Storage proteins in wheat (*Triticum aestivum L.*) and impact of mycotoxins affecting quality and quantity with focus on nitrogen supply

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Abstract: The paper is presenting a work plan and a literature review on storage protein formation and mycotoxin performance in a field trial. Grain quality and quantity parameters will be tested in relation to the impact of nitrogen supply and effects of mycotoxins on it. Nitrogen supply is planned to be given with different timing, doses and means of application. Sown winter wheat varieties Mv Karéj, Mv Nádor, Mv Krajcár, Mv Kolompos and Alföld (*Triticum aestivum* L.) in the experimental field of Szent Istvan University's at Nagygombos will be harvested and examined. Growth and development, yield and grain samples are to be observed, recorded and analysed to determine nitrogen application impacts on quantity and quality.

Keywords: grain protein, gluten, winter wheat, mycotoxin, nitrogen

Introduction

There is more land planted to wheat in the world than any other crop. It provides 20 percent of the world's caloric consumption and for the world's poorest 50 percent, 20 percent of their protein consumption too (Washington Wheat Facts 2015/2016). The total global wheat output exceeded 749.3 million tonnes in 2016, according to FAOSTAT data (FAOSTAT 2017). Wheat contains vitamins, minerals and essential amino acids, throughout with useful metabolites and dietary fibres. However, such undesired side effects also should be noted, such as, intolerance or allergic symptoms. The goal of wheat production is twofold; provide quantity and quality. Milling and baking quality of wheat are mainly determined by the genetic basis, however, it can be influenced by management techniques (Grimwade et al 1996; Pollhamer 1981; Pepó 2010; Vida et al. 1996). In wheat production, nitrogen plays an essential role, since it affects yield levels and quality; nevertheless, it can exert undesirable effects on the environment due to losses by leaching, denitrification and volatilisation. Storage proteins are more than half of the total proteins in mature cereal grains. Gluten proteins - gliadins and glutenins of wheat determine the quality of the grain for bread making and their amount and composition can be influenced by agronomic impacts leading to changes in dough properties and that of baking quality (Lásztity, 1999; Shewry and Halford 2001, Győri 2008). With the special requirement of end-users, ongoing and prospective investigations involve more features on their projects, such as reduced chemical content, stability, higher/lower ingredient etc. Different types of quality and contents needs for different proposes and different users e.g. different for pasta production and bread or production of biscuits, such as the hardness of grain and protein content. Long-term intake of cereal products (bread, pasta, biscuits, etc.) that are contaminated with these mycotoxins may be the cause of serious developmental and hormonal disorders, chronic poisoning, malignant tumours and other diseases, as well as deformities (Smith et al., 1994; Gregorčič et al., 2009; Casteel and Rottinghaus, 2000). Williams and Hammitt (2001) considered the consumers to be insufficiently aware of the threats posed by the presence of mycotoxins in food. They stated that the consumers were certain that it was primarily the pesticides and not the presence of mycotoxins that put their health at risk, however, the authors' opinion was

just the opposite: human health was exposed to increased risk due to the potential effects of mycotoxins rather than to the residues of fungicides in food. Visible signs of disease (FHB - Fusarium head blight - is a devastating disease of wheat with spikelets exhibit symptoms of premature bleaching shortly after infection by the fungal plant pathogen of genus Fusarium spp.) that may be present in all parts of the plant, especially in the grains and inflorescences (spikes, cobs and wiper), reduce the quantity and quality of crop yields (Tajnsek L. et al. 2014). Fungal contamination causes significant yield decrease, but the losses are even greater because of mycotoxins produced by these fungi (Havlova et al., 2006). Carried out researches clearly demonstrate that mycotoxins have a negative effect on the yield quality and quantity also health impaction on humans and animals, however, linkage with nitrogen (N) applications needs to be investigated.

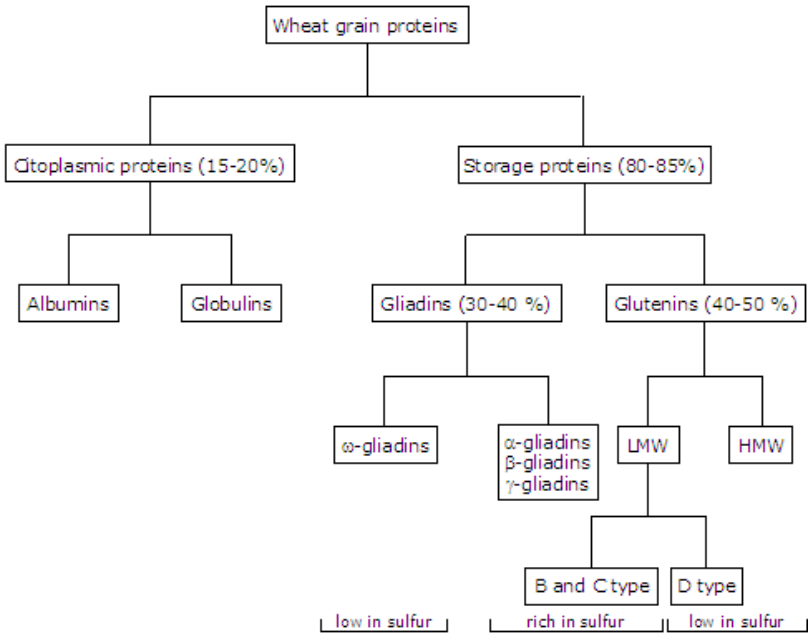

Figure 1: The classification of wheat grain proteins. Source: Shewry and Halford (2002)

Wheat's storage proteins

Thomas Burr Osborne (1859-1929) categorised grain proteins according to water-solubility: Albumins: water-soluble, globulins: salt-soluble, prolamins (gliadins): alcohol-soluble, glutelins (glutenins): alkali-soluble. The different types of wheat proteins can be separated according to size. In general, wheat flours contain 45% glutenin, 45% gliadin and 10% soluble proteins. Wheat proteins are responsible for most of quality characteristics of flour. Figure 1 is comprises a scheme on the relations of wheat proteins.

The impacts of fertilisers/manure on plant development, yields and quality

Studies from various countries show that topdressing with nitrogen fertiliser can effectively increase winter wheat grain yields. According to Zhao et al. (2015) investigation,

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topdressing with N fertiliser resulted in significant increases in wheat yield, wheat biomass production, and N concentrations and uptake in wheat grain, straw, and chaff. The genetically determined quality of the various wheat varieties may only be attained by applying appropriate agronomical techniques. In the array of up-to-date agricultural techniques, proper application of fertilisers is the means that can have the most profound impact on the quality and quantity of wheat yields.

A number of authors have come to the conclusion that the improvement of the genetic stock contributes 30-50 %, while agricultural techniques contribute 50-70 % to increasing yields (Jolánkai 1985). Crop growth is influenced by management practices such as cereal crop was grown, variety and planting date, and also by soil and climatic conditions (Kismányoky and Ragasits 2003, Horváth 2014).

The nitrogen supply for a cereal crop comes from fertiliser, but also from manure and mineralisation. Mineralisation is the release of plant-available nitrogen from soil organic matter and crop residues as a result of soil microbial activity. The dosages of N fertilisers have a significant impact not only on protein content but – through the protein content – on the alcohol yield as well.

Factors influencing wheat response to nitrogen fertiliser

The utilization of applied nitrogen fertilisers up to several factors such as soil nitrogen and loose from applied fertilisers. However wheat cultivar, available soil nitrogen, delayed or late seeding, weed competition, disease infestation, soil moisture and texture.

Other factors' impacts on the quality and quantity of the yield

According to Dupont and Altenbach (2003) when the grains are filling up environmental factors have a major impact on both yield and flour quality. Grain yield and yield quality of winter wheat are highly influenced by the meteorological conditions of the given crop year, especially the amount and distribution of precipitation and the actual temperature (Grimwade et al 1996, Győri 2008, Pepó 2010). Weather conditions are evaluated and labelled favourable or non-favourable in relation to the optimum requirements of the crops' phenophases (Lásztity 1999; Ványiné and Nagy 2012).

Beside of nitrogen, other fertilization activities also increase to parameters of the effect of nitrogen, such as macro-micro fertilisers unless restriction each other. As it also well knows the influence of breeds with suitable environment expects. Disease and insect harms cause up to 20-30% time by time, therefore integrated plant protection applications allow us to keep them under economic loss threshold.

Influence of nitrogen sources on fungal growth

According to the Bouras N. et al. (2016) growth of the fungal species, isolates was measured on the synthetic medium in the presence of several nitrogen sources (mineral and organic). Individual isolates exhibited variable growth rates depending on the nitrogen source added to the medium. The mean colony diameter ranged from 6.0 ± 0.5 mm to 83.0 ± 7.9 mm various media (Fig. 2).

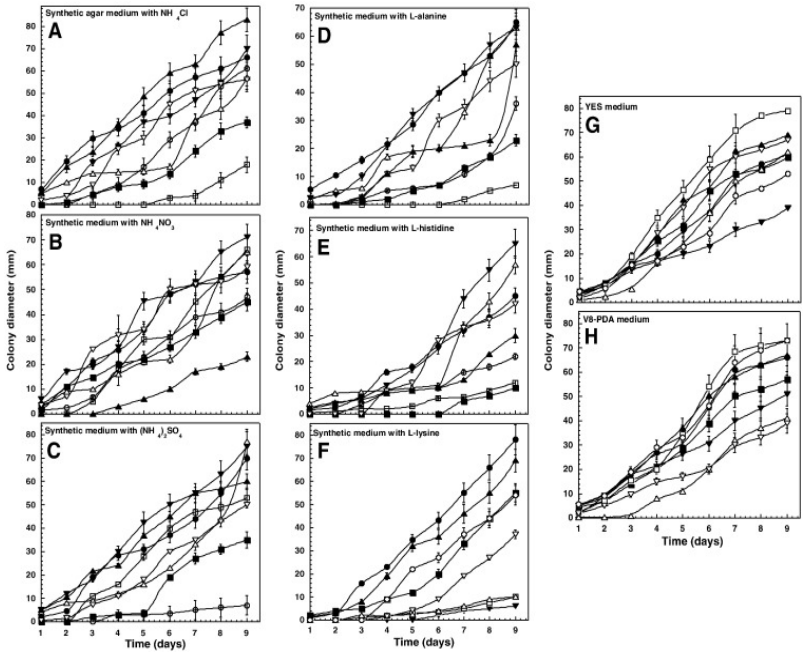

Figure 2. The Growth of Pyrenophora tritici-repentis on different culture media over a 9 day period. (A–F) Modified synthetic agar medium (SAM) containing: NH4Cl (A), NH4NO3 (B), (NH4)2SO4 (C) (Bourasa N. et al. (2016))

Effect of mycotoxin on grain and impactions on health

The harms of fungal diseases on crop products are well known. However, the factors of their interactions with N application and correlations with grain protein quality-quantity have to be studied on. According to Homdork et al. (2000), artificial Fusarium inoculation lowered yield significantly by 24.2-45.0%. Mycotoxins have significant economic impacts in numerous crops, especially wheat, maize, peanuts and other nut crops, cottonseed, and coffee. The Food and Agriculture Organization has estimated that 25% of the world's crops are affected by mycotoxins each year, with annual losses of around 1 billion metric tonnes of foods and food products. Economic losses occur because of: 1) yield loss due to diseases induced by toxigenic fungi; 2) reduced crop value resulting from mycotoxin contamination; 3) losses in animal productivity from mycotoxin-related health problems; and 4) human health costs. Neither of these estimates included human health impacts or crop yield losses. Reduced crop value is a significant component of the losses caused by mycotoxins. Human health impacts of mycotoxins are the most difficult to quantify. It is clear that mycotoxins affect human health, especially aflatoxins in developing countries.

These effects are due to acute (single exposure) toxicoses and immunosuppression by mycotoxins, as well as chronic (repeated exposure) effects. (Zain, 2010). Over then quality-quantity properties effect, it also effects on human and animals health. Mycotoxins may be harmful to human and animal health more than fungicides residues on the crops. Williams and Hammitt (2001) consider the appearance of natural toxins to be influenced by agronomic management practices.

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Materials and methods

For long-term field trials high milling and baking quality winter wheat varieties Mv Karéj, Mv Nádor, Mv Krajcár, Mv Kolompos and Alföld (*Triticum aestivum L.*) were sown. The small plots trial with four replications run at Nagygombos, experimental field Crop Production Institute of Szent Istvan University, Hungary. The size of each plot is 10 m^2. Soil type of the experimental field is chernozem (calciustoll). Annual precipitation of the experimental site belongs to the 550-600 mm belt of the Northern edges of the Hungarian Great Plain. Identical agronomic treatment applied to each plot. Supply of N fertiliser planned for single and divided doses. Applications of N topdressing will be done by 6 levels: 0, 80, 120, 160 kg/ha N in single supply and 80+40, 120+40 kg/ha N in two applications. After harvest, samples going to be analysed in the laboratory of Crop Production Institute of Szent Istvan University.

Expected results and outcomes

Experimental results (Yield, thousand kernel weight, grain proteins (gliadin and glutenin), baking quality, grain hectolitre weight, fusarium infection and mycotoxin contamination will enable us to compare and find out the correlations for questions below:

Can we find any relationship between single and divided dose application of N fertiliser with regard to yield quality and quantity?

Can we find any relationship between different levels of N supply with regard to yield quality and quantity?

Can we find any relationship between overall soil fertility management strategies, resulting in different overall plant available nitrogen levels and different nitrogen dynamics, and the presence of mycotoxins in wheat and effect on grain parameters?

Can we find any relationship between increased levels of plant available nitrogen during the stages, realized by additional fertiliser application, and the presence of mycotoxins in wheat?

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