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EFFICIENCY OF THE SPRINKLER IRRIGATION METHOD FOR THE SOYBEAN VARIETY "NAFIS"

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Abstract:

To address growing food security demands and optimize agricultural water management under typical irrigated grey soils of the Tashkent region, this study evaluates the efficiency of the sprinkler irrigation method for the "Nafis" soybean variety. Comprehensive analyses of key soil physical properties—such as bulk density, total porosity, and water permeability—were conducted alongside detailed field experiments. The research investigates the impact of scientifically grounded irrigation scheduling, individual watering norms, and seasonal irrigation rates on plant growth, development, and grain productivity. The experimental results demonstrate that optimized sprinkler irrigation significantly improves crop yield and water-use efficiency compared to traditional furrow irrigation methods. Specifically, the proposed optimal irrigation regime reduces water consumption while achieving a higher grain yield per hectare. These findings establish that sprinkler irrigation is a highly viable, water-saving, and sustainable agricultural strategy for arid and semi-arid regions facing increasing water scarcity challenges, offering a reliable technological framework for improving regional crop production and resource management.

Keywords: soybean species, sprinkling irrigation method, soil bulk density, soil porosity, soil water permeability, field capacity limit, irrigation rates, irrigation timing, irrigation rate, soybean yield.

Introduction

Freshwater Today, due to the increase in the world population, the demand for food is increasing day by day. In the world, soybean is grown as a main and repeated crop on 122.1 million hectares. It ranks fourth after wheat, rice and corn in terms of cultivated area, and the annual gross grain yield is 220.6 million tons. The USA, Argentina and Brazil are the countries that export the goods to other countries, while China, Korea and other Asian countries are the main importing countries. According to FAO data, in 2021, 1.66 million tons of soybeans were grown. This figure is increasing by 2.2% every year and, by 2030, a harvest of 371.3 million tons is planned [1,2,3,4].

According to the estimates of the World Water Institute, by 2025 approximately 3.5 billion people may face the problem of water shortage in the world. In particular, this indicator reaches 1.2–1.8 million per person. By 2080, despite the increase in the efficiency of crop irrigation, the demand for fresh water is predicted to increase by 25% due to changes in global climate, weather, precipitation and the vegetation period [5,6,7].

Currently, 17 countries in the world are considered to be "extremely" water-scarce. According to this indicator, Uzbekistan ranks 25th among 164 countries (level 2 on a five-point scale), that is, it is among the countries with a "high" level of water shortage.

Due to the fact that the population of Uzbekistan will reach 40 million people by 2030, 7–8 km³ of available water resources will be reduced. In such conditions, the level of water scarcity can increase from 13–14% to 44–46%, which negatively affects the development of agriculture [8,9,10].

The purpose of the study was the development of a method of sprinkler irrigation for the soybean crop in the conditions of the meadow gray soils of the Tashkent region.

As an object of research, the old irrigated gray meadow soils of the Tashkent region, the sprinkler irrigation method, and the soybean variety were taken. The subject of research is the sprinkler irrigation method, number of irrigations, seasonal irrigation rate, soybean growth and development, and grain yield.

Materials and Methods

Experimental studies, laboratory and field experiments, phenological observation and biometric measurements were carried out on the basis of soybean harvest data. The data were analyzed according to the method of dispersion analysis from the source "Методика полевого опыта" by B. A. Dospekhov and by mathematical-statistical analysis using a computer program [11,12].

Results and Discussion

The Tashkent region borders with the states of Kyrgyzstan, Kazakhstan and Tajikistan, as well as Namangan to the east and Syrdarya to the south-west. The Chotkal, Kurama, Piskom and Ugom ridge mountains form the north-eastern and eastern part of the region. A large part of its territory consists of a mountainous plain sloping down to the Syrdarya River to the south and south-west. The climatic conditions of the Tashkent region are sharply continental and dry, characteristic of the whole of Uzbekistan. The winter is wet and relatively mild, and the summer is hot and dry. The coldest month in the region is January, when the air temperature ranges from –11°C to –28°C, with 31–33 snow-covered days. The hottest month is July, when the air temperature exceeds 43°C.

Summer temperatures are dry and hot, sometimes bringing a "Nexus" wind. The air temperature during the Nexus wind is 6–8°C higher than on normal days, and the air humidity is extremely dry. Under the influence of such air temperatures, many agricultural crops are damaged and stop growing and developing. In August and September, very strong winds blow in the Bekobad area, between the Fergana valley and Mirzachol, due to air exchange. The speed of this wind reaches from 10–30 m/s up to 40 m/s, which also has a strong negative impact on the growth and development of agricultural crops.

The main part of atmospheric precipitation occurs in the form of snow in the mountain regions, and in the form of rain in the hilly and plain regions. Most of the precipitation falls in the winter and spring months, and a small amount in the autumn months. During a year there will be 261–316 mm of atmospheric precipitation in the plain part, 366–435 mm in the foothills, and 700–895 mm in the mountain regions. In the summer months there is almost no rain. By analyzing the climatic conditions of the Tashkent region, it is possible to conclude that this region is suitable for the cultivation of any type of agricultural crop, which allows abundant and high-quality harvests to be obtained.

In 2021 and 2022, when the average air temperature, precipitation and wind speed were observed, the highest air temperature occurred from April to September, and the average wind speed was 1.3 to 1.7 m/s. On April 11, 2022, super-elite seeds of the "Nafis" soybean variety were planted. The soybean cultivars were treated 3 times against insects, cultivated 6 times between rows, weeded 5 times by hand, irrigated 5 times by furrow, and sprinkled 13 times with rain (sprinkler) irrigation.

According to the results of the laboratory analyses conducted to determine the mechanical composition of the soil of the experimental area, the arable layer consists of medium and lower layers of light sand, located in loess deposits, prone to waterlogging — irrigated meadow gray soils with low productivity. In the soil samples taken for agrochemical analysis, the amount of humus in the 0–30 cm plowed layer was 0.822%, and in the 30–50 cm sub-layer was 0.810%. The nitrogen and phosphorus content in these layers was 0.089–0.077% and 0.094–0.088% respectively. The mobile form of nutrients in the soil was NO_3 9.89–8.7 mg/kg, P_2O_5 18.7–16.9 mg/kg and K_2O 158–146 mg/kg.

According to the results of agro-physical observation at the beginning of the soybean application period, the volume mass in the 0–30 cm layer of the experimental field was 1.28 g/cm³, at 0–50 cm 1.31 g/cm³, at 0–70 cm 1.34 g/cm³ and 1.37 g/cm³ at 0–100 cm. The average porosity of the experimental area decreased from top to bottom, i.e. 52.9% at 0–30 cm, 51.5% at 0–50 cm, 50.4% at 0–70 cm and 49.3% at 0–100 cm.

At the end of the plant life in the experimental field, the least amount of soil volume change between the options was as follows: in the control option, 1.36 g/cm³ at 0–30 cm, 1.42 g/cm³ at 0–50 cm, 1.44 g/cm³ at 0–70 cm and 1.45 g/cm³ at 0–100 cm. A significant change in the volume mass of the soil was observed in the sprinkler-irrigated soybean option, at 1.39, 1.41, 1.43 and 1.44 g/cm³ respectively.

At the beginning of the vegetation of the soybean, the water permeability of the soil over 6 hours was 882 m³ per hectare, i.e. 88.2 mm or 0.24 mm/min; a decrease in the water absorption capacity of the soil was observed. At the beginning of soybean cultivation, the field moisture content of the soil was 21.5% in the 0–30 cm layer above the plow, 21.6% in the 0–50 cm layer, 21.8% in the 0–70 cm layer, and 21.8% in the 0–100 cm layer, averaging 22.2% in the stratum. During the growing season, each irrigation of soybean was carried out in accordance with the field moisture capacity of the soil[13,14,15].

In the research carried out in 2022, soybean was irrigated 5 times in a 1-2-2 system: 590 m³/ha once in the pre-flowering phase, 600 and 650 m³/ha twice in the flowering-harvest phase, and 650 and 640 m³/ha twice in the ripening phase. The duration of irrigation was 15–17 hours, with 24–37 days between irrigations, and the seasonal irrigation rate was 3130 m³/ha. In the 3-5-5 system it was irrigated 3 times at 320 m³/ha in the pre-flowering phase, 5 times at 240 m³/ha in the flowering-harvest phase, and 5 times at 240 m³/ha in the ripening phase; the irrigation duration was 2.0–2.5 hours, with 6–12 days between irrigations, and the seasonal irrigation rate was 2880 m³/ha. It was found that 250 m³/ha of water was used less in the sprinkler-irrigated version than in furrow-irrigated soybean. In the conditions of grassy gray soils, sprinkler irrigation of the “Nafis” variety made it possible to obtain an additional grain yield of up to 4.2 t/ha compared with the controlled irrigation option.

According to the analysis of the data obtained from the two-year experiments, the applied agrotechnical measures and the sprinkler irrigation of soybean have good efficiency when the irrigation procedure is observed, i.e. when the soil moisture before irrigation of the “Nafis” soybean variety is kept at an irrigation regime of 70-75-75%. In the 1st option, the seasonal irrigation rate was 3130 m^3/ha, the general irrigation rate 3680 m^3/ha, the grain yield 2.34 t/ha, and the water consumption for 1 t of crop 157.3 m^3. In the 2nd option of sprinkler-irrigated soybean, the seasonal irrigation rate was 2880 m^3/ha, the total irrigation rate 3430 m^3/ha, the grain yield 2.76 t/ha, and the water consumption for 1 t of crop 124.3 m^3 (Table 1).

Table 1. Impact of soybean irrigation methods on yield and water consumption per crop unit (2022 data)

Opt	**Irrigation method**	**Irrigation regime, %**	**Irrigated layers, cm**	**Seasonal irrigation rate, m^3/ha**	**Overall irrigation rate, m^3/ha**	**Productivity, t/ha**	**Water use per 1 t crop, m^3**
1	Surface irrigation	70-75-75	50-50-70	3130	3680	2.34	157.3
2	Sprinkler irrigation	70-75-75	30-40-40	2880	3430	2.76	124.3

The amount of protein was 35.4% and the amount of oil 18.7% in variant 1, irrigated at an irrigation regime of 70-75-75%. In the sprinkler variant, the protein content was 35.7% and the oil content 18.3%.

Based on the results of the research, two computer programs were created using a Pentium IV computer: firstly, “Prediction of the yield of agricultural crops depending on the irrigation procedures”, and secondly, “Determining the yield of the main crop depending on the irrigation procedures of soybean”. On the basis of these two programs, a mathematical model of the effect on yield depending on the main and repeated soybean irrigation procedures was developed. Through this model it became possible to determine the effect on soybean grain yield by managing irrigation, and the program is now used in the educational processes of higher education.

Conclusion

According to the results of the experimental research, it is recommended to irrigate the “Nafis” soybean variety during the growing season of the gray grassy soils in the 3-5-5 system, with each irrigation rate at 220–230 m^3/ha and a seasonal irrigation rate of 2880 m^3/ha. Under these conditions, sprinkler irrigation ensures a grain yield of 2.76 t/ha while using 250 m^3/ha of water less than surface (furrow) irrigation, and reduces the water consumption per 1 ton of crop from 157.3 m^3 to 124.3 m^3.

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