Influence of different soil tillage methods on the development of root rot in spring wheat

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Abstract. The study was carried out in the grain-fallow-hoed crop rotation in the stationary field experience of the Minderlinskoe academic and experimental facility of Krasnoyarsk State Agrarian University. A positive effect of green manure rapeseed fallow on the phytosanitary condition of the spring wheat crops in the traditional moldboard ploughing by 20-22 cm was found: the root rot rate declines by 8.2-10.9% compared to the absence of any soil tillage. The best conditions for the growth and tillering were identified in the variant when the wheat was preceded by green manure rapeseed fallow with the soil ploughed by 20-22 cm; this variant provided the largest crop yield from 1 ha. The paper presents the mycoflora analysis of the daughter seeds of the Novosibirskaya-15 spring wheat cultivated on the soil tilled with different methods. The study showed that the mycoflora of the daughter seeds of the Novosibirskaya-15 spring wheat cultivated on the soil tilled with different methods is mostly represented by Fusarium sp., p. Alternaria sp., Bipolaris sp., Penicillium sp. The plant pathogenic fungi of Alternaria sp. was found to dominate in all the variants of the experiment. Statistic significance of the difference (p<0.001) between the experiment variants in the intensiveness and prevalence of the disease has been found. The greatest disease development index was found in the spring wheat cultivated without basic soil tillage, and the smallest index was demonstrated by the variant with the moldboard ploughed soil (20-22 cm).

1. Introduction
Root rots are the most common and harmful crops diseases in the Krasnoyarsk Territory. The annual shortfall of wheat grain production exceeds 7%. According to the regional plant protection station, the root rots are especially harmful in the subhumid (forest-steppe) and arid steppe areas. According to the data collected over the years, the average root rot incidence rate in the region is 20.7%. In the hyperarid years, this index reaches 60-80%, increasing by 30% [1].

At the present moment, the crops protection is the actual focus of the cultivation technology as the incidence of plant pathogenic fungi in the soil and the sowing seeds is reaching a critical level. In the sowing seeds used at different farms, there is hardly any healthy seeds found; almost every batch of seeds is infected with the pathogenic microorganism to a certain extent. Common root rot agents are the microorganisms most frequently revealed during diagnostics of crop seeds [2], [3], [4].

According to E. Yu. Toropova, O. A. Kazakova et al. [5], generally the problem of fusarium-caused root rot and Helminthosporium blight incidence in Western Siberia and Trans-Urals may be successfully solved with a series of agrotechnical methods of the refinement and increasing the suppressiveness of
soil. Such fundamental techniques include the phytosanitary seed rotation and use of predecessors, organic and mineral fertilizer application and optimization of the soil tillage systems.

Soil tillage is required not only to loosen the soil but also to combat the harmful microorganisms including their inactive forms. In well-tilled fields, the lower disease incidence is observed. The agrotechnical method is one of the main ones in the overall plant disease combating complex [6].

Within the aforementioned problem, our researches cover the influence of the spring wheat predecessors in crop rotation with basic soil tillage (moldboard ploughing by 20-22 cm) and without basic soil tillage (fertilized and non-fertilized background) on the incidence and development of spring wheat diseases, as well as the prevalence of plant pathogenic fungi on the daughter seeds of spring wheat.

The objective of the research is to study the influence of predecessors on the incidence and development of spring wheat diseases when cultivated on the moldboard ploughed soil (ploughing by 20-22 cm) and without basic soil tillage (none) on the spring wheat crop yield, as well as the influence of soil tillage on the prevalence of plant pathogenic fungi on the daughter seeds of spring wheat.

2. Methods and results
The study was carried out in the grain-fallow-hoed crop rotation in the stationary field experience of the Minderlinskoe academic and experimental facility of Krasnoyarsk State Agrarian University.

The object of study is leached chernozem with high humus content (6.1-8.0%) and neutral soil solution reaction (pH 6.1-7.0). The granulometric composition of leached chernozem is heavy argillaceous; another object of study is the plant pathogenic fungi on the daughter seeds of the Novosibirskaya-15 spring wheat cultivated on the soil tilled with different methods. The spring wheat was preceded by green manure fallow.

In the top-soil layer of the leached chernozem, excessive labile phosphorus content (200-250 mg/kg of soil) and very high exchangeable potassium content of over 150.1 mg/kg K2O was found.

The research was carried out in crop rotation of the following sequence: green manure fallow – spring wheat – barley – corn – spring wheat.

The spring wheat breed used for the experimental seeding was Novosibirskaya-15.

The experiment pattern included the following variants: 1. Moldboard soil tillage (ploughing by 20-22 cm). 2. Non-moldboard tillage (subsurface ploughing by 20-22 cm). 3. Minimal tillage (disk ploughing on 8-10 cm). 4. No basic soil tillage.

The total area of the field experiment is 10 hectares. The number of replications – 4 times. The term for sowing of spring wheat is the third decade of May. The agricultural methods of cultivating the spring wheat are the common ones used in this soil and climatic zone [7].

For every variant, the spring wheat was sown in two backgrounds, fertilized and non-fertilized. As a mineral fertilizer, ammonia nitrate was applied at the dose of 34.7 kg/ha.

During the vegetation period and in the laboratory conditions, the following observations and examinations were carried out:

1. Incidence and development of diseases for the period established by the standard methods, assessed with the scales (score, per cent) recommended by the All-Russian Institute of Plant Protection [8]. Phytoexpertise of the seeds with the damp roll method. The seed infestation was detected upon germination in a humid chamber with the roll culture method in accordance with GOST 12044-93 ‘Agricultural seeds. Methods for determination of disease infestation’ [9]. Moreover, during the experiment, the sprouts growth dynamics, length of coleoptile and aerial parts of the plants were checked after 14 days. 4. The research results were mathematically treated with the classic statistical method of the one-way analysis of variance. The qualitative composition of the mycoflora of the infested seeds was assessed with the arbitrary sized contingency tables with the x2 criterion (Chi-square) [10]. The used software was MS Office XP and statistic calculator by Social science statistics. 5. The harvest structure analysis was carried out before harvesting the grain cultures with the method of experimental sites divided with the diagonal lines drawn in equal intervals for all the experiment variants replicated 4
times. 6. The seed productivity was calculated based on the harvest structure data (productive plant stand, ear grain content, weight per 1000 kernels).

In autumn 2017, the stubble wheat samples were taken to assess the root rot infestation; the wheat was preceded by green manure rapeseed fallow and corn. The samples were collected for different kinds of basic soil tillage methods and for the fertilized and non-fertilized plant nutrition backgrounds (table 1).

| Basic soil tillage methods | Background          | Wheat preceded by green manure fallow | Wheat preceded by corn |
|----------------------------|---------------------|---------------------------------------|------------------------|
|                            | Fertilized          | Infestation, %                        | Infestation, %         |
| Ploughing by 20-22 cm      | No fertilizer       | 15.5                                  | 25.0                   |
|                            | Fertilized          | 30.2                                  | 38.0                   |
| No basic soil tillage      | No fertilizer       | 26.4                                  | 51.5                   |

In our crop rotation, the grain crops saturation is 60%; in such situation, it is very important to distinguish the spring wheat by different phytosanitary predecessors. Comparing the spring wheat predecessors and the effect they make on the root rot development, we notice a decline in the infestation of the underground organs of the spring wheat preceded by green-manure fallow on the soil ploughed by 20-22 cm and on the non-tilled soil, compared to the spring wheat preceded by corn. It should be noted that the application of nitrogen fertilizers to the wheat preceded by green manure fallow causes the increase in the root rot rate regardless of the basic soil tillage method by 3.8-7.5% (table 1).

In the years 2017 and 2018, after the spring wheat harvest, the seeds were examined with the damp roll method. The phytoexpertise results (2017) showed the infestation of the seeds with the following pathogenic organisms: *Bipolaris sorokiniana* – from 31.0% to 48.0% on ploughed and non-tilled soil (fertilized) for wheat preceded by green manure fallow; *Fusarium* sp. – from 9% to 14% on the same variants, i.e. the dominating fungi were *B. sorokiniana* and *Alternaria* sp. in the ratio of 1:3.

In 2018, the rate of seed infestation with pathogenic organisms ranged from 25% to 46%. The greatest infestation rate was found for the zero soil tillage variant (no-tillage) against the fertilized background – 44% and 46% for both wheat preceded by corn and by green manure fallow.

The research of the spring wheat seeds harvested in 2019 showed that the mycoflora of the daughter seeds of the Novosibirskaya-15 spring wheat cultivated with different soil tillage methods is represented mostly by the plant pathogenic fungi *Fusarium* sp., *Alternaria* sp., *Bipolaris sorokiniana*, and *Penicillium* sp. (figure 1, figure 2).

Figure 1. Microscopic fungi *Fusarium* sp. (left) and *Alternaria* sp. (on right).
Figure 2. Microscopic fungi *Bipolaris sorokiniana* (left) and *Penicillium* sp. (on right).

Generally, the \( \chi^2 \) criterion-based (Chi-square) table assessment demonstrated that between the different experimental variants, no statistically significant difference in the seed infestation mycoflora composition is found. However, there are statistically significant differences \((p<0.001)\) in the disease intensiveness between different experimental variants. Thus, the moldboard ploughing (20-22 cm) caused a statistically significant decline in the disease development index of 28.0 pct, or by 2.0 times less compared to the variant with no basic soil tillage at all.

The harmful level of the root and foot rots was assessed by the crops examination carried out twice a season: in the tillering phase and the milky-wax kernel ripeness phase. According to the research results, at the beginning of the tillering phase the root rot development was more intensive on the non-tilled soil compared to the soil ploughed by 20-22 cm, both for the fertilized background: from 23.0 to 39.7\% (for wheat preceded by green manure fallow on ploughed soil and non-tilled soil), from 26.0 to 27.5\% (for wheat preceded by corn), and the non-fertilized background: from 34.3 to 35.2\% (wheat preceded by green-manure fallow), from 40.0 to 52.3\% (wheat preceded by corn). The infestation of the underground organs with root rots was below the harmful level only for the wheat preceded by green-manure fallow and the wheat preceded by corn, with the basic soil tillage method being the ploughing by 20-22 cm against the fertilized background. Severe infestation rate was found for the wheat preceded by corn on the non-tilled soil and without nitrogen fertilizer applied. For other experimental variants, the infestation was moderate.

By the milky-wax kernel ripeness phase, the root rot infestation rate grew higher, and the intensiveness of the root diseases increased by 1.2-2.5 times. The warm dry soil and the stressful situation for plants (the precipitation in June-July was 2.1-2.3 times lower than the average annual level) created comfortable conditions for the development of Helminthosporium blight.

In the year 2018, the weather did not facilitate the transmission of the airborne infection agents from one plant to another. The year was very arid. In the majority of cases, the disease development level was below the harmful level (10-15\%) in the grain formation period: wheat preceded by corn (14.5 and 15.2\%) on ploughed soil by 20-22 cm and wheat preceded by green manure fallow on the non-tilled soil (14.1-11.0\%) against the fertilized and non-fertilized background.

The basic soil tillage system plays a special role in disease development. The absence of such tillage is believed to cause an excessive amount of infection agents compared to the ploughed soils in both humid and arid years. In our experience, cultivating wheat preceded by corn against a non-fertilized background without soil tillage causes an increase in the disease intensiveness by 10.6-13.0\% and by 16.8\% compared to the traditional soil tillage i.e. moldboard ploughing by 20-22 cm for the same variants. The predecessors of the wheat, the nitrogen fertilizers applied and the basic soil tillage methods made an impact on the biometric properties and the crop yield of the cultivated spring wheat.

The seed productivity of the spring wheat ranged from 36.0 to 51.0 centners/ha on the soil tillage with the ploughing by 20-22 cm (table 2). Spring wheat cultivation without soil tillage decreases the crop yield to 26.5-33.37 centners/ha.
Comparing the influence of the predecessors, the greatest efficiency (by 18-19%) was attributed to the variant that foresaw cultivating wheat preceded by green-manure rapeseed fallow against either the fertilized or non-fertilized background, compared to the wheat preceded by corn on the soil ploughed by 20-22 cm. On the non-tilled soils, the best wheat predecessor was corn, causing 18-26% higher crop yield compared to green manure fallow.

The best conditions for the growth and tillering were identified in the variant when the wheat was preceded by green-manure rapeseed fallow with the soil ploughed by 20-22 cm; the plants thickened out to the maximum and provided the largest crop yield from 1 ha. The plant stand density per 1 m² (380 pcs) and the sprout density (84%) were also higher for this variant.

**Table 2. Seed productivity of spring wheat, 2018.**

| Variant                        | Backgrou  | Productive ears, pcs | Ear grain content, pcs | Weight per 1000 kernels | Seed productivity (centners/ha) |
|-------------------------------|-----------|-----------------------|------------------------|--------------------------|-------------------------------|
| Ploughing by 20-22 cm         |           |                       |                        |                          |                               |
| 1. Wheat preceded by green manure fallow | Fertilized | 432                   | 36                     | 32.8                     | 51.0                          |
|                                | Non-      | 418                   | 33                     | 32.4                     | 44.7                          |
|                                | fertilized|                       |                        |                          |                               |
| 2. Wheat preceded by corn      | Fertilized| 330                   | 36                     | 34.9                     | 41.5                          |
|                                | Non-      | 350                   | 32                     | 32.2                     | 36.0                          |
|                                | fertilized|                       |                        |                          |                               |
| Non-tilled soil                |           |                       |                        |                          |                               |
| 1. Wheat preceded by green manure fallow | Fertilized | 316                   | 33                     | 32.0                     | 33.37                         |
|                                | Non-      | 289                   | 30                     | 30.6                     | 26.5                          |
|                                | fertilized|                       |                        |                          |                               |
| 2. Wheat preceded by corn      | Fertilized| 378                   | 36                     | 33.4                     | 45.4                          |
|                                | Non-      | 343                   | 29                     | 32.4                     | 32.2                          |
|                                | fertilized|                       |                        |                          |                               |

The crop yield increased mostly due to the increased productive plant stand and the ear grain content. The weight per 1000 kernels did not make a significant impact on the harvest formation.

3. Conclusion

A positive effect on the phytosanitary condition of the sown spring wheat preceded by green manure fallow is made by traditional ploughing by 20-22 cm; the root rot development decreases by 8.2-10.9% compared to the non-tilled variant.

The mycoflora analysis of the daughter seeds of the Novosibirskaya-15 spring wheat cultivated on the soil tilled with different methods showed that it is mostly represented by mycomycetes Fusarium sp., Alternaria sp., Bipolaris sp., Penicillium sp. At that, in all the years of research and in all the variants the dominating fungi species was plant pathogenic fungus Alternaria sp.

The greatest infestation of seeds with pathogenic organisms was found on the non-tilled soils (fertilized) for wheat preceded both by green manure fallow and by corn.

During the tillering phase (2018), the infestation of the underground organs with root rots was below the harmful level only for the wheat preceded by green manure fallow and the wheat preceded by corn, with the basic soil tillage method being the ploughing by 20-22 cm against the fertilized background. Severe infestation rate was found for the wheat preceded by corn on the non-tilled soil and without nitrogen fertilizer applied.
Cultivating wheat preceded by corn against a non-fertilized background on non-tilled soils causes an increase in the intensiveness of septoria spots by 16.8% compared to the traditional soil tillage, i.e. ploughing by 20-22 cm for the same variant.

The variant providing the most stable effect in productivity and phytosanitary condition of the wheat seeds is the traditional ploughing by 20-22 cm. The best conditions for the growth and tillering were identified in the variant when the wheat was preceded by green manure rapeseed fallow with the soil ploughed by 20-22 cm; this variant provided the largest crop yield from 1 ha.

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