Impact of Nitrogen Fertilization on Fusarium Foot and Root Rot and Yield of Durum Wheat

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ABSTRACT

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This study investigated the influence of nitrogen fertilization on Fusarium foot and root rot. Disease index, percentage of white heads, grain yield, weight of 1000 grains and nitrogen content were evaluated in durum wheat after artificial inoculation with *Fusarium culmorum* under field conditions. The trial was conducted using Karim wheat cultivar during growing season 2016/17. Five nitrogen rates, 0, 50, 100,150 and 200 kg N/ha were evaluated. Nitrogen supply at higher rates (150 and 200 kg/ha) significantly increased disease index, the percentage of white heads, the grain yield, the weight of 1000 grains and nitrogen content. These results suggest that high amounts of nitrogen fertilization may increase infection of wheat by Fusarium foot and root rot disease by influencing the plant physiology.

Keywords: Durum wheat, *Fusarium culmorum*, nitrogen rates

Fusarium foot and root rot is one of the most important diseases of cereals throughout the world and has been reported since the 1970's in Tunisia (Gargouri et al. 2001; Ghodbane et al. 1974). Different cereals can be infected including durum wheat, representing more than 50% of the total cereal areas cultivated in Tunisia (Anonymous 2013; Slama et al. 2005), which is the most susceptible (Wallwork et al. 2004). Up to 26% yield losses have been recorded on durum wheat in Tunisia which were attributed to Fusarium foot and root rot disease (Chekali et al. 2013). The disease is caused by a complex of *Fusarium* species among which *F. culmorum* is the most important ones (Gargouri et al. 2007). This pathogen produces lesions on the coleoptiles, roots, and sub-crown internodes of host plants, and cause browning of the stem bases at or near the soil surface, from soil- or residue-borne inoculum. Damage to cereals is often unnoticed until white heads appear shortly before the crops mature or until shriveled grain is noted during harvest

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(Burgess et al. 2001). Various studies suggest that the application of integral wheat protection measures such as cultivation of resistant cultivars, crop rotation, tillage, and application of appropriate fertilizers and fungicides can significantly reduce wheat infection by *Fusarium* species (Lemmens et al. 2004; Osborne and Stein 2007). The present study investigated the effect of nitrogen fertilization on *F. culmorum* infections in durum wheat under field condition.

MATERIALS AND METHODS

Inoculum production.

Four isolates of *F. culmorum*, obtained from stems of durum wheat collected at Jendouba (2014) were used in this study. The identification on these isolates was based on typical morphological characteristics of the colony on PDA (carmin red, fast growing colony) and the shape of macroconidia (short and stout) as described by Burguess et al. (1994). *F. culmorum* isolates were maintained on PDA medium at 4°C until used. For inoculum production, oat grains were soaked in water overnight and excess water was drained off and a grain sample of 250 cm^3 was autoclaved twice over 2 days at 120°C for 20 min. Pieces from PDA plates colonized with each of the 4 selected isolates were added to oat grains and incubated for 3 weeks at 25°C. The colonized oat grains were air-dried on filter paper ground in laboratory mill and passed through a 2-mm sieve.

Field trial and nitrogen application.

This study was carried during the growing season 2016/17 in the experimental field of the *Institut National des Grandes Cultures* (INGC) in Tunisia using the Karim durum cultivar. After preparation of the seed bed, seeds were sown at a density of 350 seeds/m^2. Each plot consisted of six rows, 2 m long and 25 cm apart. Fungal inoculum (2.5 g/row) was sprinkled on top of seeds in corresponding plot and closed over. The control treatments consisted of non-inoculated plot. Five nitrogen (N) fertilization levels: 0 kg N/ha (T0), 50 kg N/ha (T1), 100 kg N/ha (T2), 150 kg N/ha (T3) and 200 kg N/ha (T4) were applied manually as follows: 30% at the beginning of tillering, 40% at the end of tillering and 30% at heading (Alan and Gash, 2012). The experiment was carried out according to a randomized complete block design (RCBD) with four replicate blocks.

Measured parameters.

At the end of April (anthesis stage), twenty plants from each plot were pulled out and washed. Disease symptoms for each individual plant were assessed by calculating the proportion of the length of stem discoloration and rated using a 0-5 scale (0 = no discoloration; 1 = trace to 25%; 2 = from 25 to 50%; 3 = from 50 to75%; 4 = more than 75%; and 5 = dead plant) as described by Tinline (1986) with minor modifications.

Disease severity was also estimated by counting the number of white heads in each plot. The yield was estimated by weighing the grains harvested per plot and reported as q/ha. The 1000 grain weight and the protein content were also determined.

Data analysis.

Statistical analysis was performed using SPSS 20. Comparisons of means were conducted using analysis of variance (ANOVA) including Tukey-B test ($P \leq 0.05$). Correlation analysis was carried out by calculation of Pearson correlation coefficients.

RESULTS

Effect of nitrogen fertilization on disease severity.

Artificial inoculation significantly increased disease severity ($P < 0.05$) compared to the control (non-inoculated plots). Under natural pathogen pressure, a significant effect of nitrogen on infection was observed. In addition, the effect of nitrogen rate on disease severity was significant ($P < 0.05$). Nitrogen applied at higher rates (150 and 200 kg/ha) significantly increased disease severity (Fig. 1), and nitrogen rates significantly affected the percentage of white heads in inoculated plants (Fig. 2). Nitrogen supply at higher rate (150 and 200 kg/ha) significantly increased the percentage of white heads. However, under natural pathogen pressure no effect of nitrogen on the percentage of white heads was observed (Fig. 2).

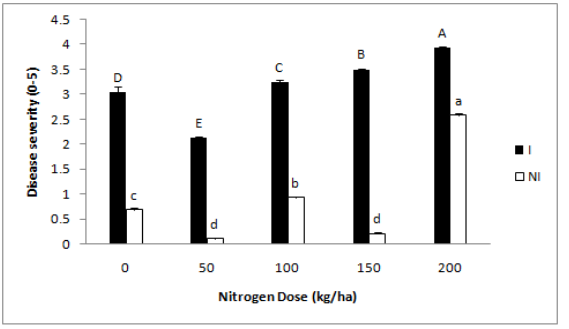

Fig. 1. Effect of nitrogen rates on the severity of Fusarium foot and root rot of wheat under natural infection (NI: non-inoculated) and artificial inoculation (I: inoculated) by *Fusarium culmorum*. Bars with the same letter within the same inoculation treatment are not significantly different according to Tukey test (at $P \leq 0.05$).

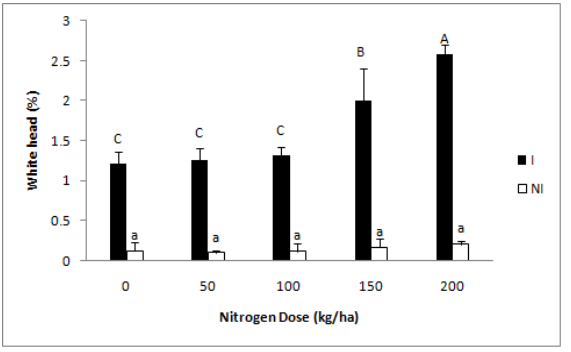

Fig. 2. Effect of nitrogen rates on the percentage of white heads of wheat under natural infection (NI: non-inoculated) and artificial inoculation (I: inoculated) by *Fusarium culmorum*. Bars with the same letter within the same inoculation treatment are not significantly different according to Tukey test (at $P \leq 0.05$).

Effect of nitrogen rates and inoculation by *F. culmorum* on grain yield.

The grain yield of Karim was significantly ($P < 0.05$) affected by the rate of nitrogen (Fig. 3). Grain yield increased significantly with the increase of nitrogen application regardless the inoculation with *F. culmorum*. Moreover, the effect of nitrogen rate on weight of 1000 grains was significant ($P < 0.05$) (Fig. 4). Indeed, nitrogen application resulted in significant increases in 1000 grain weight and the highest weight of 1000 grains was obtained in plants supplied with the highest rate nitrogen rate (200 kg/ha) regardless the pathogen inoculation (Fig. 4).

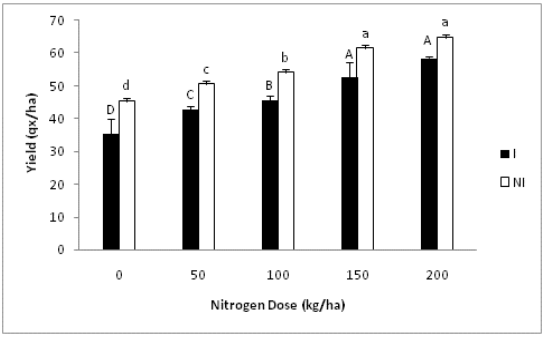

Fig. 3. Effect of nitrogen rates on yield of durum wheat under natural infection (NI: non-inoculated) and artificial inoculation (I: inoculated) by *Fusarium culmorum*. Bars with the same letter within the same inoculation treatment are not significantly different according to Tukey test at ($P \leq 0.05$).

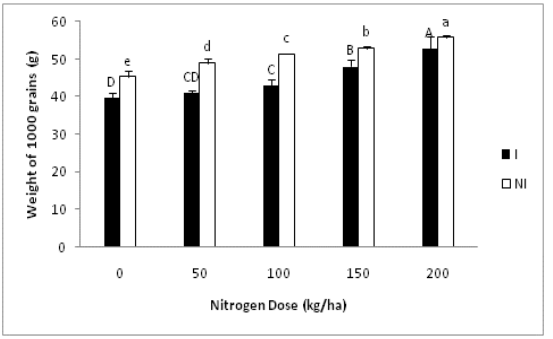

Fig. 4. Effect of nitrogen rates on 1000 grain weight of durum wheat under natural infection (NI: non-inoculated) and artificial inoculation (I: inoculated) by *Fusarium culmorum*. Bars with the same letter within the same inoculation treatment are not significantly different according to Tukey test (at $P \leq 0.05$).

This study revealed a significant difference in grain protein content between the different nitrogen treatments both in inoculated and non-inoculated plots. However, there was no correlation between nitrogen rate and percentage of grain protein content (Fig. 5).

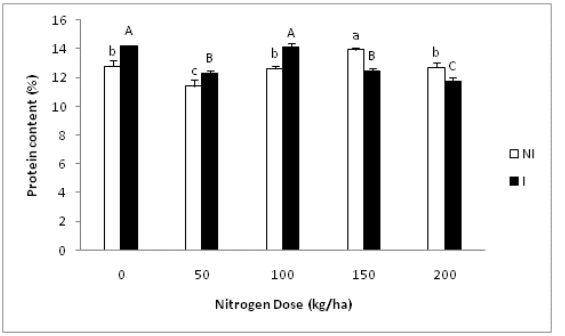

Fig. 5. Effect of nitrogen rates on grain protein content of durum wheat under natural infection (NI: non-inoculated) and artificial inoculation (I: inoculated) by *Fusarium culmorum*. Bars with the same letter within the same inoculation treatment are not significantly different according to Tukey test (at $P \leq 0.05$).

DISCUSSION

F. culmorum is one of the five main *Fusarium* species attacking cereals in the temperate cereal growing areas of the world (Hogg et al. 2007). This pathogen can cause extensive yield losses, especially in durum wheat, with over 50% reductions in grain yield being common observed (Smiley et al. 2005). Various studies suggested weather conditions, plant development, and genetic or morphological cultivar characteristics, nitrogen fertilization as factors influencing the epidemiology of Fusarium-induced diseases (Osborne and Stein 2007). Our results showed that nitrogen supply at higher rates (150 and 200 kg/ha) significantly increased Fusarium foot and root rot disease index, the percentage of white heads, the grain yield, the weight of 1000 grains and the grain protein content. These results are in agreement with field studies of Ma et al. (2004) and Lemmens et al. (2004) who noted an increase in Fusarium head blight in wheat with increasing nitrogen input. Probably the presence of nitrogen leads to the creation of lavish crops with succulent plants sensitive to infection. According to Lemmens et al. (2004), high nitrogen rates (up to 80 kg/ha) significantly affected Fusarium head blight development in wheat where deoxynivalenol (DON) level was also significantly increased. In addition, Martin et al. (1991) showed that an increase in nitrogen rates from 70 to 170 kg/ha significantly increased the occurrence of Fusarium foot and root rot disease in wheat, barley, and triticale.

In summary, field experiments demonstrated a considerable impact of nitrogen fertilization on durum wheat infection with *F. culmorum*. Although nitrogen influence appeared negligible at low inoculum pressure, nitrogen application showed significant effects on Fusarium foot and root rot under conditions with high pathogen pressure. Thus, adjusted nitrogen fertilization may limit this disease. Nevertheless, nitrogen may act differently on infection by other agents belonging to the *Fusarium* species complex or other fungal genera attacking wheat, because of differences in lifestyles, infection strategies, or production of secondary metabolites. These differences should be kept in mind in nitrogen fertilization within an integrated pest management strategy against Fusarium diseases in wheat.

RESUME

Hemissi I., Gargouri S., Hlel D., Hachana A., Abdi N. et Sifi B. 2018. Effet de la fertilisation azotée sur le rendement et la résistance du blé dur à *Fusarium culmorum*. Tunisian Journal of Plant Protection 13 (si): 31-38.

Cette étude a porté sur l'effet de la fertilisation azotée sur la fusariose du collet et des racines du blé dur. La sévérité de la maladie, le pourcentage des épis blancs, le rendement en grains ainsi que la teneur en azote ont été évalués chez le blé dur après inoculation artificielle par *Fusarium culmorum* dans des conditions de champ. L'essai a été réalisé en utilisant le cultivar de blé Karim pendant la campagne agricole 2016/17. Cinq doses d'azote (0, 50, 100, 150 and 200 kg/ha) ont été évaluées. Les doses d'azote les plus élevées (150 et 200 kg/ha) ont augmenté la sévérité de la maladie, le pourcentage d'épis blancs, le rendement en grains, le poids de 1000 grains ainsi que la teneur en azote. Ces résultats suggèrent que la fertilisation azotée excessive peut augmenter l'infection du blé par la fusariose du collet et des racines en influençant la physiologie de la plante.

Mots clés: Blé dur, doses d'azote, *Fusarium culmorum*

ملخص

هميسي، إيمان وسامية قرقوري ودرصاف هلال وأميرة حشانة ونائلة عابدي وبوعزيز صيفي. تأثير التسميد النيتروجيني على محصول القمح الصلب/القاسي ومقاومته للفطر *Fusarium culmorum*.

Tunisian Journal of Plant Protection 13 (si): 31-38.

أجريت هذه الدراسة لتقييم مدى تأثير التسميد النيتروجيني/الأزوتي (N) على المرض الفوزاري للقمح. تم تقييم شدة المرض ونسبة السنابل البيضاء وانتاجية الحب ووزن الألف حبة وكمية النيتروجين في القمح الصلب بعد الإلقاح الاصطناعي بالفطر *Fusarium culmorum* تحت الظروف الحقلية. أجريت التجربة باستخدام صنف كريم خلال موسم الفلاحي 17/2016. تم تقييم خمسة جرعات من النيتروجين (0 و50 و100 و150 و250 كلغ/هك). أدت المعاملات بجرعات نتروجين مرتفعة (150 و 200 كلغ/هك) إلى ارتفاع في شدة المرض ونسبة السنابل البيضاء وانتاجية الحب ووزن الألف حبة وكمية النيتروجين. هذه النتائج تشير إلى أن الكميات المرتفعة من التسميد النيتروجيني قد يزيد من الإصابة بالمرض الفوزاري للقمح من خلال التأثير على فسيولوجية النبتة.

كلمات مفتاحية: جرعات نيتروجين، قمح صلب، *Fusarium culmorum*

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