THE VARIABILITY OF SOME CHARACTERS AND THEIR CORRELATIONS WITH THE YIELD OF AN EXTENSIVE ASSORTMENT OF AUTUMN WHEAT VARIETIES, TESTED ON THE CHERNOZEM FROM ARDS CARACAL

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ABSTRACT

In 2021 year, 120 cultivars of winter wheat were tested on the Caracal chernozem in microplots. The following traits were determined: yield, thousand kernel weight, test weight, days from 01.01 to heading date. The variability of the characters was studied by the method of boxplots and variability coefficients. The obtained yield registered values between 12306 kg / ha for the Romanian cultivar Ursita and 5803 kg / ha for the KWS Marvel cultivar. The plant height had values between 110 cm for the Kapitol cultivar and 69 cm for the Avenue cultivar. The test weight showed values in the range 78 kg / hl (Apexus) - 64.2 kg / hl (Atuan). The thousand kernel weight recorded values between 47.2 g for the SY Starlord cultivar and 29.29 g for the Amburgo cultivar. The period from 01.01 to heading date lasted between 143 days (Sophie and Lennox) and 123 days (Tata Mata and Felix). The highest coefficient of variability was presented by the yield, this being over 10%. The lowest variability was registered by the test weight and the period from 01.01 to heading date, the values being around 3%.

The analysis of the variability of the yield by the boxplot method highlighted a negative outlier (KWS Marvel cultivar). From the point of view of plant height, by the same method, three positive outliers were observed - Kapitol, Bezostaia and Exotic. Their height - 110, 109, and 108 cm, respectively, is significantly larger than that of all other cultivars.

The values of the calculated correlation coefficients suggested that in the climatic conditions of 2020-2021 agricultural year, the yield was not correlated with any of the studied characters, the coefficients being below

0.21 (the value from which the correlation could be considered significant at P = 5%).

INTRODUCTION

World food production is limited primarily by environmental stresses. Drought is one of the most common environmental stresses that affects growth and development of plants through alterations in metabolism and gene expression.

Wheat (*Triticum aestivum L.*) is the first important and strategic cereal crop for the majority of world's populations, which is cultivated over a wide range of climatic conditions and plays a key role in traditional health care system for humans (Pathak and Shrivastav, 2015; Păunescu, 2009) and animals (Colă and Colă, 2020, 2021; Yang and Shen, 2018). Therefore, wheat is grown all over the world, with different varieties sown according to the various climates and accounts for 30% of global grain production and for 45% of cereal nutrition, thus representing a major food crop species. In recent years the actual rate of wheat production increased by only 0.5% per year; therefore, improved wheat production must be achieved by further increasing the grain yield per area (Philipp et al., 2018).

In 2020, the world's main wheat producing regions were China, India, Russian Federation, United States, Canada, Ukraine, Pakistan, Turkey, Argentina, Iran, France, Australia (Statista, 2020). Most of the currently cultivated wheat varieties belong to hexaploid wheat which is known as common bread wheat and valued for bread making. Wheat grain contains all essential nutrients and various bioactive compounds like alkaloids, saponins, glycosides, terpenoids, steroids, flavonoids and tannins (Băbeanu et al., 2011a, 2010b; Păunescu et al., 2016).

The wheat spike contains a variable number of around 24 to 28 spikelets, each with several florets. Grains can differ in terms of developmental stage, weight, number and fruiting efficiency when compared among different spikelets and even within individual spikelets (Li et al., 2016). The yield components of wheat cover two main parameters: grain yield per area and grain yield per spike. Grain yield per area includes grains per spike, grain weight and spikes per area; whereas grain yield per spike comprises spikelet number per spike, grain number and grain size per spike and/or spikelet (Philipp et al., 2018).

According to Păunescu (2018), the correlation between the stem length ratio to 20% PEG versus the control stem length after 15 days and the loss of water from the flag leaf after 4 hours was significant. This suggests that it would be more efficient to use the determination of water loss because the actual time used to determine it is shorter.The number of grains in the spike is an important component of wheat production. This production component is dependent on the ability to differentiate fertile spikelets into spikes and the level of nutrition that the plants have at that time. There are multiple interactions and compensation mechanisms between the different yield's components, dependent on genotype and environment.

The 1000-grains weight is an element of productivity with implications on quality, of indisputable importance, because on it depend the size of the embryo and the amount of reserve substances for germination and emergence. The 1000-grains weight is closely linked to production, as large-grained varieties may have a higher production capacity. The number of harvested spikes per unit area is one very important component of wheat production, on this depends to a large extent the other production component which forms the harvest or production of wheat. This production component depends on the sowing density, the productive twinning capacity of the varieties and the nutrient and moisture reserves in the soil (Braileanu, 2014).

The yield of production is achieved along the vegetation phases, from sowing to the filling of the grains, by the successive formation of the different components of wheat production; also, the plant height plays a pivotal role in plant morphological architecture and is associated with yield potential in wheat (Whang et al., 2020). In this sense, important yield-related traits such as grain weight and grain number are often negatively correlated (Gegas et al., 2010; Slafer et al., 2014).

The results of many researches show that the number of spikes per plant as the most important primary component of production per plant for wheat (Abdelkhalik, 2019; Ibrahim, 2019; Okuyama et al., 2004). The number of spikes per plant is related to the twinning capacity. They noted the importance of the number of spikelets per spike as an essential element in achieving production and demonstrated that production can be indirectly increased by selection to increase grain mass. Thus, according to Okuyama (2004), the number of grains per spike correlated negatively with kernel weight

and positively with above-ground biomass and number of days to anthesis. The above-ground biomass correlated positively with grain yield. As this trait correlated positively with plant height, consequently, selection of taller plants leads to the largest amount of above-ground biomass. However, as higher plants present smaller number of spikes/m^2 and higher lodging, the choice of taller plants with larger above-ground biomass may not increase grain yield. Direct selection for higher number of spike/m^2 and/or larger number of grains per spike would be enough to increase grain yield.

Multiple yield components and spike characteristics are associated with the Q gene, present in all modern wheat varieties. Q is associated with reduced ratios of grain length to weight, leading to shorter and rounder grains (Quintero et al., 2014). When grain number and yield were increased, the proportion of smaller grains in distal spike positions also augmented, thus lowering the average grain weight (Xie et al., 2018).According to Vahamidis et al (2019), grain number per spike was reduced, depending on year, genotype and water availability level, by 12.4–58.7% and this reduction was evident almost in all spikelet positions along the spike. The number of fertile florets per spikelet was the best predictor of grain number per spike, indicating that there is still much space for further improvement for this trait in landraces. Although the number of spikelets per spike was the best unique predictor of the number of grains per spike in modern cultivars, grain set presented the highest total effect.

Other authors have reported that the number of spikelets per spike was not, or even negatively, correlated with most traits, except of grains per spike, which suggests that this trait was not favoured during breeding. The grain number and grain yield distributions along the spike were measured and compared by using a novel mathematical tool. Both traits were positively correlated. Comparing yield-related traits between genetic resources and elite varieties can help to assess and understand the progress in breeding and selection (Philippet al., 2018).

In some studies, days to start heading had strong correlation with spike length and number of spikelets per spike. Flag leaf area had positive relationship with peduncle length and yield related traits.The 1000-grains weight and grains yield were also correlated with each other (Ullah et al., 2021). Garcia del Moral et al. (2006) suggest that concerns for the formation of common wheat and durum wheat production should focus on the study of spike as an element of

wheat productivity. The number of grains in the spike and the mass of 1000 grains are two of the most important components of wheat production.

The grain yield improvement it may possible by increased biomass partitioned to the grains (Brancourt-Hulmel et al., 2003). Although there are very close direct correlations between production and its components, the production components show strong compensatory effects, which leads to the existence of negative correlations between them. This compensation makes it almost impossible to improve two or more production components simultaneously. The only way to increase production capacity in breeding programs based on production components is to improve a single component, provided that the others remain unchanged (Braileanu, 2014).

Ensuring the world's food supply must be guaranteed, even in pandemic situations (Paraschivu and Cotuna, 2021). At the same time, food safety and security requirements must be constantly optimized through sustainable production or crop protection technologies (Paraschivu et al., 2020; Partal and Paraschivu, 2020). In this context, the plant breeders are continuously working to improve the yield per unit area of wheat crop, through selecting superior lines as parents.

MATERIAL AND METHOD

In 2021, 120 varieties of autumn wheat were tested on the Caracal chernozem in microplots in the cereal collection. These included many Romanian wheat varieties, both older and more recent, and most of the foreign varieties that entered the country with Romania's accession to the European Union and are becoming increasingly widespread. The following were determined: yield, mass of 1000 grains, hectolitre mass, size and number of days from 01.01 to sowing. The variability and distribution of the values determined for the characters studied were studied using the box-plot method and the coefficients of variability.

The boxplot was used to present the distribution of values in a data series. The figure below shows the boxplot for a single series and how it displays the data (Figure 1).

The bold line represents the median of the data series. The boxplot contains 50% of the values and the interquartile range is the difference between the values marking 25% and 75% of the values. The upper and lower T limits represent the maximum and minimum

values of the series (not including outliers and extreme values). Outliers are values between 1.5 and 3 bin lengths (1.5 x interquartile; 3 x interquartile) and outliers are values greater than, above or below 3 bin lengths.

The coefficients of variability were calculated using the statistical function Correl in Excel.

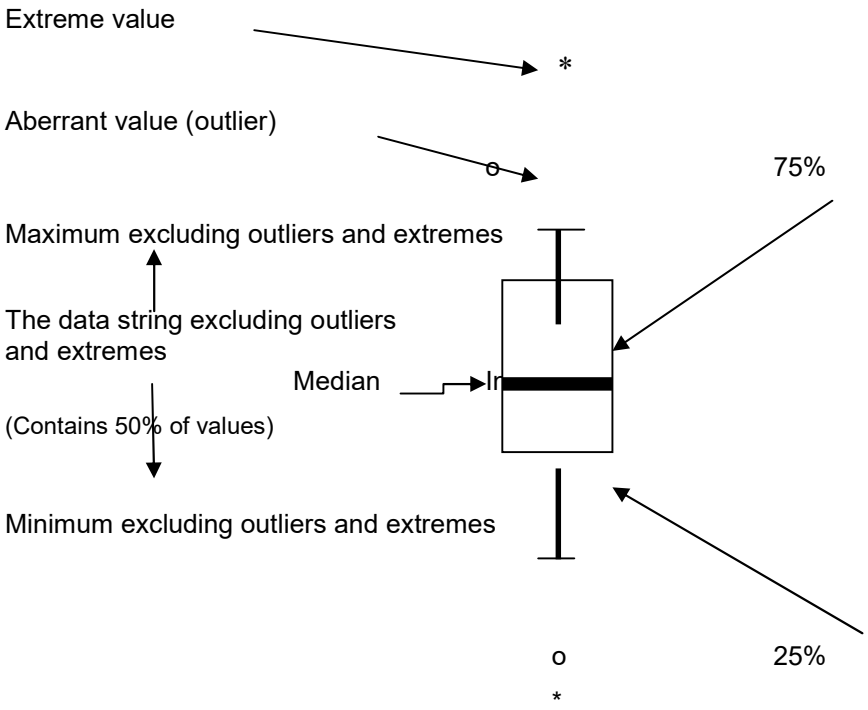

Figure 1. Boxplot for a single data series

RESULTS AND DISCUSSIONS

1.Production variability

The obtained yield registered values between 12306 kg / ha for the Romanian cultivar Ursita and 5803 kg / ha for the KWS Marvel cultivar.

The values between which 50% of the yield results for the varieties tested fell were 10522 kg/ha and 9319 kg/ha with an interquartile range of 1203 kg/ha (Figure 2). There was also a

negative outlier value - 5803 kg corresponding to KWS Marvel. This is the only variety that is significantly different from the other cultivars. The box-plot is relatively thin indicating that a very large number of values are concentrated in a very small segment of the samples. In other words, several varieties obtained similar, even identical yields. The median of 9989 kg/ha and the mean of 9944 kg/ha are practically equal, leading to the conclusion that the box plot is centred.

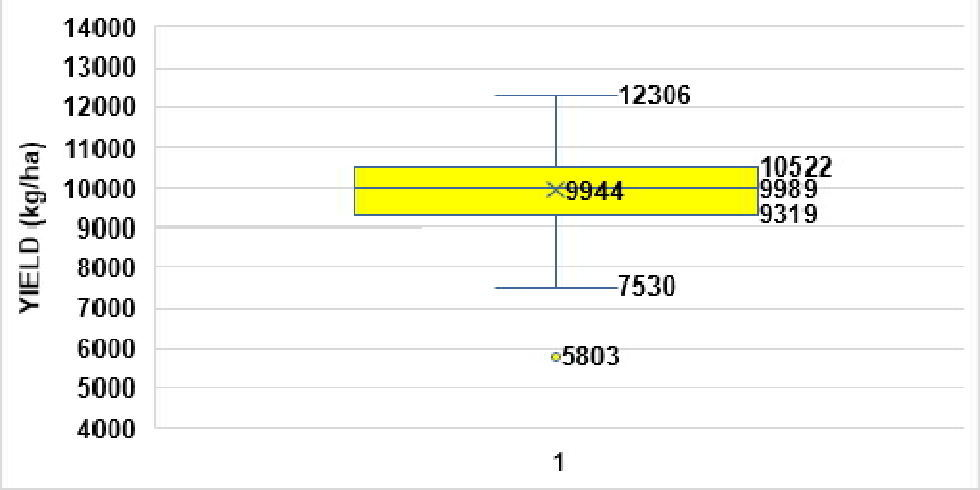

Figure 2. Yield variability in 120 varieties of autumn wheat tested on the Caracal chernozem represented by the box-plot method

2. Variability of the plant height

The plant height had values between 110 cm for the Kapitol cultivar and 69 cm for the Avenue cultivar.

The values between which 50% of the height determinations of the varieties tested fell were 90 cm and 80 cm with a 10 cm interquartile range (Figure 3). Three positive deviant values (outliers) were found - 108 cm, 109 cm and 110 cm corresponding to Kapitol, Bezostaia and Exotic varieties respectively. The box-plot is thin which indicates that a very large number of varieties had fairly close waist values. The box-plot being shifted towards the bottom (low waist values) is positive. The aspect is confirmed by the large number of positive outliers.

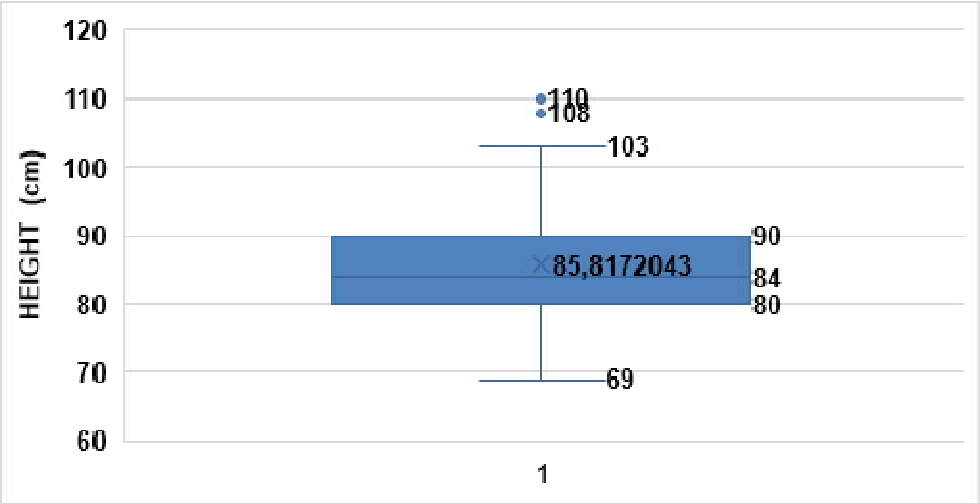

Figure 3. Variability of the plant's height in 120 varieties of autumn wheat tested on the Caracal chernozem represented by the box-plot method

3. Variability of the hectolitre mass

The hectolitre mass showed values in the range 78 kg/hl (Apexus) - 64.2 kg/hl (Atuan).

The values between which 50% of the hectolitre mass results for the varieties tested were 71.2 kg/hl and 75.1 kg/hl with an interquartile range of 3.9 kg/hl (Figure 4). A negative outlier value - 64.2 kg/hl was found corresponding to the Autan variety. The thinnest box was found for this characteristic. The boxplot was shifted towards the lower value so it was positive (more values above the mean). It is slightly shifted towards low values, therefore being positive.

4. Mass variability of 1000 grains

The mass of 1000 grains ranged from 47,2 g in the SY Starlord variety to 29,29 g in the Hamburg variety.

The values between which 50% of the 1000-grain mass results for the varieties tested fell were 37.34 g and 41.2 g with an interquartile range of 3.86 g (Figure 5). Several deviating values (outliers) both positive and negative were evident. Positive outlier - 47.2 g hectolitre mass in SY Starlord. Negative outliers - 29.29 g, 29.9 g and 30.7 g - values corresponding to Amburgo, Kapitol and KWS Extrem respectively. The median and average are practically equal which makes the boxplot centred.

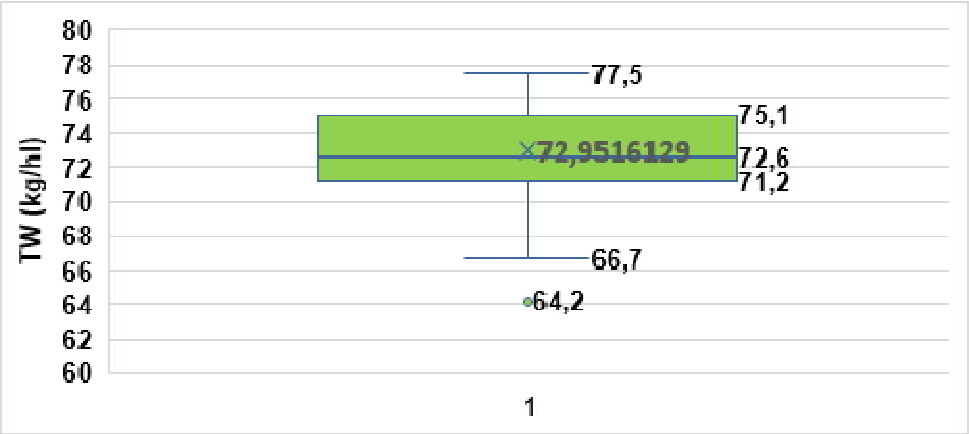

Figure 4. Variability of the hectolitre mass in 120 varieties of autumn wheat tested on the Caracal chernozem represented by the box-plot method

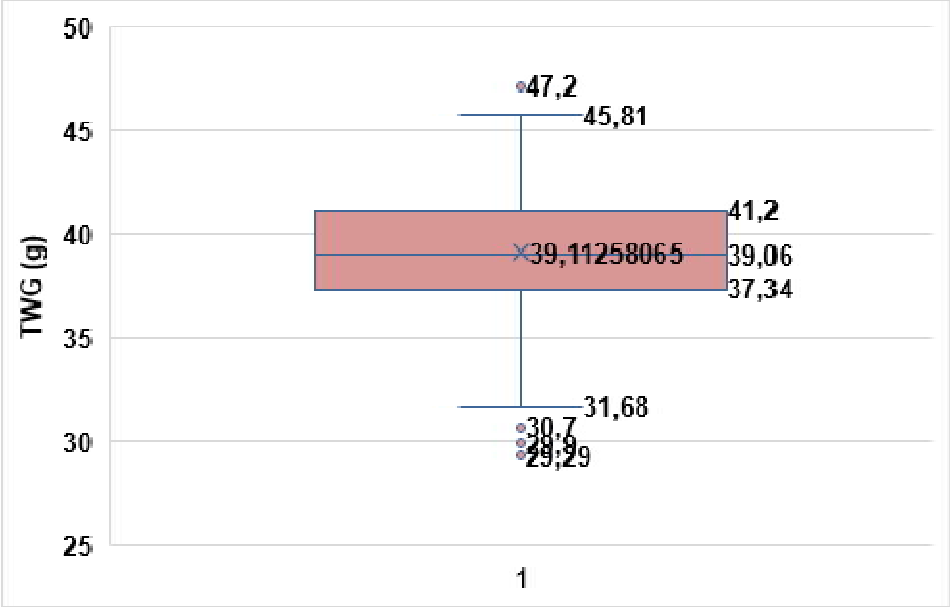

Figure 5. Variability of the mass of 1000 grains in 120 varieties of autumn wheat tested on the Caracal chernozem, represented by the box-plot method

5. Variability of days from 01.01 to ear formation

The period from 01.01 to ear formation spanned 143 days (Sophie and Lennox) and 123 days (Tata Mata and Felix). The values between which 50% of the results fell were 133 days and 138 days with 5-day interquartile range (Figure 6). There were 2 negative

deviant values (outliers) - Felix and Tata Mata varieties. The box-plot is very thin indicating that a very large number of varieties had fairly close values of days from 01.01 to ear formation. As in the case of the mass of 1000 grains, the median and average are practically equal.

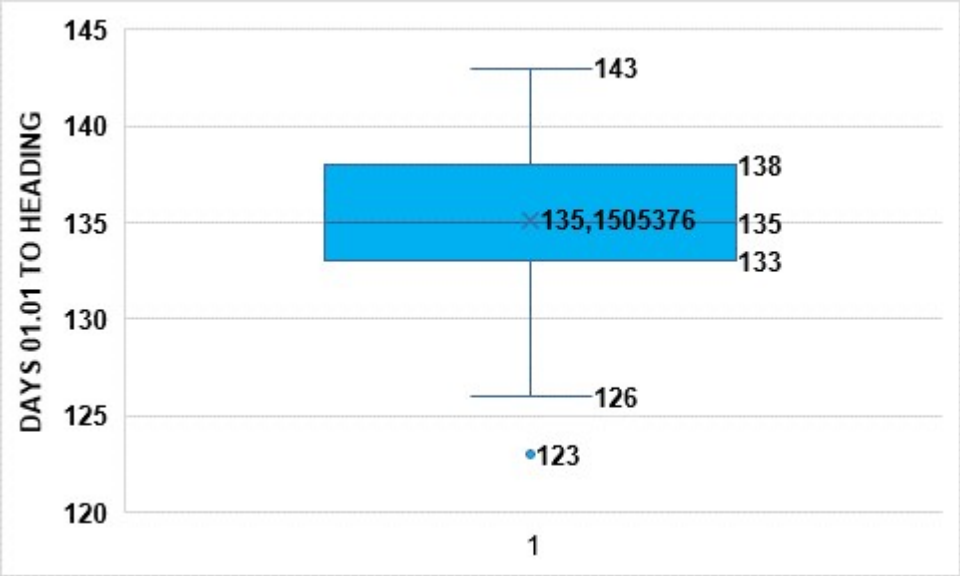

Figure 6. Variability of the number of days from 01.01 to ear formation in 120 varieties of autumn wheat tested on the Caracal chernozem, represented by the box-plot method

The coefficients of variability calculated for the characters studied showed that yield is the least stable of them, the value being above 10%. The most stable characters were found to be hectolitre mass and number of days from 01.01 to ear formation (3.52% and 3.16% respectively) (Figure 7).

According to the calculated value, we can say that hectolitre mass, mass of 1000 grains, height and number of days from 01.01 to ear formation are stable characters and the yield has medium stability, on the Caracal chernozem.

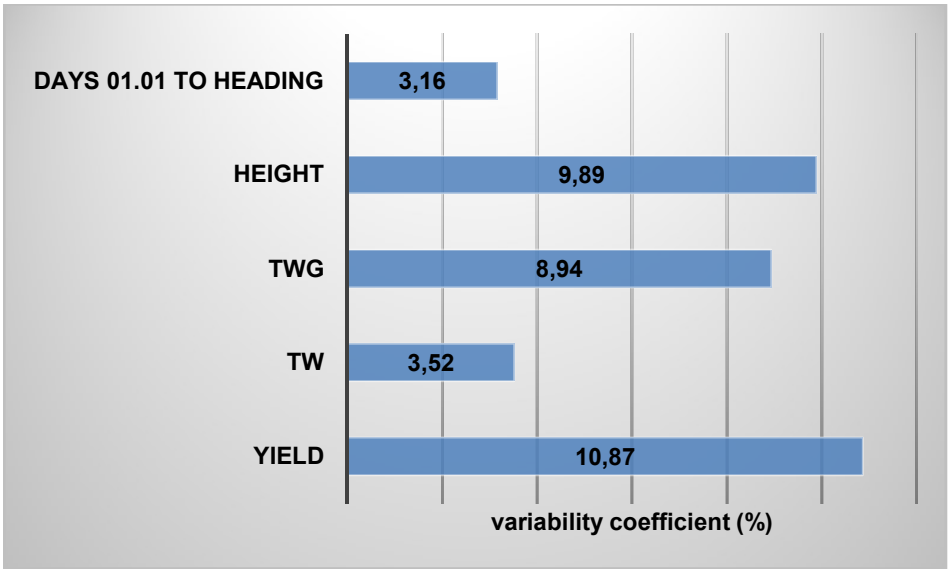

Figure 7. Coefficients of variability of the characters studied

The correlation between yield and hectolitre mass in an extended assortment of autumn wheat varieties tested on the Caracal chernozem showed that it was very weak, with a correlation coefficient of r = 0.096. The coefficient being below 0.21 (the value at which the correlation could be considered significant at P = 5%), we can say that hectolitre mass is not influenced by yield and vice versa.

The variability of the one is influenced by the other by only 0.9%. However, we can highlight the varieties Andino and Ursita which showed high yield and high hectolitre mass at the same time (Figure 8).

The correlation between yield and height in an extensive assortment of autumn wheat varieties tested on the Caracal chernozem showed that it was practically non-existent (Figure 9), with a correlation coefficient of r = 0.017. The coefficient being below 0.21 (the value at which the correlation could be considered significant at P = 5%), we can say that the height is not influenced by yield and vice versa. The variety Epilog stands out as it showed both a high yield and height.

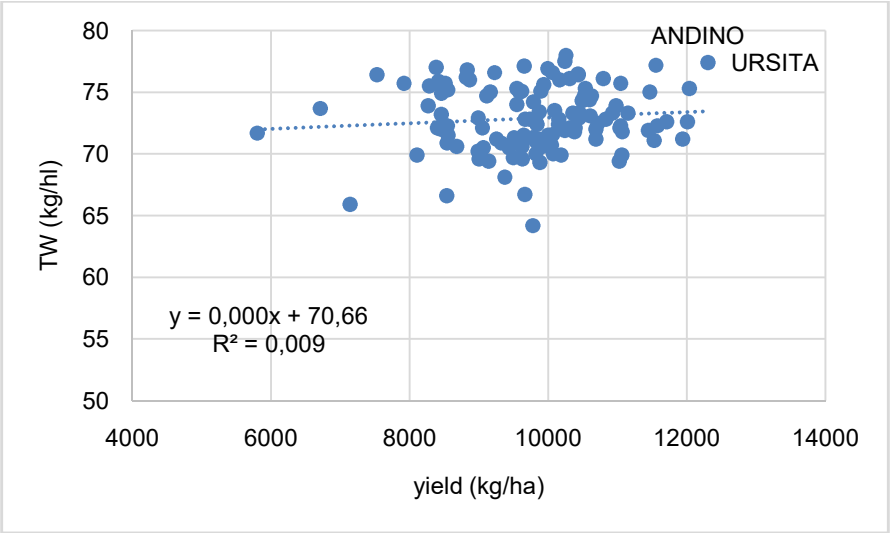

Figure 8. Correlation between yield and hectolitre mass in an extended assortment of autumn wheat varieties tested on the Caracal chernozem

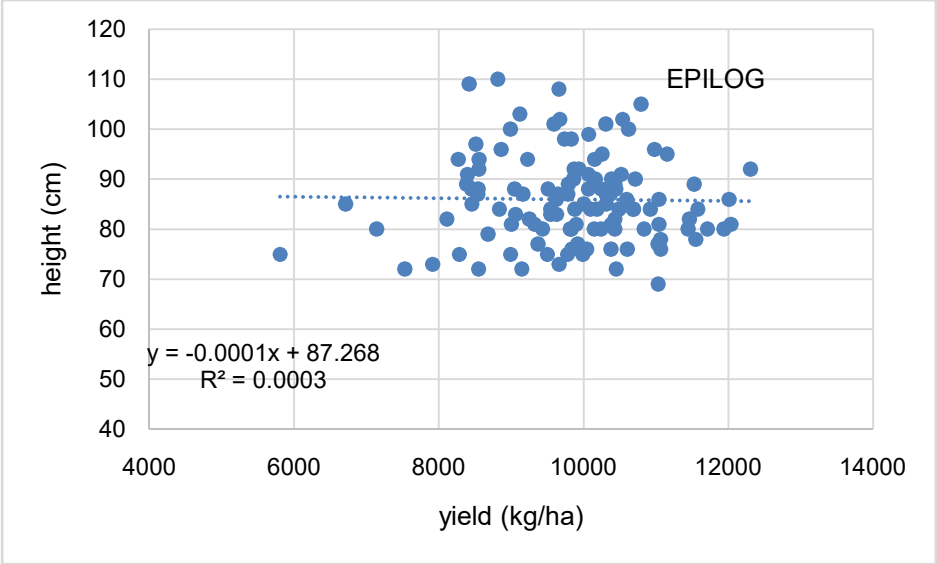

Figure 9. The correlation between yield and height in an extended assortment of autumn wheat varieties tested on the Caracal chernozem

The correlation between yield and 1000-grain mass in an extended assortment of autumn wheat varieties tested on the Caracal chernozem showed that it was weak, with a correlation coefficient of r = 0.126.

The coefficient below the value at which the correlation could be considered significant at P = 5%, shows that the mass of 1000 grains is influenced to a small extent by yield and vice versa. The variability of one is influenced only 1.6% by the other. From the graphical representation, it was found that there are varieties which showed both high yield and high 1000-grain mass (SY Starlord, SY Passion, Ursita) (Figure 10).

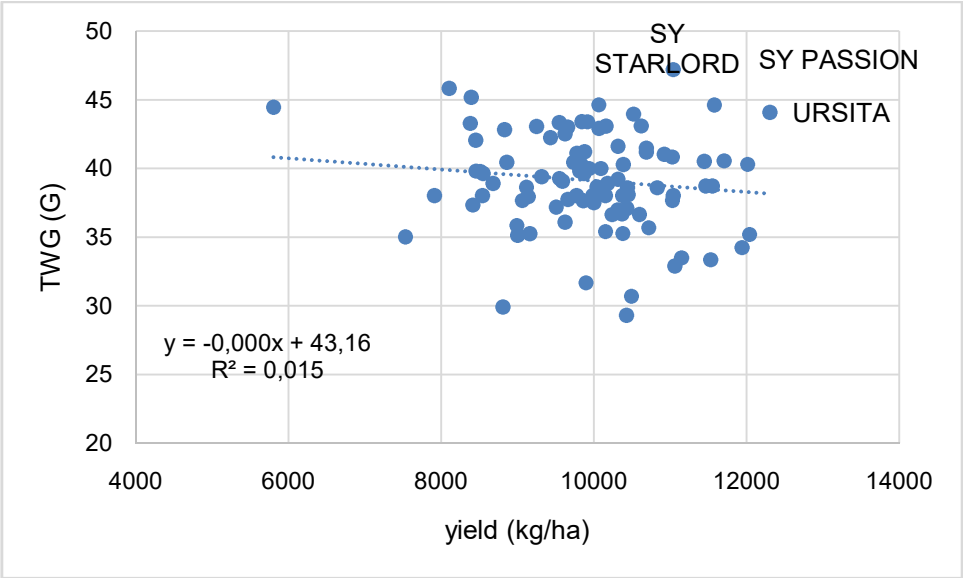

Figure 10. The correlation between yield and mass of 1000 grains in an extended assortment of autumn wheat varieties tested on the Caracal chernozem

The figure below (Figure 11) perfectly highlights the total lack of correlation between production and days from 01.01 to ear formation. The line is practically straight and the dots are spread chaotically above and below it. Varieties are sought that achieve high yields although the growing season is shorter. The only one to fall into this category was SY Exception with a yield of 11463 kg/ha obtained in 126 days from 01.01 to ear formation.

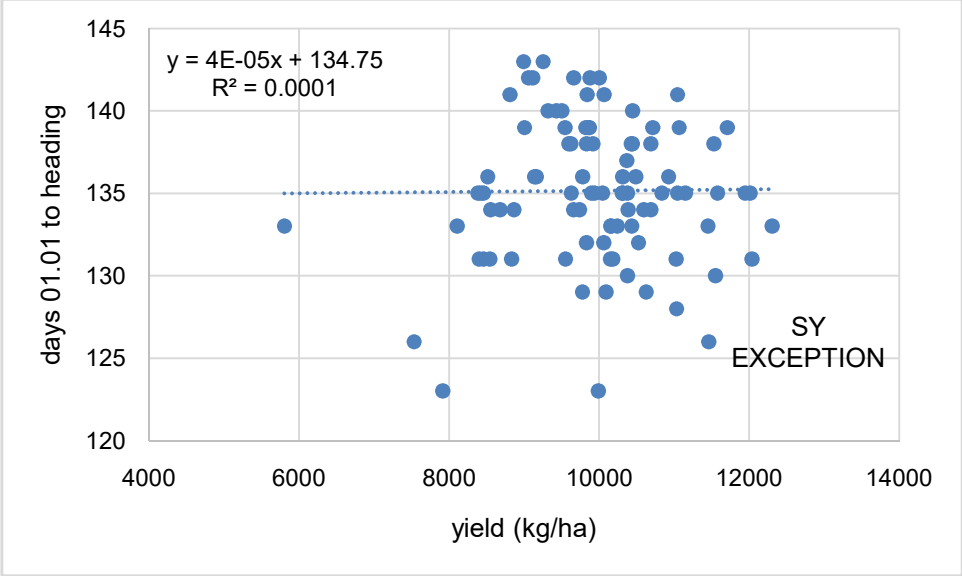

Figure 11. The correlation between yield and days from 01.01 to ear formation in an extended assortment of autumn wheat varieties tested on the Caracal chernozem

CONCLUSIONS

The boxplot method best highlights the distribution in a range of values, thus the variability, and highlights varieties that deviate significantly.

Analysis of yield variability using the boxplot method revealed one negative outlier - the variety KWS Marvel. In terms of size, three positive deviant variants - Kapitol, Bezostaia and Exotic - were observed using the same method. Their heights of 110, 109 and 108 cm respectively are significantly larger than all other varieties. A negative outlier was found for hectolitre mass - 64.2 kg/hl corresponding to Autan. For hectolitre mass, several positive and negative outliers were found. Positive outlier - 47.2 g hectolitre mass for SY Starlord. Negative outliers - 29.29 g, 29.9 g and 30.7 g - values corresponding to Amburgo, Kapitol and KWS Extrem respectively. In the character days from 01.01 l to the spike 2 negative outliers were found - varieties Felix and Tata Mata.

The values of the calculated correlation coefficients suggested that under the climatic conditions of the 2020-2021 crop year, yield was not correlated with any of the traits studied, with coefficients below 0.21 (the value at which the correlation could be considered significant at P = 5%). The coefficients of variability calculated for the

studied traits showed that yield is the least stable of them, the value being above 10%. The most stable characters were found to be hectolitre mass and the number of days from 01.01 to ear formation (3.52% and 3.16% respectively). According to the calculated value, we can say that the hectolitre mass, the mass of 1000 grains, the height and the number of days from 01.01 to ear formation are stable characters and the yield has medium stability, on the Caracal chernozem.

Variants that deviate from the correlations between production and other traits are essential to the improvement process, even if these correlations are weak or even non-existent. The results obtained suggest that the varieties Andino and Ursita with high yield and high hectolitre mass at the same time, the varieties with high yield and high 1000-grain mass at the same time (SY Starlord, SY Passion, Ursita) and the variety SY Exception with high yield obtained in a shorter period from 01.01 to ear formation.

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