Ecological stability of triticale samples in the conditions of the Khabarovsk territory

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Abstract. The new grain crop triticale is of great interest for cultivation in the soil and climatic conditions of the middle Amur Region; therefore, this study assessed the environmental stability of yield formation for a collection of triticale samples. The varieties with the maximum yields identified in the study were the following: AC Certa (Canada), Lana (Belarus), Dagvo (Russia), Golden Scallo (Russia), Ulyana (Belarus), Uzor (Belarus), Lotos (Belarus), Mykola (Ukraine), Victoria (Ukraine), Sandio (Switzerland), Wanad (Poland) and Yarik (Russia). The AC Certa (Canada) variety was characterised by high demands on growing conditions \( (S^2 = 0.69, A = 30.03) \) and unstable yield \((1.8-7.0 \, \text{t/ha})\). The Victoria (Ukraine) variety was characterised by high ecological stability of yield \( (S^2 = 0.99, A = 27.45) \) in various years \((2.5-3.1 \, \text{t/ha})\). Results indicated that the yield formation of the collection samples were strongly dependent on weather conditions \( (R=0.554) \). Lastly, a model of spring triticale yield formation dependent on weather factors was constructed using regression analysis. The most significant climatic factor was photosynthetically active radiation during the active vegetation period.

1. Introduction

In light of recent global climate changes, there is a growing need to increase the adaptive potential of crops, both in the ecological gradient and in the ability to form a stable level of production under different climatic conditions [1-2]. New solutions that would improve energy efficiency in agricultural production, increase the competitive advantage of economies and contribute to environmental protection are needed [3]. Triticale \((X \, Triticosecale \, Wittmack)\) is a cereal obtained from the crossing of wheat \((Triticum aestivum)\) and rye \((Secale cereale)\) [4]. Triticale is a versatile species that can be grown in even unfavourable biotic and abiotic conditions [5]. Triticale is well-adapted to a wide range of environments where wheat is commonly grown [6]. It is tolerant to dry and nutrient-poor soils, as well as to low environmental temperatures [7]. In the baking industry, triticale flour can be an alternative to wheat-rye flour mixtures [8]. The economic importance of triticale is reflected by a significant acreage in Europe, which accounts for 90% of the global production [9].

The main goal of a breeder is to generate new varieties [10]. Despite the intensive breeding process this cereal has been exposed to in recent decades, triticale remains in the early stages of its evolution and use as a crop [11]. In triticale breeding, combining strong disease resistance with high productivity has yielded favourable results [12]. Newer generations of triticale species exhibit significantly improved biological properties and higher quality grains due to increased protein content, especially lysine [13]. To determine the environmental plasticity and stability of varieties, many mathematical
and statistical research methods have been developed [14-17]. The possibility of using triticale and its several varieties for different purposes requires more detailed studies of new varieties that focus on their efficient utilisation in production [18]. The purpose of this study was to determine the environmental stability of a collection of triticale varieties in the soil and climatic conditions of the Khabarovsk territory.

2. Materials and methods

The experiment was conducted from 2015-2019 at the Far Eastern Research Institute of Agriculture (Russia, Khabarovsk Territory, 135° east longitude, 48° north latitude). Research was carried out on a collection of 84 varieties of spring triticale having various ecological and geographical origins. The standard variety is the regionalized triticale, Ukro, which is recommended for cultivation in the region. The soil is a meadow-brown, podzolized-gley, heavy, loamy soil formed on relief elements with a slight slope, characterised by an acidic soil reaction (pH salt. 4.1-4.4) and low base saturation. The humus content in the arable layer is 3.5-4.9%. The arable layer has a low availability of mobile phosphates and a high to very high availability of exchange potassium. Sowing was carried out by the SSFK-7M seeder. Plots were 4 m² and replicated three times. The seeding rate was 5.5 million germinating grains per hectare. Harvesting was carried out by the method of sub-land threshing by the Hehe-125 combine.

All censuses and observations were carried out according to generally accepted methods of fieldwork [19] and state variety testing [20]. The environmental stability of each triticale collection variety was calculated according to the method proposed by N.A. Sobolev [21], according to which the stability of the samples was estimated by the stability coefficient (St²) and the criterion of the average stable yield (A). Correlation coefficients (R) were calculated using the Statistica 10.0 software (StatSoft, Inc., USA).

The region is characterized by low heat in June with drastic fluctuations in the daytime and nighttime temperatures of the surface air layer and high precipitation. Weather conditions during the years of research varied significantly both in temperature, precipitation levels and in distribution according to the phases of growth and development of the studied varieties.

3. Results and Discussion

The productivity of the standard Ukro variety during the years of research ranged from 1.4 to 4.2 t/ha with an average value of 2.6 t/ha (figure 1). The maximum yield was established for the varieties Wanad (Poland) – 9.7 t/ha (2017) – and Yarik (Russia) – 9.2 t/ha (2019). On average, throughout the study period, the highest yields were observed for the varieties AC Certa (Canada), Lana (Belarus), Dagvo (Russia), Golden Comb (Russia), Ulyana (Belarus), Uzor (Belarus), Lotos (Belarus), Mykola (Ukraine), Victoria (Ukraine), Sandio (Switzerland), Wanad (Poland) and Yarik (Russia) - the excess over the standard variety was 0.2-3.1 t/ha. Yield variability of spring triticale collection samples in the Khabarovsk territory are represented in figure 1.

Indicators of the relative stability of yield in the collection samples of triticale were in the high range (St² = 0.69-0.99), while the criterion of average stable yield in most varieties was low (A ≤ 30). This is due to the unstable formation of yield over the years. The minimum indicator of relative stability and a high value of the attribute criterion for AC Certa (Canada; St² = 0.69, A = 30.03) indicates a strong variability in yield over the years (1.8-7.0 t/ha). A high indicator of the relative stability of yield and its criterion was noted in the variety Victoria (Ukraine; St² = 0.99, A = 27.45), which indicates stable yield formation in various environmental conditions (2.5-3.1 t/ha).

The yield level of the collection samples of spring triticale was closely dependent on weather conditions, as evidenced by the multiple correlation coefficient (R = 0.554). In the conditions of the Khabarovsk territory, the average grain yield of spring triticale of 30.7% (determination coefficient (R²) x 100%) was determined by the climatic conditions of the growing season.
As a result of calculations, the mathematical equation of multiple regression was obtained (1), where $T$ is the temperature of the surface air layer; $O$ is the amount of precipitation during the active vegetation period; and $F$ is photosynthetically active radiation:

$$Y = 274.4078 + 0.2811T - 0.2671O - 0.5533F$$

The multiple regression equation showed that the temperature of the surface air layer, the amount of precipitation and the value of photosynthetically active radiation during active vegetation periods had a significant impact on the formation of spring triticale yields. With an increase in air temperature by 1°C, the yield level of triticale samples increased by an average of 0.2811 t/ha, and an increase in other characteristic factors led to a decrease in this indicator. According to the regression model, the most influential weather factor in increasing triticale yields was photosynthetically active radiation during the growing season.

4. Conclusion
The studied varieties of spring triticale in the soil and climatic conditions of the Khabarovsk territory were characterised by a strong variability in yield over the years and showed significant differences in average and stable yield. The yield formation of spring triticale was dependent on a combination of weather factors that affected the yield levels. The mathematical regression equation serves as a tool for reducing damage from adverse environmental conditions and increasing the stability and productivity of triticale varieties.

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