ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Increasing Spread of *Claviceps purpurea (Fr). Tul*. And It's Effect on the Quantity and Quality of Winter Rye.

M. Ponomareva*, S. Ponomarev, G. Mannapova, and L. Gilmullina.

Federal State Budgetary Scientific Institution «Tatar Scientific Research institute of Agriculture», Orenburg tract, 48, 420059, Kazan, Tatarstan, Russia.

ABSTRACT

Tatarstan Republic is the largest region for the rye production in Central Russia. Problem of increasing infection *Claviceps purpurea* on winter rye has become very important in this region. The aim of this work was to evaluate the occurrence and harmfulness of ergot in Tatarstan. Our experimental findings revealed the ergot of rye to be widespread in Tatarstan Republic. The Russian standard for food grain is 0.05% ergot by weight and there are strict limits on ergot in certified rye seed. Ergot on rye developed in close connection with environmental factors (amount of precipitation, average temperature and relative humidity). We studied that presence one sclerotia in spike significantly reduced the number of grain (19%) and the kernel weight per ear (18.4%). When the number of sclerotia per ear increased to 6, the amount of winter rye grains decreased by 51.4% as compared to healthy ears. We investigated the variability of the infection reaction to *C. purpurea* in more than 90 cultivated varieties Russian and Foreign selection, aiming to find possible sources of resistance for use in the rye breeding program. We identified 6 Russian and 7 foreign varieties with the smallest defeat ergot (0.01-0.03%).

Keywords: *Claviceps purpurea,* winter rye, ergot fungus, resistance, variety, Tatarstan Republic

Corresponding author

ISSN: 0975-8585

INTRODUCTION

Ergot is invoked widely specialized fungus *Claviceps purpurea (Fries ex Fries) Tulasne.* Pathogen is capable of infecting more than 400 species of plants, but most of them are rye in connection with the nature of cross-pollination. Economically most important is the infection of rye (*Secale cereale* L.) which is a major crop in Germany, Russia, Poland, Belarus, Scandinavia and Ukraine [1].

Ergot has a negative impact on the quality of causing contamination of grain toxic alkaloids to humans and animals [2-4]. The toxic properties of ergot alkaloids are the most limiting factor restricting the use of contaminated grain in baking and feed purposes [5-7].

The spread of the disease observed in Europe, Asia, North America (except for the Far North) [8], in North Africa, parts of Australia and South America (Argentina, Mexico) [9]. The most favorable for the development of ergot are areas with high relative humidity (>70%) and moderately warm weather during the flowering rye (22-24 °C) [10, 11].

Resistance to ergot should be treated with the attention on rye genotypes with high pollen ability [12]. Susceptible to defeat by a fungus *Claviceps purpurea* male sterile plants significantly exceeds the level of destruction of rye population [13-15]. This is especially the case when a hybrid cultivar is not fully restored to fertility and the flowering times of the seed and pollen parent are not fully synchronized [16]. In recent years, with the creation of hybrid varieties, priority is given to increase the completeness of pollination using effective genes of fertility restoration for which are molecular markers [17].

The introduction the minimum methods of soil tillage, ergots imported in the seed, the growth of non-cultivated land, the lack effective machines for grain cleaning and fungicides causes the resumption of pathogenesis [18].

The most toxic ergot is a year of harvest [19]. Dried sclerotia stay infectious for 9–12 months [20]. Viability physiologically ripe sclerotia reaches 90%, the number of sclerotia germinated last year is less than 10%, while keeping sclerotia for two years makes them completely non-viable. The situation is further complicated because all of these mechanisms are highly affected by weather shortly before and at flowering. Complex interactions between weather, fungal infection and spread, and pollen availability must be considered. In all crops, rainy weather at flowering time reduces pollen shedding and pollen movement [18].

A genetic source of resistance to ergot within genus *Secale L.* (cultivated and wild species of rye) is still not detected. There are no resistance genes known in cereal crops; obviously, the fungus has adapted optimally to its hosts. For improving disease resistance in plant breeding, following steps are required: evaluation of genetic resources and selection of resistant germplasm; crossing selected genotypes with elite breeding materials and evaluation of segregating progeny and selection of the most promising progenies and using the best ones as resistance donors in cultivar development [16].

The objective of this work was to determine spread of *Claviceps purpurea* and harmful of ergot fungus in central part of Russia. The study reported about the occurrence of ergot in outstanding rye region in Tatarstan, which provides great value for farmers and industry.

MATERIALS AND METHODS

The study was carried out at the Tatar Research Institute of Agriculture. Tatarstan is situated in the centre of Russia Federation, in place of confluence two largest Europe rivers - Volga and Kama (latitude 55_◦47_19__ N, longitude 49_◦07_19 __ E).

According to methodology, specialists of the Russian State Plant Protection Station annually assessed the ergot incidence in commercial fields at the ripening growth stage (GS 87-89) of cereals. The incidence of ergot was observed in 150 commercial fields of winter rye in different regions of Tatarstan Republic annually over the period of 1998-2012. The incidence of ergot and percentage of infected ears were determined in winter rye varieties of own selection Tatar 1, Estafeta of Tatarstan, Radon, Tantana, Ogonek.

With a view of estimating the effect of ergot on the number of grain and kernel weight per rye ear, the spikes with different incidence of ergot from 0 (control) to 6 sclerotia were collected and evaluated. The amounts of grain per ear, the grain weights on the ear were found to have equal variances and distributions and were analyzed by ANOVA. A relationship between the sclerotia weight per ear and kernel weight was determined by linear regression and correlation analysis. Statistical significance of linear trends was assessed by Student's test, which, if the sample size in 15 years, corresponding to the value of $R^2 \geq 0.26$ at a significance level of 95%.

For evaluation of genetic resources we were examined varieties breeding of Tatar Research Institute of Agriculture, samples obtained from N.I. Vavilov Russian Scientific Research Institute of Plant Production (Saint Petersburg) in the competitive strain testing of rye and collection nursery in 2008-2012 in natural infectious background. For this purpose, we investigated 200 plants of each variety in two replications. Average of the sample of grain (not less than 100 g) stood out weighed and infestation of sclerotia was calculated using the formula:

$$X = 100 \times P / A,$$

where P - sclerotia weight in grams; A - grain weight in grams; X - the percentage of infestation.

RESULTS AND DISCUSSION

The winter rye is a unique agricultural crop for Russia with exclusively greater economic value, and the increase in manufacture of its grain was and remained an actual problem of agriculture. In addition, the main cereal crop in the Volga region of Russia is a winter rye, the potential for productivity and quality of grain, which is caused by genetics of varieties. The first place among all the regions of Russia on rye production takes Tatarstan [21].

Problem of increasing infection *Claviceps purpurea* on winter rye has become very important in many regions of Russian Federation. The analysis showed that until 1996 ergot was not economically significant disease. It was found that over the past 15 years have been reported four strong epiphytoties (2003, 2007, 2011, 2012) and only three years (1998, 1999, 2010) there was no disease (Fig.1). The Russian standard for food grain is 0.05% ergot by weight and there are strict limits on ergot in certified rye seed. Five years from 15 ergot contamination on average exceeded maximum permissible norms for food rye. Depressive disease was observed in years with strong summer drought. Complex interactions between weather, fungal infection and spread, and pollen availability must be considered [16].

One reason for disease amplification is the weather conditions favorable for development pathogen. Correlation between ergot susceptibility and average daily temperature 2 ten days of June (beginning of flowering) r = -0,689** ± 0,256 (F =3.9), relationship between infestation ergot and average temperature June r = -0,614* ± 0,196 (F = 3.13). An increase in temperature during flowering rye reduces the defeat ergot. Negative correlation was found between the defeat of ergot and relative humidity in 3 ten days of June r = 0,691** ± 0,176 (F = 3.94). Consequently, ergot on rye developed in close connection with environmental factors (amount of precipitation, average temperature and relative humidity).

Regression analysis of long-term data showed that an increase in temperature during flowering rye 1 degree Celsius is reduced ergot infected plants by 0.13% (Fig.2). The regression equation between parameters relative humidity - number of infected plants has the form: y = 0,0511x - 2,635 (Fig.3). Therefore, if the relative humidity of air increases at 1%, those infestations increase of 0.05%.

Claviceps purpurea is a ubiquitous pathogen of cereals, causing ergot disease, which results in substitution of grains by sclerotia [23]. We studied the influence of the amount of sclerotia per spike on the number of grains as well as kernel weight per ear (fig.4). Presence one sclerotia in spike significantly reduced the number of grain (19%) and the kernel weight per ear (18.4%). When the number of sclerotia per ear increased to six, the amount of winter rye grains decreased by 51.4% as compared to healthy ears.

Yield losses consist of direct damage (no grain, instead of which is formed sclerotia) and indirect (as a result of a large number of empty spikelet, adjacent to those which form ergot). Increasing the number of sclerotia in the ear reduces the number of grains per spike and grain weight from the ear (r = -0.76-0.80). We

have established significant damage from ergot on the rye ear productivity The increase in infestation of ear 1 sclerotia reduced the weight of grain from the ear to 0.19 g and the number of grains per ear by 4.73 (Fig.4).

Currently plant breeders need to investigate their potential varieties for ergot resistance; they make systematic assessment of the flowering characteristics that may be associated with escape ergot. Prerequisite for the successful breeding of winter rye for resistance to *Claviceps purpurea* is to identify resistant samples from the collection of VIR [24]. Therefore, we investigated the variability of the infection reaction to *C. purpurea* in the cultivated varieties Russian and Foreign selection, aiming to find possible sources of resistance for use in the rye breeding program.

Field observations have indicated that some varieties of winter rye are more susceptible than others, but experimental evidence of resistance has not been reported. During 2008-2012 were estimated more than 90 varieties in natural infectious background. Absolutely resistant genotypes have not been found. Most of the Russian samples were moderately susceptible varieties. Infestation of grain mass ergot sclerotia varied from 0.01 to 0.76%. Were identified 5 Russian (IL 23/94, Ilmen, Kama 3, Siberian, 82, Ržanka) and 7 foreign varieties ((Pallada (Ukraine), Pudmericke (Czech Republic), $J_0$3374 (Finland), P-8, A-8 (Netherland), Frederick (USA), Gaderovo (Poland)) with the smallest defeat ergot (0.01-0.03%). Among of own population varieties of rye for resistance to ergot should be allocated variety Tatar 1. The mechanism of resistance to ergot this variety is a great synchronicity of stems, a short time of flowering and high pollen shedding ability. Research by Mirdita et al. showed that among 245 rye entries ergot severity ranged from 1.19%–8.07% sclerotia in grain by weight. Analyses of variance revealed high heritability despite high genotype–environment interactions [24].

Miedaner et al. believe that the ergot incidence (percentage of affected heads) and ergot severity (percentage of sclerotia in grain by weight) are the most representative resistance traits when using pollen-shedding material. In rye, both traits are highly correlated (r = 0.69–0.97) and have similar heritability (h^2 = 0.90 and 0.89, respectively) [25]. The situation is further complicated because all of these mechanisms are highly affected by weather shortly before and at flowering. Further studies need to be conducted to complex interactions between weather conditions, fungal spread, pollen shedding availability and synchronicity of stems.

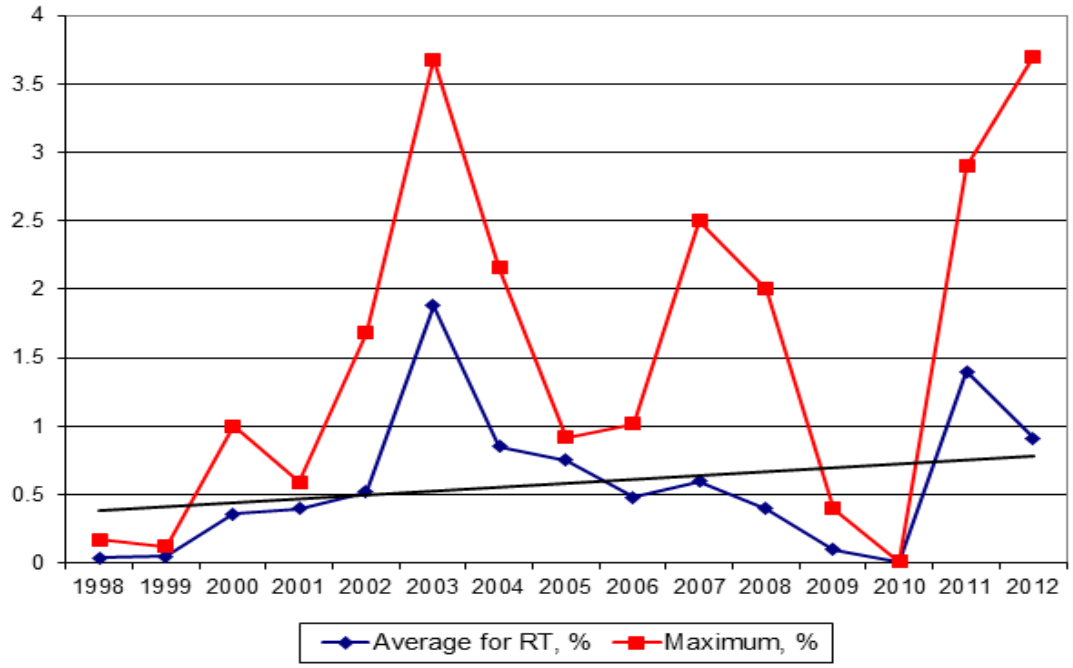

Fig.1: Dynamics of destruction ergot of winter rye in Tatarstan (%)

ISSN: 0975-8585

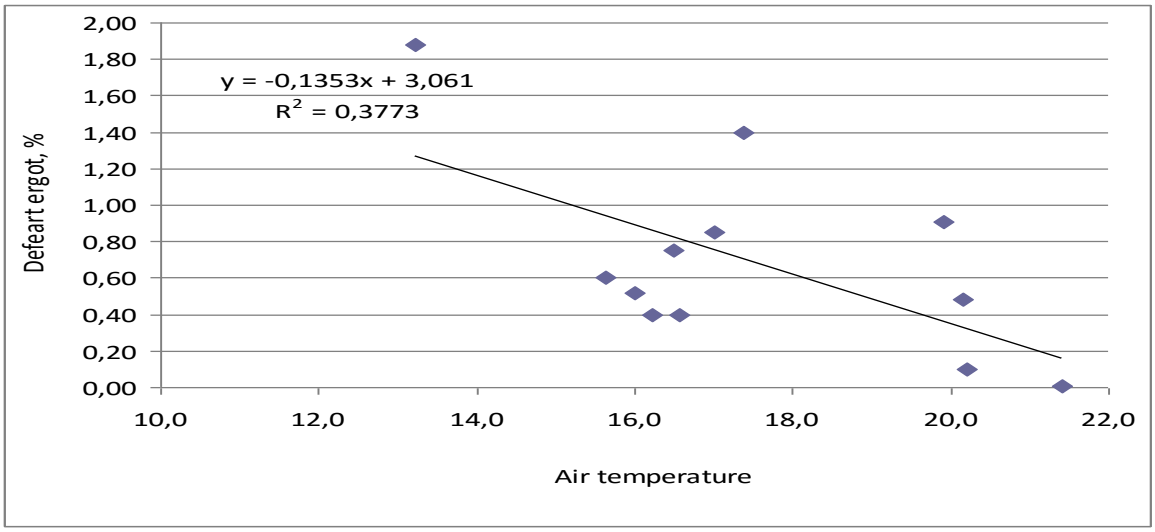

Fig.2: Dependence of winter rye ergot defeat on the air temperature in June

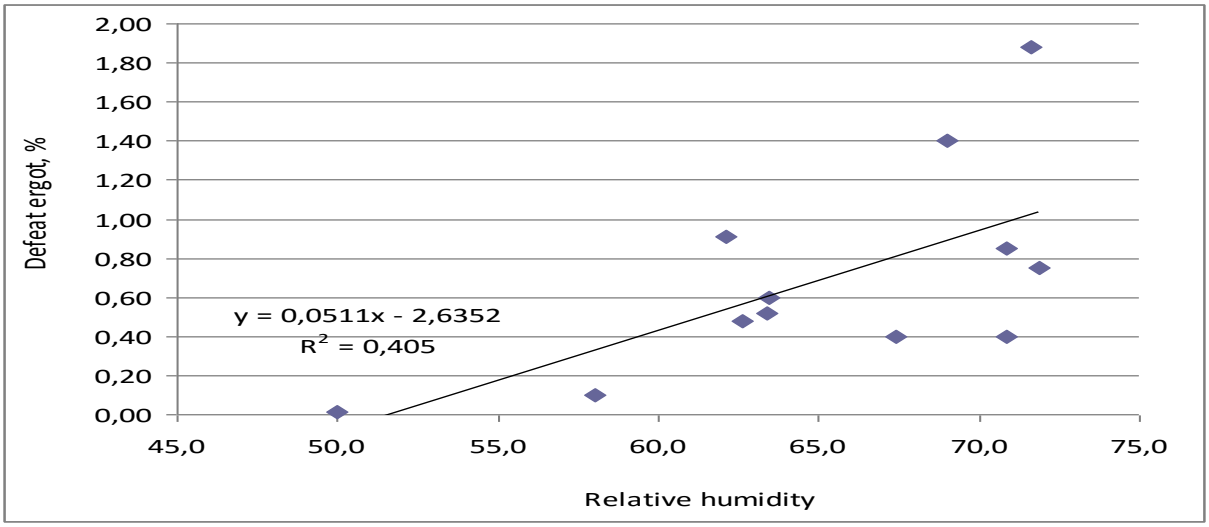

Fig.3: The dependence of the defeat of winter rye ergot the relative humidity in June

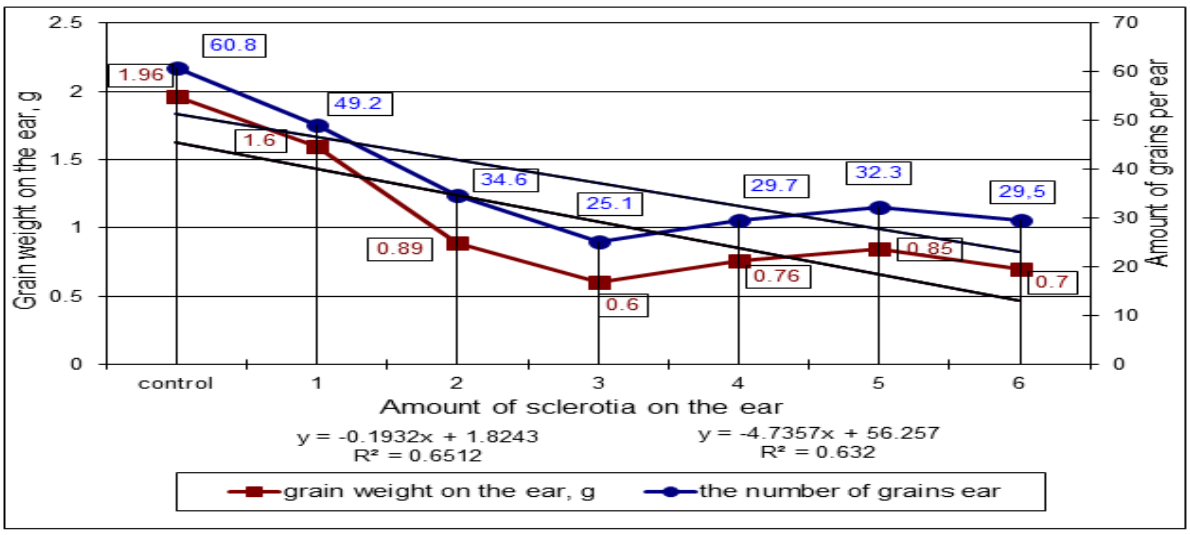

Fig.4: Dependence of grain weight and number of grains per ear

ISSN: 0975-8585

CONCLUSIONS

Ergot fungus of rye is widespread in Tatarstan Republic, which is the largest region for the rye production in Central Russia. The Russian standard for food grain is 0.05% ergot by weight and there are strict limits on ergot in certified rye seed. It was found that five years from 15 ergot contamination on average exceeded maximum permissible norms for food rye. Problem of increasing infection *Claviceps purpurea* on winter rye has become very important in this region. Ergot significantly reduced the number of kernel and weight of grain per ear by 51.4% as compared to healthy spikes in winter rye crops. Spread of *Claviceps purpurea* on rye developed in close connection with environmental factors during flowering (amount of precipitation, average temperature and relative humidity). We identified 6 Russian and 7 foreign rye varieties with ergot incidence (0.01-0.03%).

REFERENCES

[1] Geiger HH, Miedaner T. Rye breeding. In Cereals (Handbook of Plant Breeding), Springer: New York, NY, USA, 2009;157–181.

[2] Nemkovich AI. Ergot of cereals, J Protection and Plant Quarantine 2006;6:25-26.

[3] Mielke H, Betz G. Bedeutung des Mutterkorns und pflanzenbauliche Möglichkeiten zur Bekämpfung bei Roggen Gesunde Pflanzen 1995;5:76-84.

[4] Mielke H. Studien über den Pilz *Claviceps purpurea (Fries) Tulasne* unter Berücksichtigung der Anfälligkeit verschiedener Roggensorten und der Bekampfungsmoglichkeiten des Erregers, Mitt. aus Biol. Bundesanst. fur Land- und Forstwirtschaft, Berlin 2000;66 p.

[5] Dignean MA. Schiefer HB, Blair R. Effects of feeding ergot-contaminated grain to pregnant and nursing sows, Zbl. Veter.-Med. Reihe 1986;10:757-766.

[6] Oresanya TF, Patience JF, Zijlstra RT e.a. Defining the tolerable level of ergot in the diet of weaned pigs. Canad.J.Anim.Sc 2003;3:493-500.

[7] Munzing R, Pottebaum K, Wolf K. Mutterkorn im Roggen und Konsequenzen für die Mühle. Getreide Mehl Brot 2004; 6:349-356.

[8] Riesselman J, Baldridge D, Rumney JS. J. Ergot and its control. Crop. Protect. 1983;5:3-4.

[9] Workneh F., Rush CM, Evaluation of relationships between weather patterns and prevalence of sorghum ergot in the Texas Panhandle. Phytopathology 2002;6:659-666.

[10] Buga SF, Nemkovich AI. The role of hydrothermal conditions in the germination of sclerotia *Claviceps purpurea (Fr.) Tul*. Plant Protection. - Minsk 1998;21:28-33.

[11] Montes-Belmont R, Mendez-Ramirez I, Flores-Moctezuma E. Relationship between sorghum ergot, sowing dates, and climatic variables in Morelos. Crop Protect 2002;10:899-905.

[12] Wilde P. Mutterkorn matt setzen. Hybridsorten mit besserer Pollenbildung kommen *DLZ* Agrarmag. AgroBonus 2000;9:68-71.

[13] Gaspar I, Ignatescu I, Madej L. Posibilitate de folosire a formelor androsterile de secara in producerea sclerotior de *Claviceps purpurea (Fr.) Tul*. An. Inst. Cerc. Cereale Plante Tehn. Fundulea. – Bucaresti 1990;41-59.

[14] Mantle PG, Swan DJ. Effect of male sterility on ergot disease spread in wheat. Plant Pathol 1995;2:392-395.

[15] Kolasinska I, Maluszynska E. Factors influencing the ergot infection of male sterile rye. Polish phytopathology Soc. Poznan 2004;15-23.

[16] Miedaner Th., Geiger HH. Biology, Genetics, and Management of Ergot (Claviceps spp.) in Rye, Sorghum, and Pearl Millet. Toxins 2015;7: 659-678; doi:10.3390/toxins7030659

[17] Hackauf B, Stojalowski S., Wortmann H., Wilde P., Fromme F.J. e.a. Minimierung des Mutterkornbefalls im Hybridroggen durch Ansätze der Prazisionszuchtung. Journal für Kulturpflanzen 2009;61:15-20.

[18] Shekleina LM, Sheshegova TG Immunological status of promising breeding populations of rye Agricultural Research Institute of the Northeast Scientific and technological agriculture 2012;6:23-26.

[19] Afanasova MA, Sheshegova TK, Kedrova LI. Purple ergot (*Claviceps purpurea (Fr.) Tul*.) on rye. Agricultural science Euro- Northeast 2003;3:67-70.

[20] Frederickson DE, Mantle PG, Milliano WA. J. Windborne spread of ergot disease (*Claviceps. africana*) in sorghum A-lines in Zimbabwe. Plant Pathol 1993;42:368–377.

[21] Ponomareva ML, Ponomarev SN, Tahirov M.Sh. Dynamic factors of production and use of grain rye in the Russian Federation and Tatarstan Republic. Zemledelie: 2014;8:6-9.

[22] Tudzynski P, Scheffer J. *Claviceps purpurea*: molecular aspects of a unique pathogenic lifestyle - Molecular Plant Pathology 2004;V.5, Issue 5:377–388.

[23] Khaziev AZ, Ponomareva ML. Damage from ergot on rye and its prevention measures. Journal of Kazan State Agrarian University 2007;2:80-82.

[24] Mirdita V, Dhillon BS, Geiger HH, Miedaner T. Genetic variation for resistance to ergot (*Claviceps. purpurea [Fr.] Tul.*) among full-sib families of winter rye (*Secale. cereale L.*). Theor. Appl. Genet 2008;118:85–90.

[25] Miedaner T, Mirdita V, Rodemann B, Drobeck T, Rentel D. Genetic variation of winter rye cultivars for their ergot (*Claviceps. purpurea*) reaction tested in a field design with minimized interplot interference. Plant Breed 2010;129:58–62.