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Zoning of rice growing territory of Krasnodar region by the set of features of *Pyricularia oryzae Cav.* isolation

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Abstract. The geographical location and relief of the Krasnodar Territory determines a wide variety of agro-climatic and agro-technological conditions for the production of crops. On the territory of the Krasnodar Territory there is the largest part of agricultural land intended for the production of rice crops in Russia. Annual infection of rice plants with pathogenic *Piricularia Orizae Cav.* due to a wide range of strain diversity and indicates a significant dependence of the population genotype on the territorial distribution area. Therefore, the identification of zones that determine the conditions for the spread of blast within the population plays an important role in studying the dynamics of pathogen development in the territory of rice cultivation. The results of the research work showed that the Krasnodar rice growing area has a uniform landscape without sharp changes in the relief profile. The location of adjacent geographical objects affects the agro-climatic conditions of the southern part of the territory, which indicates the likelihood of isolation of the population of rice blast strains in the southern part of the rice growing area. An analysis of the agricultural zoning of the Krasnodar Territory showed the isolation of the southern part of the rice-growing territory according to the characteristics of the soil cover and the isolation of the conditions of agrotechnological measures. Features of the water regime of the irrigation systems of the Krasnodar Territory indicate the differentiation of the factors of infection and the spread of the pathogen on the basis of the isolation of irrigation flows. The territory has a clear division along the channels of the Kuban and Protoka rivers.

1 Introduction

Krasnodar region is located in the northwestern part of the North Caucasus. The territory of the region is washed by the waters of the Azov and Black Seas. Krasnodar region is divided by the Kuban River into two parts: the northern one, located on the Kuban-Azov lowland, and the southern one, located in the western highland part of the Greater Caucasus.

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The relief of Krasnodar region is diverse. More than half of the territory of the region is occupied by plains represented by the Kuban-Priazovsky plain, the Kuban sloping plain and the Delta of the Kuban River [1].

On the territory of Krasnodar region there is the largest part of agricultural land intended for the production of rice crops in Russia. According to the data of the Federal State Statistics Service for 2021, the sowing area of this territory amounted to 118.1 thousand hectares (1181 km^2), which is 62.2% of rice sowing area in Russia [2]. However, the rice growing area includes both sowing areas and agricultural infrastructure facilities serving rice production. Such infrastructure includes irrigation, transport and melioration systems. The structure of such objects is quite complex and can occupy a significant part of the rice-growing area. Therefore, the territory of rice cultivation in Krasnodar region covers an area of 5751 km^2, significantly exceeding the area under rice.

Cultivated areas of the rice-growing territory of Krasnodar region are annually exposed to Pyricularia oryzae Cav. Pathogen/ This phenomenon is primarily due to agro-climatic conditions, which stimulate the intensive development of the pathogen on rice plants during the entire growing season. However, primary infection does not depend on the conditions of the dynamics of climate change and can be determined by a combination of many factors. These factors are different and are associated both with territorial geographical features and with the features of anthropogenic impact.

A wide range of Pyricularia oryzae Cav. Strains detected on the territory of Krasnodar region and the South of Russia indicates a significant dependence of the population genotype on the territorial distribution area of the strain [3]. Therefore, the identification of zones that determine the conditions for the spread of blast disease within the population plays an important role in studying the dynamics of pathogen development in the territory of rice cultivation. Such zones should have a conditionally isolated character according to the geographical principle and the conditions of agrotechnological measures, since they determine the isolation of a pathogen population with a similar or homogeneous genotype.

2 Materials and methods

Research work includes the study of materials obtained from various data sources. A deep analysis of multidirectional data makes it possible to identify a wide range of features of the territory and establish the most accurate definitions for setting the boundaries of rice-growing areas.

To establish zones, it is necessary to identify a number of geographical and administrative features of the location of the territory of rice cultivation in Krasnodar region, as well as to establish the dependence of the possibility of occurrence of infection conditions on the applied agrotechnological measures.

The relief of the territory and the relative position of geographic objects can have a significant impact on the spread of the pathogen [4], as it determines the direction and speed of the infecting material (conidia). The geographical location of Krasnodar region as a whole determines the landscape of the rice-growing zone and sowing areas. Therefore, the analysis of the relief profile is a factor that sets the parameters of zoning the territory.

The production of rice crops requires high-level technologies that require the implementation of many agrotechnical approaches. The need for a unique method of tillage and preparation of plots (checks) complicates the technology and requires a thorough science-based approach [5]. The water regime often depends on a highly skilled and timely organization. These factors have a great influence on the culture of rice production and the final yield [6]. However, they may carry additional risks of blast infection. Therefore, the identification of geographically determined factors of agricultural technology and irrigation can reveal the causes of population differentiation of P. oryzae strains.

The basis for division according to agrotechnological characteristics can be natural-agricultural zoning. Natural and agricultural zoning is a system of dividing the land fund of a territory into separate zones characterized by similar natural, climatic and soil conditions. It provides for the allocation of natural and agricultural belts, zones, provinces and districts [7].

The organization of the water regime for irrigation of rice growing area in Krasnodar region is carried out with the help of melioration and irrigation complex, which is a complex network of irrigation and discharge canals [8]. Features of the implementation of the irrigation system can have a direct impact on the delivery of infecting material to parts of rice plants during the entire growing season.

Territory zoning involves the processing and analysis of geographic data that has a multi-format representation. To implement research work with such data, it is necessary to use technological solutions that allow efficient processing of geo-referenced information data. Such systems include geographic information systems (GIS) [9].

Geographic information systems are widespread in the information technology environment and have a different implementation format from proprietary to freely distributed applications. The most developed today is the QGIS system (qgis.org). The system supports working with spatial information of various formats, providing a wide range of analytical tools.

To implement the research work, a set of spatial data was collected that allows obtaining digital information about the relief, administrative boundaries and agricultural zoning zones. In addition, work has been carried out on the vectorization of the melioration and irrigation complex.

The relief of the territory is described by the ASTER GDEM (Version 3) dataset, built on the basis of radiometric survey data of the earth's surface using the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) sensor. The ASTER sensor installed on the Terra satellite (NASA) performs high-resolution remote sensing of the land in 15 bands of the electromagnetic spectrum with a resolution of 15 to 90 meters. The sensor has the ability to take stereoscopic surveys along the flyway with two telescopes shooting in nadir and back in the near infrared range with a resolution of 15 m [10].

The ASTER GDEM (Version 3) data set is a collection of images, each of which is 1° apart in width and height. The image pixel value corresponds to the height above sea level in the WGS84 system [11]. The territory of Krasnodar region is covered by 30 tiles arranged in a square covering the territory from 36° to 42° east longitude and from 43° to 47° north latitude.

3 Results and discussion

3.1 Analysis of the landscape of rice growing territory in Krasnodar region

The rice growing zone of Krasnodar region is located in the western part of the region in the delta valley of the Kuban River and the Protoka of the Kuban-Azov Lowland. The landscape of the zone has a uniform profile and conditional homogeneity in terms of natural and climatic parameters. The Kuban and Protoka rivers geographically divide the territory into three parts: western (Slavyansky district and part of Temryuksky district), eastern (Krasnoarmeisky district and part of Kalininsky district) and southern (rice growing area located south of the Kuban River).

The analysis of the relief profiles of the rice-growing territory indicates the uniformity of the relief throughout its entire length. However, the geography of the region can have a direct impact on the natural and climatic features of the territory.

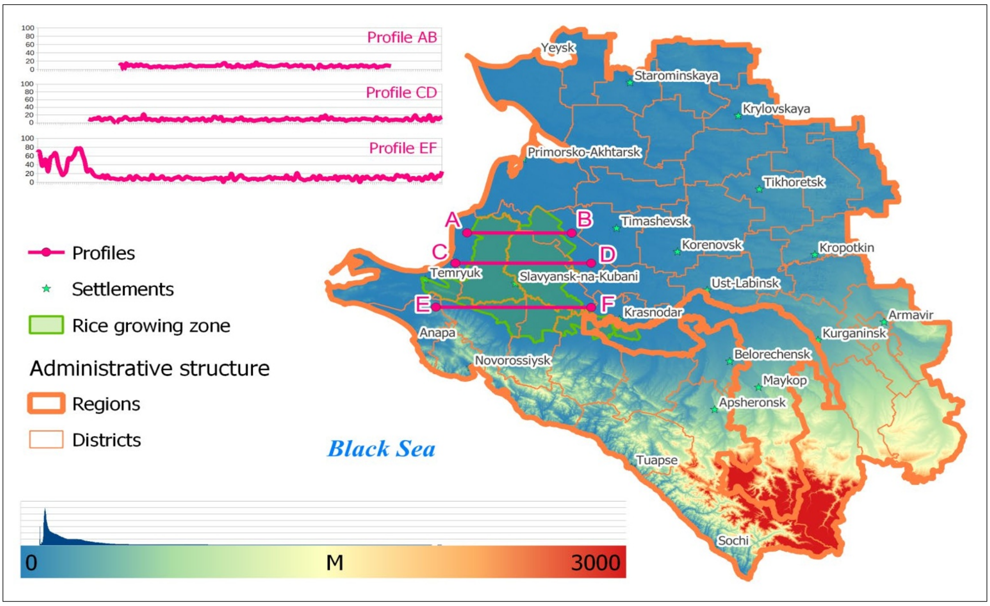

Fig. 1. Landscape of Krasnodar region

In general, the landscape of rice-growing territory in Krasnodar region can be divided into three conditional zones, which are separated by natural boundaries along the Kuban and Protoka rivers. These zones have differences in natural, climatic and geographic conditions of location, which may affect the factors of infection with blast.

The winddirection plays an important role in the spread of blast infection, since the air masses moved by the wind pick up the conidia of the pathogen and carry them over long distances [4]. This may contribute to the spread of the P. oryzae genotype and expansion of the population range within the rice growing zone (Fig. 2, 3).

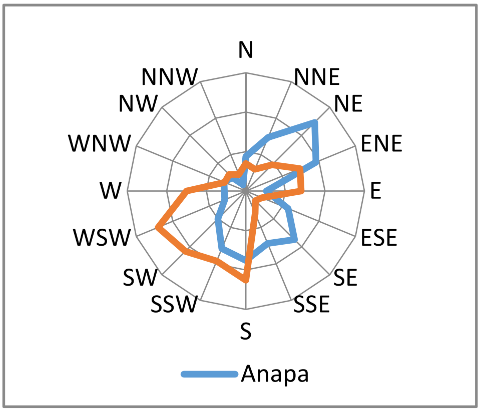

Fig. 2. Wind direction on the line Anapa-Krymsk.

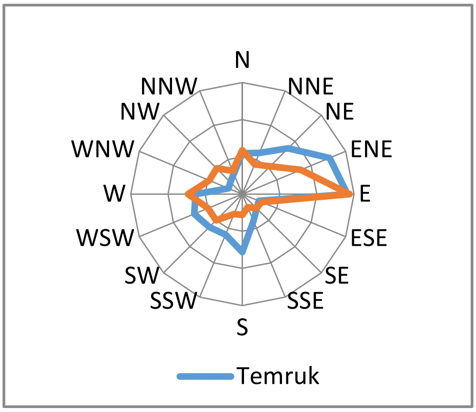

Fig. 3. Wind direction on the line Temryuk-Slavyansk

Studies of data on the prevailing wind direction (Fig. 2, 3) show that a change in the prevailing wind direction is observed on the Anapa-Krymsk geographic line, and such changes are not significant on the Temryuk-Slavyansk-on-Kuban line. This indicates the influence of relief objects located on the Anapa-Krymsk line on the natural and climatic characteristics of a separate territory, while the absence of a natural barrier on the Temryuk-Slavyansk-on-Kuban line does not affect climatic conditions. In addition, the data show that in the strip of the western and eastern zones, the number of days with wind in the east direction prevails, and in the territory of the southern zone, the number of days with wind in the south and south-west direction.

3.2 Analysis of agricultural zones in Krasnodar region

Agricultural zoning of Krasnodar region divides the territory into seven agricultural zones: Northern (I), Central (II), Western Delta (III), Anapa-Taman (IV), South Foothill (V), Black Sea (VI) and Mountain Forest (VII) (Figure 4).

Fig. 4. Agricultural zoning of Krasnodar region.

Most of the region's rice growing area is included in the Western Delta zone, located in the western part of the region on the territory of the Slavyansky, Krasnoarmeysky and Kalininsky districts. The agricultural zone is dominated by meadow-chernozem, meadow and meadow-marsh soils. The humus content in the arable layer of soils ranges from 3.8 to 4.2%, and the thickness of the humus horizon can be from 50 to 110 cm. Due to the open influence of air masses, the soils of the territories are subject to weak wind erosion (reference).

The southern part of the rice growing area is located in the first subzone of the South Foothill Agricultural Zone. It occupies part of Krymsk, Abinsk and Seversky districts. This zone is characterized by meadow-steppe and marsh soils. The humus content here varies widely (2.0 - 5.0%), and the thickness of the humus horizon is 50 - 100 cm. The natural and climatic conditions of the zone do not contribute to the manifestation of erosion processes (link).

Thus, agricultural zoning indicates the differentiation of rice-growing area along the Kuban River according to division of agricultural zones. Agro-climatic conditions and homogeneity of periods and methods in agro-technological measures contribute to the closure of the circulation of the infecting material and the isolation of the pathogen population.

3.3 Analysis of the water regime for irrigation of rice systems in Krasnodar region

Shortened irrigation regime is generally accepted in rice cultivation in the rice-growing regions of Russia. It promotes desalinization, inhibits weeds, and provides rice with water at low irrigation rates [8]. This irrigation regime implies flooding the field with a layer of water by 5-10 cm immediately after sowing, which provides moisture before germination. After seedling emergence, watering is done again. After emergence of 3-4 leaves and top dressing, the water layer is increased to 10-15 cm and maintained in this state until the beginning of the wax ripeness of the grain (Figure 5).

Continuous contact of the leaf blade and plant organs with irrigation water can create additional conditions for the transfer and spread of infecting material. Such processes may occur on the territory of the field, as well as stimulate the spread of conidia along the channels of the irrigation system that communicate with each other [12].

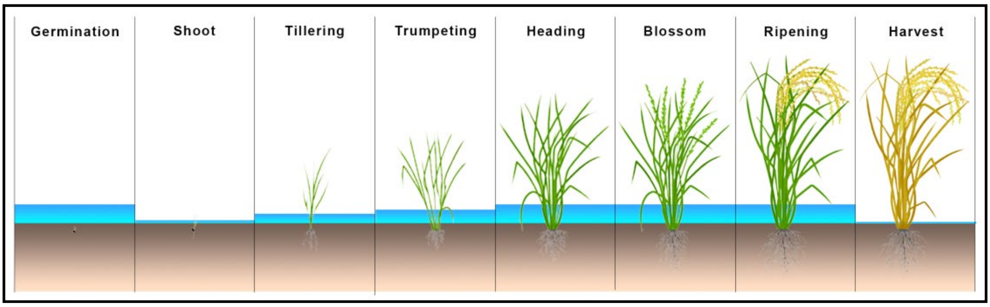

Fig. 5. Water regime for irrigation of rice systems.

The irrigation system of rice-growing zone in Krasnodar region is a set of technologically connected channels that deliver (irrigate) and divert (drain) water flows intended for controlled flooding of rice plants during the growing season. An irrigation system is a complex hydraulic structure with an extensive network of canals, the location and design of which depends on many factors, including geographical (relief) and administrative (conditions for the implementation of agrotechnical measures).

The main source of water mass for the irrigation system of Krasnodar region is the waterway of the Kuban and Protoka rivers. The geographical features of the rice-growing area determine a sufficiently large number of water mass withdrawal points for irrigation canals. This is due to the low slope of the rice growing area and the need to inject a large volume of water mass for distribution in the system. There is a hydroelectric complex on the Kuban River, which pumps water mass into the territory of rice cultivation in Krasnoarmeystsky and Kalinin districts, as well as in a southerly direction in the southern part of the rice cultivation territory. A network of water intakes located on the Protoka River irrigates the rice systems of Slavyansk district.

It should be noted that irrigation systems are conditionally isolated (Fig. 6). The eastern part of the rice-growing zone is irrigated by a system of canals, which are filled by a single hydroelectric complex located on the Kuban River. The western part of the zone is irrigated by the water masses of the Protoka River. The southern part of the zone is filled by a system of canals from the Kuban River (southern bank) and reservoirs. Features of the irrigation system can contribute to the circulation of the infecting material in the zones of conditionally closed irrigation, since migration along the water surface between zones in such conditions is not possible, and movement along the irrigation line contributes to the development of the population.

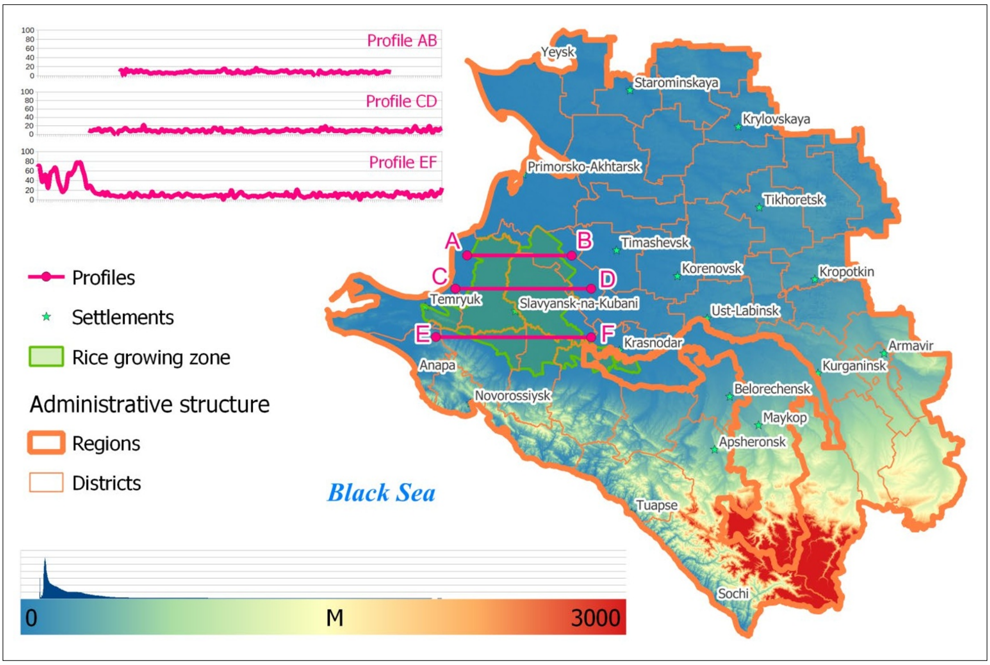

Fig. 6. Rice irrigation systems of Krasnodar region

Studies of the basin of the irrigation system show that the territory of rice cultivation is differentiated according to the principle of isolation of irrigation flows along the line of the channel of the Kuban and Protoka rivers. The zones reflect the probability conditions for isolating a population of pathogen strains within their limits (Fig. 7).

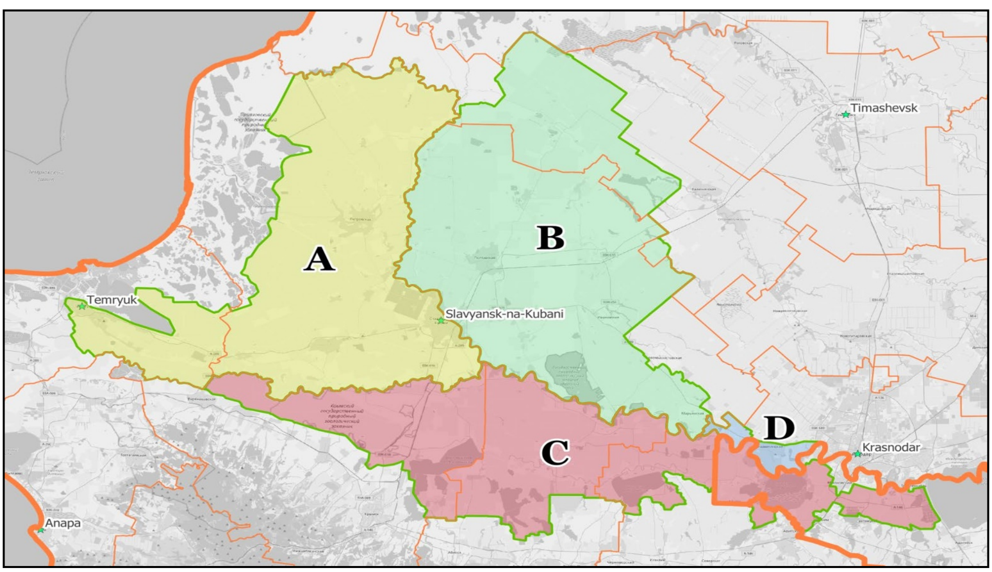

Fig. 7. Zoning of the territory of Krasnodar region

Thus, we believe that the rice growing area of Krasnodar region is differentiated by the totality of features of separation of the rice blast population into four zones: Western zone (A), Eastern zone (B), Southern zone (C), Krasnodar (Experimental) zone (D)

4 Conclusion

The results of the research work showed that the rice growing area in Krasnodar region has a uniform landscape without sharp changes in the relief profile. The location of adjacent geographical objects affects the agro-climatic conditions of the southern part of the territory, which indicates the likelihood of isolation of rice blast strains population in the southern part of the rice growing area.

An analysis of the agricultural zoning of Krasnodar region showed the isolation of the southern part of rice-growing territory according to the characteristics of the soil cover and the isolation of the conditions of agrotechnological measures.

Features of the water regime of the irrigation systems in Krasnodar region indicate the differentiation of the infection factors and spread of the P. oryzae pathogen basing on isolation of irrigation flows. The territory has a clear division along the waterways of the Kuban and Protoka rivers.

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