American Journal Of Agriculture And Horticulture Innovations

VOLUME Vol.05 Issue11 2025
PAGE NO. 13-16
DOI 10.37547/ajahi/Volume05Issue11-02

Water Exchange Indicators Of Soybean Varieties Under Different Moisture Conditions

Kholliyev Askar Ergashovich
Doctor of Biological Sciences, Professor, Bukhara State University, Bukhara, Uzbekistan

Aminjonova Charoskhon Akmalovna
Basic Doctoral Student, Bukhara State University, Bukhara, Uzbekistan

Received: 12 September 2025; **Accepted:** 04 October 2025; **Published:** 07 November 2025

Abstract: The study investigated the water exchange indicators of seven soybean (Glycine max L.) varieties—Arisoy, Zara, Zamin, Chara, Olmos, Bars, and Optima—under different soil moisture conditions (70%, 50%, and 30% of total field capacity) in the meadow-alluvial soils of the Bukhara region. Field experiments were conducted to evaluate diurnal leaf water deficit using physiological measurements at various growth stages (budding, flowering, and pod formation). The results showed significant varietal differences in leaf water deficit depending on soil moisture and phenological phases. The highest deficit was recorded in Bars, Optima, and Zara varieties under 30% moisture, while Arisoy and Zamin maintained lower values, indicating better drought tolerance. Overall, decreased soil moisture increased water deficit across all varieties. These findings highlight the importance of selecting drought-tolerant soybean genotypes for stable yield under arid and semi-arid conditions.

Keywords: Soybean varieties, water deficit, drought stress, physiological indicators, soil moisture, Glycine max L.

Introduction: Soybean (Glycine max L.) is one of the most widely cultivated leguminous crops in the world, grown on approximately 250 million hectares, ranking fourth globally in production volume after maize, wheat, and rice [1]. In Africa, over 2.5 million hectares are used for soybean cultivation, with Nigeria being the second-largest producer after South Africa, accounting for 29–40% of the continent's total soybean production [2]. This figure is expected to increase as a result of population growth, rising demand, and changes in food consumption patterns. Globally, demand for soybean is growing steadily, and production is projected to double by 2050 compared to 2020 levels [3].

Heavy dependence on international soybean trade places pressure on household budgets and poses risks to food security and nutrition initiatives. Therefore, increasing per-hectare productivity of soybean is essential to meet both national and regional food demands while minimising environmental impacts [4]. Soybean is a major source of plant protein and essential amino acids, providing valuable nutrition for both humans and animals. Soybean oil also contains beneficial unsaturated fatty acids, vitamins, minerals, and other bioactive compounds essential for health [5].

Moreover, similar to other leguminous crops, soybeans possess the ability to fix atmospheric nitrogen, making them a valuable source of nitrogen for the soil and subsequent crops. This process depends on symbiotic relationships with nitrogen-fixing bacteria, which convert atmospheric nitrogen into a form usable by plants [6]. Considering the potential role of soybean cultivation in alleviating protein-energy malnutrition—and with global cases of malnutrition projected to exceed 160 million by 2044 [7]—enhancing soybean adaptability and yield stability under drought conditions becomes a key priority.

The more drought-tolerant a variety is, the greater its potential for cultivation in arid regions and for contributing to the fight against malnutrition. In recent years, changing climatic conditions have introduced many unpredictable risks to soybean growth, adversely affecting production [8]. Drought is one of the main abiotic stresses that influences global crop productivity [9]. Drought stress causes water deficiency in plants, leading to cellular dehydration and disruption of normal physiological functions. It reduces growth rate, leaf area, water potential, and photosynthetic activity [10].

Drought also triggers the production of reactive oxygen species (ROS), which can cause oxidative damage and, under extreme conditions, plant death. Plants have developed tolerance mechanisms that include reallocating resources to root systems, resulting in increased root number and length [11,12]. They also synthesise complex antioxidant systems to counteract ROS generation. Antioxidant enzymes such as catalase, peroxidase, superoxide dismutase, and ascorbate peroxidase play crucial roles in scavenging these reactive oxygen species. Another adaptive mechanism involves the accumulation of osmolytes such as soluble proteins, sugars, and proline. These compounds help maintain intracellular water balance during drought stress, reduce membrane permeability, scavenge free radicals, buffer redox potential, stabilise cell structures, and activate cellular pathways [13]. The accumulation of hydrogen peroxide (H_2O_2) has been identified as a predictive marker of oxidative stress responses in plants [14].

Hence, data derived from this research can be useful in assessing the feasibility of cultivating soybean in specific regional conditions and in understanding physiological mechanisms that may be applied in breeding climate-resilient crops. The higher the drought tolerance, the greater the opportunity to cultivate the crop successfully in arid zones and to contribute to nutritional security.

Drought is one of the major causes of reduced agricultural production and yield decline [15]. Drought stress can lead to an increase in the production of reactive oxygen species, changes in enzyme activity, accumulation of osmoregulatory substances, and alterations in pigment composition [16]. These responses can cause damage to biological molecules and cellular organelles. However, plants possess natural mechanisms to limit ROS accumulation, maintaining membrane stability and reducing drought-induced damage.

Drought stress affects the rates of photosynthesis, respiration, and other physiological processes, which in turn influence plant energy reserves and growth. Limited water availability leads to plant dehydration, reduced leaf water content, and loss of leaf turgor, eventually causing stomatal closure [17].

Soybean crops are exposed to numerous unfavourable environmental conditions, among which drought stress causes the greatest yield losses. Increasing crop productivity may be limited by stress-related factors, with theoretical yield potential stabilising around 80% in recent years. These stress factors, especially abiotic ones such as drought, affect all stages of plant growth and development and lead to significant yield reduction. Under field conditions, such stresses often occur simultaneously, restricting plant growth and endangering sustainable agriculture. Field studies assessing varietal performance under different drought conditions are crucial for identifying genotype-specific response mechanisms. As drought events continue to intensify and become more frequent worldwide, the identification and development of drought-tolerant soybean varieties are of increasing importance.

METHODS

The objects of the study were seven soybean (Glycine max L.) varieties: Arisoy, Zara, Zamin, Chara, Olmos, Bars, and Optima. These varieties are currently cultivated across several regions of the Republic. The experiments were conducted under the conditions of meadow-alluvial soils, which are widespread and represent the main soil type of the Bukhara region.

The experiments were carried out under three different soil moisture regimes — 70%, 50%, and 30% of total field capacity (TFC). All research activities were performed under field experimental conditions. During the experiments, diurnal leaf water deficit was measured and analysed under varying moisture conditions using the thermostatic method.

Observations and biometric measurements were performed on model plants within odd replications. In all experiments, the variants were arranged sequentially in tiers and replicated three times. For agrochemical analysis, soil samples were taken from the experimental plots at a depth of 1.2 metres, in layers, and repeated three times. The samples were analysed in laboratory conditions according to standard methods.

All physiological and phenological observations were conducted during the budding, flowering, and pod formation stages of soybean development. To determine all parameters, the 3rd–4th fully developed leaves from the upper part of the stem were collected. For each variety, ten plants were sampled to assess individual indicators. Each experiment was carried out with four biological replications and three analytical replications, ensuring statistical reliability of the results.

RESULTS AND DISCUSSION

Leaf water deficit occurs when the rate of transpiration from the leaves exceeds the rate of water absorption by the roots. Under varying moisture conditions, the degree of water deficit depends on environmental parameters. Under the soil and climatic conditions of the Bukhara region, significant differences were observed among soybean varieties in the average daily leaf water deficit during the growing season.

According to the obtained data, the diurnal water deficit in soybean leaves varied depending on the growth and development phases of the plants as well as the soil moisture levels. In all varieties, from the budding to the pod formation stages, the values of this indicator increased to different degrees depending on the variety. It was also determined that the degree of leaf water deficit changed in accordance with the level of soil moisture. Among all varieties, the highest leaf water deficit occurred during the pod formation stage, while the lowest values were recorded at the budding stage. As soil moisture levels decreased below the optimum, the degree of leaf water deficit increased in all varieties, although to varying extents. Under optimal soil moisture conditions, the deficit remained low, whereas under 30% soil moisture, the maximum leaf water deficit was recorded for all varieties, with distinct variations among them.

In particular, the leaf water deficit in the Arisoy variety during the flowering stage was 11.3% under 70% soil moisture, 12.0% under 50%, and 12.9% under 30%. In the Zara variety, these values were 14.9%, 15.7%, and 16.4%, respectively. In Zamin, the values were 11.8%, 12.5%, and 13.0%; in Chara—12.6%, 13.4%, and 13.9%; in Olmos—13.5%, 14.6%, and 15.1%; in Bars—13.9%, 14.8%, and 15.6%; and in Optima—14.5%, 15.2%, and 15.9%. Similar relationships were also found during the budding and pod formation stages in all studied varieties.

Overall, under different soil moisture conditions, the degree of leaf water deficit in all studied soybean varieties was found to vary depending on their biological characteristics. Under water deficit conditions, the level of leaf water shortage was highest in the Bars, Optima, and Zara varieties, while the Arisoy and Zamin varieties exhibited comparatively lower values. These findings indicate that Arisoy and Zamin are more tolerant to water scarcity and therefore suitable for cultivation in relatively arid environments, where they can maintain higher productivity levels.

CONCLUSIONS

The presented data clearly demonstrate the response of soybean leaves to diurnal water deficit under varying moisture conditions. A general trend was observed across all varieties: as soil moisture decreased, the degree of leaf water deficit increased. However, the rate of this increase differed among varieties, which can be attributed to their genetic characteristics, physiological activity, and ability to conserve water. These differences indicate the potential for selecting and cultivating soybean varieties with higher drought tolerance and improved water-use efficiency for sustainable production in arid and semi-arid regions.

REFERENCES

1. Fried, H. G., Narayanan, S., & Fallen, B. (2019). Evaluation of soybean [Glycine max (L.) Merr.] genotypes for yield, water use efficiency, and root traits. PLoS One, 14(2), e0212700. https://doi.org/10.1371/journal.pone.0212700
2. Martin, J., Devkota, K. P., Terence, E. E., & Tarik, C. (2023). Exploring the potential of mapped soil properties, rhizobium inoculation, and phosphorus supplementation for predicting soybean yield in the savanna areas of Nigeria. Frontiers in Plant Science. https://doi.org/10.3389/fpls.2023.1120826
3. FAOSTAT. (2022). FAOSTAT. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat/en/#data/QCL
4. Helfenstein, J., Diogo, V., Bürgi, M., Verburg, P., Swart, R., & Mohr, F. (2020). Conceptualizing pathways to sustainable agricultural intensification. In Advances in Ecological Research (Vol. 63, pp. 161–192). https://doi.org/10.1016/bs.aecr.2020.08.005
5. Szpunar-Krok, E., & Wondołowska-Grabowska, A. (2022). Quality evaluation indices for soybean oil in relation to cultivar, application of nitrogen fertiliser, and seed inoculation with Bradyrhizobium japonicum. Foods, 11(5), 762. https://doi.org/10.3390/foods11050762
6. Slamani, R. M., Bejger, R., Włodarczyk, M., & Kulpa, D. (2022). Effect of humic acids on soybean seedling growth under polyethylene glycol-6000-induced drought stress. Agronomy. https://doi.org/10.3390/agronomy12051109
7. Jiang, W., Zhao, Y., Wu, X., Du, Y., & Zhou, W. (2023). Health inequalities of global protein-energy malnutrition from 1990 to 2019 and forecast prevalence for 2044: Data from the Global Burden of Disease Study 2019. Public Health, 225, 102–109. https://doi.org/10.1016/j.puhe.2023.10.003
8. Goulart, H. M. D., van der Wiel, K., Folberth, C., Boere, E., & van den Hurk, B. (2023). Increase of simultaneous soybean failures due to climate change. Earth's Future, 11(4), e2022EF003106. https://doi.org/10.1029/2022EF003106
9. Arya, H., Singh, M. B., & Bhalla, P. L. (2021). Towards developing drought-smart soybeans. Frontiers in Plant Science. https://doi.org/10.3389/fpls.2021.750664

10. Tatar, O., Cakalogulları, U., Tonk, F. A., Istıplıler, D., & Karakoç, R. (2020). Effect of drought stress on yield and quality traits of common wheat during grain filling stage. Turkish Journal of Field Crops, 25(2), 236–244. https://doi.org/10.17557/tjfc.834392

11. Kalra, A., Goel, S., & Elias, A. A. (2024). Understanding role of roots in plant response to drought: Way forward to climate-resilient crops. The Plant Genome, 17(1), e20395. https://doi.org/10.1002/tpg2.20395

12. Zhang, Y., Wu, X., Wang, X., Dai, M., & Peng, Y. (2025). Crop root system architecture in drought response. Journal of Genetics and Genomics, 52(1), 4–13. https://doi.org/10.1016/j.jgg.2024.05.001

13. Liu, B. H., Jing, D. W., Liu, F. C., Ma, H. L., Liu, X. H., & Peng, L. (2021). Serendipita indica alleviates drought stress responses in walnut (Juglans regia L.) seedlings by stimulating osmotic adjustment and the antioxidant defence system. Applied Microbiology and Biotechnology, 105, 8951–8968.

14. Saddique, M. A. B., Zulfiqar, A., Sher, M. A., Farid, B., Ikram, R. M., & Ahmad, M. S. (2020). Proline, total antioxidant capacity, and gene activity in radical and plumule of rice are efficient drought tolerance indicator traits. International Journal of Agronomy, Article 8862792.

15. Qi, Y., Ma, L., Ghani, M. I., & Peng, Q. (2023). Effects of drought stress induced by hypertonic polyethylene glycol (PEG-6000) on Passiflora edulis Sims physiological properties. Plants, 12(12), 2296. https://doi.org/10.3390/plants12122296

16. Wang, X., Li, X., & Dong, S. (2022). Screening and identification of drought tolerance of spring soybean at seedling stage under climate change. Frontiers in Sustainable Food Systems. https://doi.org/10.3389/fsufs.2022.988319

17. Li, S., Zhou, L., Addo-Danso, S. D., Ding, G., Sun, M., Wu, S., & Lin, S. (2020). Nitrogen supply enhances the physiological resistance of Chinese fir plantlets under polyethylene glycol (PEG)-induced drought stress. Scientific Reports. https://doi.org/10.1038/s41598-020-64161-7