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FUSARIUM SPECIES: THE OCCURRENCE AND THE IMPORTANCE IN AGRICULTURE OF SERBIA

ABSTRACT: *Fusarium* species have been isolated from over 100 plant species in Serbia. From the economic aspect, they have been and still are the most important for the production and storage of small grains and maize, and are exceptionally important for some other species. Total of 63 species, 35 varieties (var.) and 19 specialised forms (f. sp.) of basic species, particularly of *F. oxysporum* (4 var. and 12 f. sp.) and *F. solani* (7 var. and 3 f. sp.) were identified. Species *F. langsethiae* and *F. thapsinum*, recently identified, have been isolated from wheat and sorghum seeds, respectively. *F. graminearum* is the most important pathogen for wheat, barely and maize, while *F. poae* is also important for wheat and barely. Furthermore, species of the section *Liseola* (*F. verticillioides*, *F. subglutinans* and *F. proliferatum*) are important for maize and sorghum. In recent years, species of the section *Liseola* have been increasingly occurring in wheat and barley. The June—October period in Serbia is the most critical period for quality maintenance of stored maize, as the abundance and frequency of fungi, particularly of toxigenic species of the genus *Fusarium*, are the greatest during that period.

In general, there is a lack of data about fusarioses of industrial crops in Serbia. There are mere descriptions of specific cases in which the development of *Fusarium* species was mostly emphasised by agroecological conditions. The presence of recently determined *Fusarium* species in kernels of these plant species indicates their importance from the aspect of the yield reduction and grain quality debasement and the mycotoxin contamination.

Root rot and plant wilt are characteristic symptoms of fusarioses for forage and vegetable crops, while pathological changes in fruits provoked by *Fusarium* species are less frequent. *F. oxysporum* and its specialised forms prevail in these plant species.

KEY WORDS: *Fusarium*, diseases, cereals, industrial crops, forage crops, vegetables

INTRODUCTION

The importance of *Fusarium* species is mostly estimated through damages that they cause either by destroying crops, grain, nursery plants, stored fruits, finished products, processed products, or by causing the decrease in the livestock production or death of animals, human diseases, etc. The majority species of the genus *Fusarium* are capable of causing diseases (mycoses) in plants, animals and humans or mycotoxicoses in animals and humans. These fungal species parasitise on living cells, tissues or organs that are often weakened by other factors and cause infections of a mycosis type. These fungi form mycotoxins in infected plants and if these plants are involved in a food chain they can cause intoxication of humans and animals known as mycotoxicoses.

There is almost not a single place in Serbia where fungi of the genus *Fusarium* were not observed (L e v i ć, 2008). They are identified as pathogens of wheat, industrial, forage, vegetable, fruit, forest, ornamental, aromatic, medicinal and weed plants, then as parasites of fungi, parasitic flowering plants and insects. Furthermore, they are isolated from the human eye, feed and food, soil, water and air. More important secondary metabolites (fusariotoxins) formed by certain species of the genus *Fusarium* were determined, as well as the effects of food contaminated by these metabolites on human and animal health.

Although *Fusarium* species have been isolated from over 100 plant species in Serbia, they have been and still are, from the economic aspect, the most important for the production and storage of small grains and maize, and are exceptionally important for some other crops (L e v i ć, 2008; L e v i ć et al., 2008b). Total of 63 species, 35 varieties (var.) and 19 specialised forms (f.sp.) of basic species, particularly of *F. oxysporum* (4 var. and 12 f. sp.) and *F. solani* (7 var. and 3 f. sp.) were identified. There are over 225 publications that discuss *Fusarium* spp., but it is not known whether in the described species are only the identified ones or maybe there are unidentified new species. Such a great number of unidentified species is a result of insufficient experience of the majority of researchers, who easily determine the observed fungi up to the genus, but not to a species. In spite of such a great number of identified species, not more than ten are the most distributed, while this number is much smaller with regard to the economic and mycotoxicological importance.

The first occurrence of species of the genus *Fusarium* was determined in Serbia as teleomorph forms (*Gibberella pulicaris* (Fries) Sacc., *Nectria episphaeria* (Tode), *Gibberella saubinetii* (Mont.) Sacc.) at the end of the 19th and the beginning of the 20th century, while the anmorph form (*Fusarium roseum* Link) was distinguished as late as 1911 (R a n o j e v i ć, 1902, 1910; 1914).

Numerous species of the genus *Fusarium* were isolated from different fodder components and mixtures. These species contribute to the yield reduction and quality debasement of fodder, especially in regard to mycotoxins (B o č a r o v - S t a n č i ć et al., 2008, 2001; J a j i ć et al., 2007; S t a n k o v i ć et al., 2008d). Zearalenone and its derivatives, as well as type A trichothecenes (T-2 toxin, DAS) were mainly studied and determined in Serbia, while type B trichothecenes (deoxynivalenol) or fumonisines were significantly less observed and determined (L e v i ć et al., 2004; B o č a r o v - S t a n č i ć et al., 2008). In recent times, greater attention has been given to these and other fusariotoxins, such as beauvericin, fusaproliferin and moniliformin (A b r a m o v i ć et al., 2005; S t a n k o v i ć et al., 2007, 2008a, 2008b, 2008c, 2008d).

The importance of species of the genus *Fusarium* in Serbia can be considered on the basis of their distribution, abundance, pathogenic properties related to crops, consumption of contaminated products, damages caused by natural infections, mycotoxin contamination and the number of published papers. The most numerous studies state results obtained on the occurrence of species on certain parts of different plants species and various substrates depending on biotic and abiotic factors. There are the least data on human diseases (endophthalmitis) caused by species of the genus *Fusarium* (S r d i ć et al., 1993).

This study encompasses the occurrence and importance of certain *Fusarium* species in agriculture with regard to cereals, industrial, forage and vegetable plants.

CEREALS

Due to great economic damages, species of the genus *Fusarium* were the most important agents causing root and stalk rots of maize (*Zea mays* L.) and wheat (*Triticum vulgare* L.) in Serbia up to the mid-1980s (D r a g a n i ć, 1978; B a l a ž et al., 1985). In the majority of cases of root and stalk rots of both maize and wheat, the species *F. graminearum* was the most frequent pathogen. Due to the intensive activities of phytopathologists and breeders on the development of resistant genotypes, the symptoms of maize stalk lodging could hardly be recorded in fields in Serbia since the 1990s (L e v i ć et al., 1995). As far as wheat is concerned, root and stem rot is of a weaker intensity than earlier, but it can occur more intensively under certain conditions, for instance under conditions of wheat-maize rotation and without the fertiliser application (B a l a ž et al., 1998).

In Serbia, besides root and stalk diseases, *Fusarium* species used to be and still are the most important agents causing ear roots and fusarioses of spikes of both wheat and barley (*Hordeum vulgare* L.). Barley is one of the first crops for which a compulsory phytopathological seed test was established in Serbia in 1930 in order to prevent the introduction and distribution of the species *F. roseum* Link (Report on the activities of the Agricultural Experimental and Testing Station from 1919 to 1932, published in 1936).

The presence of the *Fusarium* species on maize ear or spikes of small grains is noticed during each year, but with different infection intensity or frequency of certain species. The literature data on their distribution and frequency are numerous, sometimes even drastically different although they were obtained during the same year by various researches. These great differences are the result of effects of particular or combined factors, and are mostly related to: (i) impacts of agroclimatic conditions during the growing season; (ii) the susceptibility of observed genotypes; (iii) the representability of samples; (iv) the number of analysed samples and deficient information on each sample; (v) the number of locations and years of investigation; (vi) applied methods for the isolation and the identification of fungi; (vii) the routine in the identification of certain species; and (viii) the impossibility of the conservation of isolated cultures in an appropriate way so that the confirmation of the identification or re-identification could be done by reanalyses.

In the last decades, the amount of local precipitation during the wheat flowering time had a significant effect on the variation of the intensity of

Fusarium head blight (FHB) and on the wheat grain yield in Serbia. In such a way, it was determined in 2005, when the intensity of spike fusariosis was, on average, high, that the grain yield reduction varied from 3.5 to 38.3%, depending on the agroecological conditions and resistance of wheat varieties (Lević et al., 2008c).

The type of isolation media for fungi is of a special importance for the identification of a particular *Fusarium* species. For instance, potato dextrose agar (PDA) is a medium most suitable for distinguishing *F. langsethiae* and *F. thapsinum* from *F. poae* and *F. verticilioides*, isolated from wheat and sorghum kernels, respectively. On PDA, *F. langsethiae* forms a powdered colony whose colour varies from white to dark red, while *F. thapsinum* forms a colony with a yellow pigment in the medium. These types of colonies are never formed by *F. poae* and *F. thapsinum*.

The medium containing 2% agar is a very efficient medium for the determination of the *Fusarium* species in the maize kernel, as fungi abundantly sporulate, but scarcely form aerial mycelium. This provides *in situ* identification of numerous *Fusarium* species both on and around kernels.

The distribution and frequency of *F. oxysporum* can be used as an example of differences in results obtained in the studies of mycobiota in wheat and maize kernels. Dopuđa and Lević (2004) and Stanković et al. (2007) established that this species was present up to 3%, i.e. that it was absent in the tested samples of wheat kernels. On the contrary, the results obtained by Stojanović et al. (2005) show that this fungus was present in wheat kernels even in 45.7% of samples. Studies carried out by Bočarov-Stančić (2001) point out that different results were obtained when the kernel infection with *Fusarium* species was determined in dependence on the fact whether kernels were surface sterilised or not. In cases when kernels were not surface sterilised, the obtained results are many-fold higher.

The intensity of the occurrence of *F. oxysporum* has been changed in maize. During the 1980s, *F. oxysporum* spread pretty much in stored maize. In some cases, even 56% of surface sterilised maize kernel samples was infected (Muntañola-Cvetković, 1982; Noory (1983). However, recent results gained by Lević et al. (2003) indicate that this species is very seldom isolated from surface sterilised maize kernels.

In spite of the stated differences in the determination of the intensity of frequency of *Fusarium* species, conclusions on their frequency and importance for cereals can be drawn according to the results of long-term analysis. Data presented in Tables 1 (unpublished data) and 2 point out that the most important pathogenic species for wheat, barley and maize is *F. graminearum*. Furthermore, *F. poae* is also important pathogenic species for wheat and barley, while species of the section *Liseola* (*F. verticillioides*, *F. subglutinans* and *F. proliferatum*) are also important for maize and sorghum (Lević et al., 1997, 2008). Under agroecological conditions of Serbia, *F. graminearum* is mainly developed along the rachis (Lević et al., 2008c), which points out that cultivated varieties of wheat do not possess the type II resistance or resistance to the spread of pathogens on spikes. On the other hand, *F. poae* is the most often developed on the rachis tip, and although it is very frequent it does not express pathogenic effects on wheat seedlings (L e v i ć et al., 2008d).

Tab. 1 — The number of positive samples[a] with determined occurrence of *Fusarium* spp. in kernels of wheat, barley, maize and sorghum in the 2004—2007 period

Fusarium species	Wheat	Barley	Maize	Sorghum
F. avenaceum		1/29		
F. culmorum		1/29		
F. equiseti		5/29	4/67	1/60
F. graminearum	71/75	26/29	21/67	
F. langsethiae	3/75			
F. oxysporum		1/29		
F. poae	37/75	18/29	2/67	
F. polyphialidicum		2/29	1/67	
F. proliferatum	10/75	4/29	25/67	32/60
F. sambucinum		1/29		
F. semitectum		5/29		2/60
F. solani			1/67	6/10
F. sporotrichioides	9/75	21/29	8/67	2/60
F. subglutinans	75/5	1/29	24/67	8/60
F. thapsinum				34/60
F. tricinctum	4/75	2/29		
F. verticillioides	27/75	1/29	38/67	60/33

[a] Number of samples infected with *Fusarium* spp./total number of tested samples. A total of 100 kernels per each sample was tested — kernels were rinsed under tap water for two hours, then surface sterilised with 1% NaOCl for 10 seconds, then they were washed with sterile water three times and dried out on soft sterile paper.

The frequent occurrence of *F. verticilioides* and *F. proliferatum* in wheat kernels is an interesting data from the toxicological aspects, as it was thought that fumonisins, synthetised by these fungi, were less important for wheat than for maize (V i s c o n t i and D o k o, 1994). In accordance with these results, it was determined that 59.3% of samples of wheat harvested in 2005 and 2006 were contaminated with fumonisins, provided that the FB_1 concentration was > 20,000, 2,300—16,700 and < 2,000 ppb in 50.0, 20.8 and 29.2% samples, respectively (L e v i ć et al., 2008a; S t a n k o v i ć et al., 2008d). These results point out that it is necessary to determine natural contaminations of wheat and barley kernels with fumonisins under agroecological conditions of Serbia.

Tab. 2 — Occurrence of *Fusarium* species (given in descendent values) in kernels of cereals in Serbia[a]

Plant species			
Wheat	Barley	Maize	Sorghum
Occurrence > 16%			
F. graminearum	*F. graminearum*	*F. graminearum*	
F. poae	*F. poae*		
	F. sporotrichioides		
		F. subglutinans	
		F. verticillioides	
			F. proliferatum
			F. thapsinum
Occurrence 6—15%			
F. proliferatum	*F. proliferatum*	*F. proliferatum*	
F. verticillioides	*F. verticillioides*		*F. verticillioides*
F. subglutinans	*F. subglutinans*		
F. avenaceum		*F. avenaceum*	
F. oxysporum		*F. oxysporum*	
F. sporotrichioides			
F. culmorum			
		F. poae	
Occurrence < 5%			
F. semitectum	*F. semitectum*	*F. semitectum*	*F. semitectum*
F. equiseti	*F. equiseti*	*F. equiseti*	*F. equiseti*
F. tricinctum	*F. tricinctum*	*F. tricinctum*	
F. chlamydosporum		*F. chlamydosporum*	
	F. crookwellense	*F. crookwellense*	
	F. avenaceum	*F. avenaceum*	
	F. culmorum		
	F. oxysporum		
	F. polyphialidicum		
	F. sambucinum		
F. acuminatum			
F. arthrosporioides			
F. compactum			
F. langsethiae			
F. anthophilum			
		F. solani	*F. solani*
		F. sporotrichioides	*F. sporotrichioides*
			F. subglutinans

[a] Data source: Lević (2008).

The June—October period in Serbia is the most critical period for quality maintenance of stored maize, as the abundance and frequency of fungi, particularly of toxigenic species of the genus *Fusarium*, are the greatest during that period (Krnjaja et al., 2007b). The positive correlation (r = 0.598**) between the dynamics of the occurrence and the frequency of isolated fungi indicates that fungi with greater frequency of occurrence maintain longer in maize kernels during storage. According to these authors, *F. verticillioides* and *F. subglutinans*, out of total six identified species of the genus *Fusarium*, are present in kernels during the whole year and with the highest frequency (24.7% and 5.9%, respectively). During the year, *F. verticillioides* (22.0/39.5%) and *F. subglutinans* (8.012.5%) are mainly present from February to October and April to October, respectively, while both species are the least isolated during the winter period (December—January — 4.0—8.0% and 0.5—1.0%, respectively). *F. graminearum* is the third toxigenic species of the genus *Fusarium* that could be significant from the mycotoxicological aspect for the June—September period when it occurs in the highest percent (5.0—11.0%). Lately, the occurrence of the remaining species of the genus *Fusarium* has been sporadic (1.3% *F. proliferatum*, 1.0% *F. sambucinum* and 0.5% *F. poae*).

INDUSTRIAL CROPS

In general, fusarioses of industrial plants, have been very little studied in Serbia. Exceptionally, there are sporadic literature data on excess cases that are most often caused by impacts of agroclimatic conditions. *Fusarium* species mainly cause plant wilt in industrial plants as a result of root rot (Table 3). *F. oxysporum* is the species most often isolated from roots of these plants.

In Serbia, for a long time, *Fusarium* species have not been considered the important causative agents of diseases of sugar beet root (*Beta vulgaris* L. var. *saccharifera* Lange). However, the occurrence of leaf chlorosis, caused by necrosis and rotting of roots, has been very frequent during the last decade. Leaf chlorisis has caused great economic damages (J a s n i ć et al., 2005a). *F. oxysporum* was mainly isolated from infected plants, while *F. solani* was not often isolated (Table 4). This root rot occurrence is attributed to the effects of droughts, which have been very frequent in Serbia during the growing season of sugar beet.

There is a lack of results obtained from the studies of soybean (*Glycine max* (L.) Merrill) fusarioses in Serbia, although several *Fusarium* species that cause root and stem rots, wilting and infections of pods and seeds, have been isolated and identified during the last several years (Table 3). *Fusarium* species, especially *F. oxysporum* and *F. semitecum*, are the most frequently isolated from soybean seeds (Table 4). The pathogenicity test shows that *F. oxysporum* caused the decrease in seed germination and plant emergence and also led to the increase of rotten soybean kernels (J a s n i ć et al., 2005b).

Sunflower (*Helianthus annuus* L.), as well as soybean is not a sufficiently studied industrial plant from the aspects of diseases caused by *Fusarium* spp., although the most recent studies show that these diseases can be important due to a frequent and sometimes intensive, occurrence, in kernels (Tables 3 and 4), (B o č a r o v, 1983). The first more important data about sunflower fusariosis was described more than four decades ago, when *F. avenaceum* caused important diseases of sunflower plants during rainy summer months.

Complex of species of the genus *Fusarium* (*F. oxysporum, F. verticillioides, F. proliferatum, F. solani*, etc.) often cause root rot and wilting of hop (J a s n i ć et al., 1996). In addition, it was revealed that *Fusarium* species isolated from hop are potentially toxigenic species (S t a n k o v i ć et al., 2008b). The mycotoxin production of strains shows that all isolates of *F. proliferatum* and

F. verticillioides produced fumonisin B_1 (250,000—300,000 ppb), five out of six isolates of *F. proliferatum* produced beauvericin (400,000—500,000 ppb), three strains of *F. proliferatum* produced fusaproliferin (400.000—450,000 ppb) and all isolates of *F. verticillioides* produced fusaproliferin (up to 400,000 ppb).

Tab. 3 — Fusarioses of industrial plants[a]

Plants	Symptoms	Causative agents
Sugar beet	Seedling wilt, root necrosis	*F. oxysporum var. orthoceras, F. oxysporum*
	Chlorosis, wilt and death of plant, bearded root and root rot	*F. oxysporum, F. graminearum F. equiseti*
Soybean	Necrosis of root and above ground stem part and plant wilt Infection of pod and kernel	*F. oxysporum F. graminearum, F. semitectum*
Sunflower	Plant wilt and root rot	*F. avenaceum*
	Infection of kernel	*F. verticillioides*
Hop	Rot of root and above ground stem part, leaf chlorosis, wilt	*Complex Fusarium species*
Tobacco	Wilt of young plant, white loose fungal mycelium in leaf and seed	*F. argillaceum*

[a] Data sources: Lević (2008); Jasnić et al. (2005a, 2005b); Balaž and Stojšin (1997); Lević (2008, unpublished data).

Tab. 4 — *Fusarium* species in industrial plants in Serbia[a]

Plants			
Sugar beet	Soybean	Sunflower	Hop
Prevailing *Fusarium* species			
F. oxysporum	*F. oxysporum*	*F. oxysporum*	*F. oxysporum*
	F. semitectum		
			F. culmorum
Additionally occurring *Fusarium* species			
F. graminearum	*F. graminearum*	*F. graminearum*	
F. acuminatum		*F. acuminatum*	*F. acuminatum*
F. solani		*F. solani*	*F. solani*
F. proliferatum			*F. proliferatum*
	F. sporotrichioides	*F. sporotrichioides*	
		F. verticillioides	*F. verticillioides*
F. oxysporum f. sp. betae			
F. semitectum			
F. culmorum			
F. equiseti			
	F. poae		
	F. equiseti		
		F. avenaceum	
		F. camptoceras	
		F. dimerum	
		F. equiseti	
		F. roseum	
		F. semitectum var. majus	

[a] Data source: Lević (2008).

F. oxysporum and *F. solani* are the most frequent causative agents of root rots and plant wilt of lucerne (*Medicago sativa* L.) and clover (*Trifolium* spp. L.), while *F. verticillioides* causes the greatest damages to seeds (Tables 5 and 6). Strong wilt of red clover was recorded only in one case, in an area intended for the production of fodder and seed in the region of Kruševac in 1997 (Urošević et al., 1999).

F. culmorum, *F. semitectum* and *F. sporotrichioides* were isolated from 16.7 to 33.0% of samples of healthy lucerne plants and plants with wilting symptoms (Bočarov-Stančić et al., 2005). Lucerne wilt is caused by several species of the genus *Fusarium*, and according to some authors a specialised form of *F. oxysporum* f. sp. *medicaginis* is the most important (Todorov et al., 1995). A smaller number of isolates of *F. oxysporum*, originating from lucerne roots, were observed by the vegetative compatibility group method and these observations did not confirm the presence of *F. oxysporum* f. sp. *medicaginis* in Serbia (Krnjaja et al., 2007a). This indicates that further comprehensive studies on lucerne fusarioses and the identification of specialised forms of widely spread species *F. oxysporum* are necessary.

Tab. 5 — Fusarioses of forage plants[a]

Plants	Symptoms	Causative agents
Clover	Tracheomycosis plant wilting	*F. oxysporum*
	Seed infection	Complex of *Fusarium* species
Lucerne	Root rot and plant wilting	*F. oxysporum, F. solani*
	Seed infection	Complex of *Fusarium* species

[a] Data sources: Lević (2008); Krnjaja and Lević (2005); Krnjaja et al. (2005a, 2005b).

Tab. 6 — *Fusarium* species in forage plants in Serbia[a]

Occurrence of *Fusarium* spp.	Plant species	
	Clover	Lucerne
Prevailing species:		
	F. oxysporum	*F. oxysporum*
		F. oxysporum f. sp. medicaginis
	F. solani	*F. solani*
Additionally occurring species:		
	F. proliferatum	*F. proliferatum*
	F. subglutinans	*F. subglutinans*
	F. verticillioides	*F. verticillioides*
		F. acuminatum
		F. arthrosporioides
		F. avenaceum
		F. equiseti
		F. graminearum
		F. semitectum
		F. sporotrichioides
		F. tricinctum

[a] Data sources: Lević (2008); Bočarov-Stančić et al. (2005); Krnjaja et al. (2005a, 2005b, 2007a).

VEGETABLES

In Serbia, *Fusarium* species periodically cause significant diseases of onion (*Allium cepae* L.), garlic (*A. sativum* L.), tomato (*Lycopersicon esculentum* Mill.), potato (*Solanum tuberosum* L.) and watermelon (*Citrullus vulgaris* Schrad.), especially wilting type of disease (table 7). Usually, *Fusarium* species rarely occur in the majority of vegetables, and if they occur they are often of a weaker intensity. *F. oxysporum* is the most often causative agent for these diseases (Table 8).

The significance of the *Fusarium* basal rot of onion has been increasing in Serbia. The disease is important not only for the green onion production, but also for the production of onion sets and bulbs. Especially expressed damages in the onion production occur in onion continuous cropping or in a short-term crop rotation. Species of the genus *Fusarium* can cause rots up to 53.2% of onion seedlings (Klokočar-Šmit et al., 1988). The following species were most often isolated from infected bulbs, onion sets and seedlings, as well as from soil: *F. oxysporum* Schlecht. f. sp. *cepae* (Hanz.) Snyd. & Hans. and *F. solani*, upon that *F verticillioides* (syn. *F. moniliforme*) and *F. oxysporum* (Klokočar-Šmit et al., 1990).

F. proliferatum, *F. oxysporum* and *F. solani* were isolated from cloves of garlic (Table 8). *F. proliferatum* caused golden-yellow to tan spots on the inoculated plants, while water-soaked, soft and tan necrotic spots with mildly wrinkled tissue occurred on cloves (Stanković et al., 2005). Isolates of *F. proliferatum*, originating from garlic, are good mycotoxin producers (Stanković et al., 2007).

Wilting, vessel necrosis and death of plants of tomato, aubergine and pepper caused by *Fusarium* species were determined during the 1980s (*cit.* after Lević, 2008). *F. oxysporum* f. sp. *lycopersici* is stated as the most often causative agent of tomato fusariosis, although it was not identified in all cases with certainty. It is considered that the application of systemic fungicides in the production of this vegetable is a reason for rare occurrence of fusarioses on tomato in Serbia.

Two out of several cases of the intensive occurrence of fusarioses in potato tubers are the most important in Serbia. The first case was during the 1960s with the infection level up to 50% (Martinović, 1961), when *F. coeruleum* was identified as a principal pathogen that caused dry rot of tubers (mummified tubers). In the second case during 1992, there was an outbreak of tuber rot in all regions of Serbia at the end of the growing season of potato. The infection intesity in some plots was 30.0%, but in some smaller plots it ranged from 1.0 to 80.0% (Stojšin and Marić, 1995). Infected tubers may completely rot, shrivel, and become mummified. *F. oxysporum* Schel. var. *tuberosi* Snyd. & Hans. and *F. solani* were mainly isolated from such tubers, while *F. solani* var. *coeruleum* and *F. avenaceum* were rarely identified very rare.

Tab. 7 — Fusarioses of vegetable plants[a]

Plants	Symptoms	Causative agents
Onion	Root and bulb rot, death of seedlings	*F. oxysporum* var. *cepae, F. solani*
Garlic	Water-soaked, soft and tan necrotic spot with mildly wrinkled tissue of clove	*F. proliferatum*
Cabbage	Wilting, rot of root and root collar	*F. oxysporum* f. sp. *conglutinans*
Pepper	Wilting, root necrosis	*F. annuum, F. oxysporum*
Watermelon	Wilting and dying of plant, seed and fruit infection	*F. oxysporum* f. sp. *niveum*
Cucumber	Rot of lower part of stems, wilting and dying of plant	*Fusarium* spp.
Tomato	Necrosis of vascular vessels, wilting	*F. oxysporum* f. sp. *lycopersici*
Bean	Root rot and chlorosis from the base to the top of the plant	*F. oxysporum* f. sp. *phaseoli*
Pea	Necrosis and rot of root	*F. solani* var. *redolens*
Potato	Dry rot, dark tissue of the central part of tuber, mummified tuber	*F. coeruleum, F. oxysporum* var. *tuberosi, F. solani*
Broad bean	Rolling and wrinkling of leaf, parchment appearance, root rot	*F. oxysporum, F. oxysporum* f. sp. *fabae, F. oxysporum* f. sp. *pisi*

[a] Data sources: Lević (2008); Ivanović et al. (1987, 1997); Stojšin and Marić (1995); Stanković et al. (2007).

The first outbreak of Fusarium wilting of watermelon was recorded in the 1970s, when *F. oxysporum* f. sp. *niveum* caused the disease in 60.0—70.0% of watermelon plants, especially those cultivated in continuous cropping (*cit.* after Lević, 2008). The disease symptoms in grown watermelon plants also occurred in fruits. Due to the application of watermelon grafting onto rootstock of gourd that is resistant to *Fusarium* species, cases of fusarium diseases of watermelon in Serbia have been occurring less and less since the 1990s.

Tab. 8 — *Fusarium* species (given in descendent importance) in vegetable plants in Serbia[a]

Plant species			
Onion	Garlic	Tomato	Potato
F. oxysporum	*F. oxysporum*	*F. oxysporum*	*F. oxysporum*
F. solani	*F. solani*		*F. solani*
F. proliferatum	*F. proliferatum*		
F. acuminatum			
F. cepae			
F. equiseti			
F. oxysporum f. sp. *cepae*			
F. verticillioides			
		F. incarnatum	
		F. oxysporum f. sp. *lycopersici*	
		F. semitectum	
			F. coeruleum
			F. avenaceum
			F. oxysporum var. *tuberosi*
			F. solani var. *coeruleum*
			F. oxysporum f. sp. *solani*
			F. sambucinum

[a] Data source: Lević (2008).

Fusarium rot of pepper roots and root collars and fusarium wilt occurred in the intensity of up to 10% in the late 1950s and 1970s (*cit.* after Lević, 2008). At the end of 1990s, Todorović and Horvat (1997) also pointed out to *Fusarium* diseases of pepper grown under controlled conditions. *F. annuum* and *F. oxysporum* f. sp. *lycopersici* were identified.

Data on fusarioses of bean (*Phaseolus vulgaris* L.) and string bean are scarce (*cit.* after Lević, 2008). The occurrence of root rots, necrosis of vascular vessels of the above ground parts of stems and plant wilting were recorded during the 1980s. Infected plants obviously lagged in growth and were of a chlorotic appearance. Chlorosis spread from the base to the top of a plant until the plant died. *F. oxysporum* f. sp. *phaseoli* was mainly isolated from infected plants.

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FUSARIUM ВРСТЕ: ПОЈАВА И ЗНАЧАЈ У СРБИЈИ

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Резиме

Врсте рода *Fusarium* су у Србији изоловане са преко 100 биљних врста, а са економског аспекта, биле и остале, најзначајније за производњу и чување стрних жита и кукуруза. Само изузетно су значајне и за неке друге биљне врсте. Укупно је до сада идентификовано: 63 врсте, 35 варијетета (var.) и 19 специјализованих форми (f. sp.) основних врста, посебно врсте *F. oxysporum* (4 var. и 12 f. sp.) и *F. solani* (7 var. и 3 f. sp.). *F. langsethiae* и *F. thapsinum* су новоидентификоване врсте изоловане са зрна пшенице, односно сирка. *F. graminearum* је најзначајнији патоген пшенице, јечма и кукуруза, а *F. poae* и патоген пшенице и јечма. Врсте из секције *Liseola* (*F. verticillioides*, *F. subglutinans* и *F. proliferatum*) значајни су и патогени кукуруза и сирака, мада је последњих година утврђена све чешћа појава ових врста на зрну пшенице и јечма. У Србији је период јун—октобар најкритичнији за очување квалитета ускладиштеног кукуруза јер су бројност и учесталост гљива у том периоду највеће, посебно токсигених врста рода *Fusarium* (43,5—62,5%).

Генерално, фузариозе индустријских биљака су мало проучаване у Србији. Описи су само појединачни случајеви у којима је развој *Fusarium* врста најчешће потенциран повољним агроклиматских условима. Присуство *Fusarium* врста на семену индустријских биљака, које је последњих година све чешће утврђено, указује да ове патогене гљиве у Србији могу бити значајне са становишта смањења приноса и квалитета зрна, посебно у погледу контаминираности микотоксинима.

Трулеж корена и увенулост биљака су карактеристични симптоми фузариоза крмних и повртарских биљака, док је појава патолошких промена на плодовима ређа. На овим биљним врстама доминирају *F. oxysporum* и њене специјализоване форме.