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DRIP IRRIGATION EFFICIENCY IN SOYBEAN CULTIVATION IN SOUTHEAST ROMANIA, A SUSTAINABLE APPROACH TO WATER MANAGEMENT

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Abstract

Cultivating soybeans holds significant importance in ensuring food security and economic stability. In the context of climate challenges and limited resources, efficient water resource management becomes crucial. This article explores the sustainable approach of drip irrigation in soybean cultivation, specifically in Southeast Romania. Drip irrigation proves effective in Southeast Romania by delivering water directly to the soybean roots, minimizing losses from evaporation and runoff. This contributes to the conservation of water resources in the region. The precise water distribution of drip irrigation ensures uniformity in water supply, preventing both over-irrigation and under-irrigation, with significant benefits for soybean crops in Southeast Romania. Drip irrigation systems are tailored to the soil types and climate conditions present in Southeast Romania, ensuring optimal water usage efficiency. Given the variable weather patterns in the region, the ability of drip irrigation to adapt and respond to changes in climate contributes to the resilience of soybean crops. Through the use of advanced technology and local expertise, customized drip irrigation configurations are implemented to suit the specific needs of soybean cultivation in Southeast Romania.

Key words: *advanced technology, crop efficiency, uniform water distribution.*

INTRODUCTION

Over the years, it has been proven that people adapt easily to climate change, while ecological systems are more vulnerable and less flexible to such changes (Burghila et al., 2015). Water resources at a global level represent one of the most pressing challenges in ensuring food security. Scenarios indicate that the agricultural sector will need to increase its production by 60% worldwide and by 100% in developing countries by the year 2050 (Alexandratos & Bruinsma, 2012). It is very important to correctly use irrigation strategies and available technologies to use water efficiently and save energy since irrigation systems are large energy consumers (Drăcea et al., 2003). These measures should be implemented at the level of large agricultural farms to achieve significant improvements in terms of water use efficiency and crop productivity.

Thus, we will be able to achieve higher yields using the same amount of water, thereby reducing the pressure on limited water resources (Odhiambo et al., 2012). Water stress is one of the most significant factors limiting yield in soybean production in many regions of the world, and the way soybean productivity responds to different levels of water.

Stress under various sowing epochs and irrigation norms is not fully understood. In the absence of weeds, diseases, nutrient deficiencies, or other stress factors, the effect of yield reduction due to lack of water is determined by the development stage of the plant. Some studies have highlighted the sensitivity of soybeans to water stress at different stages of development (vegetative, flowering, pod formation, and seed filling) (Brevedan & Egli, 2003). The application of fertilizers at the beginning of the vegetation period plays an essential role in achieving significant agricultural production and in protecting the soil against erosion (Balan & Patru, 2014). According to research, the application of supplementary or deficit irrigation during the growing season or at a specific growth stage can significantly increase water use efficiency and the yield of the soybean crop (Giménez et al., 2017; Jha et al., 2018).

The response to irrigation is influenced by climatic conditions, the amount of rainfall during the growing season, soil characteristics, soybean variety, agronomic practices, and the experimental methods used (Evett et al., 2000).

Research has shown that by applying a single irrigation at different critical water stages, both the yield and its quality can increase in early soybean varieties, compared to the non-irrigated crop (Sweeney & Kirkham, 2003). It has been found that in soybeans, the leaf water potential is sensitive to soil moisture variations, so the leaf water potential, which is relatively easy to determine, can be used to schedule the necessary irrigations for the crop (Jovanovici et al., 1993).

Limited irrigation can have a significant impact on crop productivity in various environments. According to studies, deficit irrigation can be useful under conditions of decreasing water availability. Additionally, understanding how the crop responds to water stress throughout the growing season is important for better predicting and managing crop performance in various conditions. This information can be useful for making water management decisions and for improving its use in agriculture (Djaman et al., 2013; Akcay & Dagdelen, 2016). Drip irrigation holds particular importance in the solutions proposed for the water crisis. The average daily evapotranspiration will increase by about 6% if the average air temperature rises by 2°C and by about 15% at an average temperature of over 5°C (Nitu et al., 2023). Confidence in the water-saving potential of drip irrigation is often supported by impressive statistics and measurements. Drip irrigation has the potential to double the yield of agricultural crops, including most vegetables, cotton, sugarcane, and grapevines. The higher efficiency of water application and increased yields result in a doubling or even tripling of water productivity (Postel, 2000). Drip irrigation is an advanced and water-efficient method, ensuring that plant roots maintain optimal moisture conditions over extended periods, thereby favoring both physiological activity and crop development (Yan et al., 2022). It has been observed that drip irrigation, compared to furrow irrigation, not only increases production but also significantly improves the quality of squash fruits (Amer, 2011). This irrigation method minimizes electrolyte loss from leaves, thus contributing to a notable improvement in physiological activity and corn yield (Cakmakci & Sahin, 2021). Other studies have indicated that drip irrigation helps reduce the levels of salt ions in the soil near the dripper, creating a conducive environment for plant growth in the root zone and mitigating the negative effects of soil salinization on crop development (Zhang et al., 2019). Some studies have also found that salt ions in crop root zone soil can migrate to the wetting front under the action of high-frequency drip irrigation, thus reducing the salt ion concentration and pH value of root zone soil and ensuring the normal growth of crops in saline-alkali land (Dong et al., 2021; Liu et al., 2012). In addition, drip irrigation can regulate soil nutrient cycling by affecting root-soil-microorganism interactions (Wang et al., 2022). The objective of establishing an irrigation schedule is to precisely determine the volume and optimal timing of water application to crops (Sałata et al., 2022), based on at least one parameter from the soil-plant-atmosphere system (Kang et al., 2021). Choosing an appropriate irrigation scheduling strategy is crucial for supporting the physiological processes of plants and, consequently, for maximizing production (Kumar Jha et al., 2019).

Additionally, efficient irrigation scheduling contributes to reducing water and energy consumption (Souza & Rodrigues, 2022). On the other hand, over-irrigation, or under-irrigation, resulting from an inadequate or poorly designed irrigation plan, has generally led to reduced grain production and decreased efficiency in the use of irrigation water (Irrigation Water Productivity), as well as issues such as land flooding, soil salinization, and elevated groundwater levels (Yohannes et al., 2019; Almeida et al., 2022; Quiloango-Chimarro et al., 2022). Scientific and field development initiatives aimed at optimizing irrigation scheduling for soybeans have focused more on climate-based approaches than those related to soil or plant characteristics. Recent research has examined the accuracy of crop coefficients specific to the southern region of Brazil (da Silva et al., 2019) and assessed crop evapotranspiration using the eddy covariance method in the United States (Anapalli et al., 2022). However, the challenges in choosing an appropriate irrigation strategy for soybeans stem from the wide variations in the amount of irrigation water used and the different levels of irrigation water productivity (IWP) among soybean genotypes, influenced by their maturity group. Differences have been identified between maturity groups V and VI, both in terms of the volume of irrigation water used and IWP, namely 65 mm and 0.6 kg m^{-3}, respectively (Garcia et al., 2010). Similarly, in other legume species, the efficiency of irrigation scheduling has been correlated with variations in growth patterns (Rowland et al., 2010) and genetic differences in water use strategies (Farooq et al., 2019). Therefore, it is imperative to conduct studies that investigate various irrigation scheduling strategies, tailored to the specific characteristics of different soybean varieties.

MATERIALS AND METHODS

To achieve the purpose and objectives pursued within the research, a bifactorial experiment of the 2 x 2 type in three repetitions was set up at Fundulea, Calarasi County, during the period 2022-2023 (Figure 1).

Factor A was represented by the two soybean varieties P21T45 and PR92B63, while factor B was the cultivation technology with the following gradations:

- b_1 - non-irrigated,
- b_2 - irrigated 50% I.U.A at 0-80 cm with m = 400 m^3/ha N0P60K60,
- b_3 - irrigated 50% I.U.A at 0-40 cm, with ½ m = 200 m^3/ha N60P60K60 (Table 1).

Table 1. Experimental Variants

Factor A	Factor B		
a_1P21T45	b_1 - non-irrigated	b_2 - irrigated 50% I.U.A at 0-80 cm with m=400m³/ha N0P60K60	b_3 - irrigated 50% I.U.A at 0-40 cm, with ½ m=200 m³/ha N60P60K60
a_2PR92B63			

The experiment was conducted on a site uniform in terms of fertility and micro relief. Irrigation was applied at various growth stages, ensuring that soil moisture did not fall below the minimum threshold of 50% I.U.A, regardless of the irrigation variant. In calculating the drip irrigation rate, it was necessary to know the distance between drippers and the distance between drip hoses to obtain the value of the percentage of moistened soil (P).

$m_{brut} = 1/\eta c \cdot H \cdot Da \cdot (CC\text{-}Pmin) \cdot P$ (m^3/ha)
m_{brut} = drip irrigation norm;
H = irrigation depth;
Da = soil bulk density;
CC = field water capacity;
P_{min} = minimum soil moisture threshold;
P = percentage of moistened soil.

$$P = 100\,\frac{Su}{dp * dc}\ \%$$

For the calculation of the irrigation norm, the weighted values of the physical and hydrophysical indices of the soil from Fundulea for the active layer of 0.8 m and 0.4 m were used.

Calculation of irrigation norms for depths of 0.8 m and 0.4 m.

m_{brut} =1/0.95 • 100 • 0.8 • 1.38 • (26.45 – 19.69) • 0.50 = 396 ≈ 400 m^3/ha
m_{brut} =1/0.95 • 100 • 0.4 • 1.38 • (26.9 – 19.75) • 0.50 = 209 ≈ 200 m^3/ha

Figure 1. Image from the field

From a climatic point of view, Fundulea is characterized by the appearance of a transition between the dry steppe climate and the sub-humid forested zone. The year 2022 has a strong warming character in terms of temperature in January and February. Starting from September, monthly average temperatures close to the multi-year average have been recorded at Fundulea. Thus, in terms of temperature, we can say that the year 2022 can be considered excessively warm, with an annual average temperature of 12.7°C exceeding the multi-year average by 2.1°C. The lowest multi-year average temperature is recorded in January, at -2.6°C, while the highest is in July, at 22.4°C (Figure 2). In terms of the annual average temperature, the year 2023 recorded a difference of only 0.2°C compared to the multi-year average of 10.6°C and can be considered a drought year in terms of temperature (Figure 3).

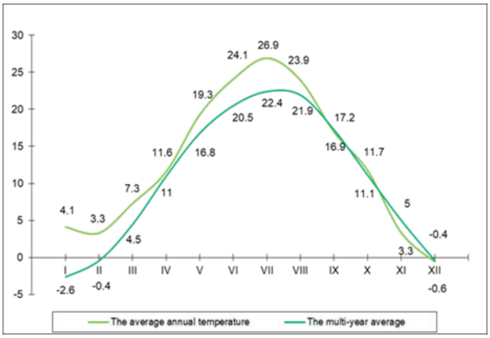

Figure 2. Monthly average air temperature recorded in the year 2022 and the multi-year average at the Fundulea meteorological station

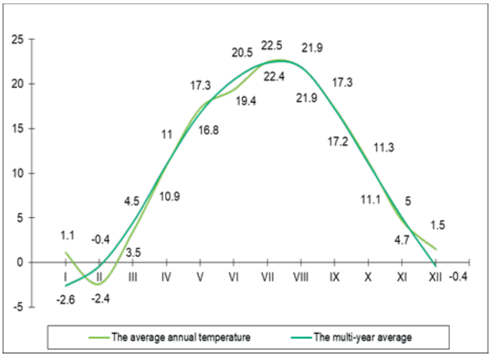

Figure 3. Monthly average air temperature recorded in the year 2023 and the multi-year average at the Fundulea meteorological station

Regarding the precipitation regime in 2022, it is deficient starting from the first month of the year. During the period from January to July 2022, the precipitation level was approximately 50% lower than normal, characterizing this interval as extremely dry. During the warm period of the year, the precipitation value recorded a decrease of approximately 32.5% compared to the multi-year average value in this area. In terms of precipitation, the year 2022 can be considered a drought year, with an interval of prolonged extreme drought throughout almost the entire growing season of spring crops (Figure 4). The year 2023 can be considered a drought year, with a drought interval from May to August. During the cold period of the year, the precipitation value recorded a decrease of 37% compared to the multi-year average value for this period, while during the warm period of the year, there was a decrease of 10% (Figure 5).

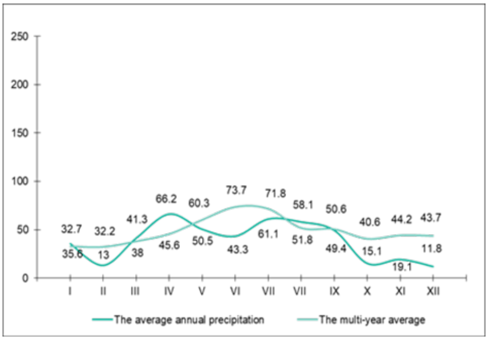

Figure 4. Monthly average precipitation recorded in the year 2022 and the multi-year average at the Fundulea meteorological station

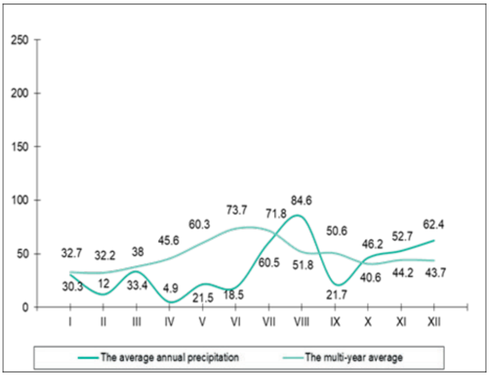

Figure 5. Monthly average precipitation recorded in the year 2023 and the multi-year average at the Fundulea meteorological station

After the maintenance works, drip hoses were also permanently positioned. The length of the irrigation pipe was 300 meters, with 1.40 meters between pipes. Irrigation was carried out according to the established experimental variants, in line with the water needs of the crop, the level of precipitation during the growing season, and the soil moisture at that time.

RESULTS AND DISCUSSIONS

Variety PR92B63 obtained a higher yield, with 36.31 q/ha, compared to variety P21T45, which had a yield of 25.17 q/ha. The production difference between the two varieties is 11.14 q/ha, statistically ensured to be very significant (Table 2).

Table 2. The influence of soybean varieties on average yield

Factor A	Production (q/ha)	Difference from Ct	Significance
a_1 P21T45	25.17	Ct	
a_2 PR92B63	36.31	11.14	***

DL= 5% 1.2; DL =1% 1.7; DL = 0.1% 2.3

Table 3. The effect of different cultivation technologies on average yield for the two soybean varieties

Factor B	Production (q/ha)	Difference from Ct	Significance
b_1 - non-irrigated	18.56	Mt	
b_2 - irrigated 50% I.U.A at 0-80 cm with m=400m^3/ha $N_0P_{60}K_{60}$	33.63	15.07	***
b3- irrigated 50% I.U.A at 0-40 cm, with ½ m=200 m^3/ha $N_{60}P_{60}K_{60}$	40.03	21.47	***

DL= 5% 1.0; DL =1% 1.4; DL= 0.1% 1.9

The production obtained under non-irrigated conditions was 18.56 q/ha, serving as the baseline level (Ct) for comparison. The introduction of irrigation and a fertilization regimen increased the production to 33.63 q/ha, resulting in a production increase of 15.07 q/ha compared to non-irrigated. Reducing the irrigation depth and intensifying fertilization led to the highest increase in production, reaching 40.03 q/ha, resulting in a highly significant production increase of 21.47 q/ha compared to non-irrigated (Table 3).

From the interaction of factors, it is evident that irrigation and fertilization significantly increase production compared to non-irrigated crops. Transitioning from non-irrigated (b_1) to irrigated with 50% IUA at 0-80 cm and irrigation with 400 m^3/ha of water together with the application of $N_0P_{60}K_{60}$ fertilizers (b_2) resulted in a significant production increase of 4.12 q/ha. The application of irrigation at 50% IUA at 0-40 cm and with a rate of 200 m^3/ha, but with a fertilization regimen of $N_{60}P_{60}K_{60}$ (b3), resulted in a statistically very significant production increase of 9.89 q/ha compared to the control variant. For the PR92B63 variety, the results showed a very significant increase in production under the influence of irrigation and fertilization. Compared to the non-irrigated variants, irrigation and fertilization according to technology b_3 resulted in an increase in production of 30.94 q/ha.

This result shows that the PR92B63 variety exhibits an enhanced capacity to respond to irrigation and fertilization strategies, indicating better adaptation to optimizing water and nutrient resources (Table 4, Figure 6).

Table 4. The impact of irrigation and fertilization on varieties P21T45 and PR92B63

Factor B	Factor A	Production (q/ha)	Difference from Ct	Significance
b_1 - non-irrigated	a_1 P21T45	16.50	Ct	
b_2 - irrigated 50% I.U.A at 0-80 cm with m=400m^3/ha $N_0P_{60}K_{60}$	a_1 P21T45	20.62	4.12	*
b_3 - irrigated 50% I.U.A at 0-40 cm, with ½ m=200 m^3/ha $N_{60}P_{60}K_{60}$	a_1 P21T45	26.39	9.89	***
b_1 - non-irrigated	a_2 PR92B63	40.86	24.37	***
b_2 - irrigated 50% I.U.A at 0-80 cm with m=400m^3/ha $N_0P_{60}K_{60}$	a_2 PR92B63	32.62	16.13	***
b_3 - irrigated 50% I.U.A at 0-40 cm, with ½ m=200 m^3/ha $N_{60}P_{60}K_{60}$	a_2 PR92B63	47.43	30.94	***

DL= 5% 3.70; DL= 0.1% 5.08; DL =0.1% 6.95

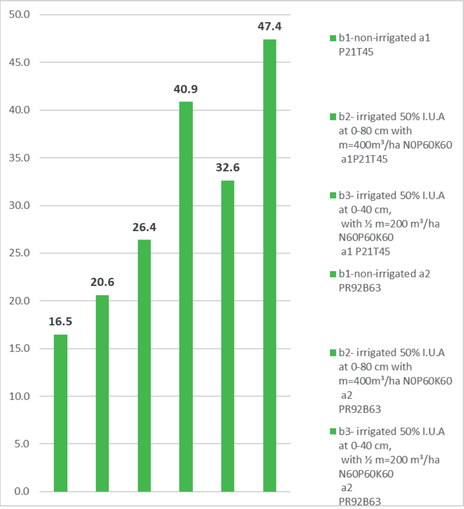

Figure 6. The impact of irrigation and fertilization on varieties P21T45 and PR92B63

CONCLUSIONS

The results demonstrate that the introduction of irrigation and an appropriate fertilization regimen has a significantly positive effect on crop production. Compared to non-irrigated conditions, where production was 18.56 q/ha, the implementation of these practices increased production to 33.63 q/ha and even 40.03 q/ha, highlighting the decisive role of water and nutrient management in optimizing crop yields.

Reducing irrigation depth combined with increase in production, highlighting the importance of optimizing resource utilization.

This suggests that a precise and well-established approach to irrigation and fertilization can lead to significant improvements in the efficiency of water and nutrient resource utilization. The PR92B63 variety has demonstrated an enhanced capacity to respond to irrigation and fertilization compared to the P21T45 variety, indicating significant genetic variability between varieties regarding adaptability and resource utilization efficiency. The production increases were statistically ensured to be highly significant indicating that the observed differences are not the result of random variations but rather real effects of the applied technology.

The results underline the potential of well-managed irrigation and fertilization to contribute to sustainable agriculture.

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