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ROOT AND FOOT ROT DISEASES OF WINTER WHEAT IN UZBEKISTAN

Batyr Achilovich Khasanov
Professor of Department of Plant Pathology, Doctor of Biological Sciences, Tashkent State Agrarian University, Tashkent, Uzbekistan

Dilfuza Tirkashbaevna Turdieva
Independent Researcher, Andijan Branch of Tashkent State Agrarian University, Andijan, Uzbekistan

Anvar Gulmirzaevich Sherimbetov
Research Assistant, Institute of Genetics and Plant Experimental Biology under Academy of Sciences, Tashkent Region, Uzbekistan

ABSTRACT
The occurrence of root and foot rot diseases on winter wheat fields has been surveyed in 16 districts of six regions of Uzbekistan. Reports about wide occurrence of Fusarium root and foot rots on wheat fields have been confirmed, and causal agents have mostly been identified. For the first time in Uzbekistan severe infection of winter wheat seedlings with common root rot (caused by B. sorokiniana) has been determined on irrigated fields in two districts of Bukhara region. For the first time in the country infection of winter wheat seedlings with a root rot caused by the new for a country incitant of the disease, a fungus Microdochium bolleyi, has been determined in the Andijan region. For the first time an infection of winter wheat seedlings with both the cereal cyst nematode belonging to the Heterodera avenae group and Fusarium sp. has been registered in one field of the Tashkent region.
KEY WORDS: *winter wheat, root and foot rot, whitehead, Fusarium spp., Bipolaris sorokiniana, Microdochium bolleyi, Heterodera avenae.*

INTRODUCTION

Winter bread wheat *Triticum aestivum* L. grown on irrigated areas may be considered as a relatively new crop for Uzbekistan because at Soviet times it has been considered as unimportant and had been cultivated exclusively on unirrigated (boghara) drylands, mostly foothills, on limited areas (100 to 250 thousand ha annually). Currently wheat occupies more than 1.4 million ha of irrigated arable lands annually. Unfortunately, crop growing system on these areas envisages dominance of wheat, and this creates favorable conditions for development not only of common diseases of this crop but leads or to appearance of new ones either to increasing frequency and severity of diseases that before were of little significance.

One group of such diseases are seedling blight, root, crown and foot rots of wheat and other cereal crops. Their symptoms include at first appearing of light brown, later becoming dark brown to black spots (necroses) on nodal and seminal roots, crowns, subcrown internodes, lower stem and lower leaf sheets. Infected plants have yellowing leaves and are stunted. At tillering stage one or more shoots can be killed. At heading stage some shoots can be stunted and fail to form ears, or may develop small heads with few or no seeds. Severe infection with aggressive pathogens (e.g., some *Fusarium* spp.) at booting-heading-early ripening stages can cause premature death of plants with spikes, producing symptoms called “white shoot” and “whitehead”.

Symptoms of root, crown and foot rots may vary depending on causal fungi. Aetiology of the disease is complicated and it can be incited by dozens of pathogenic fungi (Table 1), or unfavorable weather and soil conditions. Different species of fungi may be involved and dominate in development of infectious root, crown and foot rots of wheat in various countries. The most devastating diseases are take-all, Fusarium diseases, common root rot, in some countries or regions – eyespot, Pythium root rots, Rhizoctonia root rots, snow molds and rots, and brown root rot. Much less important are root diseases caused by weak pathogens such as chytrids, *Microdochium bolleyi*, *Curvularia* spp., *Hendersonia* sp. a.o. (Hill et al., 1983; Bockus et al., 2010; Nicol et al., 2010).

Table-1

Fungi that cause seedling blight, root, crown and foot rot diseases of wheat

**Bipolaris sorokiniana* (Sacc.) Shoem., anamorphic stage of *Cochliobolus sativus* (S. Ito et Kurib.) Drechs. ex Dastur (common root rot)
Fusarium spp. (more than 20 species), mainly **F. pseudograminearum* Aoki et O'Donnell, **F. culmorum* (W.G. Smith) Saccardo, sometimes **F. graminearum* Schwabe and others; (Fusarium root, crown and foot rot)
Gaeumannomyces graminis (Sacc.) Arx et D.L. Oliver var. *tritici* J. Walker, *G. graminis* var. *graminis* J. Walker and *G. graminis* var. *avenae* J. Walker (take-all)
Helgardia herpotrichoides (Fron) Crous & W. Gams, syns. *Pseudocercosporella herpotrichoides* (Fron) Deighton, *Cercosporella herpotrichoides* Fron, anamorphic stage of *Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams, syn. *Tapesia yallundae* Wallwork & Spooner (eyespot, or strawbreaker foot rot)
Hendersonia crastophila Sacc., syn. *Wojnowicia graminis* (McAlp.) Sacc. et D. Sacc. (root rot)
**Microdochium bolleyi* (R. Sprague) de Hoog & Hermanides-Nijhof, syns. *Gloeosporium bolleyi* R. Sprague, *Aureobasidium bolleyi* (R. Sprague) v. Arx, *Aureobasidium pullulans* (DB.) Arnaud, *Idriella bolleyi* (R. Sprague) v. Arx (Aureobasidium decay)
Microdochium nivale (Fr.: Fr.) Samuels & I.C. Hallett, syn. *Fusarium nivale* (Fr.) Ces. ex Berl. & Voglino, anamorphic stage of *Monographella nivalis* (Schaffnit) E. Muller, syns. *Calonectria nivalis* Schafnit., *C. graminicola* (Berk. et Br.) Wollenv. (pink snow mold)
Phoma sclerotioides Preuss ex Sacc., syn. *Plendomus melioti* Dearn. & Sanford (brown root rot)
Pythium spp. (more than 20 species) (Pythium root rot or browning, Pythium snow mold and rot); complex species **P. debaryanum* Hesse & Schröet. s.l. is reported to occur in Uzbekistan
Rhizoctonia cerealis van der Hoeven, anamorphic stage of basidiomycete *Ceratobasidium cereale* Mur. et Burp. (sharp eyespot)
**Rhizoctonia solani* Kühn, anamorphic stage of basidiomycete *Thanatephorus cucumeris* (A.B. Frank) Donk; *R. zeae* Voorhees, syn. *R. oryzae* Ryker et Gooch., anamorphic stage of *Waitea circinata* Warcup et P.H.B. Talbot; other *Rhizoctonia* spp. with binucleate cells (Rhizoctonia root rots)
Sclerotinia borealis Bubák et Vluegel, syn. *S. graminearum* Elenev ex Solkina (snow mold, or snow scald)
Typhula idahoensis Remsberg, syn. *T. borealis* H. Ekstr.; *T. incarnata* Lasch, syns. *T. itoana* S. Imai and *T. gramineum* P. Karst.; *T. ishikariensis* S. Imai (speckled snow mold)
An unidentified low-temperature basidiomycete
Chytrids: *Polymyxa graminis* Ledingham, *Lagena radicicola* Vanterpool & Ledingham, *Rhizophidium graminis* Ledingham, *Asterocystis radicis* de Wild., *Olpidium brassicae* (Woronin) P.A. Dang. a. o. (root rot)
***Curvularia geniculata* (Tracy et Earle) Boed., anamorphic stage of *Cochliobolus geniculatus* Nelson; **C. inaequalis* (Shear) Boed.; ***Curvularia lunata* (Wakk.) Boed., anamorphic stage of *Cochliobolus lunatus* Nelson et Haasis; other *Curvularia* spp. (root rot)

Sources: Leslie, Summerell, 2006; Bockus et al., 2010; Nicol et al., 2010 a. o.

Note. Species registered in Uzbekistan are marked off with asterisks. Common names of diseases are given in brackets.

Root, crown and foot rot diseases of wheat are little studied in Uzbekistan. The purpose of the current work was to determine occurrence of these diseases on wheat fields in central, southern regions and Fergana Valley of our country and to identify their causal agents.

MATERIALS AND METHODS

Samples of seedlings and mature plants of wheat infected with root rots have been collected during visits to farms (on a commission from the State Plant Protection Centre); some diseased plant samples had been delivered to us by farmers and scientists of the Uzbek Plant Protection Institute in 2011, 2012, 2015, 2016, and 2019. Route surveys of wheat fields for diseases have been carried out in Andijan and (partly) Fergana regions in 2019. Incidence of root rot disease symptoms including yellowing, stunting, and whitehead, has been determined and samples of infected plants were collected.

Samples were delivered to the lab of the Institute of Genetics and Plant Experimental Biology (IGPEB), and symptoms on roots and lower stems were recorded. Identification of causal agents of the diseases have been done in accordance with methods described earlier (Khasanov, 1990). Fragments 5-7 mm long had been cut off aseptically with sterile scissors from samples, and washed under tap water during c. 2 hours, surface

sterilized with 0.5% solution of sodium hypochlorite during 30 s, rinsed twice in sterile distilled water with a droplet of Silwet Gold surfactant, and dried between sterile filter papers. Then fragments were placed on surface of sterile 2% water agar or other medium in plastic Petri dishes (Ø 9 mm), 4-6 fragments per a dish. To suppress bacterial growth after cooling till ~50°C all media were added with streptomycin sulphate and penicillin (0.5 g/L + 0.5 g/L). Media in the second set of Petri dishes were not added with antibiotics for revealing bacterial growth if any. Inoculated Petri dishes were incubated during 7±3 days in growth chamber at alternating day-night conditions (4-5 Klx, 12 hours, 22±2°C day and 12 hours, 15 to 20°C night). Illumination had been provided with four L40 W/77 Fluora NUV lamps with a peak 365 nm and four fluorescent daylight lamps. Fungi that have appeared on fragments had been studied first directly (*in situ*) under microscope at low magnification (80-120X), then mounts with fungal reproductive organs were studied at higher magnification (320-400X). Conidiophores, conidia and other structures found were measured and registered and their characters were used for identification of pathogenic and accompanying fungi to species or generic level using special identification books (Nelson et al., 1983; Sivanesan, 1987; Leslie, Summerell, 2006; Bockus et al., 2010; Nicol et al., 2010). Some of these fragments were used for isolation of pure cultures of representative causal fungi. Morphology of fungi were studied on potato dextrose agar medium in Petri dishes. Slope cultures of representative isolates are stored at the collection of the IGPEB.

RESULTS

Samples of infected plants were collected from 33 fields of 16 districts, six regions of the country (Table 2). Symptoms observed were yellowing leaves, stunting, discoloration of roots and crowns, lower stems, death of tillers, and whitehead.

Incidence of the disease varied in different fields, regions and by years. On some fields at tillering (TP, 11-1; AI, A-1, A-2, A-3, A-4; BS, B-1) and booting (KH, 12-1,2,3; BJ, B-2) growth stages incidence of the disease was enough high and it has been distributed in fields more or less evenly; adverse effect of the disease in such fields consisted mainly in death of tillers, often the main shoots of the plants.

Even distribution of stunting plants and yellowing leaves has been observed also on fields with highly saline soils (AU, 13). At later growth stages (heading-flowering and further) diseased plants were registered, as a rule, in small foci, or more often, sparsely. This has been true especialy for whitehead, which has been observed sporadically, with incidence from less than 0.1% to 1-2% (Table 2).

Table-2

Incidence of root, crown and foot rot diseases in wheat fields of Uzbekistan

Year, region & district*	Sample No.	Growth stage$^{\lambda}$	Symptoms observed†	Incidence$^{\Psi}$
2011, TP (1)	11-1	22-25	YL, S, DT	~20%, E
2012, KH (3)	12-1,2,3	45-51	YL, S, DT	<50%, E
2012, KY (1)	12-4,5	55-65	YL, S, DT	~2-3%, F
2015, KS (5)	15-1,2,3	55-65	YL, S, DT	~2-3%, F
2016, TY (1)	16-1,2	37-43	YL, S	~5-6%, F
2019, AI (1)	A-1	22-25	YL, S	S
2019, AI (1)	A-2-1; A-2-2; A-3; A-4	22-25	YL, DT	~5-6%, E
2019, AK (1)	2	55-65	WH	>0,1%, Sp
2019, AK (1)	3	55-65	WH	>0,1%, Sp
2019, АД (1)	6	55-65	WH	>0,1%, Sp
2019, AS (1)	7	55-65	WH	2-3%, Sp
2019, AB (1)	10	55-65	WH	>0,1%, Sp
2019, AU (1)	12	55-65	DT, WH	~1-2%, Sp, F
2019, AU (1)	13	55-65	YL, S	~50%, E, Ss
2019, AS (1)	14	55-65	YL, S	~0,5%, Sp, Sa
2019, AU (1)	15	55-65	WH	>1-2%, Sp
2019, AU (1)	17	55-65	YL, S	~10%, E, Sa
2019, FF (1)	18	55-65	WH	>0,1%, Sp
2019, FF (1)	20	43-59	WH	>0,1%, Sp
2019, FF (1)	24	43-59	WH	>0,1%, Sp
2019, AA (1)	37	83-85	WH	>0,1%, Sp
2019, AA (1)	40	83-85	WH	>0,1%, Sp
2019, AI (1)	41-1-2; 41-1; 41-2	83-85	DS	>1%, E
2019, AI (1)	42-2-1	83-85	WH	>0,1%, Sp
2019, BS (1)	B-1	23-25	YL, DT	E on 20 ha of 30 ha in total
2019, BJ (1)	B-2	37-39	YL, S	15 to 20%, E

Districts of regions*: Andijan region: **AA – Altynkul, **AB** – Buz, **AI** – Izboskan, **AJ** – Jalaquduq, **AK** – Khodjaabad, **AS** – Shakhrikhan, **AU** – Ulugnor; Fergana region: **FF** – Fergana; Bukhara region: **BJ** – Jondor; **BS** – Shofirkon; Kashkadarya region: **KS** – Shakhrisabz; **KY** – Yakkabag; Tashkent region: **TK** – Kibray, **TP** – Pskent, **TY** – Yukari-Chirchik; Khoresm region: **KH** – Khazorasp. No. of fields surveyed are shown in brackets.

λ*Growth stages* are given after Zadoks et a., 1974**.**

†*Symptoms*: **YL** – yellowing of leaves; **S** – stunting; **DT** – death of seedling tillers; **DS** – death of stems of mature plants; **WH** – whitehead (and white shoot).

Ψ*Incidence on the field*: **Sp** – sporadic; **F** – focal; **E** – more or less evenly distributed**.** *Soil*: **Sa** – saline; **Ss** – highly saline.

Table-3

Results of mycological analysis of infected with root, crown and foot rot plants of wheat

Sample No.	No. of fragments of infected roots, crowns and lower stems sown on water agar medium on Petri dishes								
	Total	No. of fragments that yielded fungi λ							No growth
		FP	FO	FS	F.sp	Mb	B.s.	Others†	
11-1	12	0	0	0	7*	0	0	6	2
12-1,2	8	2	0	0	3	0	0	4	1
12-4	6	0	0	0	2	0	0	3	2
15-1,3	8	1	0	0	3	0	0	4	2
16-1,2	7	3	0	0	1	0	0	4	1
A-1	16	3	3	0	0	0	0	2	8
A-2-1	16	1	0	0	0	5	0	2	8
A-2-2	12	0	0	2	0	3	0	0	6
A-3	17	2	0	1	0	6	0	3	5
A-4	14	0	0	3	0	5	0	2	4
7	5	0	0	0	0	0	0	4	0
12	8	0	2	0	0	0	0	1	0
15	9	0	3	0	0	0	0	1	5
20	8	2		0	0	0	0	4	1
37	8	0	2	0	0	0	1	6	2
40-1	6	3	1	0	0	0	0	3	1
40-2	6	2	2	0	0	0	0	2	1
41-1-2	7	0	0	0	0	0	0	11	0
41-1	6	0	2	0	0	3	0	9	0
41-2	4	2	0	0	0	2	0	3	0
42-2-1	6	0	0	0	0	0	0	1	5
B-1	33	0	0	0	2	0	29	1	3
B-2	52	0	0	0	3	0	11	5	31
Total	**274**	**21**	**15**	**6**	**14**	**24**	**41**	**81**	**88**
Total, %	**100**	**7,7**	**5,5**	**2,2**	**5,1**	**8,8**	**15,0**	**29,6**	**32,1**

λ FP – *Fusarium pseudograminearum*, FO – *F. oxysporum*, FS – *F. solani*, F.sp. – *Fusarium* sp., Mb – *Microdochium bolleyi*, B.s. – *Bipolaris sorokiniana*.

† Others were species of the genera *Alternaria*, *Cladosporium*, *Curvularia, Penicillium, Chaetomium* and some unidentified fungi.

* Together with *Fusarium* sp. six fragments have yielded a cereal cyst nematode *Heterodera* sp.

It should be remembered, that "whitehead" may be caused as by infection of wheat plants with root and crown rots as by infestation with wheat-stem sawfly pest (*Cephus pygmaeus* L.). Outer symptoms are identical for both cases, but these can be differentiated easily by light stretching a spike: those killed by a pest are pulled out easily together with a part of culm over damaged point; end of such part is commonly twisted and brown-colored. In contrast, at whitehead caused by infection with a fungal root rot stretching never results in pulling out a spike with a part of a culm.

Mycological analysis of samples of infected plants has revealed that the main causal agents of root, crown and lower stem rots and whitehead symptom in wheat fields of Uzbekistan were species of the genus *Fusarium* that had been registered on all 23 samples analyzed (Table 3). These species have included *F. pseudograminearum* on 10 samples, *F. oxysporum* Schlecht. emend. Sn. et Hans. on 7 samples and *F. solani* (Mart.) Appel et Wollenw. em. Sn. et Hans. on 3 samples; isolates of *Fusarium* spp. from 7 other samples have not been identified to species level (Table. 3). These fungi were causes of (i) death of wheat shoots at tillering growth stage at the "Mamatkulov Otabek" farm in Pskent district (sample 11-1); (ii) stunting plants and yellowing leaves at late-boot-heading growth stage on 3 fields in Khazorasp district, (iii) death of mature wheat plants in foci at heading-flowering growth stages on one field in Yukari-Chirchik district (16-2); and death of mature wheat plants in foci at the same growth stage on

several fields of Shakhrisabz and Yakkabag districts (Tables 2 and 3).

However, in some cases when *Fusarium* spp. were isolated also, but other fungi were dominant causal agents of root rot and damping-off diseases. One such case is related to samples (A-2,3,4) of infected plants collected in two fields of "Madad Baraka" area of Izboskan district where number of killed main shoots of wheat at tillering stage has been ~5%. Fifty nine fragments of these samples have yielded on plates with water agar 9 (18.4%) isolates of *Fusarium* spp., while 19 (38.8%) fragments have yielded a fungus *Microdochium bolleyi* – new for Uzbekistan cause of the disease. The same species has been isolated from samples of infected plants collected at the end of season at dough development growth stage (samples 41-1, 41-2) (Turdieva, 2019).

Another case has been related to infection of wheat plants with root rot disease at two farms of Bukhara region. So, disease incidence on a field of the farm "Gazelle" in Shofirkan district at tillering stage equaled to 20-25%, and on a field of the farm "Elgul Fayz Shahnoza" in Jondor district at early-boot stage it has been 15-20%. At mycological analysis 29 fragments (87.9% of total) of diseased roots of the sample B-1 have yielded a fungus *Bipolaris sorokiniana*, causal agent of the common root rot of cereals; isolation frequency of the same fungus from samples collected in Jondor district has been 21.1% (Tables 2 and 3). Koch postulates have been fulfilled, with an artificial inoculation of 12 wheat and one barley varieties with two reference isolates of *B. sorokiniana*; reisolation has been positive in 100% of cases.

It is worth attention that a disease on a sample 11-1 has turned to be complex and was caused by infection of wheat seedlings with two pathogenic organisms simultaneously, namely with a complex of *Fusarium* sp. + cereal cyst nematode, which had morphology and size similar to those of *Heterodera avenae* Wollenw. This nematode has been registered on 5 (41.7%) of 12 fragments of infected with root rot seedlings analyzed (Table 3).

DISCUSSION

Some research in the past has been done on boghara dryland in Jizzakh region where *Fusarium acuminatum* Ell. & Ev., *F. culmorum*, *F. subglutinans* (Wollenw. & Reinking) Nelson et al., *B. sorokiniana*, *R. solani* and *Pythium* sp. were registered as causal agents of root rots on wheat seedlings (Goldstein, Baygulova, 1972; Baygulova et al., 1975a,b). More detailed investigation with wheat root rot diseases have been conducted recently in conditions of saline soils of the Republic Karakalpakstan. Results of this work have shown that disease incidence on fields was between 14% and 23%, and involved fungi were 13 *Fusarium* species; prevailing species were *F. graminearum*, *F. solani* and *F. oxysporum* (Khaitbaeva, 2017). Results of the another research have noted by the way that four *Fusarium* species have been isolated from infected with root rot wheat plants including *F. sporotrichioides* Sherb. (Bukhara region), *F. fujikuroi* Nirenberg (Sir-Darya region), *F. oxysporum* (Kashkadarya region and Republic Karakalpakstan), *F. graminearum* (Khorezm region), *F. culmorum* (W.G. Smith) Saccardo, and *F. poae* (Peck) Wollenw. (Sherimbetov, 2019).

Generally, results of our investigations are in agreement with that that Fusarium root rots of wheat plants have enough wide distribution in our country. However, some questions have appeared there in regard of *Fusarium* spp. stated as the causal agents. We suppose that all references to *F. graminearum* as a cause of wheat root rot in our country should be to *F. pseudograminearum*, on the following reason. Currently it is well known that *F. graminearum* s.l. was split into two morphologically identical taxa, namely *F. pseudograminearum* and *F. graminearum* s.str. *F. pseudograminearum* is one of major pathogens causing crown rot of wheat, while *F. graminearum* s.str. is a pathogen usually causing head scab in wheat (Nicol et al., 2010). It is noted as well that "references to *F. graminearum* as the causal agent of crown rot of wheat are virtually always to *F. pseudograminearum*" (Leslie, Summerell, 2006). *F. graminearum* s.str. is homothallic, and its single-spore cultures produce perithecia on carrot agar quickly (for as little as 4 days), while *F. pseudograminearum* is heterothallic and its single-spore cultures never form perithecia alone (Leslie, Summerell, 2006). Cultures of this species did not produce perithecia in our investigations as well.

Amongst other *Fusarium* spp. registered in our country *F. culmorum* is known as another major pathogen causing crown rot of wheat (Nicol et al., 2010). *F. acuminatum* also sometimes may be involved in disease of wheat (Leslie, Summerell, 2006), but *F. sporotrichioides* usually occurs only on wheat grains (Gagkaeva et al., 2011). *F. oxysporum*, *F. solani*, *F. subglutinans* and *F. fujikuroi* are not reported as causal agents of root rot of wheat. And what is more, "saprophytic members of *F. oxysporum* (and many other *Fusarium* spp.) commonly colonize necrotic roots as secondary invaders, and are readily isolated, and mistakenly assumed to be primary causes of necrosis" (Leslie, Summerell, 2006). It is highly probable that *F. oxysporum*, *F. solani*, *F. subglutinans*, *F. fujikuroi*, and also *F. poae* and *F. sporotrichioides* reported in our country also were not primary pathogens of wheat root diseases but only secondary invaders.

It has been a surprise to register a high incidence of severe infection of seedlings and mature plants with a common root rot in fields of two districts of Bukhara region (Table 2). To our knowledge, this is the first record of severe infection of winter wheat plants with a root rot caused by *Bipolaris sorokiniana* on irrigated areas in Uzbekistan. Previously this fungus was found causing some infection of wheat seedlings on boghara areas in Jizzakh region; incidence of the disease has not been reported by authors (Goldstein, Baygulova, 1972; Baygulova et al., 1975a,b).

Also for the first time we have recorded infection of wheat seedlings with a complex *Fusarium* sp. + species of the *Heterodera avenae* group. Till the current report there were no reports about infecting wheat plants

with any of cereal cyst nematodes (CCN) in Uzbekistan. Taxonomy of CCN is complex and *H. avenae* group contains ~12 species (Nicol et al., 2010; Smiley et al., 2017). It has been reported that one species of this group, namely *H. filipjevi* (Madzhidov) Steiner, was present in many regions of Tadjikistan, a neighboring country to Uzbekistan (Madzhidov, 1991). These nematodes are causal agents of economically important diseases of wheat crop causing all stunting plants, chlorosis on leaves, death of shoots, decreasing both number of roots and plant stand (Nicol et al., 2010; Smiley et al., 2017).

CONCLUSIONS

1. Reports about wide distribution of Fusarium root, crown and foot rots on wheat plants in Uzbekistan were confirmed.

2. For the first time in Uzbekistan severe infection of winter wheat seedlings and mature plants with *Bipolaris sorokiniana*, causal agent of the common root rot of wheat was registered in Shofirkon and Jondor districts of Bukhara region.

3. For the first time in the country infection of winter wheat seedlings and mature plants with *Microdochium bolleyi*, causal agent of root rot and seedling blight of wheat was registered in Izboskan district of Andijan region.

4. For the first time in Uzbekistan infection of winter wheat seedlings with a complex *Fusarium* sp. + species of the *Heterodera avenae* group has been recorded in Pskent district of Tashkent region.

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