INTEGRATED DISEASE MANAGEMENT OF FUSARIUM HEAD BLIGHT, A SUSTAINABLE OPTION FOR WHEAT GROWERS WORLDWIDE

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ABSTRACT

Fusarium Head Blight (FHB) is a devastating disease of wheat (Triticumaestivum L.) worldwide, mainly caused by Fusariumgraminearum-telemorphGibberellazeae – leading to important yield losses, reduced seed quality and accumulation of mycotoxins such as Deoxynivalenol (DON) and Nivalenol (NIV) which are injurious to both human and animal health. Management of FHB and the associated mycotoxins have not been achieved by any single control measure. An integrated approach which includes resistant varieties, chemical and biological control and cultural control measures is critical to obtain the most efficient FHB management. The use of resistant varieties is very much welcomed by resource-poor farmers because it does not require additional cost and is environment-friendly.

INTRODUCTION

Integrated Disease Management (IDM) involves an extended knowledge about cropping systems as well as pathogen biology, host-pathogen interaction, crop`s life cycle and specific requirements for nutrients and environmental factors, combining different measures which can be divided into preventive measures (avoidance of pathogen source in neighborhood of field, soil suppresiveness, biological soil disinfection, catch crops, crop rotation, tillage, etc.), tactical preventive measures (choice of variety, seed quality, seeding time, crop structure, residue management, etc.) and control measures (physical, chemical and biological measures).

IDM can be defined as a decision-based process involving use of multiple tactics for optimizing the control of pathogen in an ecologically and economically way (Khokhar and Gupta, 2014). Beside biological, cultural, physical and chemical control strategies, monitoring environmental factors (temperature, soil moisture, air moisture, dominant wind speed, dew, temperature difference between day and night, soil pH, nutrients uptake, etc.) disease forecasting and establishing economic thresholds are important, too (Khoury and Makkouk, 2010). All these measures should be applied in a harmonized manner leading to maximize the benefits of each component of management scheme and to maintain disease pressure below an economic injury treashold.The greatest benefit of IDM is that disease control is greater than that achieved by individual method maintaining or increasing the cost-effectiveness of disease management program. Whatever the measures used must ne compatible with the cultural practices essential for the crop being managed.

Appearance of Fusarium Head Blight (FHB) in wheat and small grains is cause of concern especially for grain growers, livestock producers and processors due of the pathogen (*Fusariumgraminearum*Schwabe – telemorph*Gibberellazeae*Schwein) ability to completely destroy a potentially high-yielding crop within a few weeks of harvest and to contaminate grains with mycotoxins such as Deoxynivalenol (DON) and Nivalenol (NIV). These mycotoxins are injurious to both human and animal health (Desjardins, 2006).The Food and Drug Administration has set 1 ppm the maximum contamination limit in the food products fit for human consumption (Schmale and Bergstrom, 2003). However damage from FHB is multifold: reducing yield, discolored seeds, shriveled kernels, reduction in seed quality, test weight, difficulties on marketing because of lower market grade, etc. Control of this disease has been difficult because of the complex nature of the host-pathogen interaction. However, management of FHB and the associated mycotoxin DON have not been achieved by any single control measure. An integrated approach is critical to attending the best possible management of FHB and DON in any given environment.

Within FHB management scheme are four key-recommendations: monitoring scab risk, host-plant resistance, chemical and biological control and cultural control practices.

MONITORING SCAB RISK

For an efficient monitoring of disease incidence and development it is important to inspect wheat crop up to heading and flowering, especially under favorable environmental conditions. A warm, moist environment characterized by frequent precipitation or heavy dew is highly favorable to fungal growth, infection and development of disease in head tissues. Wheat is susceptible to head infection from the flowering period up through the soft dough stage of kernel formation. Previous research emphasized that environmental effects accounted 48% of the variation in deoxynivalenol (DON) across all fields, followed by variety (27%) and previous crop (14 % to 28%) (Schaafsama and Hooker, 2007). FHB risk should be assessed before to make a decision if a fungicide application is needed. The assessment should be done for each field and variety as they begin to develop heads in anticipation of flowering. For fields that have not yet begun to flower FHB monitoring is recommended.

RESISTANT VARIETIES

The use of genetic resistance is still the most economic and feasible mode of disease control. Cropping wheat varieties resistant to FHB is one of the most important components to diminish losses; although is no known immunity to this disease in wheat germplasm. Research efforts worldwide are focused in both breeding for host resistance to infection (Type I) and spread of the pathogen within the heads (Type II) and improving grain quality. Numerous gene expression experiments were conducted to identify genes that are differentially expressed in wheat after *F. graminearum* inoculation or treatment with DON (Schweiger et al., 2010; Shin et al., 2012). The most successful strategy for developing resistant cultivars has been to make crosses among adapted moderately susceptible to susceptible cultivars select first for high yield and then selected for resistance.

Growing moderately resistant cultivars and timely application of an effective fungicide has been demonstrated significantly reduce kernel absorption, kernel damage and mycotoxin contamination (Odenbach et al. 2008; D`Angelo et al. 2011; Salgado et al. 2012).

CHEMICAL AND BIOLOGICAL CONTROL

The experiences developed worldwide clearly showed that fungicides application had a batter impact when was used within on Integrated Disease Management strategy (De Waard et al. 1993). Applying foliar fungicide at the proper time has high efficacy in managing FHB in wheat. The best application timing is considered to be when wheat plants are on early anthesis stage (Freeks growth stage 10.5.1). The fungicides available for FHB management all belong to triazole class of fungicides (metoconazole, prothioconazole and mixed models of action prothioconazole/tebuconazole). For achieving the best results is important also to follow label recommendations and consider the preharvest interval requirements (30 days). Fungicides that contain strobilurin active ingredients are not labeled for control of FHB increasing the risk of higher DON levels in grains. Determining rain fast and residual life of fungicide on wheat spikes Andersen et al. (2012) showed that rainfall closer to fungicide application (60, 105, 150 minutes after application) reduced fungicide efficacy resulting in higher mean FHB intensity and DON than later rainfall (195 minutes after application) or no rainfall.

On the others side the use of naturally bio-control agents (antagonists) can permit the reduction of pathogeninoculum potential below injury level (Khokhar and Gupta, 2014). Adding composts or manure and stimulating resident microbial useful population on residues by using mulches may increase the antagonistic microflora. Bleakley et al. (2012) showed that yield losses can be controlled or reduced by using fungicides alone or in combination with biological control agents (BCAs). The combination of Bacillus1BA or 1D3, plant oil and Prosaro can reduce FHB incidence and FBH disease index in wheat more that a single application of Prosaro.

CULTURAL CONTROL PRACTICES

Cultural practices are an important pillar that supports Integrated Management of FHB which not only serve in promoting healthy wheat crop, but are also effective in inoculum reduction (crop rotation, plowing, remove of previous crop residues, etc.) and in enhancing the biological activity of antagonists (crop rotation, mulching, zero tillage, residue management, etc.).The management scheme includes also cropping system, crop structure, tillage, crop rotation, residues management, nutrients management, etc.

*Crop rotation.*The use of FHB-susceptible crops in rotation with wheat increases disease risk. Disease severity is higher in wheat following maize than in wheat following wheat and soybean.*Fusarium spp*. can survive and multiply on maize residues for several years (Leonard and Bushnell, 2003). Avoiding short rotation maize-wheat will substantially reduce risks of FHB epidemics especially in areas where climatically conditions are favorable. On the areas where maize is not grown, infested residue of wheat, barley and rice is a more important source of inoculum. Thus, rotation schemes with wheat grown after other cereals should generally be avoided. Non-host crops that can be incorporated into rotations include sunflower, beans, canola and forage legumes.

*Residue managemen.*Infected crop residues as well as infected small grains and maize, light-weight kernels, infected wheat and barley heads, glumes or other head parts returned to the soil surface during harvest serve as important sites of overwintering of the pathogen. If residue is the main source of primary inoculum, the amount of primary inoculums will probably be related to the density of crop residues on the soil (Leonard and Bushnell, 2003). Pereyra and Dill-Macky (2008) observed that wheat and barley residues produced more ascospores of *Gibberella zelle* than maize and other gramineous residues. Sunflower residue did not support ascospores production.Ascospores of *Gibberella zeae* were still produced on residue pieces after 23 months and these spores were capable of inducing disease. Yi et al. (2002) underlined the favorable effect of removing the crop residues of previous crops by plowing them into the soil.

Dill-Macky and Jones (2000) showed that the deoxynivalenol content was influenced by the previous crop residue. DON was significantly lower in wheat following soybean than inwheat following wheat or maize. DON levels werehigher in wheat following maize, than in wheat following wheat. Despite higher risk of FHB leaving large amounts of residue on the soil surface is a more desirable farming practice in order to reduce soil erosion from wind and water, retaining more moisture, increasing water infiltration, improving wild flora activity and beside zero-tillage and adequate crop rotation resulted in more stabile and higher yields compared with conventional agriculture with or without residue incorporation (Govaerts et al. 2005).

*Tillage.*Using reduced or zero-tillage system will increase FHB risks especially if much more residues will be presented on the soil surface.Fernandez et al. (2005) showed that FHB index was highest under minimum tillage and lowest under zero-tillage. Dill-Macky and Jones (2000) observed that disease incidence was lower in mouldboard plowed plots than in either chisel plowed or zero-tillage plots. Among the previous crop tillage combinations, disease incidence was significantly higher in the chisel plow and zero-tillage treatments of maize residues than in any other treatment combination. Several studies have examined the effect of tillage practices on DON levels (Dill-Macky and Jones, 2000; Schaafsma et al., 2001; Yi et al., 2001), but no difference among tillage systems was noticed. Schaafsma et al. (2001) observed that less than 3% of the variation in DON levels was associated with tillage. The average DON levels in minimum tillage (3.9 ppm) systems were higher than in zero-tillage (3.3 ppm) and conventional tillage systems (2.5 ppm). DON levels were lower in wheat harvested from mouldboard plowed treatments and were higher in grain harvested from zero-tillage treatments than from chisel plowed treatments for the previous crop residues of wheat and maize (Dill-Macky and Jones, 2000).

CONCLUSIONS

Fusarium Head Blight affects grain fill leading to direct yield losses and in addition Deoxynivalenol (DON) and Nivlenol (NIV) mycotoxins affect also grain quality. The integration of host resistance, chemical and biological control and cultural control practices is the most effective approach for managing FHB. Several moderately resistant winter wheat varieties are available, but they have usually low yielding potential and quality traits. However these cultivars could be an option for resource-poor farmers who cannot afford to use chemical treatments. The fungicides available for FHB management all belong to triazole class of fungicides (metoconazole, prothioconazole and mixed models of action (prothioconazole/tebuconazole), but their efficacy is dependent on climatically conditions and pathogen aggressiveness. Cultural control practices help to reduce inoculum amount and in enhancing the biological activity of antagonists. Disease severity is higher in wheat following maize than in wheat following wheat and soybean.Avoiding short rotation maize-wheat will substantially reduce risks of FHB epidemics especially in areas where climatically conditions are favorable. DON was significantly lower in wheat following soybean than inwheat following wheat or maize. Using reduced or zero-tillage system will increase FHB risks especially if much more residues will be presented on the soil surface.Despite of this reduced and no-till cropping practices in addition with leaving previous crop residues achieve soil conservation leading to higher yields. However, integrated FHB management often provides higher level of disease and mycotoxins control in wheat comparatively with individual management strategies.

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