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INFLUENCE OF SOME AGRONOMY FACTORS ON SPIKE COMPONENTS AFTER A RARE INCIDENCE OF FUSARIUM HEAD BLIGHT EPIPHYTOTY OF WINTER WHEAT
I. EFFECT OF LONG-TERM CROP ROTATION, MINERAL FERTILIZATION AND SOWING TERM

T. K. TONEV, V. KIRYAKOVA and G. MILEV
Dobroudja Agricultural Institute, BG – 9520 General Toshevo, Bulgaria

Abstract

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The investigation was performed in two field experiments during the spring of 2005 in the region of north-east Bulgaria. The year was characterized with fusarium epiphytoty on common winter wheat rare for this region. In the first trial a long-term rotation of wheat as a continuous crop and two-course rotation with maize were studied and the following rates of mineral fertilization were investigated: $N_0P_0K_0$, $N_{60}P_{50}K_{30}$, $N_{120}P_{100}K_{60}$, $N_{180}P_{150}K_{60}$. The second trial investigated wheat grown after spring peas in an ecological agriculture system. Four sowing terms (earlier than optimal, two sowing dates within the optimal term, and later than optimal) and four sowing rates (400, 500, 600 and 700 germinating seeds per m^2) were analyzed. Variety Enola was sown in both trials. The number of visibly fusarium-infected spikes was established per unit area. The main spike components were determined at stage full maturity in both visibly healthy and visibly infected spikes: number of grains and grain weight per spike, as well as 1000 grain weight. In the first trial the number of spikes infected with fusarium varied within 1.0-12.7 items per m^2. The highest degree of visible infection was registered after predecessor maize fertilized with the maximum fertilization rate. The number of spikes infected with fusarium after previous crop spring peas in the second trial varied from 0.1 to 6.6, being limited by the sowing term and increasing with the higher crop density. Fusarium infection had a strong negative effect on spike components. In the first trial highest reduction was registered in grain weight per spike, which in the infected spikes accounted for 40-45 % of the mean grain weight in the visibly healthy spike. The relative damage caused by the infection increased with the higher fertilization rates. Wheat grown after predecessor peas had higher values of the visibly healthy spike components. At the sowing date most favorable for fusarium infection (5^{th} October), the mean number of grains per infected spike constituted 59.3 % from the visibly healthy one. Thousand grain weights were reduced twice and grain weight per spike – 3.4 times. The increase of the sowing rate had a slight negative effect on the values of the fusarium infected spike components.

Key words: wheat, *Fusarium,* epiphytoty, predecessor, mineral fertilization, sowing term, sowing rate

tonev@dai-gt.org

Introduction

Fusarium head blight caused by the fungus *Fusarium graminearum* (Schwabe) is not a common disease on winter wheat under the conditions of Bulgaria. Therefore this disease is not considered economically dangerous and the development of varieties with genetically determined resistance is not a priority of breeding by now.

The incidence of total infection, however, can be considered natural because the range of occurrence of this disease is expanding towards non-typical regions in the recent decades as a result from the changes in the agricultural system and in the climate (Dubin and Gilchrist, 2002; Gilchrist et al., 1997).

Head blight is considered a serious problem in the wheat-producing regions with conditions for almost annual infection due to the rather significant damages on yield, on the one hand (Viedma, 1989), and on the other – due to the highly deteriorated quality of grain and flour caused by toxins harmful to human and animal health (Baht et al., 1989; Desjardins, 2006; Luo, 1988; Marasas et al., 1988; Snidjers, 1989). Worldwide, special attention is paid to the genotype resistance to this disease (Bai and Shaner, 2004; Kriel, 2006).

It is well known that the risk of total fusarium infection is based on the complex interaction of several factors: a combination of rainfalls and warm weather during anthesis, use of maize as previous crop and minimal pre-sowing soil tillage after harvesting of this risky predecessor (Mattews, 2006).

The aim of the present study was to evaluate the effect of a rare total fusarium infection on the spike components of winter wheat as influenced by some agronomy factors in a region where the occurrence of this disease is not typical.

Material and Methods

The investigation was carried out during the spring of 2005. A rare instance of fusarium epiphytoty on winter wheat spikes was registered in Dobroudja region (north-east Bulgaria). The infection occurred in a natural background of plant residues from predecessor maize. The specific coincidence of meteorological conditions and phenological development of winter wheat favored the infection.

The spike components of wheat variety Enola were investigated in two field trials:

1) A long-term field experiment, initiated in 1957, in which wheat was grown as a continuous crop and in two-course rotation after predecessor grain maize. Four rates of NPK fertilization were investigated (potassium fertilization was applied only to the continuous crop): $N_0P_0K_0$, $N_{60}P_{50}K_{30}$, $N_{120}P_{100}K_{60}$, $N_{180}P_{150}K_{90}$. Sowing was done on 21 October 2004 with 550 germinating seeds per m^2.

2) A field experiment for analyzing the possibility of biological cultivation of wheat after predecessor spring peas. Four sowing terms (earlier than optimal – 21 September 2004; two dates within the term optimal for the region – 5th and 15th October 2004; later than optimal – 2nd November 2004), and four sowing rates (400, 500, 600 and 700 germinating seeds (g.s.) per m^2) were investigated.

Having established the visible damages on wheat caused by fusarium (spikes becoming whitish in color), the following procedures were performed in three replicates per each variant:

• 5 visibly healthy and 5 visibly infected spikes were marked on 15 June 2005.

• Number of infected spikes per ¼ m^2 was registered in each of the replicates.

The marked spikes were collected at maturity stage and morphological analysis was carried out to determine the number of grains and grain weight per spike, as well as 1000 grain weight.

Dispersion analysis (ANOVA) was applied to find out significant differences in comparison to the control variant and independent effects of the studied factors using the statistical software BIOSTATÓ (Penchev et al., version 1.0).

Results and Discussion

Heading and anthesis of wheat occurred later than normal in the spring of 2005 in Dobroudja regions.

The third decade of May was characterized with alternation of high (up to 29.0 °C) and low (9.8 °C) air temperatures, rainfalls (24.9 mm for the period 21-31 May) and high relative air humidity (82.6 %). Following the humid summer of 2004, the yields from maize were high and large amounts of post harvest residue from this crop were left in the fields. The natural infection in the fields was further increased by the protective forest shelters which provided poor aeration thus contributing to the rare occurrence of fusarium epiphytoty on subsequent wheat.

Two weeks following the infection, a visible effect was evident on the crop as whitish spikes on a part of the plants (Table 1).

The samples taken showed that the variation of the investigated spike components was different in the two field experiments.

In the trial with long-term study on crop rotation, the number of visibly infected spikes per m^2 changed according to the investigated factors from 1.0 to 12.7, and a susceptible difference between the two predecessors was evident in the highest tested fertilization rate. Averaged for the investigated mineral fertilization rates, wheat grown after maize had a highest number of visibly fusarium-infected spikes per unit area although in the trial design the plots after the two predecessors were adjacent to each other. The independent effect of the high fertilization rates (of nitrogen fertilization, in particular) had very high degree of statistical significance (F = 15.64***). This could be explained by the higher crop density as a result from the higher biological yield, the higher relative humidity in the crop and the higher water content in all plant parts.

In the trial investigating the sowing terms and rates after predecessor spring peas, variation was within a lower range – from 0.1 to 6.6. A susceptible difference between the first three sowing dates was not established in this trial because heading and anthesis occurred almost simultaneously, and the difference between the earliest sowing date and sowing on 15th October was only 3 days. Heading and anthesis after the latest sowing date occurred at the end of May – beginning of June, when there were less suitable conditions for infection. Therefore the number of visibly infected plants per area unit was lowest.

Finally, the results indicated that the risk of infection increased with the higher crop density.

On the whole, the high severity of fusarium infection significantly deteriorated the physical properties of grain, and to a high degree reduced yield value and quality of production.

The measurements on the spike components in the trial investigating long-term rotation and mineral fertilization showed that the spikes visibly infected with fusarium contained averagely 10.3 grains less than the

Table 1

Number of visibly *Fusarium* -infected spikes per 1m^2 of wheat crop, variety Enola, according to previous crop, mineral fertilization, sowing term and norm

I. Trial with crop rotations			2. Trial with sowing terms and sowing rates				
Mineral fertilization	Predecessor		Sowing rate (g.s. per m^2)	Sowing date			
	Wheat	Maize		21.09.	05.10.	15.10.	02.11.
$N_0P_0(K_0)$ - Control	1	1.9	400 – Control	2.9	1.5	1.7	1.6
$N_{60}P_{50}(K_{30})$	6.4***	6.8***	500	4	1.2	1	1.8
$N_{120}P_{100}(K_{60})$	7.7***	7.5***	600	4.2	3.9	2.4	0.1
$N_{180}P_{150}(K_{90})$	7.5***	12.7***	700	6.6*	4.5*	3.6	0.1
L.S.D. at: 0.05	2.3		L.S.D. at: 0,05	2.8			
0.01	3.2		0.01	3.8			
0.001	4.4		0.001	5			

*, *** - Significant differences according to the control variant for *P* levels 5 and 0.1 %, respectively

visibly healthy spikes. The mean grain weight per spike and 1000 grain weight had mean values lower with 0.93 and 17.0 g, respectively (Table 2).

Severe *Fusarium* infection had the strongest relative effect on grain weight per spike – grain weight of infected spikes was 40-45 % from the weight of the visibly healthy ones. Lowest was the reduction of the number of grains per spike – a mean of 17-28 % from the same character of visibly healthy spikes. Being a character determined by the above two character, 1000 grain weight was reduced to a lower degree than grain weight per spike.

It is undoubtedly important from an agronomic point of view to find out how much these three characters were dependent on the type of predecessor. The decrease of the investigated spike components of wheat grown after maize, regardless of the lack of spatial isolation between the two previous crops, was significant. In comparison to the continuous crop, the mean decrease was as follows: 4.9 % in grain weight per spike, 5.4 % in number of grains per spike and 2.0 % in absolute grain weight. Therefore it could be assumed that in fusarium epiphytoty on wheat grown after a predecessor, which was unfavorable (in this case grain maize) there was almost equal decrease in the values of number and weight of grains per spike.

Mineral fertilization within the investigated range had in general a positive effect on the spike components. This effect was clearly expressed in the visibly healthy spikes. The use of the maximum nitrogen fertilization (N_{180}) in combination with PK increased the mean number of grains per spike with 42.0 %, and the mean grain weight per spike with 56.2 %. Highest value of absolute grain weight was registered at fer-

Table 2

Averaged changes of spike component values in visibly healthy and visibly *Fusarium*- infected spikes depending on predecessor and fertilization rate

Studied factor	Grain weight per spike, g			Number of grains per a			1000 grain weight, g		
	Visibly healthy spikes	Visibly Fusarium-infected spikes	Fusarium-infected to healthy spikes, %	Visibly healthy spikes	Visibly Fusarium-infected spikes	Fusarium-infected to healthy spikes, %	Visibly healthy spikes	Visibly Fusarium-infected spikes	Fusarium-infected to healthy spikes, %
A. Predecessor									
Wheat – Control	1.67	0.75	44.9	39.5	30.2	76.5	42.1	25	59.4
Maize – ± D	-0.07^{NS}	-0.11^{NS}	40	-0.1^{NS}	-2.2^{NS}	71.1	-2.2^{NS}	-2.1^{NS}	57.4
B. Fertilization									
$N_0P_0K_0$ – Control	1.21	0.68	56.2	31.7	26.3	83	37.9	25.6	67.5
$N_{60}P_{50}K_{30}$ – ± D	+0.35*	-0.01^{NS}	42.9	+7.4***	$+1.2^{NS}$	70.3	$+1.9^{NS}$	-1.4^{NS}	60.8
$N_{120}P_{100}K_{60}$ – ± D	+0.65***	$+0.05^{NS}$	39.2	+10.3***	+4.2*	72.6	$+6.5^{NS}$	-1.6^{NS}	54.1
$N_{180}P_{150}K_{90}$ – ± D	+0.68***	$+0.03^{NS}$	37.6	+13.3***	+6.0**	71.8	$+4.1^{NS}$	-3.6^{NS}	52.4
L.S.D. at: 0,05	0.28	0.24		2.6	3.3		8.8	9.2	
0.01	0.39	0.34		3.6	4.5		12.2	12.7	
0.001	0.54	0.47		5	6.3		17	17.7	

*, **, *** - Significant differences according to the control variant for *P* at 0.05, 0.01 and 0.001, respectively; ^{NS} – Non-significant differences

tilization with N_{120} – 44.4 g (with 17.2 % higher than the control variant). Some increase in the mean values of the first two spike components as affected by mineral fertilization was observed also in the visibly infected spikes. A permanent decrease was registered for 1000 grain weight under the effect of the increasing fertilization rate.

The results up to now lead to the conclusion that the negative effect of fusarium head blight increases with the higher nitrogen rates, and supports the previous conclusions about the number of infected spikes per unit area.

The distinct independent effect of the investigated factors on the components of the visibly healthy spikes was confirmed by the results from the ANOVA analysis. Only in one of these components – grain weight per spike, the *F* value related to the independent effect of the predecessor, was significant (*F*=4.62*). In two components – grain weight per spike and 1000 grain weight, the effect of mineral fertilization was significant at the highest degree (*F*=12.76*** and 17.17***). The lack of significant independent effect of the agronomic factors on the components of fusarium-damaged spikes was undoubtedly due to the simultaneous effect of these factors: on productivity, on the one hand, and on the severity of infection, on the other.

The complex negative effect of fusarium epiphytoty on wheat had a negative reflection on the grain yield obtained from harvest plots in four replicates. The grain yield obtained in 2005 after the two different predecessors, and at fertilization with $N_{120}P_{100}K_{60}$ was compared to the mean yield for the period 1983-2000 (Table 3). During the long-term period, two winter wheat varieties were grown successively in the field trial: Pliska (1983-1999) and Enola (2000-2005). These varieties are similar by their earliness of maturation and productive potential. A part of the results from this investigation were already published (Tonev & Shtereva, 1996, 2006).

The yield data showed that in long-term aspect the predecessor grain maize was more favorable for growing of wheat under the conditions of north-east Bulgaria. The investigated varieties grown after this

Table 3
Grain yield from wheat after fertilization with $N_{120}P_{100}K_{60}$ in 2005 averaged for the period 1983-2005

Crop rotation	2005	1983-2005
2-course rotation – Control, kg.ha^{-1}	3994	5545
Continuous crop		
Grain yield, kg.ha^{-1}	4102	4847
Relative yield, %	102,7	87.4

predecessor realized a mean yield of 5545 kg/ha at optimal mineral fertilization. The mean yield in long-term continuous crop was with 698 kg/ha (12.6 %) lower.

Previous analyses showed that the difference in favor of predecessor maize was higher during years with better moisture reserves and at severe attack by root rot. In some years with high moisture deficiency growing of wheat as a continuous crop was more advantageous. Pre-sowing ploughing and successive disking (ploughing after previous crop maize was not done) favored moisture accumulation during the autumn-winter period and improved the moisture-retaining capacity of soil.

The conditions in 2005 were specific in the history of this trial because the reason for the low grain yield was not moisture deficiency but fusarium epiphytoty. Undoubtedly, the lower grain yield after predecessor maize was due to the considerably deteriorated physical properties, 1000 grain weight in particular. When determining this yield component from representative samples after harvesting, it was established that 1000 grain weight from the optimal fertilization variant of long-term continuous crop was 45.20 g, and after predecessor maize it was 45.07 g using the same fertilization rate. These values after predecessor wheat almost coincided with the data obtained from the visibly healthy spikes (45.1 g). They, however, were higher than the values regarding the visibly healthy spikes after previous crop maize (43.7 g). This implies that even in the visibly healthy spikes of wheat were damaged by fusarium, formed low 1000 grain weight and were lost at mechanized threshing.

The final conclusion is that yield decrease was due to two main reasons: the higher percent of non-standard wheat grains (with lower size and weight) and the losses during harvesting.

In the second trial wheat was grown after predecessor spring peas in organic agriculture system and the positive effect of the previous crop was well expressed through the mean values of the visibly healthy spike components. Their absolute values were the following:

• Mean number of grains per spike was 44.2. The same values were 39.5 and 39.4 after predecessors wheat and grain maize, respectively, in the first trial discussed above;

• Mean 1000 grain weight was 46.9 g (in comparison to 42.1 and 39.9 g, respectively);

• Mean grain weight per spike was 2.07 g and after the other two predecessors it was 1.67 and 1.60 g, respectively.

Comparing the data from both field experiments it was established that the differences between the components of fusarium-infected spikes were minimal as affected by predecessor. On the other hand the relative values of mean number of grains, mean 1000 grain weight, and mean grain weight per fusarium-infected spike, in relation to the same values of visibly healthy spikes, were considerably lower as follows (Table 4).

• After predecessor spring peas – 56.3, 64.9 and 36.7 %;

Table 4
Mean changes in the values of spike components in visibly healthy and visibly *Fusarium*- infected spikes according to the sowing term and rate

Studied factor	Grain weight per spike, g			Number of grains per spike			1000 grain weight, g		
	Visibly healthy spikes	Visibly Fusarium-infected spikes	Fusarium-infected to healthy spikes, %	Visibly healthy spikes	Visibly Fusarium-infected spikes	Fusarium-infected to healthy spikes, %	Visibly healthy spikes	Visibly Fusarium-infected spikes	Fusarium-infected to healthy spikes.,%
A. Sowing date									
21.09. – Control	1.99	0.65	32.6	46.7	28	60.1	42.7	23.2	54.2
05.10. – ± D	+0.13^{NS}	-0.03^{NS}	29.3	-2.6*	-1.8^{NS}	59.3	+5.5**	+0.6^{NS}	49.4
15.10 – ± D	+0.04^{NS}	+0.22**	42.9	-4.6***	+3.5**	74.9	+5.5**	+4.3^{NS}	74.9
02.11. – ± D	+0.13^{NS}	+0.24**	42	-3.0**	+0.9^{NS}	66.1	+5.7**	+7.7**	63.8
B. Sowing rate									
400 g.s./m^2 – Ctrl	2.11	0.73	34.8	45.4	28.6	63.1	46.5	25.4	54.7
500 g.s./m^2 – ± D	-0.06^{NS}	0.0^{NS}	35.6	-2.1^{NS}	0.0^{NS}	66.1	+0.7^{NS}	-0.1^{NS}	53.6
600 g.s./m^2 – ± D	-0.02^{NS}	+0.08^{NS}	28.6	-1.2^{NS}	$^{+0.3}$NS	65.4	+0.8^{NS}	+2.6^{NS}	59.1
700 g.s./m^2– ± D	-0.09^{NS}	+0.04^{NS}	37.9	-1.8^{NS}	-0.2^{NS}	65	-0.2^{NS}	+1.4^{NS}	57.5
L.S.D. at: 0.05	0.22	0.15		2.2	2.2		4	5.2	
0.01	0.3	0.2		2.9	2.9		5.4	7	
0.001	0.39	0.26		3.9	3.9		7.2	9.3	

*. **. *** - Significant differences according to the control variant for P at 0.05, 0.01 and 0.001, respectively; NS – Non-significant differences

- After predecessor wheat–59.4, 76.5and 44.9 %;
- After predecessor grain maize – 57.4, 71.1 and 40.0 %.

The role of the sowing term for the degree of damage caused by fusarium can be evaluated indirectly – through the relative decrease of the values of the investigated spike components. The data showed that the most significant reduction was at sowing date 5th October. The mean number of grains per infected spike constituted 59.3% from the visibly healthy spike. Thousand grain weights were reduced twice, and grain weight per spike – 3.4 times. Evidently at sowing date 15th October and later the negative effect of fusarium infection decreased, which reflected on the relative decrease of the values of the investigated components, as well.

The increase of sowing rate in the same experiment had a negative effect on the number of fusarium-damaged spikes per unit area. It, however, affected to a lesser extend the values of the fusarium-infected spike components. A significant independent effect of this factor on thousand grain weight was calculated both for the visibly healthy and the infected spikes (*F* = 14*** and 23.19 ***, respectively).

Conclusions

In a trial where winter wheat was grown as a long-term continuous crop and in rotation with maize, the number of visibly infected spikes varied from 1.0 to 12.7 items per m^2. In another trail, where it was cultivated after predecessor spring peas, the number of infected spikes varied from 0.1 to 6.6, being limited by the sowing term, and increasing with the higher sowing rates.

Highest decrease was registered in grain weight per spike, which in the infected spikes was averagely 40-45 % from the mean grain weight of the visibly healthy spikes. Increasing of the fertilization rate lead to higher relative damages caused on the spike components by the infection.

Under the head blight epiphitoty rare for the region, grain yield from wheat grown after grain maize was atypically low – 97.4 % according to the yield from the long-term continuous crop.

Winter wheat grown after peas had higher values of the healthy spike components. The same parameters in the infected spikes were similar to the data obtained after grain maize and winter wheat predecessors but the relative decrease according to the visibly healthy spikes was more significant.

The mean number of grains per infected spike was reduced with up to 59.3 %, 1000 grain weight decreased twice and grain weight per spike – 3.4 times. The increase of the sowing rate had a slight negative effect on the values of the fusarium-infected spike components.

In general, fusarium head blight epiphytoty classically had a high negative effect on spike components and subsequently on grain yield and quality. In spite of its rare occurrence in the region of North-east Bulgaria, the breeding efforts on winter wheat improvement should involve genotype resistance to this disease, as well.

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