University of Technology and Life Sciences, Bydgoszcz, Poland

# WINTER WHEAT STEM BASE INFESTATION AND FUNGAL COMMUNITIES OCCURRING ON STEMS IN DEPENDENCE ON CROPPING SYSTEM[1]

A. Łukanowski

## Abstract

Wheat stem base infestation by pathogenic fungi depended on particular system (organic, integrated, conventional and monoculture) and plant growth stage. Both in shooting phase and milk maturity stage the pathogens were represented mainly by *Fusarium* spp. During the whole investigation period the number of these fungi isolates was distinctly lower in organic system as compared to other systems. The results suggested that the organic cultivation may have favoured the growth of *Gliocladium* species in soil and due to their antagonistic properties they could have played some role in limiting the development of pathogenic fungi.

**Key words:** winter wheat, stem bases, health, fungi, cropping systems

## Introduction

Wheat is one of the most susceptible to fungal diseases cereal species. Such situation may be easily solved in conventional cropping system with chemical control (seed treatment and spraying with fungicides).

On the other hand, over the past several years, there is evidence of a significant increase of consumer interest in the so-called *organic food* and, hence, the farmers tend to change plant production from intensive (conventional) to organic (biological) or integrated. There are attempts to use such cropping systems to improve plant health, due to beneficial relationships between microorganisms, which is the basic rule of non-chemical control of disease (Knudsen et al. 1995, Teich 1994) in organic system.

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Unfortunately, information on the organic system in Poland is often presented in publications or popular literature by authors not involved in scientific research, mostly not based on results of independent research. Many of them suggested that total giving up chemical pesticides and fertilizers is a guarantee of food production of higher quality than that deriving from conventional crops.

That is why the aim of this study was to determine the effect of different cropping systems on health of winter wheat stem bases, as well as formation and structure of wheat stem base fungi communities.

## Materials and methods

The studies were conducted in Osiny in 1999–2001, on fields owned by Institute of Soil Science and Plant Cultivation in Puławy. Stem bases of winter wheat cv. 'Roma' grown in organic, integrated, conventional systems and monoculture were investigated. The forecrop in organic, integrated and conventional system was respectively: mixture of red clover with grass, faba bean and winter oilseed rape. Weather conditions during the study are presented in Table 1.

**Table 1**

Weather conditions during the study, Puławy

| Month | Temperature (°C) | | | Rainfall (mm) | | |
|---|---|---|---|---|---|---|
| | 1998/99 | 1999/2000 | 2000/01 | 1998/99 | 1999/2000 | 2000/01 |
| I | 0.2 | –1.8 | –0.4 | 15.3 | 22.0 | 32.6 |
| II | –1.3 | 2.2 | –0.7 | 41.2 | 31.8 | 24.4 |
| III | 4.4 | 3.3 | 2.7 | 17.0 | 64.8 | 41.9 |
| IV | 9.8 | 11.9 | 8.8 | 96.6 | 48.7 | 88.9 |
| V | 12.2 | 15.1 | 14.9 | 38.4 | 59.2 | 15.3 |
| VI | 18.5 | 17.4 | 15.5 | 147.7 | 29.7 | 58.4 |
| VII | 20.4 | 17.0 | 21.0 | 51.2 | 173.9 | 139.5 |
| VIII | 17.8 | 18.0 | 19.3 | 45.1 | 62.4 | 84.4 |
| IX | 13.1 | 15.0 | 11.7 | 36.3 | 28.7 | 60.8 |
| X | 7.6 | 8.1 | 11.1 | 47.5 | 39.2 | 12.4 |
| XI | –1.7 | 1.5 | 6.6 | 31.6 | 42.2 | 32.7 |
| XII | –3.0 | 0.3 | 1.5 | 19.9 | 20.7 | 44.6 |

Evaluation of stem base infestation was carried out on 200 plants (4 × 50) during shooting phase and milk maturity stage with a 6–degree (0–5°) scale where 0° meant healthy stem base, 1° – browning only on leaf sheath, 2° – slight browning directly on stem base, 3° – browning covering about 50% of stem base circumference, 4° – browning covering over 50% of stem base circumference, 5°– stem base completely rotten.

Infestation degrees were transformed into "disease index" values (DI) according to formula of Townsend and Heuberger (Wenzel 1948), statistically analysed with variance analysis for single factor experiments and means were compared with Tukey's test.

For mycological analysis 5 mm long inocula of diseased stem bases were washed in running tap water for 45 min and then 3 × 10 min in sterile water, 30 of them put onto potato dextrose agar (PDA) in Petri dishes and incubated for 10 days at 23°C. Fungi were identified according to Gilman (1957), Domsch and Gams (1972) and Kwaśna et al. (1991).

## Results

Stem base infestation in shooting phase was highly differentiated in particular years and systems (Table 2). There were no significant differences in stem base health between organic system (DI: 12.0%) and monoculture (DI: 10.8%) in 1999. The lowest infestation was noted in 2000, but differences between systems were statistically significant. The lowest infestation was noted for integrated system and the highest one for conventional, while organic system and monoculture were not significantly different. In 2001 organically grown plants showed the highest infestation of stem bases, while significantly lower infection was observed in the case of the other three systems, and there were no significant differences between these combinations.

**Table 2**

Stem base infestation depending on cultivation system in shooting phase, Osiny

| System | Disease index (%) | | |
|---|---|---|---|
| | 1999 | 2000 | 2001 |
| Organic | 12.0 c | 1.6 b | 10.0 a |
| Integrated | 23.2 a | 1.0 c | 2.8 b |
| Conventional | 18.8 b | 2.4 a | 1.8 c |
| Monoculture | 10.7 c | 1.5 bc | 2.4 bc |

Values in the same column followed by different letters are significantly different.

In milk maturity stage, in 1999 and 2000 the significant highest stem base infestation was noted in monoculture (DI: 57.6–60.2%, Table 3), what was also confirmed by mean DI value for all research years (DI: 57.9%). An exception was year 2001 where the highest infestation was in organic system. Health of stem bases in other systems was, however, differentiated and depended on particular year of investigations.

In shooting phase during three years of research 75 colonies from organic system, 56 from integrated, 67 from conventional, and 49 from monoculture were obtained (Table 4). The symptoms on stem bases were mainly caused by fungi from *Fusarium* genus. In average they represented 26.7% of isolates in the organic system, 53.7% in the integrated system, 37.4% in the conventional system and 32.6% in monoculture. During the entire time of study the main pathogenic species was

**Table 3**

Stem base infestation depending on cultivation system
in milk maturity stage, Osiny

| System | Disease index (%) | | |
|---|---|---|---|
| | 1999 | 2000 | 2001 |
| Organic | 36.6 b | 35.8 d | 59.6 a |
| Integrated | 39.1 b | 48.6 b | 50.0 c |
| Conventional | 32.6 c | 40.6 c | 51.4 bc |
| Monoculture | 60.2 a | 57.6 a | 55.8 ab |

*F. avenaceum* – in average 12.0%, 26.8%, 17.9% and 18.4% of isolates, respectively in organic, integrated and conventional system and monoculture. Pathogenic *Fusaria* were every year most numerous in integrated system. From among other pathogens, *Rhizoctonia* spp. were isolated relatively often, especially in monoculture in 2001 (25.0%). Results for non-pathogenic *Fusarium* species varied and depended on year (with the exception of 2000, when no isolates were obtained) and there was no distinct relationship between the number of isolates and particular system. In average, the highest number of these fungi isolates was noted in integrated system (16.1%).

Among saprotrophic species *Penicillium* spp. dominated. Their average number was the highest in organic system and monoculture (14.7% and 12.2%, respectively), and distinctly lower in other systems (1.8% and 3.0% in integrated and conventional system, respectively). Antagonistic species represented by *Gliocladium* and *Trichoderma*, so desirable in the soil environment due to their antagonistic properties, were isolated in 1999 and 2000 only in organic and conventional system, with the exception for monoculture in 2001 where *Trichoderma viride* consisted 25.0% of all fungi isolates, but it must be indicated that they were obtained only from four diseased stem bases. These fungi were more often represented in organic system as compared to the conventional one (2.7% and 1.5%, respectively).

During milk maturity stage 125 colonies of fungi were isolated from organic system, 99 from the integrated one, 109 from the conventional system and 99 from monoculture (Table 5). Similarly to the previous phase, pathogenic fungi isolated from stem bases were those belonging to genus *Fusarium*, and among them *F. avenaceum*, *F. culmorum*, *F. solani* and *F. oxysporum* were most numerous. The highest number of pathogenic *Fusaria* was noted in monoculture in 1999 and 2000 (74.2% and 31.6%, respectively), while in 2001 they dominated in the integrated system (86.7%). Stem bases of organically grown plants were to the lowest extent infected by *Fusarium* spp. This tendency was observed every year and visible also in the three-year average. Generally, the number of *Penicillium* spp. and *Aspergillus niger*, contrary to previous term of isolation, was lower. It concerns both particular years of isolation and the average calculated for the whole period of the study. The total number of antagonistic species of *Gliocladium* and *Trichoderma* genera did not depend on particular system and highly varied each year.

**Table 4**

Fungi isolated from stem bases of wheat cultivated in four systems in Osiny, shooting phase (%)

| Fungus | 1999 | | | | 2000 | | | | 2001 | | | | 1999–2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | I | C | M | O | I | C | M | O | I | C | M | O | I | C | M |
| *Alternaria alternata* | 21.4 | 13.3 | 17.2 | 6.3 | 11.8 | 30.0 | 13.8 | – | 3.3 | – | – | – | 12.0 | 12.5 | 13.4 | 4.1 |
| *Arthrinium phaeospermum* | – | – | – | – | – | – | – | – | 3.3 | – | – | – | 1.3 | – | – | – |
| *Aspergillus niger* | 3.6 | – | 6.9 | – | – | 20.0 | 3.4 | 23.1 | 3.3 | 6.3 | 11.2 | – | 2.7 | 5.4 | 6.0 | 6.1 |
| *Aureobasidium pullulans* | – | – | – | 6.3 | 17.6 | – | 10.3 | – | – | – | – | – | 4.0 | – | 4.5 | 4.1 |
| *Bipolaris sorokiniana* | – | 6.7 | 6.9 | – | – | – | – | – | – | 6.3 | – | – | – | 5.4 | 3.0 | – |
| *Botrytis cinerea* | 3.6 | – | – | – | – | – | – | – | – | – | – | – | 1.3 | – | – | – |
| *Cladosporium herbarum* | – | – | – | 3.1 | – | – | – | – | – | – | – | 25.0 | – | – | – | 4.1 |
| *Epicoccum nigrum* | 7.1 | – | 3.4 | 6.3 | 11.8 | – | – | 7.7 | – | – | – | – | 5.3 | – | 1.5 | 6.1 |
| *Fusarium avenaceum* | 14.3 | 20.0 | 20.7 | 15.6 | 5.9 | 20.0 | 10.3 | 23.1 | 13.3 | 43.8 | 33.3 | 25.0 | 12.0 | 26.8 | 17.9 | 18.4 |
| *Fusarium culmorum* | – | 10.0 | 6.9 | – | – | – | 10.3 | 7.7 | – | – | – | – | – | 5.4 | 7.5 | 2.0 |
| *Fusarium graminearum* | – | 6.7 | – | – | – | – | 3.4 | – | – | – | – | – | – | 3.6 | 1.5 | – |
| *Fusarium oxysporum* | – | – | – | 6.3 | – | – | – | – | – | – | – | – | – | – | – | 4.1 |
| *Fusarium solani* | 7.1 | – | – | – | – | 10.0 | – | – | 3.3 | – | – | – | 4.0 | 1.8 | – | – |
| **Total pathogenic *Fusarium*** | **21.4** | **36.7** | **27.6** | **21.9** | **5.9** | **30.0** | **24.0** | **30.8** | **16.6** | **43.8** | **33.3** | **25.0** | **16.0** | **37.6** | **26.9** | **24.5** |
| *Fusarium equiseti* | – | – | 3.4 | 9.4 | – | – | – | – | 20.0 | 18.8 | 33.3 | – | 8.0 | 5.4 | 6.0 | 6.1 |
| *Fusarium poae* | 7.1 | 13.3 | 10.3 | – | – | – | – | – | – | – | – | – | 2.7 | 7.1 | 4.5 | – |
| *Fusarium sporotrichioides* | – | 6.7 | – | 3.1 | – | – | – | – | – | – | – | – | – | 3.6 | – | 2.0 |
| **Total non-pathogenic *Fusarium*** | **7.1** | **20.0** | **13.7** | **12.5** | – | – | – | – | **20.0** | **18.8** | **33.3** | – | **10.7** | **16.1** | **10.5** | **8.1** |
| **Total *Fusarium*** | **28.5** | **56.7** | **41.3** | **34.4** | **5.9** | **30.0** | **24.0** | **30.8** | **36.6** | **62.6** | **66.6** | **25.0** | **26.7** | **53.7** | **37.4** | **32.6** |
| *Gaeumannomyces graminis* | – | 6.7 | – | – | – | – | 6.9 | – | – | – | – | – | – | 3.6 | 3.0 | – |
| *Gliocladium catenulatum* | – | – | 3.4 | – | – | – | – | – | – | – | – | – | – | – | 1.5 | – |
| *Gliocladium roseum* | – | – | 3.4 | – | – | – | – | – | – | – | – | – | – | – | 1.5 | – |
| *Mucor* spp. | 7.1 | – | – | 9.4 | 11.8 | 10.0 | 10.3 | – | 26.7 | 12.5 | 22.2 | – | 16.0 | 5.4 | 7.5 | 6.1 |

**Table 4 – cont.**

| Fungus | 1999 | | | | 2000 | | | | 2001 | | | | 1999–2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | I | C | M | O | I | C | M | O | I | C | M | O | I | C | M |
| *Paecillomyces lilacinus* | – | 3.3 | 3.4 | – | – | – | – | – | – | – | – | – | – | 1.8 | 1.5 | – |
| *Penicillium* spp. | 14.3 | – | 6.9 | 15.6 | 17.6 | – | – | 7.7 | 13.3 | 6.3 | – | – | 14.7 | 1.8 | 3.0 | 12.2 |
| *Phoma* sp. | 3.6 | – | – | 6.3 | – | – | – | – | 3.3 | – | – | – | 2.7 | – | – | 4.1 |
| *Rhizoctonia* spp. | 7.1 | 3.3 | – | 9.4 | – | – | 13.8 | – | 6.7 | – | – | 25.0 | 5.3 | 1.8 | 6.0 | 8.2 |
| *Rhizopus nigricans* | – | 3.3 | – | – | – | – | – | 15.4 | – | – | – | – | – | 1.8 | – | 4.1 |
| *Trichoderma koningii* | – | – | – | – | 11.8 | – | – | – | – | – | – | – | 2.7 | – | – | – |
| *Trichoderma viride* | 3.6 | – | – | – | 5.9 | – | – | – | – | – | – | 25.0 | 2.7 | – | – | 2.0 |
| Non-sporulating fungi | – | – | 6.9 | 3.1 | 5.9 | 10.0 | 17.2 | 15.4 | 3.3 | 6.3 | – | – | 2.7 | 3.6 | 10.4 | 6.1 |
| Number of isolates | 28 | 30 | 29 | 32 | 17 | 10 | 29 | 13 | 30 | 16 | 9 | 4 | 75 | 56 | 67 | 49 |
| Number of diseased stem bases | 26 | 30 | 28 | 30 | 14 | 7 | 22 | 8 | 30 | 16 | 9 | 4 | 70 | 53 | 59 | 42 |

O – organic system, I – integrated system, C – conventional system, M – monoculture.

**Table 5**

Fungi isolated from stem bases of wheat cultivated in four systems in Osiny, milk maturity stage (%)

| Fungus | 1999 | | | | 2000 | | | | 2001 | | | | 1999–2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | I | C | M | O | I | C | M | O | I | C | M | O | I | C | M |
| *Acremoniella fusca* | – | – | – | – | 5.9 | – | – | – | – | – | – | – | 2.4 | – | – | – |
| *Acremonium strictum* | 4.9 | – | – | 3.2 | – | – | – | – | – | – | – | – | 1.6 | – | – | 1.0 |
| *Alternaria alternata* | 4.9 | 25.0 | – | 3.2 | – | 3.0 | – | 2.6 | – | – | – | – | 1.6 | 10.1 | – | 2.0 |
| *Aspergillus niger* | – | 8.3 | 3.2 | – | 13.7 | 12.1 | 4.2 | 10.5 | – | – | – | – | 5.6 | 7.1 | 2.8 | 4.0 |
| *Aureobasidium pullulans* | 14.6 | – | – | – | – | – | – | – | 15.2 | – | – | – | 8.8 | – | – | – |
| *Botrytis cinerea* | – | – | – | – | 2.0 | – | – | 2.6 | – | – | – | – | 0.8 | – | – | 1.0 |
| *Cladosporium herbarum* | – | – | – | – | 13.7 | 18.2 | 12.5 | 7.9 | – | – | – | – | 5.6 | 6.1 | 5.5 | 3.0 |
| *Coniothyrium fuckelii* | 7.3 | – | – | – | – | – | – | – | – | – | – | – | 2.4 | – | – | – |
| *Epicoccum nigrum* | 7.3 | – | 9.7 | 6.5 | – | – | – | – | 3.0 | – | – | 6.7 | 3.2 | – | 2.8 | 4.0 |
| *Fusarium avenaceum* | 12.2 | 22.2 | 35.5 | 61.3 | 3.9 | – | 6.3 | 7.9 | 24.2 | 76.7 | 40.0 | 43.3 | 12.0 | 31.3 | 23.9 | 35.4 |
| *Fusarium cerealis* | – | – | – | – | – | – | – | – | 3.0 | – | – | – | 0.8 | – | – | – |
| *Fusarium culmorum* | – | – | – | 12.9 | 3.9 | 6.1 | 12.5 | 13.2 | – | – | 10.0 | – | 1.6 | 2.0 | 8.3 | 9.1 |
| *Fusarium graminearum* | – | – | – | – | – | 6.1 | – | 10.5 | – | – | – | 3.3 | – | 2.0 | – | 5.1 |
| *Fusarium oxysporum* | 2.4 | 13.9 | 9.7 | – | 3.9 | 6.1 | – | – | – | – | – | – | 2.4 | 7.1 | 3.0 | – |
| *Fusarium solani* | – | – | 3.2 | – | 2.0 | 3.0 | 2.1 | – | 12.1 | 10.0 | 13.3 | 3.3 | 4.0 | 4.0 | 5.5 | 1.0 |
| **Total pathogenic *Fusarium*** | **14.6** | **36.1** | **48.4** | **74.2** | **13.7** | **21.3** | **20.9** | **31.6** | **39.3** | **86.7** | **63.3** | **49.9** | **20.8** | **46.4** | **40.7** | **50.6** |
| *Fusarium equiseti* | 7.3 | – | – | – | 5.9 | 6.1 | – | – | 3.0 | – | 3.3 | 6.7 | 5.6 | 2.0 | 0.9 | 2.0 |
| *Fusarium poae* | 2.4 | – | – | 6.5 | 7.8 | – | 16.7 | – | 3.0 | 3.3 | – | – | 4.8 | 1.0 | 7.3 | 2.0 |
| *Fusarium sporotrichioides* | – | – | – | – | – | – | – | – | – | 3.3 | – | – | – | 1.0 | – | – |
| **Total non-pathogenic *Fusarium*** | **9.7** | – | – | **6.5** | **13.7** | **6.1** | **16.7** | – | **6.0** | **6.6** | **3.3** | **6.7** | **10.4** | **4.0** | **8.2** | **4.0** |
| **Total *Fusarium*** | **24.3** | **36.1** | **48.4** | **80.7** | **27.4** | **27.4** | **37.6** | **31.6** | **45.3** | **93.3** | **66.6** | **56.6** | **31.2** | **50.4** | **49.0** | **54.6** |
| *Gliocladium catenulatum* | – | – | – | – | – | – | – | – | 3.0 | – | – | – | 0.8 | – | – | – |

**Table 5 – cont.**

| Fungus | 1999 | | | | 2000 | | | | 2001 | | | | 1999–2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | I | C | M | O | I | C | M | O | I | C | M | O | I | C | M |
| *Gliocladium roseum* | – | – | – | – | 17.6 | 6.1 | – | 21.1 | – | – | – | – | 7.2 | 2.0 | – | 8.1 |
| *Mucor* spp. | 2.4 | 11.1 | 12.9 | 3.2 | 3.9 | 9.1 | 16.7 | – | 6.1 | 6.7 | 3.3 | 10.0 | 4.0 | 9.1 | 11.9 | 4.0 |
| *Penicillium* spp. | 9.8 | 8.3 | 6.5 | – | – | – | 4.2 | 2.6 | 9.1 | – | – | 6.7 | 5.6 | 3.0 | 3.7 | 3.0 |
| *Phoma* sp. | – | 2.8 | – | – | – | – | – | – | – | – | – | – | – | 1.0 | – | – |
| *Pythium* sp. | 7.3 | – | – | – | – | – | – | – | 3.0 | – | – | – | 3.2 | – | – | – |
| *Rhizoctonia* spp. | – | – | – | – | – | 6.1 | 6.3 | – | – | – | – | 6.7 | – | 2.0 | 2.8 | 2.0 |
| *Trichoderma hamatum* | – | – | – | – | 2.0 | – | – | – | – | – | – | – | 0.8 | – | – | – |
| *Trichoderma koningii* | 2.4 | – | 9.7 | 3.2 | 5.9 | 9.1 | 8.3 | 5.3 | 9.1 | – | – | – | 5.6 | 3.0 | 6.4 | 3.0 |
| *Trichoderma viride* | 2.4 | 2.8 | 9.7 | – | – | – | – | 10.5 | 3.0 | – | 30.0 | 13.3 | 1.6 | 1.0 | 11.0 | 8.1 |
| Non-sporulating fungi | 12.2 | 5.6 | – | – | 9.8 | 9.1 | 10.4 | 5.3 | 3.0 | – | – | – | 8.8 | 5.1 | 4.6 | 2.0 |
| Number of isolates | 41 | 36 | 31 | 31 | 51 | 33 | 48 | 38 | 33 | 30 | 30 | 30 | 125 | 99 | 109 | 99 |
| Number of diseased stem bases | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 120 | 120 | 120 | 120 |

O – organic system, I – integrated system, C – conventional system, M – monoculture.

## Discussion

Wheat stem base infestation varied and largely depended on the development phase. Mycological analysis of diseased stem bases showed that these symptoms were caused by numerous species of *Fusarium*. It was also confirmed by other authors, who recognized these pathogens (apart from fungi causing foot and root rot of cereals) as one of major causes of wheat diseases and indicated their special importance (Majchrzak and Mikołajska 1982, Wakuliński and Chełkowski 1993, Pląskowska 1997, Lemańczyk 2001).

*Fusarium* spp. occurred in higher number on stem bases of plants grown in integrated and conventional system as well as in monoculture (in both development phases) than on those studied in the organic system. It may indicate less favourable conditions in the organic system for *Fusarium* development in the soil, commonly reported as the primary source of infection for the plants.

The results of studies conducted on winter wheat by Łukanowski and Sadowski (2002) revealed that *Fusarium* spp. were not more serious problem in organic systems as compared to conventional and integrated ones. Kernels obtained from organically grown wheat may be even less infected by *Fusarium* spp., what is extremely important because of their high potential to produce mycotoxins. However, other authors (Champeil et al. 2004) obtained contradictory results, finding no clear relationship between disease severity and mycotoxin content in plant material.

A smaller number of *Fusarium* fungi in organic system was probably connected with more numerous isolates of fungi from *Gliocladium* and *Trichoderma* genera, which due to their antagonistic properties may have limited the development of plant pathogens in soil. The importance of this phenomenon was also reported by Doran et al. (1996), who claim that the interdependencies between organisms and plants create equilibrium in agroecosystem. It has a dynamic nature, which may be disturbed by introduction of chemicals into the soil or by sudden change of physico-chemical properties of soil, which may take place in the case of chemical treatments commonly used in the conventional cropping system. Soil, apart from grain, is the most important source of infection, especially if we take into account any changes caused by fertilization (particularly mineral) and the cropping system (Truszkowska et al. 1980).

*Fusarium* spp. were most numerous on stem bases of plants grown in integrated system in shooting phase. Such dependence was previously observed by Kurakov and Kostina (2001), who reported these fungi as settling plants earlier than saprotrophic and hyperparasitic species such as *Trichoderma* spp., *Gliocladium* spp. or *Penicillium* spp. – a situation which may result in more intense disease symptoms. Knudsen et al. (1999) claimed that the high activity of cultivated soils in the organic and integrated system was not always correlated with a high ability to limit pathogens’ development. It should be indicated here that in integrated system wheat was grown after field bean. The work of Mikołajska and Majchrzak (1996) showed significant effect of field bean cultivation on increased number of *Fusarium* spp. isolated from its roots and soil.

Taking into consideration the average size of *Fusarium* spp. population in the three years of study, its gradual increase in the milk maturity stage as compared to previous analysed phase was observed. This phenomenon may have resulted from the fact that fungi from this genus, in late cropping season, when susceptibility of ageing tissues to infection increased, have become primary pathogens of stem bases and, according to Ibrahim and Owen (1981) from the fact that these fungi had higher thermal requirements. Root secretions and decayed plant debris may have also stimulated the growth and activity of pathogenic fungi. *Fusarium* spp. is also able to survive as chlamydospores in the soil on plants which are not hosts typical of these fungi (Wagner 1995, Pląskowska 1997). High share of cereals in crop rotation in Poland (over 70%) is considered one of the main reasons of *Fusarium* infection potential increase in soil and it was reported by Lemańczyk (2001). *Fusarium* species isolated in the presented studies were also reported by other authors as potentially able to infect stem bases, roots, leaves, ears as well as kernels (Liggitt et al. 1997, Narkiewicz-Jodko et al. 2003).

There is an opinion that cultivation of plants in accordance with the rules of organic cropping system, due to high soil fertility enhancing natural biocontrol of pathogens, results in relatively good plant health and limits the incidence of pathogens (Prior 1992, Grünwald et al. 2000). The results obtained here confirmed a lower number of pathogenic *Fusaria* isolated from stem bases of organically grown plants. Unfortunately, this fact has not been correlated with better health status of the plants. The reason for such contradiction may be the fact that the living stem base is host to a diverse community of such fungi (Mäkelä and Mäki 1980) that may affect disease development, while the interactions occurring in environment are little known. Communities of nonpathogenic fungi on shoots differ with season and cereal species (Mäkelä and Mäki 1980). It is likely that primary colonization of the living plant above ground is often by specialized pathogens such as *Oculimacula* spp., with subsequent invasion of damaged tissue by less specialized pathogens, such as *Fusarium* spp. (Bateman 1993) and by saprotrophic, nonpathogenic microorganisms. The other reason of such situation could be caused by other pathogenic species like *Gaeumannomyces graminis*, which did not grow on the acidified PDA medium used in this study. Under such growth conditions the fungus is very difficult to isolate because of very slow growth and being overgrown by other pathogens or saprotrophic species such as *Trichoderma, Mucor, Penicillium* and *Aspergillus* (Bateman et al. 1997, Bateman and Kwaśna 1999).

The occurrence of *Fusarium* pathogens on stem bases often affects the threat posed by this situation for the ears. The existence of this problem was confirmed by Snijders (1990), who after artificial inoculation of stem bases with *F. culmorum*, found the mycelium of this species in the stem tissues about 70 cm above soil surface. Jordan and Fielding (1988) after artificial inoculation of spring wheat grain with *F. culmorum*, sown in the pot experiment, noted the presence of the pathogen mycelium in all nodes and ear tissues. It may indicate the ability of the species (and possibly other species) to develop systemically in plant and subsequently infect developing ears. There is a report by Polley and Turner (1995) on systemic infection of winter wheat by *Fusarium*. The authors isolated *Fusarium* species from the top internode of some stems sampled at GS 73-75. The gradual upward movement of the pathogen was also linked to symptomless disease which developed after splashing conidia from lower to higher leaves with rain droplets (Zinkernagel et al. 1997).

In this study, apart from *Fusarium* spp., numerous fungi were isolated which are considered common in soil and stem bases, suggesting that they get to the plants from the soil environment. These represented genera: *Alternaria, Aspergillus, Botrytis, Cladosporium, Gliocladium, Mucor, Penicillium, Phoma, Rhizopus, Trichoderma* and other. Many authors (Warcup 1971, Truszkowska et al. 1980, Pląskowska 1997) confirmed that they occurred in the environment of cultivated plants and are considered cosmopolitan.

In the case of *Penicillium* spp. smaller number of isolates was obtained in organic system as compared to the other ones. The opposite results were reported by Hansen et al. (2001), who observed more conidia of this genus in soil under organic cultivation. The genus is considered antagonistic towards pathogens causing cereal stem diseases, however, from the other point of view, these fungi may produce toxic secondary metabolites inhibiting seed germination and seedling growth (Hasan 1999) and dangerous to people and animals (Moss 2002).

## Conclusions

1. Stem base health highly varied in particular cropping systems. No clear relationship between a system and phytosanitary status of plants occurred, while the relationship mostly depended on the study year.

2. *Fusarium* spp. dominated in all systems among the pathogenic species isolated, but their number was lower in the organic system, and highest in the integrated one. This may indicate that possible risk of organic plant products contamination with mycotoxins is not higher than in other systems.

3. It is suggested that the organic cultivation may favour the growth of *Gliocladium* spp. in soil and because of their antagonistic properties they could play some role in limiting the development of pathogenic fungi.


## Streszczenie

### PORAŻENIE PODSTAWY ŹDŹBŁA PSZENICY OZIMEJ PRZEZ PATOGENY ORAZ ZBIOROWISKA GRZYBÓW WYSTĘPUJĄCE NA ŹDŹBŁACH W ZALEŻNOŚCI OD SYSTEMU UPRAWY

Porażenie podstawy źdźbła pszenicy ozimej przez patogeniczne grzyby w poszczególnych systemach uprawy (ekologicznym, integrowanym, konwencjonal-

nym i monokulturze) było zróżnicowane i zależało od fazy rozwojowej roślin. Zarówno w fazie strzelania w źdźbło, jak i w fazie dojrzałości mlecznej wśród patogenów dominowały grzyby rodzaju *Fusarium*. W całym okresie badań zauważalnie mniej izolowano ich z roślin pochodzących z systemu ekologicznego niż z roślin z pozostałych systemów. Wyniki wskazują, że uprawa ekologiczna może sprzyjać wzrostowi w glebie gatunków rodzaju *Gliocladium*, które ze względu na właściwości antagonistyczne mogą odgrywać pewną rolę w ograniczaniu rozwoju patogenicznych gatunków grzybów.

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## Author's address:

**Dr. Aleksander Łukanowski,** Department of Phytopathology, University of Technology and Life Sciences, ul. Kordeckiego 20, 85-225 Bydgoszcz, Poland, e-mail: luk-al@utp.edu.pl

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