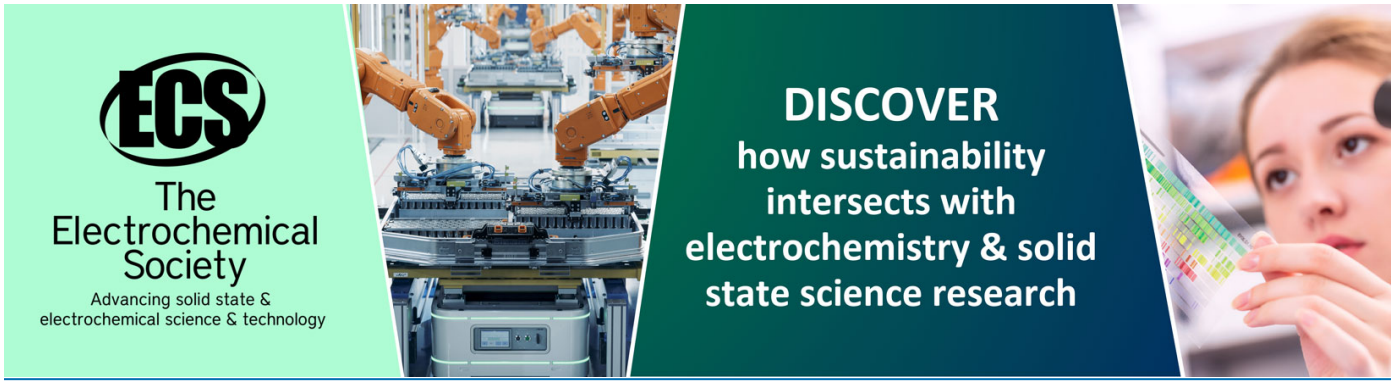
Biochemical grain quality indicators and photosynthetic rate of leaves in modern varieties of winter wheat



Biochemical grain quality indicators and photosynthetic rate of leaves in modern varieties of winter wheat

A V Amelin[1,3], E I Chekalin[1], V V Zaikin[1], V I Mazalov[2] and R A Ikusov[1]

[1] Federal State Budgetary Educational Institution of Higher Education Orel State Agrarian University named after N.V. Parakhin, Orel, Russia
[2] Federal State Budgetary Scientific Institution Federal Research Center of leguminous and cereal crops, Streletskiy, Russia

[3] E-mail: amelin_100@mail.ru

Abstract. Modern agriculture is waiting for selection to create varieties, forming high, stable and high-quality grain crops in different conditions of cultivation. Although, recognized varieties of winter wheat don't always ensure getting high and good quality grain crops. Resolution of this problem is seen in more profound study of photosynthetic activity of plants and and using its indices in selection. During the years of research the interval of genotypic variation in crop power of culture grain was somewhere in between 2.6…5.5 t/ha. Content of protein and fibrin in the studied breeds was varying average from 13.5 to 16.0 % and from 21.1 to 28.5 %, respectively. Between indices of crop power and content of protein the correlation parameter was changing from -0.27 to +0.16, but with fibrin in content – from -0.16 to +0.18. Connection of photosynthesis and transpiration activity with grain quality was more considerable. Correlation coefficient between photosynthetic rate of leaves and content of protein and fibrin was positive and equal to 0.62 and 0.47 respectively, but between transpiration rate and content of protein and fibrin amounted to -0.34 and -0.15, respectively. It's established that the higher the correlation of photosynthetic rate with transpiration activity of leaves among varieties of culture, the better the quality of developing grain crops. Evaluating the genotypes of winter wheat taking into consideration the effectiveness of using water allowed establishing a broad range of indices variation – from 1.88 to 4.19. Varieties with high value of this index (from 3.41 to 4.19 CO_2/H_2O) were characterized by increased content of both protein and fibrin: Moskovskaya 39 - 14.5 % and 24.1 %, respectively, Moskovskaya 40 - 15.0 % and 24.8 %, respectively.

1. Introduction

Winter wheat is the important food crop both in the world and in Russia as well [1]. Although, in modern manufacturing conditions, it's not always possible to get a high and good quality crop of culture [2].

One of preferred directions of solving this problem is creation of varieties, which form not only high, stable, but also good-quality grain crops in different conditions of cultivation [3].

In connection to this, the highly relevant works are represented by papers studying physiological-biochemical parameters of plants and mainly photosynthetic activity [4], with the help of which, 95% of crops' dry basis is formed [5].

Given article is precisely dedicated to results of such researches, which had an aim to identify genotypic specificity of plants photosynthetic activity in modern varieties of winter wheat due to the

fact that they develop high and good quality grain crops in conditions of the Central-Chernozem region of Russia.

2. Methods

Researches were carried out in the years 2017-2020 at the premises of Federal State Budgetary Educational Institution of Higher Education Orel State Agrarian University in Resource Sharing Centre «Genetic plant resources and usage of them» under joint program with Shatilovo agricultural experiment station of Federal State Budgetary Scientific Institution Federal Research Centre of leguminous and cereal crops.

The 35 modern varieties and advanced strains of winter wheat from leading selection institutions of Russia became subject of research. Experiment material was sowed in selective farming rotation on working plots of 25 m^2 in quadruple repeatability, distribution – randomized.

Biochemical values of grain (fibrin, protein, starch, sedimentation, moisture) were defined with the help of grains analyser Infratec 1241 Foss, on the whole grain of experiment varieties of culture.

Measurement of photosynthesis and plants leaves' transpiration rates was made in the field environment with usage of a portable gas analyser of GFS-3000 FL brand, with illumination level in measuring chamber equal to 1000 mcM/m^2s. For measurements, it was decided to pick 5-7 plants, typical for genotype, and growing in the middle of working plot, and leaves of which didn't have pest and disease damages. Record of physiological parameters was carried out on flag leaf between 8:00 and 11:00 o'clock of Moscow time, when the genotypic differences manifest more expressively.

Effectiveness of using water by plants was defined by the ratio between photosynthetic rate and transpiration rate [6].

Mathematical and statistical processing of received research results was done with the usage of modern computer software and in accordance with «Field plot technique» [7].

3. Research results

Based on the results of the research conducted, grain crop capacity among modern varieties of winter wheat in conditions of environmental experiment in Shatilovo agricultural experiment station during research years was average equal to 4.4 t/ha. Interval of genotypic variation of index was in the range of 2.6…5.5 t/ha. Content of protein and fibrin in the studied species was varying from 13.5 up to 16.0 % and from 21.1 to 28.5 %, respectively (figure 1).

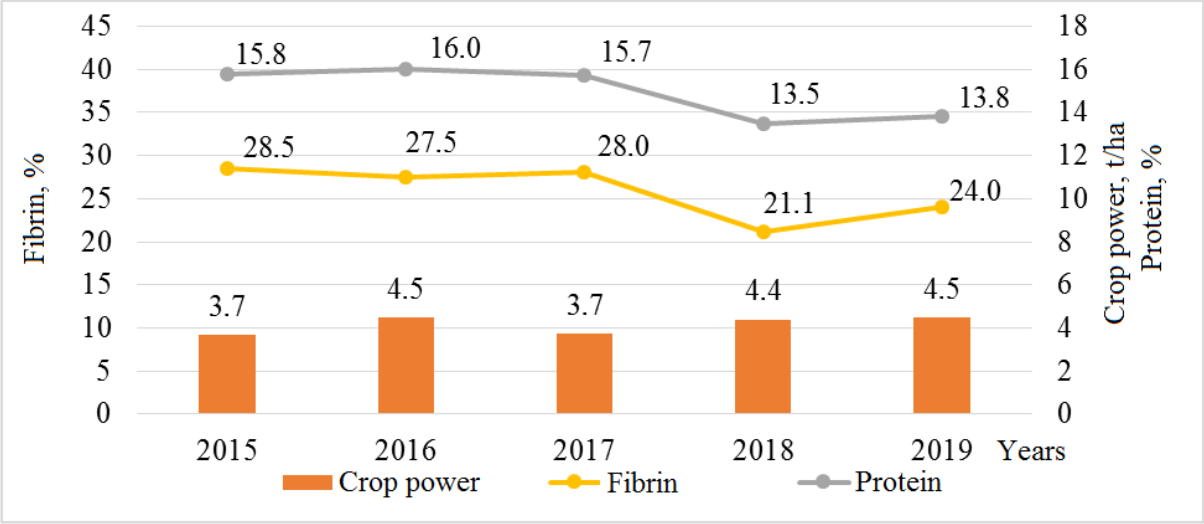


Figure 1. Correlation of crop power and quality of winter wheat grain in the years of research.

Correlation ratio between crop power rate and content of protein was varying from -0.27 to +0.16, but with content of fibrin – from -0.16 to +0.18. In other words, this is a proof of provision that between quality characteristics and crop power of culture there's negative correlation [8, 9], which can be considerably affected by weather conditions of vegetation [10, 11].

For example, prominent drought conditions of plants vegetation (year 2018), were making negative impact to a greater degree on establishment of grain quality, but not on crop power of winter wheat varieties, at the same time, insignificant shortage of precipitations and moderate temperature of air (years 2015, 2017) contributed towards getting good-quality, but relatively low crop of grain. The most favourable conditions for formation of both, high and good-quality crops were registered in 2016 when during vegetation of plants the weather was warm and sunny, with abundant precipitations (figure 2).

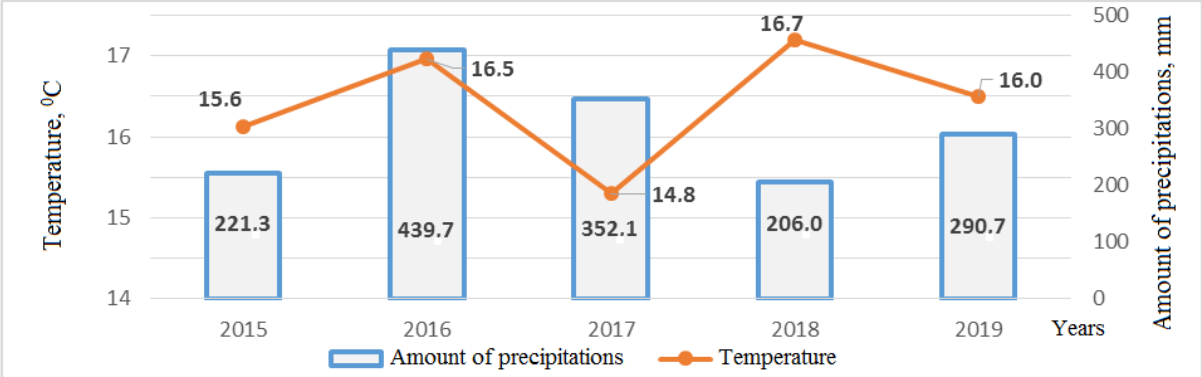


Figure 2. Weather conditions of vegetation of winter wheat plants during the years of research.

Nonetheless, practice shows that the selection of winter wheat in terms of combination of high crop power and quality of grain absolutely can be resultative [9].

In our research, the varieties (Moskovskaya 40, Nemchinovskaya 17) forming not only high but also good-quality grain crops were standing out.

Detailed morpho-physiological analysis of their plants showed that, most commonly, the high photosynthetic activity of leaves while moderate transpiration in the period of caryopsis plumpness, is characteristic for high-yielding varieties of winter wheat, and this was observed in vegetation during the years 2017-2019 (figure 3).

It is known that photosynthesis is the main source of transformed natural power of the sun and factor of production process of plants, due to which 95% of the dry basis of crops is developed [5].

It is justifiable that other researchers also mark the positive relation of winter wheat crop power with photosynthesis rate, which increases considerably due to the result of selection [12]. According to experimental data of Jiang G.M. et al. [13], in modern varieties of culture, the photosynthesis rate per unit area of leaves is 44 % higher than in varieties created in the 1950s. Besides, for six phenological phases (during the period starting from leaf-tube formation and until milky stage of grain), tight correlation dependence of crop volume from photosynthetic rate of leaves ($r = 0.61$) and stomatal conductance was identified ($r = 0.67$).

In this case, increase of photosynthetic rate is achieved with the help of improving kinetic properties of ferments [14, 15, 16, 17], optimization of photo protection reactions [18] and light-harvesting complexes of photosystems [19, 20], change in architectonics of plants and dropping [21].

At the same time, strict (linear) dependence of crop power of recognized culture varieties from photosynthetic rate was not found. In our research work the correlation coefficient between these indices was changing from 0.02 to 0.42. Correlation of grain crop productivity with transpiration rate of plant leaves was negative to a greater extent and varied year-wise from -0.76 to +0.27.

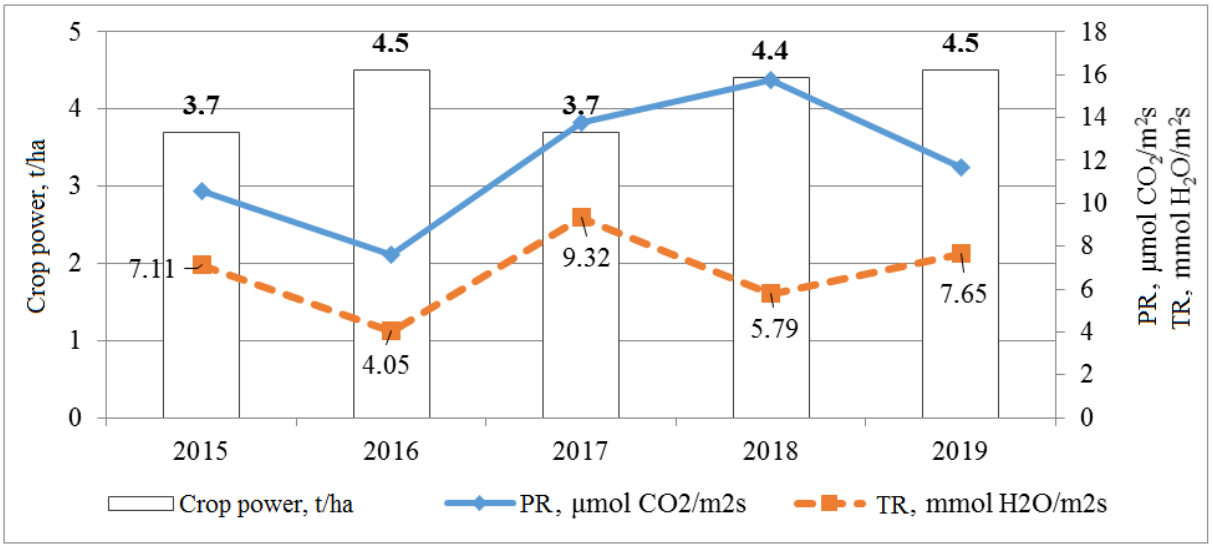


Figure 3. Photosynthetic and transpiration activity of leaves in connection to crop power of plants of winter wheat during years of research.

In many instances, a similar type of correlation manifested in grain quality as well. Correlation coefficient between photosynthetic rate of leaves and content of protein and fibrin was also positive (0.62 and 0.47 respectively), but between transpiration rate and content of protein and fibrin - negative (-0.34 and -0.15, respectively) (figure 4).

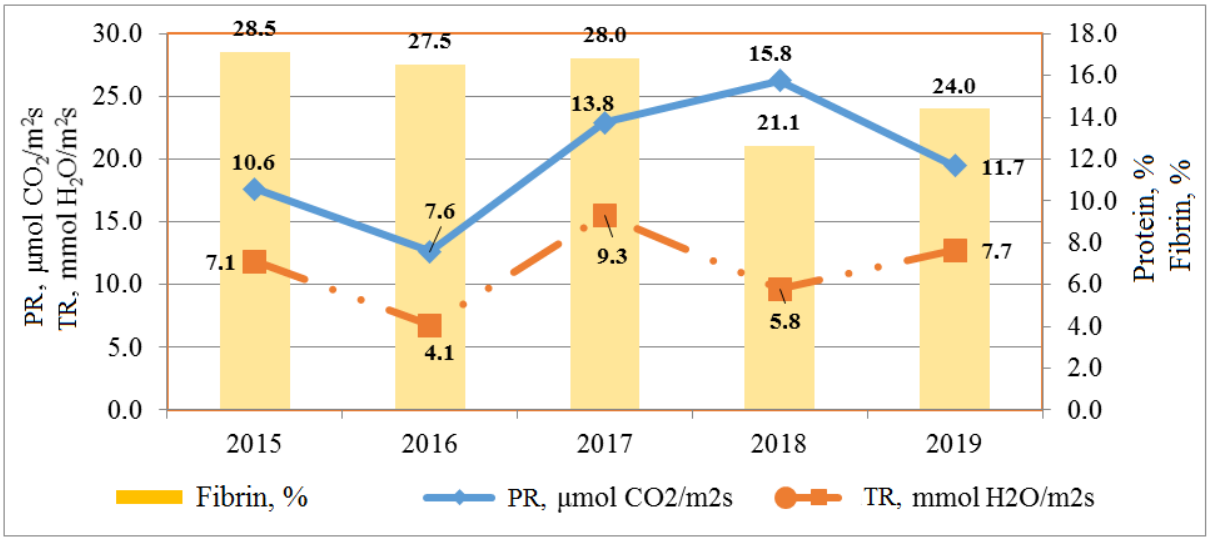


Figure 4. Photosynthesis and transpiration rate of plant leaves in connection to quality of crops of winter wheat grain during the years of research.

In this case, correlation of these two leading physiological processes in ontogenesis of plants was of great importance for grain quality of winter wheat varieties. As it is known, photosynthesis is the basic source of transformed natural power of sun and main factor of production process of plants [21], while the transpiration protects plants from overheat and dehydration in dry and hot weather by ensuring transportation of mineral substances absorbed from the soil up the plant [22, 23].

These two processes are tightly connected between each other by conductance of the leaves stomatal system, through which, not only assimilation of CO_2 is fulfilled, but also evaporation of water steam [24, 25].

In view of the fact that more than 60 % of sun energy, which is transformed through photosynthesis, can be spent for transpiration of leaves, it's preferable for plants to have high activity of photosynthesis while moderate transpiration for formation of high and good quality grain crops. For this purpose, it's suggested to take into account the index of «water use efficiency - WUE», which is found with the help of ratio of photosynthetic rate to transpiration rate [6].

It's established that the higher the correlation of photosynthetic rate with transpiration activity of leaves in plants of winter wheat, the better the quality of developing grain crops will be. Evaluation of experiment varieties of winter wheat according to WUE, allowed establishing the broad range of index variation – from 1.88 to 4.19. Genotypes with high index of water use efficiency (from 3.41 to 4.19 CO_2/H_2O) were characterized also by increased content of protein and fibrin: Moskovskaya 39 - 14.5 % and 24.1 %, respectively, Moskovskaya 40 - 15.0 % and 24.8 %, respectively (figure 5).

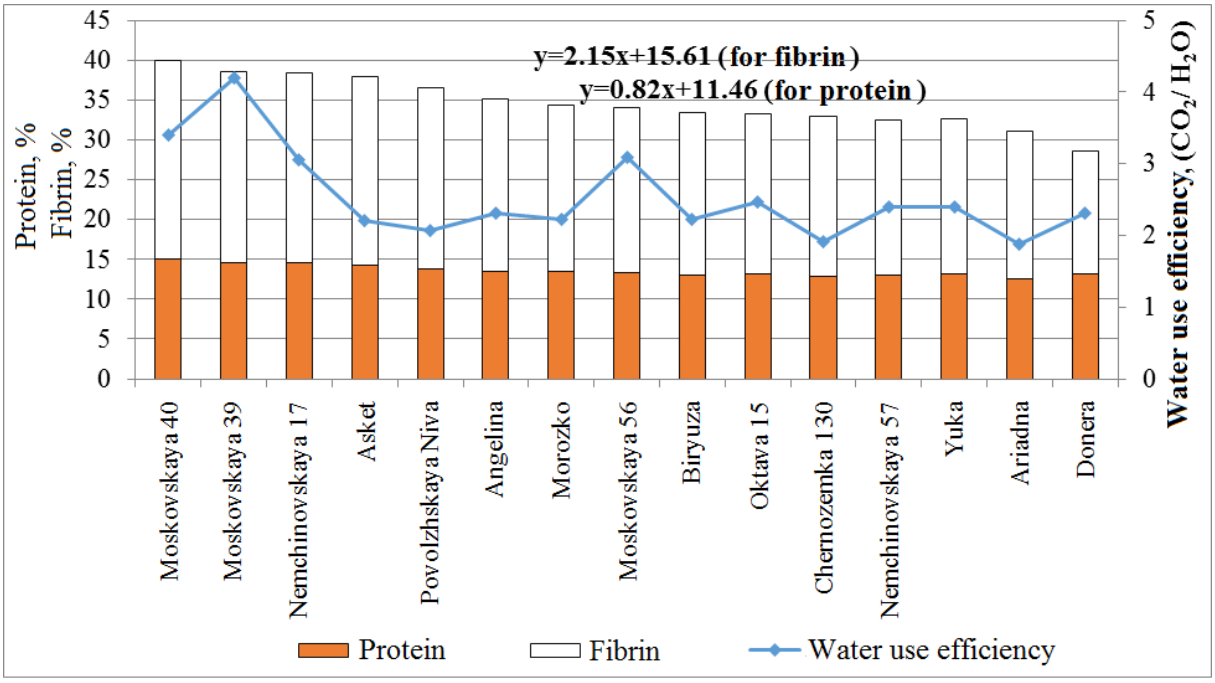


Figure 5. Correlation of crop quality indices with plant's water use efficiency (WUE) in modern varieties of winter wheat, in average during the years 2017-2018.

Between water use efficiency and grain quality, the correlation coefficient was considerable and in studied varieties amounted to: 0.60 – with protein; 0.41 – with fibrin (significant while P=0.05).

This allowed to develop the method of genotype selection of winter wheat with increased quality of grain according to efficiency of water use by plants for photosynthesis (patent № 2720426, publ. 29.04.2020 Bull. № 13) and to offer this for using in selection.

4. Conclusion

In varieties of winter wheat, between crop power and grain quality there's a negative correlation, which can be significantly affected by weather conditions of vegetation. Expressed drought conditions of plant vegetation, to a greater extent, have negative impact on development of grain quality, but not crop power of culture, while certain shortage of precipitations and moderate temperature of air contribute to getting grain crops of good quality but relatively low. In this context, correlation of photosynthesis and leaves transpiration rates in ontogenesis of plants, have important significance. It's established that the higher

this correlation in plants of winter wheat is, the better the quality of grain crop formation will be, which allowed developing the method of selecting the genotype of winter wheat with increased grain quality (patent № 2720426, publ. 29.04.2020 Bul. № 13) and suggesting using it in selection.

By using this method, already in early stages of selection (breeding nurseries of 1st and 2nd years) it's possible, to high precision and with minimum time investments, to carry out mass evaluation of winter wheat genotypes under field conditions (50-60 samples for 3 hours) in accordance with water use efficiency and, to select the promising ones out of them - with increased content of protein (not less than 12.0 %) and fibrin (not less than 23%) in grain, with preserving seed material for further inclusion into culture selection process.

References

[1] Dolgopolova N V, Skripin V A, Shershneva O M and Alyabyeva Yu V 2009 Role of winter and spring wheat in production of food items *Vestnik Kursk state agricultural academy* **5** 52-6
[2] Zhuchenko A A 2011 *Ways of innovative-adaptive development of Russian agro-industrial complex in XXI century* (Kirov, Russia: Agricultural Research Institute of North East)
[3] Sanduhadze B I 2010 Selection of winter wheat as most important factor of increasing crop power and quality *Scientific and technical achievements of AIC* **11** 4-6
[4] Zhu X G, Long S P and Ort D R 2010 Improving photosynthetic efficiency for greater yield *Annual Review of Plant Biology* **61** 235-61
[5] Nichiporovich A A 1979 *Energetic efficiency of photosynthesis and productivity of plants* (Pushchino, Russia: Scientific Centre of Biological Research of USSR Academy of Sciences)
[6] Polley W H 2002 Implications of atmospheric and climate change for crop yield and water use efficiency *Crop Science* **42** 131-40
[7] Dospehov B A 1985 *Methodology of field experiment (with basics of statistical processing of research results)* (Moscow, Russia: Agropromizdat)
[8] Melnyk A F 2012 Increase of effectiveness of adaptive technologies in winter wheat cultivation *Vestnik Orel State Agrarian University* **4** 21-5
[9] Sanduhadze B I 2016 Development and results of winter wheat selection in centre of non chernozem zone *Scientific and technical achievements of AIC* **30** 15-8
[10] Kazakov E D and Karpilenko G P 1995 Ways of improving grain quality *Proc. of Int. Conf. "Scientific-technical progress in reprocessable segments of AIC*" (Moscow, Russia: MGA PP)
[11] Markin B K 2000 Problems of quality improvement and stimulation of grain production in Povolzhye *Grain cultures* **4** 12-4
[12] Morgun V V and Pryadkina G A 2014 Effectiveness of photosynthesis and perspectives of increasing productivity of winter wheat *Physiology of plants and genetics* **46** 279-301
[13] Jiang G M *et al.* 2003 Changes in rates of photosynthesis accompanying the yield increase in wheat cultuvars released in the past 50 years *J. Plant Res.* **16** 347-54
[14] Gowik U and Westhoff P 2011 The path from C3 to C4 photosynthesis *Plant Physiology* **155** 56-63
[15] Raines C A 2011 Increasing photosynthetic carbon assimilation in C3 plants to improve crop yield: current and future strategies *Plant Physiology* **155** 36-42
[16] Parry M A J. *et al.* 2013 Rubisco activity and regulation as targets for crop improvement *Journal Experimental Botany* **64** 717-30
[17] Whitney S M, Houtz R L and Alonso H 2011 Advancing our understanding and capacity to engineer nature's CO2-sequestering enzyme, Rubisco *Plant Physiology* **155** 27-35
[18] Murchie E H and Niyogi K K 2011 Manipulation of photo protection to improve plant photosynthesis *Plant Physiology* **155** 86-92
[19] Chen M and Blankenship R E 2011 Expanding the solar spectrum used by photosynthesis *Trends Plant Science* **16** 427-31
[20] Ort D R and Melis A 2011 Optimizing antenna size to maximize photosynthetic efficiency *Plant Physiology* **155** 79-85

[21] Ort D R *et al.* 2015 Redesigning photosynthesis to sustainably meet global food and bioenergy demand *PNAS* **112** 8529-36
[22] Fischer R A *et al.* 1998 Wheat yield progress associated with higher stomatal conductance and photosynthesis rate, and cooler canopies *Crop Science* **38** 1467-75
[23] Davies W J, Wilkinson S and Loveys B 2002 Stomatal control by chemical signalling and the exploitation of this mechanism to increase water use efficiency in agriculture *New Phytologist* **153** 449-60
[24] Atkinson C J, Policarpo M, Webster A D and Kingswell G 2000 Drought tolerance of clonal Malus determined from measurements of stomatal conductance and leaf water potential *Tree Physiology* **20** 557-63
[25] Li F, Cohen S, Naor A, Shaozong K and Erez A 2002 Studies of canopy structure and water use of apple trees on three rootstocks *Agricultural Water Management* **55** 1-14