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Review on the Status and Management Strategies of Fusarium Head Blight (Fusarium Graminearum) of Wheat

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Abstract – **Wheat (Triticum aestivum L.) is counted among the most commonly cultivated cereal crops with over 600 million tons harvested each year. It was already cultivated over a wide range of climates with year round production. It is ranked as the third largest grain crop after corn and rice in terms of world production. In Ethiopia, wheat is one of the major cereal crops grown. It is an important crop commodity, which could contribute a major part in achieving the country's agricultural policy objective of food grain self-sufficiency. The most important constraints affecting wheat production include drought, diseases, insects and weeds. Diseases are the major limiting factors in wheat production, decreasing the yield, quality and profitability for producers. Fusarium head blight (FHB or scab) is common and damaging fungal disease of wheat that causes losses up to 70% and quality and contaminates harvested grain with mycotoxins. It is a serious problem in wheat cultivation. Fusarium head blight (FHB) is caused by one or more Fusarium species, mostly by F. graminearum (Schwabe). FHB infections cause problems concerning the quality of harvested wheat seeds by producing a variety of mycotoxins, of which deoxynivalenol (DON) is perhaps the most famous. If present in food or feed, DON can result in serious health problems. Moreover, the seeds infected with Fusarium not only have a lower 1000 grain weight but also the present Fusarium fungi can infect the seedling after sowing, thus causing less dense plant stand due to seedling blight. In certain years, the availability of uninfected seeds may be limited due to the widespread nature of FHB epidemics. The improvement of FHB resistance has become a major breeding objective worldwide. Environmental conditions have a huge influence on disease development and if prolonged humid weather persists after initial infection, severe FHB will occur. Favorable temperatures for the production of ascospores and macro conidia vary between 16°C to 36°C. Temperature is not the only primary weather condition that determines the severity of the disease, as precipitation appears to be critical in disease development. Individual management options are unlikely to fully protect crops from FHB, therefore multiple strategies (land preparation, varietal resistance, rotation, and fungicide application) provide the best means of maintaining yield potential, reducing the risk of mycotoxin contamination, protecting quality, and enhancing producer returns, but it is difficult due to confounding environmental conditions.**

Keywords **– Fusarium, Management Practices, Mycotoxin, Wheat.**

I. Introduction

Wheat (*Triticum aestivum L.*) is counted among the most commonly cultivated cereal crops with over 600 million tons harvested each year (Priyamvada *et al.,* 2011). Wheat was already cultivated over a wide range of climates with year round production about 10, 000 years ago as part of the Neolithic revolution that was distinguished as a period of transition from hunting and gathering food to one of settlement and agriculture (Gupta *et al*., 2006; Shewry, 2009). Wheat is well adapted to harsh environments, from severe dry to cold conditions, compared to other major cereal crops (Schery, 1969). The center of origin of wheat is presumed to be near present day Turkey. Findings suggest that wheat was grown in the Nile Valley around 500 B.C. and had extended through India, China, and England during the same time (Schery*,* 1969).

It is ranked as the 3rd largest grain crop after corn and rice in terms of world production (653 million MT annually) (FAO*,* 2012a). China, India, USA, Russia, and France are the leading wheat producing countries; the US ranks third among these (FAO*,* 2012b). It is the principle cereal crop grown in the US, ranking third both in terms of quantity (60 million MT), value ($8.5 billion) and total exports after corn and soybean (FAO*,* 2012c). The US is the largest exporter of wheat in the world, which exports 50% of its total annual production (FAO*,* 2012d).

Ethiopia is the 2nd largest producer of wheat in Sub-Saharan Africa. In Ethiopia, wheat is one of the major cereal crops grown between 6 and 14°N latitudes; and between 35 and 42°E longitude ranging in altitude from 1500 m to 3200 m. The most suitable regions, however, fall between 1900 masl and 2700 masl. It is the fourth most important cereal crop in Ethiopia. In area of production, it ranks 4th after teff, maize and sorghum and in total grain production, it also ranks 4th after maize, teff and sorghum. In productivity, it ranks second to maize. It is an important crop commodity, which could contribute a major part in achieving the country's agricultural policy objective of food grain self-sufficiency.

The current total area of production of both durum (*Triticum turgidum* var. *durum*) and bread wheat (*Triticum aestivum*) is about 1,627,647.16 ha with an annual production of 34,347,061.22 quintals (CSA, 2012/2013). Its productivity (21.10 q/ha) is still below the world average (65.5 q/ha) (FAO, 2013).

Wheat is used for consumption by both humans and animals (Han *et al.,* 2005). From direct use, wheat provides more than 35% of dietary calories in the developing world and 74% in the developed countries (Shiferaw *et al.,* 2013). It is predicted to remain an important crop with about 68% of the produce earmarked for direct consumption by the year 2020 and its worldwide consumption is projected to be about 746 million tons in 2020 (BFAP, 2011*).*

The most important constraints affecting wheat production include drought, diseases, insects and weeds (Shewry, 2009). One of the major limiting factors in wheat production is diseases, decreasing the yield, quality and profitability for producers. Fusarium head blight (FHB or scab) is common and damaging fungal disease of cereals that causes losses in grain yield and quality and contaminates harvested grain with mycotoxins (Buerstmayr *et al.,* 2003). It can cause yield losses up to 70% under favourable conditions (Bai *et al.,* 2000). FHB, white heads and pink mold, is mainly caused by, *Fusarium graminearum* Schw., with perfect stage of *Gibberella zeae* (Schw.) Petch., Seventeen different *Fusarium* species have been associated with the disease. Among these, *Fusarium graminearum* is the most internationally predominate, which is followed by *F. culmorum* (W.G. Smith) Saccardo and *F. avenaceum* (Parry *et al.,* 1995*;* Ruckenbauer *et al.,* 2001*).*

FHB is an important disease throughout the wheat growing areas of the world. The disease is more severe when wheat is sown in the residue from a previous host crop such as maize (*Zea mays L.*), followed by warm humid conditions during flowering. It was first reported in 1884 in England (Arthur, 1891) and was recognized as a key problem of wheat during the early twentieth century (Stack, 2003) and it is one of the most destructive diseases of wheat worldwide *(*Osborne and Stein, 2007*).*

The importance of *Fusarium* species is related not only to the diseases produced to infected plants but also to mycotoxin biosynthesis (trichothecenes) and accumulation in infected plant material. *F. graminearum* strains usually express one of three sets of trichothecenes – nivalenol and its derivates (NIV chemotype), DON and 15-acetyl deoxynivalenol (15-ADON chemotype), and DON and 3-acetyl deoxynivalenol (3-ADON chemotype) (Ward *et al.* 2002). The disease negatively affects yield and grain quality by damaging wheat kernels and contaminating the grain with mycotoxins (Gilbert and Tekauz, 2000).

Moisture appears to be the most important environmental factor influencing the severity of infection caused by *F. graminearum* in small grain cereals, given that fusarium head blight development can occur at temperatures that range from approximately 9°C to 30° C (Anon. 2011; de Wolf *et al.,* 2000*)*. Generally, the disease is more important in warm and humid areas (Dubin *et al.,* 1996). In the field, (FHB) is recognized by premature bleaching of infected spikelet and the production of orange, spore bearing structures called sporodochia at the base of the glumes. During wet weather, there may be whitish, occasionally pinkish, fluffy fungal growth on the infected heads in the field

To minimize the severity and incidence of FHB and DON content different management strategies, Cultural practices (tillage, rotation, nutrient management), Host plant resistance, Biological control (Trichoderma, Bacillus) (Da Luz et al., 2003) Fungicides (Prothioconazole, Tebuconazole) (Baturo Ciesniewska et al., 2011) are recommended.

II. Objectives

- ✓ Review on the impact of Fusarium head blight on wheat grain and quality.
- ✓ Review on the management strategies of fusarium head bligh.

III. Discussion

3.1. Distribution

F. graminearum is cosmopolitan. It has been reported wherever wheat is grown (Goswami and Kistler, 2004), and infection has reached epidemic proportions in the United States over the last decade (O'Donnell *et al.,* 2000). *Fusarium graminearum* persists within all of central Europe and south western Russia, and infects wheat fields grown along the eastern coast of China, and further inland where irrigation is used (Hope 2005; Qu *et al.,* 2008). It is also one of the important diseases of wheat in Ethiopia (Mengistu *et al.,* 1991). The incidence and severity of Fusarium head blight (also called *Gibberella zeae*) has increased worldwide (Xu*,* 2003).

3.2. Causal Agent

3.2.1. Cultural Characteristics

F. graminearum in agar culture appears gray, pink, brown, or burgundy. The temperature optimum for growth in culture ranges from 23-29^0 C.

3.2.2. Microscopic Structure

F. graminearum produces asexual spores known as macroconidia. It is slender, thick-walled, curved to straight, tapered at both ends, with five to seven septa or partitions (fig. 1). Globes chlamydospores (thick-walled asexual resting spores) are produced mainly in macroconidia, but may also form in mycelia. Chlamydospores are one means by which *F. graminearum* survives unfavorable conditions.

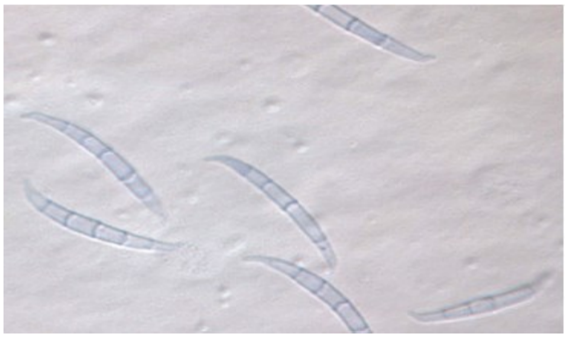

Fig. 1. Macroconidia of F. graminearum

Source: M S Saharan, 2001. The sexual stage of *F. graminearum* (*G. zeae*) produces perithecia (sexual fruiting structures) superficially on wheat heads. Perithecia are dark purple or black and form abundantly on corn stable as well as in culture perithecia can survive for more than 16 months on corn and wheat residue under field conditions. Within the perithecia, ascospores (sexual spores) develop within sacks known as asci (singular: ascus).

3.2.3. Host Range

F. graminearum survives on a wide range of hosts including not only living plants such as wheat, barley, oat, rye, corn, soybean, sorghum, rice, wild grasses and common weeds but also on dead tissue of many plant species (Shaner GE. 2003, Xu YG, Chen LF. 1993). Crop residues on the soil surface are the major reservoir of pathogens of FHB (Shaner GE. 2003). It can also cause disease in *Acacia* (Mill.), *Eucalyptus*, and carnation (*Dianthus caryophyllus* L.), (Urban, M., *et.al,* 2003).

3.3. Disease Development/ Cycle

F. graminearum overwinters as chlamydospores or mycelia in the soil or in host crop residues which serve as a source of primary (initial) inoculum in the spring. The fungus also can survive on wheat seed. *F. graminearum*, mycelium on crop debris produces sticky ascospores or macroconidia (Leplat *et al.,* 2012). By means of wind, rain, insects or rain splash, it reaches and infects the wheat ears (Goswami & Kistler, 2004; Shaner, 2003). Infections occur mostly during anthesis (stage at which anther rupture and shed pollen during flowering), partly because pollen and anthers serve as a food base for the germinating spores. During warm temperature and wet conditions, blight symptoms develop within two to four days after infection. Apparently healthy crop will shows symptoms suddenly.

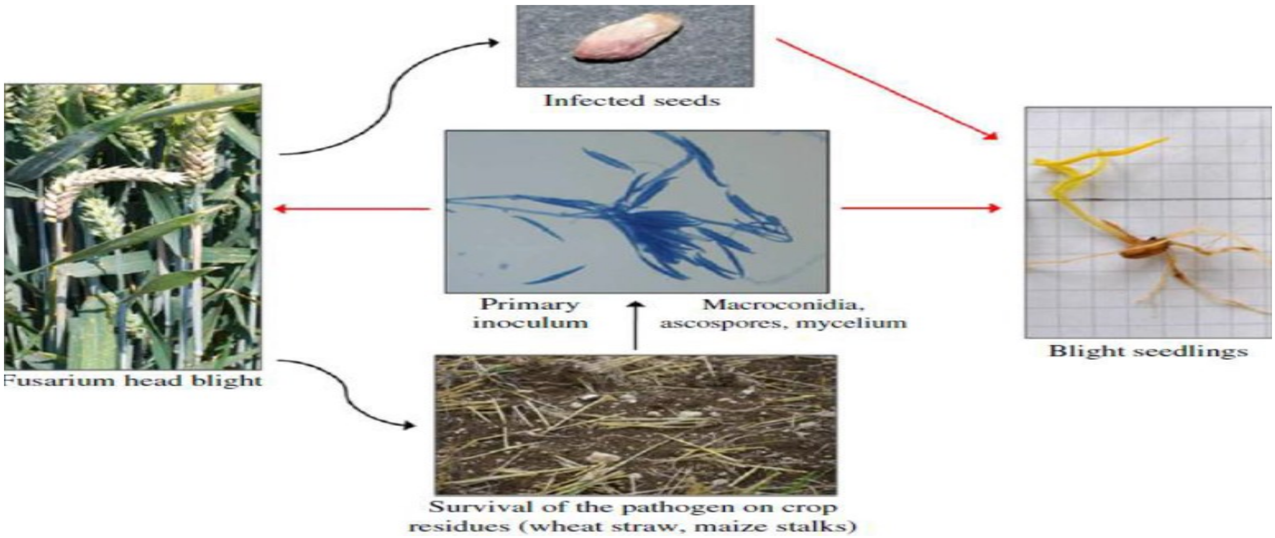

Fig. 2. Disease cycle of F. graminearum
Source: Leplat et al., 2012.

3.4. Symptoms

On immature wheat heads (spikes), one or more spikelet or the entire head appears prematurely whitened or bleached. Initial symptoms generally are visible near the middle of the head on the first florets but can occur anywhere on the head. Soon after infection, dark-brown, water-soaked spots appear on the glumes of infected florets. Later, entire florets become blighted. The dark brown symptoms usually extend into the rachis, even down into the stem tissue as the fungus spreads within a spike. The clogging of vascular tissues in the rachis can cause the head to ripen prematurely, so that even grains not directly infected will be shriveled owing to a shortage of water and nutrients (Bai GH. 1995). The bleached heads are readily visible in a green field. Partial bleaching of wheat head is a diagnostic symptom of FHB. Infection of the stem (peduncle) immediately below the head also may occur, causing a brown or purple discoloration. If the peduncle is infected early, the entire head becomes sterile. The fungus sporulates on infected spikelet and glumes during prolonged wet weather. This results in pink to salmon-orange spore masses, also diagnostic of FHB. Bleached spikelets are sterile or contain kernels that are shriveled and/or appear chalky white or pink. These kernels are often referred to as fusarium damaged kernels (FDK), scabby kernels, or tombstones. Apparently healthy kernels also may be infected, especially if infection occurred late in kernel development.

3.5. Economic Importance

3.5.1. Effect on yield

FHB can cause substantial economic losses. It can cause yield losses up to 70% under favorable conditions. Losses result from shriveled kernels with lighter weight (*Bai et al.,* 2000). In 1917, FHB caused losses estimated at 288,000 metric tons (10.6 million bushels) in 31 out of 40 states surveyed (Atanasof, 1920). In Paraguay the weather conditions in 1972 – 1975 favored FHB epidemics and accounted for losses up to 70% (Windels, 2000). To date, FHB continues to cause significant economic losses in the U.S. and other parts of the world. Epidemics of FHB result in devastating economic losses to the wheat industry and this suggests a need for more resistance sources (McMullen *et al*., 1997).

Table 1. Yield loss attributed by FHB

Country	Yield loss	Reference
USA	18.5%	Windels, (2000)
South Africa	40%	Kriel & Pretorius, (2008)
Paraguay	70%	Windels, (2000)
Uruguay	80%	Cludad Obregon, (1985)
Ethiopia	60%	Cludad Obregon, (1985)

3.5.2. Effect on Grain Quality

3.5.2.1. Grain Shriveling

The extent of damage to kernels depends on disease severity on wheat heads. Higher disease severity results in a larger extent of damage to kernels. Rubella and Kistler (2004) stated that toxin effects cause problems in marketing and processing of infected wheat grain. These significantly reduces milling quality by lowering flour yield and baking quality, increasing ash content, discoloring flour, and causing odors. The loaves of bread made with fusarium damaged wheat have an open texture and reduced volume, along with an ugly gray/ green cast. Human consumption of wheat or wheat products contaminated with high levels of DON may result in flu like symptoms, including fever, headaches, and vomiting (McCormick, 2003; Gale, 2003).

3.5.2.2. Mycotoxin

In addition to lowering grain yield and quality, *F. graminearum* is one of the group of fusarium species that produces mycotoxins. The primary mycotoxin associated with FHB is deoxynivalenol (DON). Human consumption of wheat or wheat products contaminated with high levels of DON may result in flu like symptoms, including fever, headaches and vomiting. Livestock may refuse to eat contaminated grain, which reduces weight gain (Tuite et al. 1990). Other mycotoxins associated with *F. graminearum* include, nivalenol (NIV) and T-2 toxin (McCormick, 2003; Gale, 2003). DON may frequently present at high concentrations, as high as 20 ppm in wheat. A recommended tolerance level of 1 ppm DON in grains for human use has been set by several countries, including the USA (Chu, 1997). An increase in mycotoxin content may even occur in postharvest if grain is inappropriately stored (Pirgozliev *et al.,* 2003). The toxins can also be leached out from infected plants by free water, possibly causing aquatic environmental pollution (Gautam & Dill-Macky, 2012). The United States Food and Drug Administration (FDA) has established some advisory levels for DON in food products for human consumption and feed grain feed to livestock.

Table 2. Deoxynivalenol (DON) Advisory Levels

Maximum Allowable DON Level	Consumer
1ppm	Humans
5ppm	Swine and all animal species (except cattle and poultry). Not to exceed 20% diet for swine and 40% for other animals
10ppm	Ruminating beef and feedlot cattle older than 4 months and poultry. Not to exceed 50% of diet.

Source: FDA advisoryies, 1982 & 1993.

3.5.2.3. Germination

Use of FHB infected seeds without treatment results in lower plant densities (Gilbert *et al.,* 1997; Bechtel *et al.,* 1985) due to a loss of viability, reduced emergence and post emergence seedling blight (Jones, 1999).

3.6. Disease Control

3.6.1. Cultural Practices

3.6.1.1. Tillage

Crop residues and weeds spp. (mainly quack grass, ragweed, buckwheat and mustards) left on the soil surface, enables the pathogen to over winter and these can therefore act as a source of inoculum. Hence, any tillage practices that bury, destroy or promote faster decomposition of residue from a host crop will reduce the potential inoculum for future host crop (McMullen & Stack, 1999). Where reduced tillage practices are used, maize residue is still abundant during the second spring after harvest of the maize crop, because maize residue lasts much longer than residue of small grains (Shaner, 2003).

Abundance of inoculum depends on how long the residue remains intact after harvest of the crop and how well the fungi survive in this residue (Shaner, 2003). To control FHB, early ploughing of cereal stubble and volunteer plants should be carried out wherever possible, since perithecia can only release inoculum from infested residue that is retained on the soil surface (Cook, 1981; Jones & Clifford, 1983). Jenkinson & Parry (1994) recognized the importance of weed control, especially annual broad-leaved weeds, as they suggested that a rise in FHB incidence is evident with increasing weed populations.

Table 3. F. graminearum colonies on per square meter of soil for different tillage systems

Treatment	FHB Incidence	DON level (ppm)
Mold Board Plough	63.5a	1 ppm
Chisel ploughing	71.8b	5 ppm
No tillage	70.8c	10 ppm

Source: Dill-Macky and Joneset, 2010.

3.7.1.2. Plant High quality Seed

Infested seed may be an additional source of inoculum. Planting high quality seed can minimize seedling blight. *F. graminearum* in or on buried seed may survive for at least 16 months (Inch and Gilbert, 2003b). However, a dry heat treatment of 70^0 C for 5 days was found to be an effective method of eradicating *F. graminearum* and other from wheat and barley seed (Gilbert *et al.,* 2005; Tekauz *et al.,* 2004).

3.7.1.3. Nutrient Status

Increasing fertilizer Nutrients application in the soil increases the FHB. Optimizing the use of nitrogen (N) might contribute to the control of FHB. Martin *et al.* (1991) observed that increasing N from 70 to 170 kg/ha significantly increased the incidence of Fusarium infected grain in wheat. Also Milev *et al.,* (2008) reported FHB being promoted by addition of inorganic fertilizer (120 kg N and P ha^{-1}) compared with non-fertilized controls.

Table 4. Effect of nitrogen fertilizer on FHB of wheat

Varieties	Amount of fertilizer applied (kg/ha)	Average number of infected ears on $5m^2$
Etida	150	17.3a
	100	15ab
	50	10.7c
	Control	10.3cd
Zvezdana	150	16.7a
	100	19.0a
	50	21.3a
	control	8.3b

Source: Martin *et al.,* (1991)

3.7.1.4. Rotation

Fusarium graminearum is not host specific and can be isolated from many species (Inch and Gilbert, 2003a; Pereyra and Dill-Macky 2008). A rotation involving maize, also a host of *F. graminearum,* should be avoided (Teich and Nelson, 1984; Krebs *et al.,* 2000; Schaafsma, 2001). Dill-Macky and Jones (2000) demonstrated a small but significant decrease in FHB severity and DON after planting wheat into soybean residues compared to residues of wheat or maize. Similarly, in a Swiss study, significantly less FHB developed on wheat sown into oilseed rape residues compared to maize residues (Krebs *et al.,* 2000).

Table 5. Frequency of fusarium head blight as influenced by crop rotation

Factor	No. of fields	Mean number of heads with symptoms per/100,000 plants
Previous crop		
Corn	36%	15.1a
Soybean	5.2%	7.1b
Wheat	7.2%	2.3b

Source: Schaafsma *et al.,* 2001.

3.7.2. Resistance

Breeding for resistance has been accepted as the most reliable strategy to minimize losses in yield and quality (Anderson *et al.,* 2001). This is mainly due to the difficulties related to the necrotrophic nature of pathogen and the particular pattern of pathogenicity. The resistance is multigenic and expression of resistance is dependent on the genetic background of the germplasm. Five resistance mechanisms to FHB in wheat were discussed by Mesterhazy (1995) with type I representing defence to first disease attack, type II representing defence to colonization, type III representing defence for accumulation of mycotoxins, type IV representing defence for kernel infection and type V representing tolerance. Availability of resistance genes for breeding FHB resistant cultivars can reduce losses to FHB disease (Shen *et al.,* 2003).

Type I resistance works against initial infection and is usually measured by the number of infected spikelet (Buerstmayr *et al.,* 2003). The most widely used defence mechanism is type II because it is easy to evaluate under monitored environments (Shi *et al.,* 2008). Other types of resistance are known to be present and protect some wheat lines despite the presence of FHB (McMullen *et al.,* 2008). According to Gilbert and Tekauz (2000) resistance types III, IV and V are difficult to manipulate and/or expensive to screen for and are not being used that often in breeding programs.

Table 6. Types of resistance for FHB

Type	Description
I	Resistance to initial infection (incidence)
II	Resistance to the spread of the fungus within the plant (severity)
III	Resistance to kernel infection. The rates of seed infection can differ at a given level of resistance as measured by disease severity
IV	Resistance against toxin accumulation disease
V	Tolerance to FHB where tolerant wheat maintain yield despite of the presence of the

Source: Mesterházy, 2003.

FHB resistance is a quantitative trait in wheat and is affected by environmental effects such as temperature, humidity, plant development stage and abundance of inoculum (Parry *et al.,* 1995; Ma *et al.,* 2006). The use of quantitative trait loci (QTL) analysis which identifies regions of the genome responsible for conferring resistance, has revealed that most QTLs explain a relatively small proportion of the variance associated with FHB disease traits (Buerstmayr *et al.,* 2009; Miedaner *et al.,* 2009).

3.7.3. Biological Control

Several microbial antagonists of *F. graminearum* have been identified which combined with chemical fungicides to reduce the amount of infection and DON contamination (Da Luz *et al.,* 2003). Microorganisms with potential to control *F. graminearum* on wheat includes bacteria such as *Bacillus* spp., yeasts, *Cryptococcus* spp. and filamentous fungi, *Trichoderma* spp. (Gilbert & Tekauz, 2000; Jochum & Yuen, 2001). Other strategies for biological control include the disruption of the fungal life cycle. Biological interventions must be aimed at disruption of spikelet infection and the movement of *Fusarium* within the rachis and reducing the survival of the fungus in cereal debris with subsequent ascospore production (Da Luz *et al.,* 2003). The fungus, *Clonostachys rosea* (Link: Fr.) Schroers, Samuels, Serfert and Gams (syn. *Gliocladium roseum* Bainier) has been shown to reduce FHB severity by 58%, FDK by 49% and DON by 21%.

Table 7. Effect of antagonistic microorganisms on colony size, head blight severity and kernel weight for F. graminearum in culture and when inoculated on to wheat ears.

Bio control	% Colony reduction	% FHB Severity reduction	% Kernel weight reduction	% DON content
Fusarium + Alternaria	51.5	76.0	44.7	91.4
Fusarium + Epiccocum	45.5	72.3	43.5	15.5
Fusarium + Trichoderma	64.1	59.7	41.0	113.8
Fusarium + Bacillus	52.0	80.5	44.7	69.0
Fusarium + Folicur	100.0	39.9	19.5	93.1
Fusarium + copper	100.0	52.9	26.1	76.7
Control	0.0	0.0	0.00	0.00

Source: Müllenborn, *et al*., 2007.

3.7.4. Fungicide

Fungicide application is one measure available to reduce the risk (Horsley *et al*., 2006, Baturo Ciesniewska *et al.,* 2011). Application of fungicides at flowering stage seems to be the best time for the reduction of Fusarium infection (Müllenborn *et al.* 2008). Triazole fungicides (tebuconazole and metconazole) were shown to be effective in reducing both FHB and DON production *(*Jennings *et al. 2000,* Edwards *et al. 2001*). Pirgozliev *et al.,* (2002) also showed a great reduction in FHB and DON in grain treated with metconazole, which indicates that this fungicide is very effective against *F. graminearum*.

Table 8. Effects of Fungicides on FHB and DON

Cultivar	Fungicide treatment	FHB		DON (mg kg -1)
		Incidence %	Severity %	
Common wheat	control	81.2c	73.7c	13.39c
	Prothioconazole	26.0a	26.2a	2.06a
	Prothioconazole + tebuconazole	23.8a	25.6a	2.29a
	Tebuconazole	48.2b	33.8ab	5.60ab
	Cyproconazole + prochloraz	43.5b	41.2b	5.92 b

Reference: Miriam Haidukowski1, 2012.

3.7.5. Integrated Disease Management

The best approach to managing FHB is to integrate multiple strategies (Mesterhazy, 2003; Gilbert & Tekauz, 2011) genetic resistance, cultural practices including crop rotation, tillage, seed treatment, fungicide application and biological control agents are recommended. Practices for suppressing initial inoculum, especially rotation of wheat with non-host crops like rape and soya bean and ploughing infected residues are advised for managing FHB. The most promising results have been observed under natural conditions by McMullen *et al.,* (2008) who demonstrated the incremental benefits of multiple strategies (varietal resistance, rotation and fungicide application) in reducing FHB severity and DON accumulation (Table 9).

Table 9. Effect of integrated management strategies (varietal selection, rotation, fungicide) on FHB severity, (DON) accumulation and yield of durum wheat

Integrated practices	FHB Severity%	DON ppm	Yield tonnes/ha
✍	34	3.0	3.3
❖	13	2.3	4.1
➢	6	1.9	4.2
◆	4	1.1	4.6

✍ Susceptible 'Monroe' durum planted in to wheat stubble.
❖ Susceptible 'Monroe' durum planted in to Canola stubble.
➢ Moderately resistant 'Divide' durum planted into Canola stubble.
◆ Moderately resistant 'Divide' durum planted into Canola Stubble and treated with foliar fungicide Prosaro (prothioconazole + tebuconazole).

Source: McMullen, 2008.

IV. Conclusions and Recommendation

Fusarium head blight is one of the economically devastating diseases of wheat in the world. Fusarium diseases of wheat cause significant losses worldwide and therefore are the most important factor in quality and economy sector. FHB is a difficult disease to manage so it is imperative to prevent the disease from becoming established in a field. Minimizing FHB can only be achieved through an integrated approach including cultivation practices, fungicide application and the use of resistant cultivars. However, more complete understanding of the pathogen and host mechanisms of resistance is certainly needed. The reduction of diseases and mycotoxin content in wheat is possible through the use of specific fungicides; however that does not guarantee complete elimination of the pathogen. Furthermore, pathogen populations may be resistant towards certain fungicides. Therefore, appropriate, efficient and environmentally friendly control measures to lessen such stresses need to be applied. Because of the economic importance of Fusarium infections and difficulty in FHB prevention, it is necessary to acquire profound understanding of the action mode of both the pathogens and the protective measures. This issue requires further study on the use of innovative methods of control. Best management practices for FHB include:

1. Use a tolerant variety
2. Under severe disease conditions even tolerant varieties will need fungicide application to Achieve acceptable control. Protect the flower from spore (conidia) infection by using a fungicide
3. Suspend irrigation prior to flowering until anthesis. This reduces spore dissemination from in crop residue.
4. Use tillage to incorporate the infected straw and destroy residue-borne inoculum.
5. If grain lots are identified with DON levels greater than 1 ppm, removal of the light weight infected kernels will often reduce DON levels.

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