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IMPROVING THE METHOD FOR PREDICTING SUNFLOWER YIELD UNDER OPTIMAL IRRIGATION REGIMES USING GROUNDWATER

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Abstract. Water scarcity is one of the major challenges affecting the efficiency and sustainability of agricultural production, particularly in regions with limited irrigation resources. In the Bukhara region, the use of groundwater for cultivating sunflower (*Helianthus annuus L.*) as a second crop represents a promising approach to improving agricultural productivity under water-limited conditions. The findings provide a scientific and practical basis for improving the management of second crops, predicting yield in advance, and promoting more efficient use of groundwater resources under conditions of climate change and irrigation water scarcity.

Keywords: groundwater, sunflower, yield prediction, physiological indicators, multiple linear regression, agroecology, water resource management, second crop, Python analysis, agricultural innovations.

Аннотация. Суғориш сувлари танқис бўлган шароитда қишлоқ хўжалиги ишлаб чиқаришини самарали ташкил этиш ва мавжуд сув ресурсларидан оқилона фойдаланиш долзарб вазифалардан бири ҳисобланади. Бухоро вилоятининг сув ресурслари чекланган шароитида ер ости сувларидан фойдаланган ҳолда иккинчи навбатдаги экин сифатида кунгабоқар (*Helianthus annuus L.*) етиштириш қишлоқ хўжалиги самарадорлигини оширишнинг истиқболли йўналишларидан бири ҳисобланади. Тадқиқот натижалари ер ости сувларидан фойдаланиладиган шароитларда иккинчи навбатдаги экинларни самарали бошқариш, ҳосилдорликни олдиндан баҳолаш ҳамда иқлим ўзгариши шароитида сув ресурсларидан оқилона фойдаланиш учун илмий-амалий асос бўлиб хизмат қилиши мумкин.

Калит сўзлар: ер ости сувлари, кунгабоқар, ҳосилдорликни прогнозлаш, физиологик кўрсаткичлар, кўп чизиқли регрессия, агроэкология, сув ресурсларини бошқариш, иккинчи навбатдаги экин, Python таҳлили, қишлоқ хўжалиги инновациялари.

Аннотация. В условиях дефицита оросительной воды рациональное управление сельскохозяйственным производством и эффективное использование доступных водных ресурсов приобретают особую актуальность. В Бухарской области выращивание подсолнечника (*Helianthus annuus L.*) в качестве второй культуры с использованием подземных

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вод рассматривается как перспективное направление повышения эффективности сельскохозяйственного производства в условиях ограниченного водообеспечения. Полученные результаты могут служить научно-практической основой для совершенствования управления посевами второй культуры, предварительной оценки урожайности и рационального использования подземных водных ресурсов в условиях дефицита оросительной воды и изменения климата.

Ключевые слова: подземные воды, подсолнечник, прогнозирование урожайности, физиологические показатели, множественная линейная регрессия, агроэкология, управление водными ресурсами, вторая культура, анализ на Python, инновации в сельском хозяйстве.

Introduction. In recent decades, global climate change and the shortage of natural resources have increased the need for more sustainable and innovative development of agriculture on a global scale. In regions of Uzbekistan with limited irrigation water supply, such as the Bukhara region, this requirement is becoming even more acute. Increasing the volume of agricultural production through the rational use of available resources and the cultivation of repeated crops remains a strategic task. Sunflower is a valuable repeated crop, resistant to heat and drought due to its biological properties. At the same time, since the level of yield is closely related to the physiological indicators of the plant, forecasting the yield based on these indicators is of great importance for agricultural entrepreneurs. [1-13].

Methods. The research was conducted during the 2023 vegetation season in the irrigation water-scarce areas of Bukhara region. Sunflower varieties were irrigated in a controlled manner at pre-irrigation soil moisture levels of 70–75–70% FC. For each variety, 100 plants were selected. Their physiological indicators were determined based on the following parameters: Stem height (cm), Number of leaves (pcs), Basket diameter (cm), Total weight of seeds per plant (g). After the data were collected, they were analyzed in the Python programming environment. The Pandas library was used for data preparation and processing, while the scikit-learn library was employed for building and evaluating the multiple linear regression model. The dataset was randomly split into 80% training and 20% test sets. Model quality was assessed using the coefficient of determination (R^2), mean squared error (MSE), and visualization methods. Separate regression equations were developed for each variety, and their accuracy was verified through the test data [14-20].

Results. In this case, the R^2 = 0.85 model explains changes in yield with an accuracy of 85%. This is a very high result, the error between the forecast MSE = 0.13 and the real value is small, therefore, the model is accurate. The multilinear regression model constructed to predict the yield of the Dushko F1 sunflower variety revealed that physiological indicators such as leaf count, stem length, and basket diameter have a significant positive effect on yield; the R2 value of the model is 0.85, which indicates that it is capable of explaining 85% of yield differences, and the regression equation is expressed as follows (Table 1).:

Table 1.

Regression coefficients for the Dushko F_1 variety

Indicators	**Coefficient value**
Stem height	β_1= 0,031
Number of leaves	β_2=0,043
Basket diameter	β_3=0,076

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Constant value	β_0=−2,12
R^2=0,85	
MSE = 0,13	

The regression coefficients of the Dushko F_1 variety are as follows: with an increase in stem height (β_1 = 0,031) by 1 cm, the yield increased by 0,031 kg, and the number of leaves increased. (β_2 = 0,043) the yield increases by 0,043 kg with each increase in 1 unit, and the yield increases by 0,076 kg with each increase in the basket diameter (β_3 = 0,076) by 1 cm.

The constant value (β_0 = −2,12) represents the initial yield value when all other indicators are zero, i.e., − 2,12 kg.

In this, R^2=0,82 - the model explains changes in yield with an accuracy of 82%. This is a very high result, the error between the forecast *MSE = 0,15* and the real value is small, therefore, the model is accurate.

The regression coefficients of the Dilbar variety are as follows (Table 2).

Table 4

Regression coefficients for the Dilbar variety

Indicators	**Coefficient value**
Stem height	β_1= 0.026
Number of leaves	β_2=0.039
Basket diameter	β_3=0.071
Constant value	β_0=−1,97
R^2=0,82	
MSE = 0,15	

The multilinear regression model shows a clear statistical relationship between the physiological characteristics of the Dilbar variety and yield. The proximity of the prediction level and real points on the graph confirms the adequacy and compatibility of the model.

In this case, with an increase in stem height ($\beta_1 = 0.026$) by 1 cm, the yield increased by 0.026 kg, with an increase in the number of leaves ($\beta_2 = 0.039$) by 1 unit, the yield increased by 0.039 kg, and the diameter of the basket ($\beta_3 = 0.071$) by 1 unit. With an increase of 1 cm, the yield increases by 0.071 kg. The constant value ($\beta_0 = -1.97$) indicates the initial yield value at zero for all other indicators, i.e., −2.12 kg. In both varieties, basket diameter was noted as the most important factor (see Table 2).

As can be seen from the results, the diameter of the basket is the most strongly influencing factor on yield. This circumstance confirms the importance of the seed basket in seed formation. Stem height and the number of leaves also have a positive effect, playing an important role in plant growth and photosynthesis. The results of the Dushko F_1 variety were slightly higher than that of Dilbar, which may be due to its genetic resistance. High values of the model's R^2 (0.82-0.85) indicate its reliability.

Discussion: This study confirmed the possibility of predicting yields based on the physiological indicators of sunflower varieties. The diameter of the basket manifested itself as the main factor directly affecting yield, which confirms its role in the seed formation process. Stem height and the number of leaves positively influenced the yield through increased photosynthesis efficiency and biomass accumulation. Due to physiological characteristics and genetic stability, the Dushko F_1

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variety showed higher yield indicators compared to the Dilbar variety. At the same time, for further improvement of the model, it is necessary to take into account environmental factors, the chemical composition of the soil, the properties of the root system, changes in light intensity and temperature. At the same time, the accuracy of yield forecasting can be increased by 20-30% through the widespread use of artificial intelligence and machine learning algorithms.

Conclusion: The research results showed that it is possible to effectively predict the yield of the Dushko F_1 and Dilbar sunflower varieties using groundwater under the conditions of the Bukhara region using a multilinear regression model. The diameter of the basket, stem height, and number of leaves were determined as the main physiological indicators of yield.

The obtained results serve as a scientific and practical basis for the maximum use of repeated crops, optimization of agricultural technologies, and adaptation to climate change. In the future, through the introduction of a comprehensive database and artificial intelligence technologies, it is possible to make yield forecasts more reliable and effective.

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