

Variability and interrelation of the main breeding traits of the winter soft wheat quality

Nina Kravchenko^{1*}, Sergey Podgorny¹, Natalia Ignatieva¹, and Valentina Chernova¹

¹ Federal State Budgetary Scientific Institution, Agrarian Research Center “Donskoy”, Nauchny gorodok 3, 347740 Zernograd, Russia

Abstract. Wheat bread rightfully belongs to the greatest inventions of mankind. The concept of wheat quality is very capacious and includes a wide range of characteristics: physical, chemical, rheological and consumer, which are in complex relationships with each other. The main purpose of soft wheat is the manufacture of bakery products. In this regard, the actual task of science is the creation and introduction into production of new varieties with high baking properties. The purpose of the research is to study the variability and relationships of quality traits; identification of the best varieties for use in the breeding process. It was found that the most strongly varying features were the specific work of deformation of the dough (11.7%) and the coefficient of the ratio of dough elasticity to extensibility (23.5%). The results of a correlation analysis on the conjugation of the characteristics of the quality of grain, flour and baking properties are presented. The quality of bread significantly depended on the volumetric yield of bread ($r=0.9118$) and the specific work of dough deformation ($r=0.5119$). A significant positive, strong relationship was found between the content of protein and gluten in the grain ($r=0.8471$). New varieties and lines of winter soft wheat of intensive type, distinguished by a complex of studied traits: the new variety Privolye, lines 1518/18 and 1401/19, are recommended to be used in the breeding process aimed at improving the quality of winter soft wheat grain.

1 Introduction

Wheat is the world's most important agricultural crop, which is also a priority in Russia. In the North Caucasus, including the Rostov region, winter wheat is of paramount importance, dominating in terms of sown area, gross harvest and importance in the economy of the region [1].

Russia is a leading exporter of wheat, but the quality of grain produced for domestic consumption and supply to the world market remains at a low level [2]. Improving the quality of bread products is possible through the creation and introduction into production of strong and valuable wheat varieties that consistently form high grain quality and baking properties.

* Corresponding author: ninakravchenko78@mail.ru

The concept of wheat quality integrates many features that characterize the physical and chemical properties of grain, the rheological properties of flour and baking qualities. At the same time, each sign changes quantitatively under the influence of environmental factors. Many signs are in complex relationships with each other, and thus there is a need to study and obtain general patterns of relationships between them. Correlation studies make it possible to better understand the relationship of features that characterize the quality of grain and flour. The study of the relationship between various traits is necessary for breeders in the selection of genotypes that have groups of desired useful properties [3].

Selection for the improvement of any one trait may be accompanied by a restriction on the change of other equally important ones. The scientist needs to choose a combination that will save or at least not worsen due to the strengthening of others [4].

In this regard, the widespread use of correlation analysis in agricultural science makes it possible to evaluate the relationships between various traits and identify those for which selection is possible [5].

The purpose of the research is to study the variability and relationships of quality attributes; identification of the best varieties for use in the breeding process.

2 Material and methods

Field experiments were carried out in a selection crop rotation in the nursery of competitive variety testing in 2020-2022 in the conditions of the southern zone of the Rostov region.

The object of the study was 2 new varieties and 16 lines of winter soft wheat created at the Federal State Budgetary Scientific Institution, Agrarian Research Center “Donskoy” (ARC “Donskoy”). The Ermak variety was used as a standard.

The soil of the experimental field is ordinary calcareous chernozem, heavy loamy. The content in the arable layer of the soil: humus – 3.2%; pH – 7.0; P2O5 – 18.5-20.0; K2O – 342-360 mg/kg of soil.

The climate of the zone is characterized by semi-arid hot summers and moderately mild winters. The sum of positive temperatures during the growing season averages 3450°C, the average annual temperature is + 9.7°C, the average annual precipitation is 588.8 mm, including 480.5 mm during the growing season of winter wheat [6].

The period of formation of grain quality in 2020 was characterized by a large amount of precipitation in May (155.7% of the norm) and optimal temperature (15.4 °C), which were favorable for the growth and development of winter soft wheat before harvesting, despite the lack of precipitation (54.4% of the norm) and increased temperature by 2.6 °C in June.

The spring and summer of 2021 were characterized by an abundance of precipitation. In spring, 243.9 mm (185.1%) fell, in summer 179.6 mm (103.1%). The prevailing weather conditions were unfavorable for the formation of grain vitreousness.

The spring of 2022 was characterized by a temperature regime within the average annual values and an abundance of precipitation (125.5% of the norm).

The period of grain ripening proceeded at an elevated temperature regime, in June 23.2 °C (+2.7 °C to the norm), in July – 24.1 °C (+1.0 °C to the norm). During the summer season, 104.0 mm (59.7% of normal).

Bakery and technological properties were determined in the laboratory of biochemical, technological and agrochemical evaluation of the ARC “Donskoy” in accordance with the guidelines and GOST. The quantity and quality of gluten in the grain was determined according to GOST R 54478-2011. The mass fraction of protein in the grain was determined by the Kjeldahl method according to GOST 10846-91. The physical properties of the dough were determined in accordance with GOST ISO 5530-1-2013 using a farinograph. The rheological properties were determined using an alveograph according to

GOST R 51415-99 (ISO 5530-4-91). Baking properties were determined using trial laboratory baking.

Variation of traits was determined according to the classification of V. A. Dzyub (2010): variability is considered to be insignificant or weak ($CV = 10.0\%$); medium ($CV = 10.0\% - 20.0\%$); significant or high ($CV > 20.0\%$).

Phenotypic relationships between traits were studied using correlation and linear regression analysis. All calculations were carried out using Microsoft Office 2010 and SPSS versions of PASW Statistics 10.

3 Results and its discussion

The quality of winter soft wheat consists of a number of characteristics that can be divided into the physicochemical properties of grain, the rheological properties of flour (dough) and consumer properties (the quality of the final product – bread). Due to the fact that the main purpose of wheat grain (*Triticum aestivum* L.) is the production of bread and bakery products, modern varieties must meet strict quality requirements established by the food industry [7, 8].

On average, over the years of research, the studied varieties and lines of winter soft wheat of the intensive type met the requirements for valuable and strong wheat (Table 1).

Table 1. Quality indicators of varieties and lines of winter soft wheat, 2020-2022 (mean values)

Quality mark	average value, 2020-2022.	min-max	Average variety value, Cv, % 2020-2022	min-max
Mass fraction of protein, %	13.67	12.72-15.13	3.67	1.60-8.90
Amount of gluten, %	27.62	24.55-31.66	7.06	1.78-17.06
Quality of gluten, IDC device units	74.6	62-92	8.2	2.3-15.8
Specific work of dough deformation, alveograph units	241.9	173-304	11.7	4.1-20.1
The ratio of elasticity to extensibility, P/l	1.0	0.5-2.2	23.5	10.8-43.5
Valorimetric evaluation, valorimeter units	76.1	57-98	6.8	1.6-14.9
Volume output of bread, ml	691.5	607-767	8.5	1.7-15.6
General bakery score, score	4.3	3.8-4.8	8.9	2.1-16.4

When analyzing the variability of the features, it was found that the specific work of dough deformation (11.7%) and the coefficient of the ratio of dough elasticity to extensibility (23.5%) were the most varying. At the same time, if we consider the minimum and maximum values, then, depending on the variety, all traits varied to a large extent from low values to medium and high ones. The trait "mass fraction of protein in grain" was the

most stable, the values of the coefficients of variation were low 1.60-8.90%. Valuable for selection for grain quality are genotypes with the maximum severity of traits and with their least variation, since the coefficient of variation can serve as a criterion for the stability of a variety and indicate its better adaptability to the weather conditions of the growing region.

The correlation analysis made it possible to establish that the “general bakery rating” result is mostly contributed by “bread volume yield” ($r=0.912$) and “specific work of dough deformation” ($r=0.512$) Figure 1, 2.

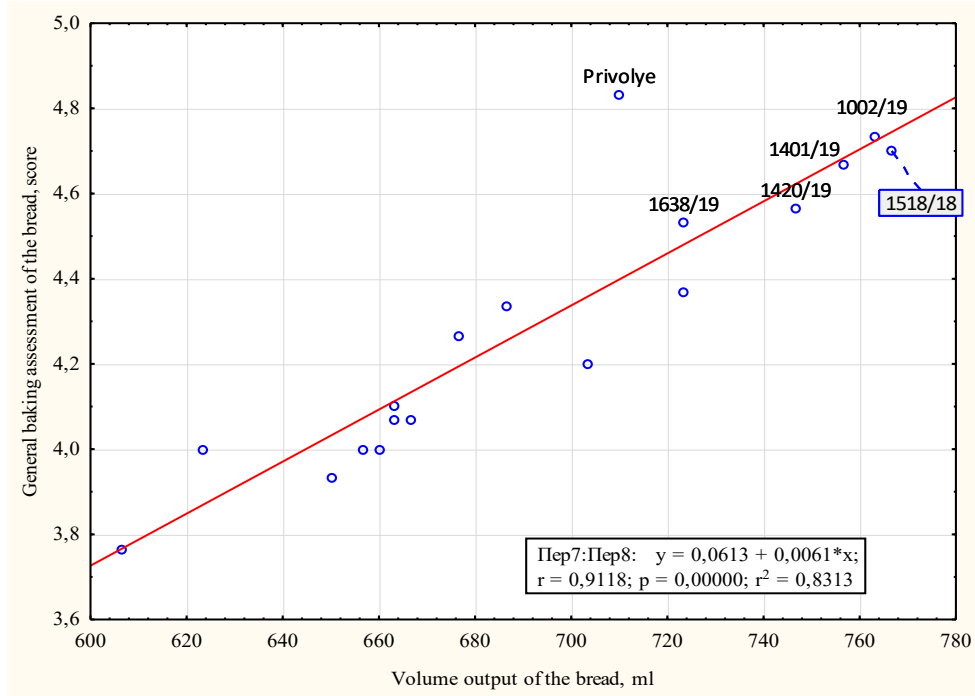


Fig. 1. Scatterplot and theoretical regression lines with a straight-line correlation between bread volumetric yield and overall bakery rating, 2020-2022

The best expression of traits, at the level of requirements for strong wheats, was characterized by: a new variety Privolye and lines 1638/19, 1420/19, 1401/19 and 1518/18.

The specific work of deformation of the dough or “flour force” (W) is determined using an alveograph, an instrument used to evaluate the baking qualities of wheat flour. The alveograph measures the viscoelastic properties of the dough bubble while it is inflating, as the alveograph method tries to mimic the bubble growth that occurs during dough fermentation and early baking [9].

As a result of the correlation analysis, a significant average positive relationship was determined between the features “specific work of dough deformation” and “general baking rating” $r=0.5119$ Figure 2.

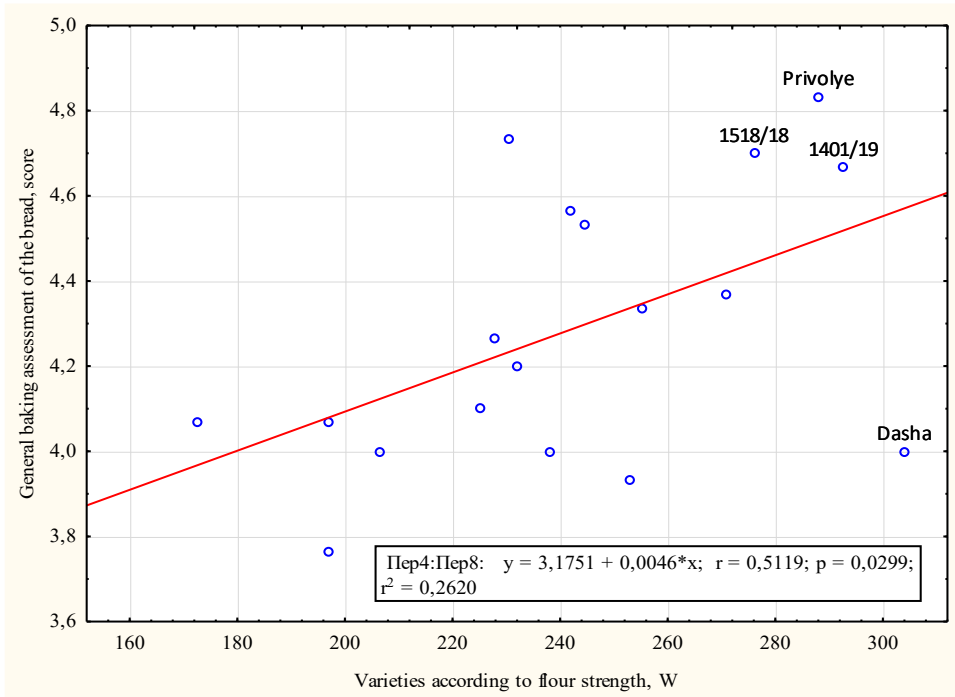


Fig. 2. Scatterplot and theoretical regression lines with a straight-line correlation between the specific work of deformation of the dough and the total bakery rating, 2020-2022.

The positive relationship of these features indicates a joint increase in the values, the higher the value of "flour strength", the higher the baking score. However, in breeding practice, genotypes with high strength (more than 300 alveograph units) are not always able to form a sufficient volume of bread. Such varieties are "improvers" of genotypes with weaker flour in the preparation of mixtures. In our studies, the improver variety Dasha was identified, which was characterized by the specific work of deformation of the dough W = 304 units of the alveograph.

Based on the results of the research, lines 1518/18, 1401/19 and a new variety Privolye with optimal rheological and baking properties were identified.

Researchers testify that the value of the correlation coefficient may vary depending on the growing conditions, features of the breeding material, and other factors [5, 10, 11]. Therefore, scientists are faced with the task of identifying signs that stably manifest themselves in different years. Such features are "mass fraction of protein" and "amount of gluten", which characterize the nutritional value of wheat grain and its suitability for obtaining high-quality bread [12-14].

An analysis of the correlation relationships between these traits made it possible to establish a significant, positive relationship $r = 0.8471$, which indicates a fairly high linear dependence and the ability to effectively use lines and varieties with a high content of protein and gluten in the selection process.

As a result of the studies, lines with the best expression for these traits were identified: 1762/17, 1401/19, 1361/19, 1343/19, 1420/19, 1120/19 and 1638/19 Figure 3.

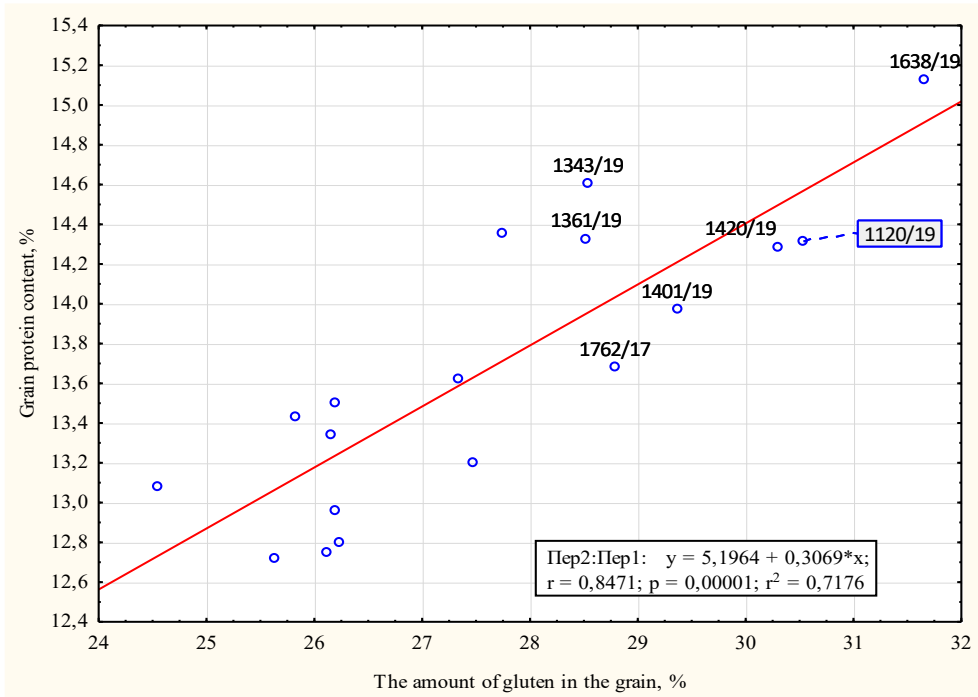


Fig. 3. Scatterplot and theoretical regression lines for a straight-line correlation between gluten amount and protein mass fraction, 2020-2022

Valorimetric assessment is a single generalizing indicator of the physical properties of the dough and key elements of the quality of final wheat products, determined using a farinograph [15]. The following requirements are imposed on varieties of “strong” quality for this trait, at least 70-85 units of the valorimeter.

The gluten deformation index (IDK) is a characteristic of the properties of gluten (elasticity, extensibility, elasticity).

As a result of the correlation analysis, a significant, negative, average relationship was established between the valorimetric assessment and the quality of gluten (GQ) ($r=-0.6028$) Figure 4.

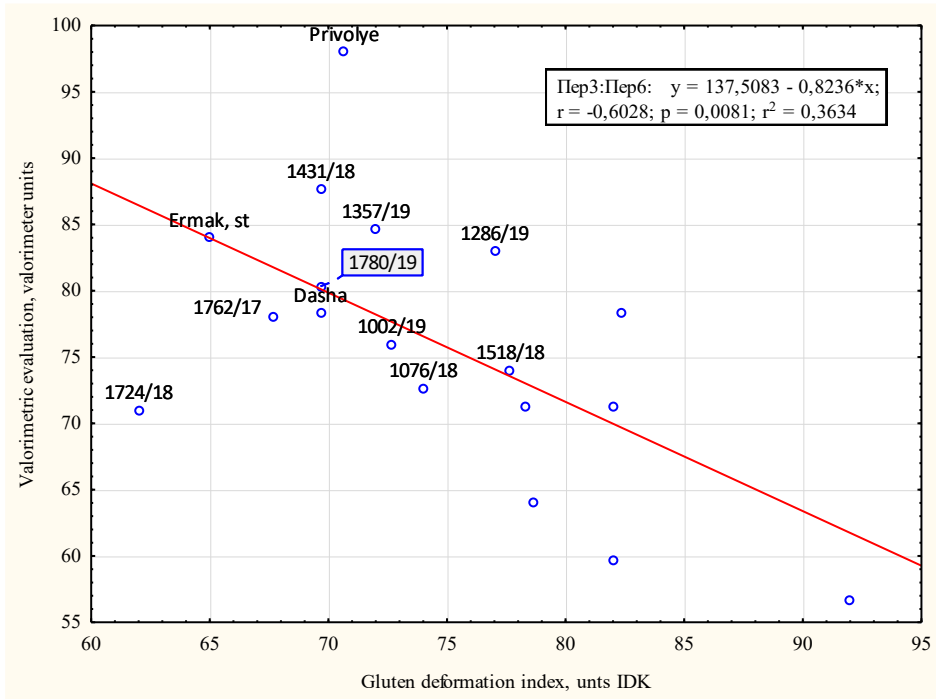


Fig. 4. Scatter plot and theoretical regression lines for a straight-line correlation between gluten quality (GQ) and valorimetric score, 2020-2022

The best expression of two traits was characterized by new varieties Privolye, Dasha and breeding lines 1762/17, 1724/18, 1076/18, 1002/19, 1780/19, 1518/18, 1286/19, 1286/19, 1357/19, 1431 /18 and standard grade Ermak.

The data obtained will serve as a recommendation in the selection of parental pairs in breeding work and in research on the creation of new material, taking into account the requirements of modern science and agricultural production for the southern zone of the Rostov region.

4 Conclusion

Based on the results of the analysis of the relationships, the main informative ones for the selection of genotypes with high grain quality were determined: the mass fraction of protein, the amount of gluten, the specific work of dough deformation, valorimetric assessment, the volumetric yield of bread and the overall baking assessment.

As a result of the study of varieties and lines of winter soft wheat, a high positive relationship was revealed between the mass fraction of protein and the amount of gluten in the grain ($r=0.8471$).

The resulting trait "general bakery rating" was significantly influenced by the volumetric yield of bread ($r=0.9118$) and, to an average degree, the specific work of dough deformation ($r=0.5119$).

New varieties and lines of winter soft wheat of intensive type, distinguished by a complex of studied traits: the new variety Privolye, lines 1518/18 and 1401/19, it is advisable to use in the breeding process aimed at improving the quality of winter soft wheat grain.

References

1. I. Kudryashov, L. Bespalova, D. Ponomarev, The relevance of varietal structures in the production of winter wheat in modern conditions. *AgroSnaBForum*, **7(147)**, 70-72 (2016)
2. I. Pototskaya, V. Shamanin, S. Shepelev, A. Chursin, O. Kuzmin, A. Morgunov, Search for genetic sources to improve the quality of wheat varieties. *Bulletin of the Omsk State Agrarian University*, **1(41)**, 45-53 (2021) doi 10.48136/2222-0364_2021_1_45
3. G. Maslova, M. Abdryaev, I. Sharapov, Y. Sharapova, Correlation analysis of yield and productivity elements of soft winter wheat varieties in arid conditions of the forest-steppe zone of the Middle Volga region. *Proceedings of the Samara Scientific Center of the Russian Academy of Sciences*, **2-4(82)**, 680-683 (2018)
4. N. Samofalova, N. Ilichkina, T. Bezuglaya, N. Kravchenko, A. Ivanisova, N. Kabanova, O. Dubinina, Conjugation of quality traits of grain, semolina and pasta in durum winter wheat. *Grain farming in Russia*, **4(14)**, 62-69 (2022) doi: 10.31367/2079-8725-2022-82-4-62-69
5. D. Pushkarev, A. Chursin, O. Kuzmin, Y. Krasnova, I. Karakoz, V. Shamanin, Correlation of yield with productivity elements of spring soft wheat varieties in the conditions of the steppe zone of the Omsk region. *Bulletin of the Omsk State Agrarian University*, **3(31)**, 26-35 (2018)
6. A. Sukharev, G. Ovsyannikova, Terms of application of ammonium nitrate in the cultivation of soft winter wheat Krasa Dona in the southern zone of the Rostov region. *Agrarian science of the Euro-North-East*, **21(6)**, 743-751 (2020) doi:10.30766/2072-9081.2020.21.6.743-751
7. M. Miroslavljević, V. Momčilović, D. Živančev, et al., Genetic improvement of grain yield and bread-making quality of winter wheat over the past 90 years under the Pannonian Plain conditions. *Euphytica* **216**, 184 (2020) <https://doi.org/10.1007/s10681-020-02724-5>
8. S. Michel, F. Löschenberger, C. Ametz, et al., Combining grain yield, protein content and protein quality by multi-trait genomic selection in bread wheat. *Theor Appl Genet* **132**, 2767–2780 (2019) <https://doi.org/10.1007/s00122-019-03386-1>
9. AS. S. Jødal, K. L. Larsen, Investigation of the relationships between the alveograph parameters. *Sci Rep*, **11**, 5349 (2021) <https://doi.org/10.1038/s41598-021-84959-3>
10. E. Vladimirova, Correlation analysis of the source material for soft spring wheat breeding in Central Yakutia. *Bulletin of the Orenburg State Agrarian University*, **5(85)**, 31-37 (2020) doi: 10.37670/2073-0853-2020-85-5-31-37
11. I. Dyomina, Correlation dependence of yield and grain quality indicators of spring wheat samples on agroecological conditions. *International Agricultural Journal*, **3(387)**, 278-281 (2022) DOI:10.55186/25876740_2022_65_3_278
12. V. Rubets, I. Voronchikhina, V. Pylnev, Y. Kotenko, A. Blinkov, *Grain quality and associated characteristics and properties of spring wheat of canadian breeding*, В сборнике: E3S Web of Conferences. Сер. "International Scientific and Practical Conference "Fundamental and Applied Research in Biology and Agriculture: Current Issues, Achievements and Innovations", FARBA 2021" 01043 (2021) <https://doi.org/10.1051/e3sconf/202125401043>
13. H. F. Gómez-Becerra, A. Abugalieva, A. Morgounov, et al., Phenotypic correlations, G × E interactions and broad sense heritability analysis of grain and flour quality

- characteristics in high latitude spring bread wheats from Kazakhstan and Siberia. *Euphytica*, **171**, 23–38 (2010) <https://doi.org/10.1007/s10681-009-9984-6>
14. O. O. Kradetskaya, I. V. Chilimova, M. U. Utebayev, Influence of the main quality indicators of spring wheat (*triticum aestivum* l.) on baking properties in the conditions of the akmola region Herald of Science of S. Seifullin Kazakh agro technical university, **2(105)** (2020) <https://doi.org/10.47100/herald.v1i2.21>
 15. M. Barakat, A. Al-Doss, K. Moustafa, et al., QTL analysis of farinograph and mixograph related traits in spring wheat under heat stress conditions. *Mol Biol Rep*, **47**, 5477–5486 (2020) <https://doi.org/10.1007/s11033-020-05638-6>