0[bc]	5.1[cd]	11.9[de]		**LSD**		**NS**	**NS**	**NS**
	Sorghum	5.8	0.0[d]	0.0[d]	0.0[e]	Weed infestation [j]	Low	57.7	24.3	19.0	28.5[a]
	Soybean	3.9	14.3[b-d]	12.8[b-d]	42.7[ab]		Medium	30.8	34.1	21.2	27.9[ab]
	Tef	28.9	28.9[bc]	19.4[bc]	28.0[bcd]		High	11.5	19.7	9.9	16.4[b]
	Wheat	15.4	36.2[ab]	36.8[a]	44.6[ab]		**LSD**		**NS**	**NS**	**11.6**
	LSD		**23.9**	**16.4**	**18.8**	Source of Seed	AGP-II [d]	13.5	47.7[a]	36.4[a]	40.8[a]
Tillage frequency before of sowing	2 times	9.6	5.0[c]	4.1[b]	14.0[b]		AgrOff[e]	36.5	25.4[bc]	20.7[b]	31.1[ab]
	3 times	26.9	22.4[b]	18.5[a]	29.8[a]		AsARC [f]	13.5	2.8[d]	2.7[d]	14.9[cd]
	4 times	28.9	31.0[ab]	21.2[a]	26.2[a]		Cascape-JU [g]	9.6	40.9[ab]	27.9[ab]	33.1[ab]
	5 times	34.6	36.2[a]	21.6[a]	26.2[a]		Farm saved	13.5	14.2[cd]	4.3[cd]	9.3[d]
	LSD		**9.4**	**6.4**	**7.4**		LC [h]	13.5	36.2[ab]	18.9[bc]	25.1[bc]
Sowing pattern	Row	73.1	28.5	21.2[a]	31.4[a]		**LSD**		**20.2**	**14.7**	**14.7**
	Broadcast	26.9	22.8	12.1[b]	19.6[b]	Fertilizer application (Kg ha^{-1})	Unfertilized	34.6	22.0	16.1	26.1
	LSD		**NS**	**8.4**	**9.1**		25 – 50	25.0	32.6	19.1	25.0
Wheat varieties	Danda'a	50.0	30.5[ab]	21.7[b]	30.6[a]		100	40.4	27.3	20.5	28.8
	Digalu	25.0	32.3[ab]	21.8[b]	28.9[a]		**LSD**		**NS**	**NS**	**NS**
	Kakaba	6.3	15.2[c]	18.0[bc]	36.2[a]						
	Kubsa	6.3	43.1[a]	32.7[a]	39.0[a]						
	Triticale	12.5	14.2[c]	4.3[c]	9.3[b]						
	LSD		**13.0**	**8.9**	**10.5**						

Mean values with the same letter within a column did not significantly differ at p < 0.05; LSD = least significant difference; FHB = *Fusarium* head blight; [a]DI is disease incidence; [b]FS is field severity; [c]IHS is infected head severity; [d]The second agricultural growth program of Ethiopia; [e]Agricultural offices of the respective districts; [f]Assosa agricultural research Centre; [g]Cascape projected implemented by Jimma University; [h]local cooperative in Dedo district; [i]areas with 1500–2300 is cool sub-humid

(*Woina-dega*) and 2300–3200 cool and humid (*Dega*) (MOA 1998); [j]Weed infestation was recorded as low (for low weed infestation); medium (moderate weed infestation) and high (no weeded fields).

In SWE, higher FHB incidences and severities were recorded from wheat fields tilled 3 to 5 times by the traditional ox traction system ahead of wheat seeding (Table 3). The traditional land tillage practiced in Ethiopia does not bury all the left-over crop residues into the soil. Also, farmers usually left crop residues in the field as it is or collected them together in small humps within the field. Those left-over remnants may serve for the saprophytic survival of FHB pathogens, which could be a source of primary inoculum for the following cropping season. Even the more intensive tractor plowing did not decrease FHB incidence as compared to conventional tillage, reasonably due to the returning effect of buried crop residues onto the soil surface (Lenc 2015). To overcome this, inverted tillage (moldboard) for land preparation had recommended to buried the *Fusarium*-infected crop residues deep into the soil in developed countries (Dill-Macky & Jones 2000, Pereyra et al. 2004, Lenc 2015, Hofgaard et al. 2016).

Relationship of FHB incidence and severity with independent variables
Analysis of multivariate linear regression revealed that 28.3 % variability in incidence and 31.3% variability in field severity had explained by nine explanatory variables (Table 4). The information brought by the total explanatory variables was not significantly better than what a basic mean would bring for both incidence and field severity (Table 4). However, the tillage frequency ahead of seeding wheat brings significant information to explain the variability in FHB incidence and field severity. Similarly, altitude brings significant information to explain the variability in field severity across SWE. Furthermore, 15.3% of the variability in incidence and 14.0% of the variability in field severity were explained significantly (at $p < 0.05$) by the total rainfall that occurred during wheat flowering to hard dough stages (Table 4). Therefore, the frequency of tillage ahead of seeding wheat, altitude, and the total rainfall that occurred during flowering to hard dough stages were the most influential variable in explaining the variability of FHB in SWE (Table 4).

Table 4 Multiple regressions for wheat scab incidence and severity on independent variables in SWE (2017) main cropping season

Independent variables	FHB incidence			FHB field severity		
	Coefficients	Type-III SS	P-values	Coefficients	Type-III SS	P-value
Intercept	-13.26	-	-	-23.46	-	-
Altitude (m)	11.90	448.14	0.317	14.86	698.17	0.042
Wheat variety	0.49	6.87	0.901	-1.24	44.69	0.657
Source of seed	-1.78	99.59	0.635	-0.25	1.98	0.925
Frequency of tillage	9.30	2878.02	0.014	6.13	1248.37	0.023
Sowing date	-2.28	42.07	0.758	4.65	175.24	0.381
Sowing pattern	-4.51	104.97	0.626	-2.23	25.68	0.736
Previous crop	2.14	364.40	0.366	0.63	31.53	0.709
Weed infestation	-6.69	750.18	0.197	-6.62	735.28	0.077
Fertilizer application	0.06	304.08	0.409	0.03	88.50	0.533
R^2		28.3 %			31.3%	
Adj. R^2		11.8 %			15.4%	
Pr > F		0.118			0.069	
Intercept	-5.60			-4.08		
Rainfall [a]	0.044	3619.35	0.006	0.03	1773.28	0.008
R^2		15.3%			14.0%	
Adj. R^2		13.4%			12.2%	

[a]The total rainfall from August to November 2017 during the period when wheat was flowering to hard dough stages; FHB = *Fusarium* head blight; SS = sum of squares

The risk of FHB disease had linked with the prevailing weather conditions such as warm and humid conditions during flowering (Xu 2003, Popovski & Celar 2013). During the flowering to soft dough stages of wheat growth in SWE (from August to November 2017), the temperature has ranged from 11.8 to 25.9°C, and the precipitation had ranged from 40.68 to 323.58 mm. These favor the infection of wheat spikes as FHB infection had favored by the frequent rainfall, high humidity, and heavy dew during flowering to soft dough stage (Osborne & Stein 2007, Popovski & Celar 2013, Nazari et al. 2018, Schöneberg et al. 2018).

Conclusions

Fusarium head blight disease of wheat is becoming a significant fungal disease of wheat across SWE, particularly in the Buno-Bedele zone of the Oromia region. As well, severe FHB disease has occurred on high-yielding improved bread wheat varieties as compared to the *Triticale* variety. In SWE, the incidence and field severity of FHB on wheat was mostly influenced by the tillage frequency ahead of seeding wheat, altitude, and the total rainfall that occurred during flowering to the hard dough stages. Therefore, due emphasis will be obliged to manage the FHB of wheat across SWE. To reduce the effect of FHB disease on wheat production management strategies will focus on the use of *Fusarium* free wheat seed, fungicide efficacy evaluation, and screening of bread wheat genotypes for FHB resistance. Also, FHB surveillances will be demanded to know the pathogen diversity (based on their phylogeny) and to determine the associated mycotoxins.

Declaration of interest:

The authors have not declared any conflict of interest.

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