The water use efficiency by plants in different breeding periods buckwheat varieties

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Abstract. In the increasing climate aridization context, water effective use by plants is important, which is strongly influenced by photosynthesis and plant transpiration. In these processes' study, buckwheat plants have pronounced variances, manifested in ontogenesis and during the day at the leaves different tiers level, which accordingly affects the water use effectiveness by plants. The water effective use greatest' values by plants are observed in the pre-dinner hours (from 9:00 a.m. to 11:00 a.m.) during active vegetative growth and mass seed pouring (20 days flowering phase), when photosynthesis processes are active and transpiration is at an average level. As a breeding result, this buckwheat plants property is enhanced, which has a positive effect on seed productivity growth. Modern crop varieties outperform local populations by an average of 19.5% in water use terms during the flowering + 20 days phase, 19.8% in photosynthesis intensity terms, 3.4% in transpiration intensity terms, and 37% in seed productivity terms. At the same time, their resistance to air and soil drought tends to decrease, which negatively affects the stability and photosynthesis, and transpiration, and yield. On this basis, it is not considered appropriate to use the water effective use indicator by plants to assess the breeding material for drought resistance but to recommend it for the only highly productive genotypes' identification. The promising forms' selection can be carried out in the field already in the selection' early stages - the 1st and 2nd years nurseries selection.

1. Introduction
Modern agriculture is characterized by development low sustainability, the planet's climate increasing aridization in part because. The water-efficient use by plants, which is highly dependent on exogenous and endogenous growth and development factors, is important here.

Among endogenous factors, photosynthesis and leaf transpiration have a significant impact on this indicator, due to their significant physiological role in the production process and the plant's protective complex [1, 2, 3].

It is known that plant photosynthesis is the sun transforming the replenished natural energy main process, due to which about 95% of the crops dry matter formed [4], and leaf transpiration ensures minerals and water active movement from the soil into plants and protects the aboveground organs from overheating and dehydration in dry and hot weather, creating the necessary conditions for active growth and development [5, 6].
At the same time, more than 60% of solar energy converted by photosynthesis can be spent on plant transpiration [7]. Therefore K.A. Timiryazev called it a necessary evil, which obviously cannot be avoided, but it is very important to reduce it [8].

Taking into account this issue relevance for buckwheat warm and moisture-loving culture, we carried out appropriate field and laboratory studies on different breeding periods buckwheat varieties' to identify the breeding process influence degree on the water use efficiency by plants and to determine ways to further increase it.

Research materials and methods. The research was carried out on the centre basis for collective use "Plant genetic resources and their use" of the Federal State Budgetary Educational Institution of Higher Education the Orel State Agrarian University under a joint program with the Federal State Budgetary Scientific Institution Federal Research Center breeders Legumes and Cereals.

The main research objects were different breeding periods culture 11 cultivars, which were conditionally divided into 3 groups: local populations from the Orel region (K-406 and K-1709); old varieties - selection from 1930-1960. (Kalininskaya, Bogatyry and Shatilovskaya 5) and modern varieties - selections 1990-2010. (Demeter, Rain, Dikul, Inzerskaya, Nine and Design). Plants were grown in the selection crop rotation of the Federal State Budgetary Scientific Institution FRC LAC, the plot area was 10 m², the repetition rate was 4.

The water use efficiency by plants (WUE) was determined by the photosynthesis intensity ratio to the transpiration intensity, following the methodological recommendations [9].

The photosynthesis intensity measurements and the plant leaves transpiration intensity were carried out in the field in the online mode using a portable gas analyzer GFS-3000 FL, at an illumination level in the measuring chamber of 1000 μmol/m²s and an air temperature of 25°C. For measurement, 5-7 plants typical for the genotype were selected, growing in the plot middle, in which the leaves were not damaged by pests and diseases. Records were taken during the main growth phases (vegetative growth, flowering+10 days, flowering+20 days, flowering+30 days) on the 3rd leaf from the top (physiologically adult) of the main stem during daylight hours-from 7:00 to 19:00 Moscow time. Records periodicity - every 2 hours.

Grain yield was determined from each plot of the variety by direct weighing on scales after threshing by a combine and structural analysis of 40-60 plants selected in test sheaves.

The obtained research results mathematical processing was carried out using modern computer software.

2. Research results

It has been established that the buckwheat gene pool is characterized by a WUE index wide polymorphism. In the research years, its importance in the studied varieties ranged from 1.03 to 2.08 μmol CO²/m² s/mmol H₂O/m² s μmol CO²/m² s. The evaporated water carbon dioxide molecules per unit greatest assimilation by the leaf surface was distinguished by modern varieties that surpassed their predecessors by an average of 24.2% (figure 1).

The increase in the water use efficiency by plants as a selection result did not affect the drought resistance and photosynthetic and production processes stability. In 2010, with a pronounced drought throughout the growing season, the WUE values for all cultivars were above the average level, while the photosynthesis and transpiration intensity, as well as seed productivity, were reduced by an average of 36%, compared to the growing season favourable weather conditions (figure 2).

This gives reason to believe that the WUE indicator for buckwheat culture cannot be used in assessing genetic resources for drought resistance, and it is advisable to use it only to identify highly productive genotypes.
In ontogenesis, the water use the highest efficiency by plants is observed during the active vegetative growth (branching) phase and the seeds’ mass formation and filling, and the lowest – during budding and flowering. In the research years, culture modern varieties exceeded local populations in this indicator terms: during the vegetative development period - by an average of 16.9%, in the flowering + 20 days phase - by 19.5%, in the flowering + 30 days phase - by 17.6%. During the buds and flowers active formation (blooming + 10 days), the intersort differences in this indicator were not significant (figure 3).

The indicator ontogenetic variability was closely related to the leaves photosynthetic and transpiration activity nature. The leaf photosynthesis intensity increases until the flowering +20 days phase, and then sharply decreases [10], while transpiration is most active during the flowering+10 days phase, and during the vegetative growth and mass seed filling (flowering +20 days) period it is minimal [11], which leads to a corresponding decrease in the water use efficiency. The correlation coefficient between WUE and the photosynthesis intensity was positive (+0.69), and negative (-0.89) with the transpiration intensity.
Due to the high transpiration activity and reduced photosynthesis intensity in the flowering + 10 days phase, modern varieties were on the same level with the old varieties of the different tiers leaves WUE value terms and were inferior to local populations by an average of 40%. At the same time, all had a pronounced tendency to reduce it from the lower tiers to the upper ones. In the flowering phase + 10 days, the water use efficiency in the lower leaves was 15.4% higher than in the middle-tier leaves and 8.4% higher than in the upper ones (figure 4).

Significant genotypic differences in the water use efficiency by buckwheat plants are also observed during the day, mainly in the pre-afternoon (from 9 to 11 o'clock Moscow time), when the photosynthesis intensity is highest [10], and transpiration is moderate [11]. In this period, modern crop varieties have an average water use efficiency of 17.5% higher than in local populations. No significant differences were found with the old varieties (selected in the 1930s) (figure 5).
Figure 5. Water use efficiency day course in different breeding periods buckwheat varieties in the flowering phase + 20 days, vegetation experience 2014-2015.

3. Conclusions
The water use efficiency by buckwheat plants is positively associated with the photosynthetic activity nature and negatively with transpiration. As a breeding result, its value increases, which has a significant impact on productivity, but not on its stability. Based on this, the WUE indicator (water use efficiency) can be used to select only buckwheat productive genotypes. The promising forms' selection can be carried out in the field with high accuracy and minimal time already at the breeding early stages (selection nurseries of the 1st and 2nd years).

References
[1] Nichiporovich A A 1956 Photosynthesis and the Obtaining High Yields Theory. Timiryazev Reading (Moscow: USSR Academy of Sciences) p 93
[2] Koshkin E I 2010 Crops stability physiology (textbook) (Moscow, Russia: Drofa) p 640
[3] Fischer R A, Rees D, Sayre K D et al. 1998 Wheat yield progress is associated with higher stomatal conductance, higher photosynthetic rate and cooler canopies Crop Science 38 1467-75
[4] Nichiporovich A A 1977 The Theory of Photosynthetic Productivity of Plants. Science and Technology Results. Plant Physiology. The Plant Productivity Theoretical Bases 3 (Moscow, Russia: The STI All-Union Institute) p 11-55
[5] Lebedev S I 1988 Plant Physiology (Moscow, Russia: Agropromizdat) p 544
[6] 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
[7] Slacher R 1970 Plants Water Regime (Moscow, Russia: Mir) p 367
[8] Timiryazev K A 1957 Selected Works 1 (Moscow, Russia: The agricultural literature State publication) p 274
[9] Polley W H 2002 Implications of atmospheric and climate change for crop yield and water use efficiency Crop Sci. 42 131-40
[10] Amelin A V, Fesenko A N, Chekalin E I, Fesenko I N and Zaikin V V 2016 Variability of photosynthesis intensity in cultivated common buckwheat Fagopyrum esculentum Moench. Depending on the ontogenetic phase and environment conditions The 13th International
Symposium on Buckwheat Section VI Ecology and environment 773-8

[11] Amelin A V, Fesenko A N, Chekalin E I, Fesenko I N and Zaikin V V 2016 Variability of leaf transpiration intensity in cultivated common buckwheat Fagopyrum esculentum Moench. Depending on the ontogenetic phase and environment conditions The 13th International Symposium on Buckwheat. Section VI Ecology and environment 767-72

[12] Chandler J W and Bartels D 2003 Drought Avoidance and Drought Adaptation (Encyclopedia Water Science) p 163-5

[13] Zhang S Q and Shan L 2002 The research advance of water use efficiency in plants Agricultural Research Arid Areas 20 1-5