

FUSARIUM HEAD BLIGHT AND CROWN ROT ON WHEAT & BARLEY: LOSSES AND HEALTH RISKS

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ABSTRACT: Wheat and Barley is the most production and consumption grains in the world. The necrotrophic *Fusarium* spp is pathogen caused many diseases on plants, the major two disease caused by *Fusarium* on wheat is *Fusarium* Crown rot (FCR) and head blight (FHB), also known as scab. These both disease caused severe damage on yield quality and quantity, and reduce yield up to 61%, as will produce mycotoxins in the grain, which lead to contamination the products that manufactured from these crops. The major FCR and FHB mycotoxins as DON, NIV, ZEN can caused many disease symptoms to consumers who consumes contaminate food, whether is human or animal, such as cancers, immunosuppression, fertilization problem, abortion and etc.

KEYWORD: Triticum spp, Hordeum vulgare, Fusarium, Mycotoxins.

INTRODUCTION

Wheat and barley is the major crops cereal produce in the word. The global statistics indicate that wheat production in the world for 2014-2015 was 707.2 million ton and for barley 135.65 million ton, which form the proportion of one-third of the world's total grain production (USDA, 2014; FAO, 2014)

Fusarium Crown Rot (FCR)

Crown rot (FCR) caused by many kinds of *Fusarium* spp as *F. pseudograminearum* and *F. culmorum* is a common pathogen to FCR while *F. gramineum* group I, *F. crookwellense*, *F. avenaceum* and *F. nivale* (Murray & Brennan, 1998; Dodman & wildermuth, 1987; Backhouse & Burgess, 2002; Scott et al, 2004). FCR disease infect the stem base of wheat and barley causing necrosis and dry rot of the crown bases always brown, often extending up 2-4 nodes, basal stem and root tissue commonly known as crown rot (Backhouse et al., 2004). In severe seasons Whitehead formation is wet start followed by dry climates, mycelium of the pathogen appeared in lower nodes during wet and moisture condition's Fig 1.

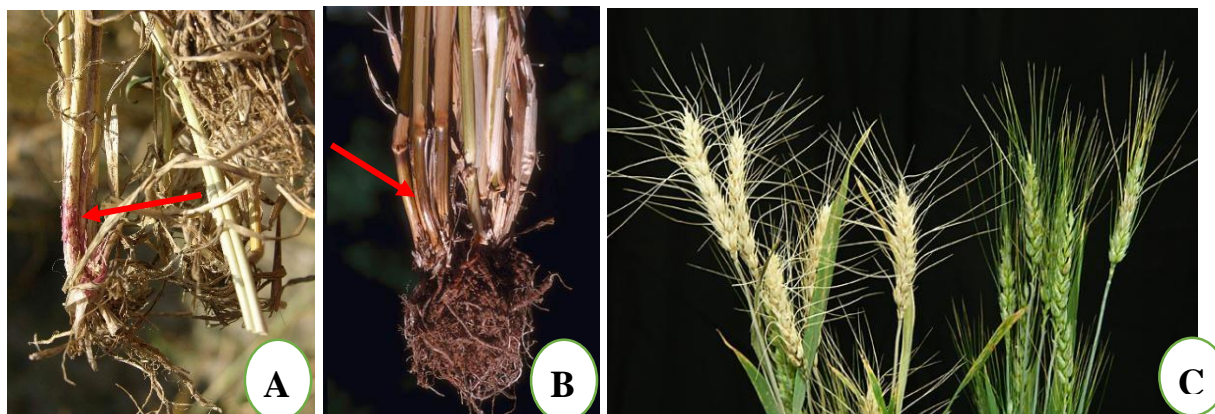
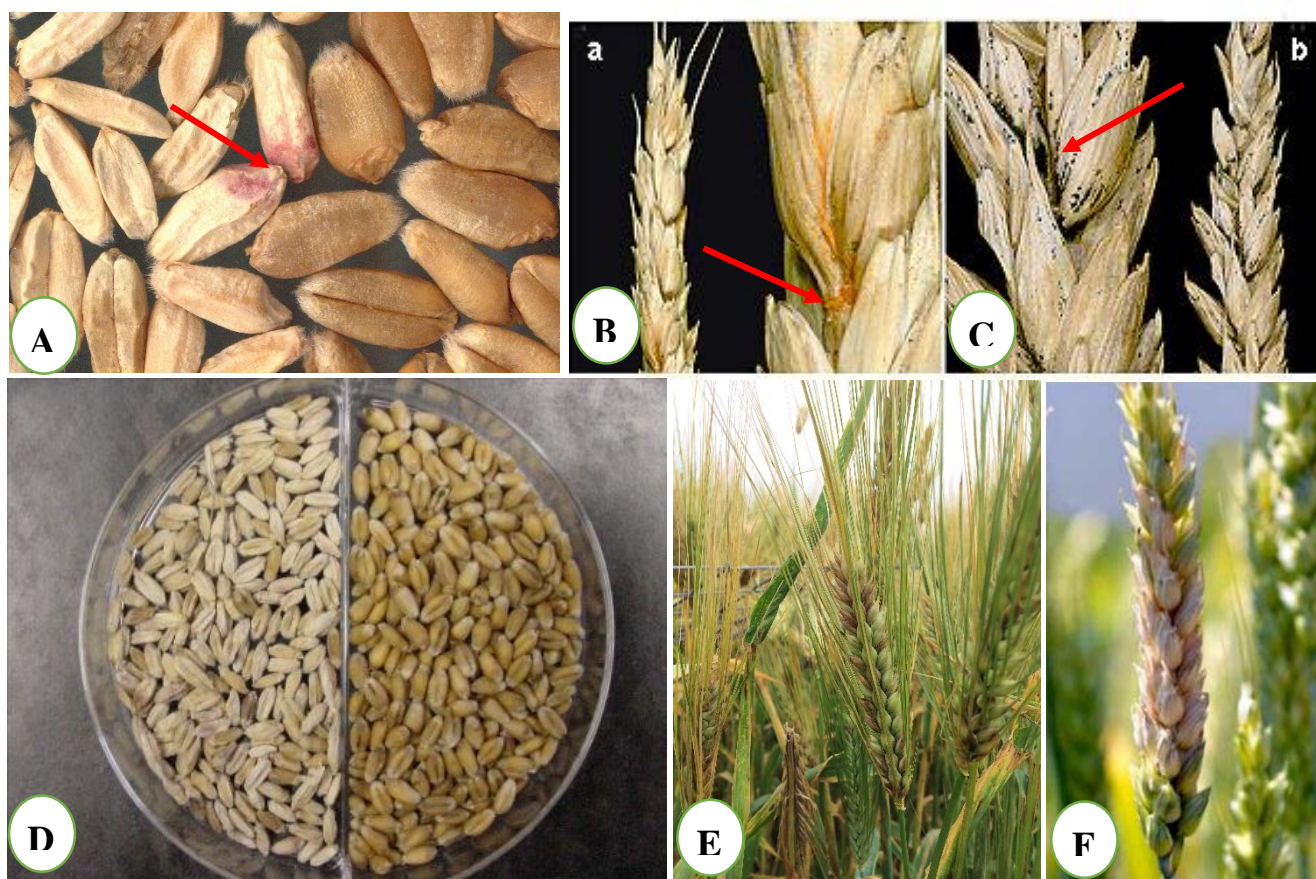


Fig 1. Different symptom and sing of Fusarium crown rot (FCR) on wheat. (A,B) Pink/red fungal mycelium and discolouration of stem bases. Photo by SIMMYT. (C) Whitehead symptom on spike right: non infected, left: infected (White head), Photo by Guihua Bai.

Fusarium Head Blight (Scab) (FHB)

FHB is caused by mainly fungus as *F. graminearum* group II (also known as *Gibberella zeae* sexual stage), *F. culmorum*, *F. poae*, *F. avenaceum* and *F. culmorum* (Snijders, 1994; Boutigny



et al., 2011). Other species, can caused the disease such as *F. langsethiae*, *F. poae*, *F. sporotrichioides*, and *Microdochium nivale* (formerly known as *F. nivale*) (Parry et al. 1995; Xu et al. 2005) Disease symptoms are confined to the head, grain, and sometimes the peduncle (neck). Typically, the first of FHB symptom is blighting of part or all of the spikelets while heads are still green. As the fungus moves up and down of infection point in spikelets that may be caused blighting all the spike. In barley the symptom is little different, infection spikelet is located and don't move in to rachis of spike. In the humid and wet condition, spore masses pink to orange are appeared in infection area (fig 2) (Wise & Woloshuk, 2004; Fernandez et al, 2000; Fernandez et al, 1999). Wet and warm weather during crop growing and maturation may favour to FHB (McMullen et al., 1997), and hot and dry conditions increase CR disease (Burgess et al., 2001).

Fig 2. Head blight symptom on wheat and barley caused by Fusarium (FHB). (A,D) small, shriveled pale white appearance and sometimes pink, infected (left) and healthy (right) Photographer by Department of Agriculture and Aquaculture Canada K. Lynch. (B,C) Orange sporodochia and Bluish black perithecia are formed at the base of the glumes, Photographer by Canadian Grain Commission . (E,F) Premature bleaching of Barley and wheat spikes.

Disease Cycle

The causal agent for FCR and FHB is interplay. Infection occurs when spores land on susceptible wheat and barley heads. In the flowering stage heads (spike) is the most susceptible to infection, If the flowers are infected after kernels appearance it will not develop. Spikelets in flowering stage that are infected later will produce creased seed. The seeds that infected by the pathogen in late stage may appear healthy, but be contaminated with mycotoxins. Fusarium crown and root rot can develop in the following season if infected seed (FHB) is planted. Also maize is one of the crops that infected by same *Fusarium* spp that infected wheat and barley, so cultivation wheat or barley near or after maize rotation will increase inoculation which led to high disease incidence fig 3 (Bushnell et al., 2003).

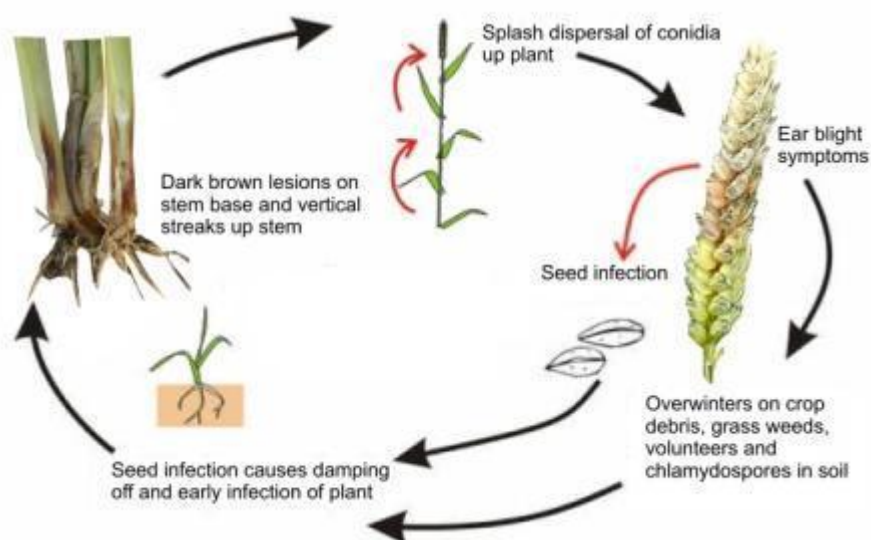


Fig 3. The typical life cycle of Fusarium in wheat Copyright: HGCA, UK

Yield Losses

Fusarium infection reduces quality and crop yield, both FHB and FCR become an endemic disease in wheat and barley grower's area in the world wide (Goswami & Kistler, 2004). *F. pseudograminearum* is the predominant CR pathogen in the 11million/ha wheat growing region in Australia (Backhouse, et al 2004) where, nearly \$80 million each year is lost from reduced grain yield and quality due to CR (Murray & Brennan, 2009). Both *F. graminearum* and *F. pseudograminearum* improved by bioassays that can caused equally severe CR disease (Akinsanmi, et al 2004).

In the Pacific Northwest of the United States, *F. pseudograminearum* can reduce winter wheat yield by up to 61% (Smiley, et al, 2005). While in during 1998–2000 FHB inflicted an estimated US\$ 2.7 billion loss due to reduced yield and price discounts from lowered grain quality in the northern Great Plains and central USA (Goswami & Kistler, 2004). It has been reported that FCR could reduce wheat yield by up to 35% in the Pacific North- West of the United States (Smiley et al, 2005).

Recent study found crown rot infestation causes an average of 25 percent yield loss in bread wheat and 58% loss in durum wheat across a wide range of environments in Australia, estimated annual yield loss of \$23 million Australian dollars per year in barley and in wheat and barley combined in Australia (Murray & Brennan, 2009; Nicol et al 2001).

The malting barley market in North and South Dakota, and Minnesota have lost 73% since 1993, with losses in Minnesota alone approaching 95%. In barley, losses have been calculated from 1993 to 1999 was totaling in excess of \$400 million (Windels, 2000). Since 1990 yield losses in wheat have exceeded 13 Tg (500 million bushels) with economic losses estimated at \$2.5 billion (Windels, 2000)

FCR losses in yield arising on grain heads will be partially or half filled (fig 2), or no grain in the head (preventing grain from forming in the heads of wheat) in severe infestation, as will reduction in grain quality and infected plants may also be contaminated with mycotoxins (Liu & Jill, 2009).

FHB can cause significant yield losses from floret sterility and light weight kernel are produced as a result of infection. Quality reduction may occur if the pathogen produces mycotoxins in seed face (McMullen et al 2008; Matny et al, 2012 a).

Mycotoxin Contamination and Risk

The mycotoxin risks connected with the consumption of contaminated forage, grain and straw by livestock must not be ignored (LBP. 2000, Matny 2013 (b)). Fusarium head blight (FHB) and crown rot disease in wheat and barley by spread and production spores in infected residue, in high humidity and frequent rainfall, the optimum temperatures for infection are between 75°F and 85°F (Burrows et al. 2012).

Chemically and thermally stable mycotoxin contaminants which give it the toxicity effects in animals and humans (Champeil et al. 2004). They can accumulate in the grain and, when contaminated grain is consumed via feed or food products, cause a potential risk to human and animal health (Pestka 2010). Matny et al (2012 b) found that most samples of animal feed that collected from market and animal farm in Iraq was contaminated with DON toxin at 722 µg/kg.

Toxigenic strains of *F. culmorum* have been divided into two types, the main type B trichothecenes produced that is DON and NIV chemotypes, strains of DON-types also produced AcDON (3-AcDON) (Miller et al., 1991; Gang et al., 1998; D'Mello et al., 1997), while strains of NIV-type were also able to produce FUS. In field trials, DON and NIV chemotypes exhibited different aggressiveness toward winter rye (Gang et al., 1998).

FHB in wheat is a widespread disease causing losses up to 25–50%, and high amounts of DON and its derivatives were frequently found in freshly harvested infected grains. In particular, a very high occurrence of DON incidence of 100%, range 7.25–36.25 mg kg⁻¹ was found on wheat affected by FHB predominantly caused by *F. graminearum*, associated with consistent levels of 4,7-dideoxy-NIV (0.16–1.25 mg kg⁻¹) (Leonov et al., 1990)

Most frequently encountered mycotoxins in field surveys in Europe infected wheat with FHB is deoxynivalenol (DON) and zearalenone (ZON) produced by *F. graminearum* and *F. culmorum* (Bottalico and Perrone 2002; Miller 2008; Matny 2013 a,b).

In Poland, samples collected from wheat naturally infected with *F. graminearum* and *F. culmorum* were found to be contaminated with DON and 3AcDON 100% and 80% respectively at very high concentrations up to 30.4 and 29.54 mg kg⁻¹ respectively, the levels of DON and 3AcDON in the chaff were 5-50 times higher than in kernels (Visconti et al., 1986).

Table 1. Mycotoxigenic species isolated from FHB of wheat in Europe. (Bottalico & Perrone, 2002)

Fungus Species	Mycotoxins
1. <i>F.graminearum</i>	DON, NIV, ZEN, AcDON
2. <i>F.avenaceum</i>	MON, ENS, BEA
3. <i>F.culmorum</i>	DON, ZOH,NIV, ZEN
4. <i>F.poa</i>	NIV, FUS, BEA, DAS
5. <i>F.equiseti</i>	DAS, ZOH, ZEN
6. <i>F.tricinatum</i>	MON
7. <i>F.cerealis</i>	NIV, ZOH, FUS, ZEN
8. <i>F.sporotrichioides</i>	T2, NEO, HT2, T2ol
9. <i>F.acuminatum</i>	T2, NEO
10. <i>F. subglutinans</i>	MON

AcDON = Monoacetyl-deoxynivalenols (3-AcDON, 15-AcDON); BEA = Beauvericin; DAS = Diacetoxyscirpenol; DON = Deoxynivalenol (Vomitoxin); ENS = Enniatins; FUS = Fusarenone-X (4-Acetyl-NIV); HT2 = HT-2 toxin; MON = Moniliformin; NEO = Neosolaniol; NIV = Nivalenol; T2 = T-2 toxin; T2ol = T-2 tetraol; ZEN = Zearalenone; ZOH = zearalenols (α and β isomers).

The could place accompanied epidemics infection with *F. sporotrichioides* and *F. poae* may be lead to occurrence of T-2 derivatives (T2, HT2, T2ol), and DAS and MAS, respectively in infected grain, NIV and FUS toxin has also been founded to correlative to the activity of *F. poae* and *F. cerealis* in Sweden and other northern countries in cereals from central to northeast Europe (Bottalico et al., 1990; Eriksen and Alexander, 1998).

MON was reported to be founded in freshly harvested durum wheat in Austria up to 0.88 mg kg⁻¹ (Adler et al., 1995). In all these surveys, the MON contamination in kernels was well correlated with the *F. avenaceum* infection (Kostechi et al., 1995).

Zearalenone is secondary metabolite produce by many Fusarium species, especially by *F. graminearum* and *F. culmorum*, this toxin has known as estrogenic properties, which means it can cause infertility, abortion, or other breeding problems. As little as 1 to 5 ppm zearalenone in a feed ration may produce an estrogenic effect in swine (Minervini & Maria, 2008).

Study done by Matny (2014) about companion Fusarium pathogens to FCR and FHB to wheat, it's found that *F. verticillioides* and *F. proliferatum* can produce with high amount of several kind of mycotoxin like DON, Fumonisin, ZEN and T2 toxin.

Economic Impact of Mycotoxins

Mycotoxins have significant economic impacts in many crops, especially in grain like wheat, maize, peanuts and other nut crops, cottonseed, and coffee. Each year 25% of the world's crops are contaminated by mycotoxins, with annual losses of around 1 billion metric tons of foods and food products, this statically were has estimated by FAO. The economic losses occur by mycotoxins is: yield loss because of diseases infections by toxigenic fungi, lower quality of crop value because of mycotoxin contamination, health problems to animal productivity from mycotoxin-related and human health costs. And there are additional costs like research and scientific studies. These impacts are effective on food and feed supply chains: farmers, grain handlers and distributors, processors, consumers, and society as a whole (due to health care

impacts and productivity losses). Reduced crop quality and quantity value is a significant related to the losses caused by mycotoxins. This affects crops entered into local trade as well as crops intended for export (Schmale, & Munkvold, 2014).

Fusarium head blight caused losses in barley producers in (1992-1997), upper Midwest of the USA more than \$364 million. Contamination of barley with Deoxynivalenol reduces barley quality, prices, and industrial characteristic of barley for malting and brewing, conditions of malting increased Fusarium growth, that lead to containing higher level of Deoxynivalenol. The malting and brewing industry in the U.S. had effects during 1994-1995, which paid and extra \$200 million to get non-infected grain from Canada (Dahleen 1997).

Mycotoxins losses costs estimation studies in US is dissimilar, one report show that \$0.5 to \$1.5 billion/year and another \$5 billion/year for the U.S. and Canada. Deoxynivalenol caused losses in crop production at \$655 million/year in US, the major losses in wheat, but in the developing countries, few estimates studies are available (Schmale, & Munkvold, 2014).

The most difficult to quantify impacts of mycotoxins is effected of human health. These effects mycotoxins act (single exposure) toxicoses and immunosuppression and chronic (repeated exposure) effects. In 1993 World Bank report that 40% of lost disability adjusted life years because of mycotoxins in the world, and \$900 million impact of mycotoxin in Southeast Asia, \$500 million of the costs were related to human health effects (Schmale & Munkvold, 2014).

Swine are the most effective by Fusarium mycotoxins, where Deoxynivalenol minimize feed intake, loss body weight. Studies showed that Deoxynivalenol also responsible on abortions, stillbirths, and weak piglets. Immunosuppression can caused increases infection and disease incidence and increases production costs (Pestka, 2007). Reproduction of swine have highly affects by Zearalenone toxin, it can caused a major economic effects in number of pigs offspring per sow per year. Based on 1991 prices, a study showed that 10 or 20% reduction in farrowing rate combined with a 10 or 20 % reduction in growth (as may occur if deoxynivalenol and zearalenone contaminated feed was consumed) would result in a 17 to 44% reduction in profit margins, due to costs increased feeding and veterinary per head, and a reduction number of pigs marketed (Charmley et al. 1995).

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