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Sustainable agriculture through optimal use of natural resources water, energy, soil and fertilizers when growing Bulgarian garlic variety

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Abstract: Green technologies and sustainable development are closely related concepts that play a key role in the transition to a more environmentally conscious society and economy. Irrigation is a major factor and an effective means of limiting or preventing the stressful impact of drought on agricultural crops and ensuring stable production in climatically different years. During the period, 2023 field experiments were conducted in the experimental station of ISSAP "N. Poushkarov", in Chelopechene, Sofia region. Regarding the air temperature, the year 2023 is characterized as warm with a guarantee of 26%. In terms of rainfall, dry with a guarantee of 62.41% (2023). Investigated variants with different irrigation techniques for optimal and disturbed garlic irrigation regime: V1 - subsoil drip irrigation - 100% irrigation rate, V2 - subsoil drip irrigation - 50% irrigation rate; V3 - surface drip irrigation - 100% irrigation rate; V4 - surface drip irrigation - 50% irrigation rate; V5 - non-irrigated variant. The trial betting method is the long lot method with four replicates. To maintain the soil moisture between 80-100% of the FC, 10 main irrigations with an average irrigation rate are needed: V_1 – 16.89 mm; V_2 – 8.44 mm, V_3 – 26 mm; V_4 – 13 mm.; V_5 – 0 mm; which are realized at different intervals depending on the development of culture and weather conditions. The different irrigation regimes affect crop production respectively: V_1 -750 kg dka^{-1}; V_2 – 580 kg dka^{-1}, V_3 – 650 kg dka^{-1}; V_4 -435 kg dka^{-1}; V_5 -230 kg dka^{-1}. The reduction in the size of the irrigation rates by 50% for surface and underground placement of the irrigation wings leads to a reduction in yield by 34 and 23% and can be applied in water deficit.

Keywords: sustainability; precision agriculture; climate; garlic; irrigation regime

INTRODUCTION

Garlic (*Allium sativum* L.) is a vegetable crop with a rich content of nutrients. It has healing and disinfecting properties. The essential oils of garlic contain large amounts of phytoncides with bactericidal action. In our country, garlic is grown in almost all regions. Garlic can be summer or winter. Garlic is one of the main vegetable crops known worldwide with respect to its production and economic value. It is one of the oldest cultivated vegetables and the second most widely produced Allium next to onion (Hamma et al., 2013; Hassan, 2015).

High temperatures are required for bulb development, but cooler conditions in the early stages favor vegetative growth and elevations from 500-2000 meters above sea level provide suitable growth condition (Rice et al., 1990). Excessive humidity and rainfall are detrimental to the vegetative growth and bulb formation. Insufficient moisture and water logging easily stress plants. So, to attain maximum yield, moisture in the top 0.30 m of soil should be maintained close to field capacity for growth (Brewster, 1994).

Sustainable agriculture has a significant impact on the chemical, biological and physical properties of soil (Cabrera-Pérez et al., 2023; Lal, 2016, Diriba-Shiferaw et al., 2015). Understanding the complex effects of these practices on soil fertility, nutrient availability, microbial interest and overall soil fitness is essential for sustainable agriculture. These practices are important for sustainable crop production and ecosystem health (Six et al., 2022). These agrotechnical measures increase soil quality and productivity, and ultimately lead to increased crop productivity (Astapati et al., 2023; Lu et al., 2023). Some of the good practices for agronomic management are tillage, nutrient management, crop rotation, soil irrigation control, etc. (Bachmann, 2001; Bu, et al., 2020; Hashimi et al., 2023).

As garlic require and sensitive to a variety of elements for growth and development, the deficiency of N, P, K elements is manifested in the detrimental effects on the growth and development of the plant (Tisdale et al., 1985, 1993). Despite its importance and increased production, garlic yield and quality is affected by various biotic and abiotic stresses, among which low and/or excess mineral nutrition, irrigation schedule or rainfall are among the major ones (Jaleel et al., 2007; Cheruth et al., 2008). Garlic crop has a shallow root system and needs optimum and regular application of water and nutrients.

Irrigation is a major factor and an effective means of limiting or preventing the stressful impact of drought on agricultural crops and ensuring stable production in climatically different years.

The main objective: is to determine the effect of micro-irrigation (drip irrigation, subsoil and surface) on yield of garlic under optimal and reduced irrigation regime.

MATERIAL AND METHODS

Field experiments were conducted on the territory of ISSAPP "N. Poushkarov" experimental field in Chelopechene in town of Sofia, Bulgaria during 2023. The experimental field with geographical coordinates: 42 °44′22.8″N, 23 ° 28′3.7″E is a part of Sofia. Field, located at 550 m above sea level. Continental climate is characterized by cold winter and hot summer. The soil is slightly humus (1.63%) Chromic luvisoil which can be defined as moderate to strong water-permeable with an average filtration capacity. It was found that mechanical compositions of these soils were medium to heavy. The water-physical properties of this subtype soil are average for the layer 0 – 0.50 m depth are the following: field capacity FC - 22.0% relative to the weight of the absolutely dry soil; soil volumetric weight - 1,47g cm^{-3}.

Object: Plantation with summer garlic of field experiment on Chelopechene.

Subject of research are: influence of the irrigation technique on the yield of summer garlic.

The experience betting method: The method of long parcels in four repetitions.

Irrigation: Drip irrigation (surface and subsoil)

Fertilization: Conventional fertilizers, ammonium nitrate and, if necessary, phosphorus and potassium fertilizers will be used.

The recommended nitrogen fertilizer rate for producers from this soil and climate region is 8 to 10 kg dka^{-1} active substance nitrogen. The results of the agrochemical analysis of the soil show that the soil's availability of mobile forms of potassium is high, with phosphorus - average, and there is no need for phosphorus and potassium fertilization.

Most of the nutrients are taken up by plants during phases of intensive growth of the leaf system. We fertilized with ammonium nitrate 10 kg dka^{-1} active substance in two doses on 20.04.2023 and in the bulb formation phase on 25.07.2023. Garlic is demanding on the humus content. After recalculation based on the total nitrogen content in the sheep manure, it was determined to apply half of the required amount of active nitrogen substance of 10 kg per decare. It develops well when fertilized with manure, during the first digging on 25.05.2023.

The meteorological factors that are decisive for crop cultivation are: air temperature and precipitation.

The outdoor air temperature is measured year-round at 7, 14 and 21 hours. Based on the measured values, the day-night average values of the indicators were calculated. Precipitation is reported from the meteorological station located on the territory all year round.

Phenological studies start from the beginning of planting the bulbs and are carried out during the growing season: The main phases of garlic development are sprouting, intensive growth, ripening of the heads.

The fields' studies include Studies of different irrigation technologies in the production of garlic grown outdoors. The following options are available:

Options:

V1 – Subsoil drip irrigation - 100% irrigation rate,

V2 - Subsoil drip irrigation - 50% irrigation rate

V3 - Surface drip irrigation - 100% irrigation rate,

V4 - Surface drip irrigation - 50% irrigation rate

V5 - non-irrigated variant.

Determination of the irrigation regime. To monitor the dynamics of soil moisture, soil samples are taken every 7-10 days at a depth of 0.40m every 0.10m, in three repetitions and processed according to the classical weight thermostat method. On the basis of the obtained results for the soil moisture, the necessary irrigation rates are submitted.

Irrigation scheduling

$$m = [10H.\alpha.(\delta\ FC - \delta\ 80\%FC)].K. \quad (1)$$

where,m - irrigation norm in mm; a - soil density in g cm^{-3}; H - depth of the active soil layer in m (H = 0,50 m); δ of FC - marginal land moisture in % relative to absolute dry weight of soil, % of soil moisture content in % relative to absolute dry weight of soil; K -reduction coefficient of irrigation rate by plants occupied area in 1 dka.

In 7-10 days, control soil samples are taken from the version irrigated with 100% irrigation rate, in order to track the dynamics of soil moisture.

The pre-irrigation humidity for garlic grown outdoors during the different development phases is different. To the moisture content of the soil and air during germination and intensive growth, garlic is particularly demanding and it is necessary to maintain 80% of the FC. During the period of intensive growth (May-June), in case of drought, growth ceases. During the ripening of the garlic, a lower soil humidity of 60-70% of the FC is needed, which decreases with the activity of biological processes and the bulb goes into the so-called relative rest.

The yield was determined in four replicates for each variant in kg dka^{-1}. The statistical processing of the yields was performed on the ANOVA (Analysis of variance) dispersion analysis for 2023.

The laboratory analyze of the soil, water and plant samples were carried out in the laboratory of ISSAPP "N. Pushkarov" according to the methods and equipment standardized in our country for the relevant analyses.

RESULTS AND DISCUSSION

A characterization of the Chelopechene-Sofia Experimental Field area was made in terms of the amount of precipitation for the period April - September. For this purpose, a 60-member statistical series was compiled for the period 1962-2023, based on which the theoretical collateral expressed as a curve was calculated, as well as the empirical collateral of all its constituent members (Fig. 1). and the collateral is determined. Regarding the air temperature, the year 2023 is characterized as warm with a guarantee of 26%. In terms of rainfall, dry with a guarantee of 62.41% (2023), presented graphically in (Fig. 1.)

The rainfall during the growing season of the crop is unevenly distributed, which necessitates the implementation of irrigation to supplement the soil stock within the limits of 80% of the PPV to 100% of the FC.

As can be seen from Table 1, the highest average daily temperatures are observed during the months of July and August, which coincides with the phase of bulb formation and ripening. The average temperatures measured for 14 hours reach 30 - 35°C, which adversely affects the development of crops and irrigation is required.

At the beginning of the growing season of the crop, soil samples were taken and examined in the laboratory from a depth of up to 0.40 m, and the soil's availability of the main nutrients nitrogen, phosphorus, potassium, etc. was determined. The soil in the upper layer 0-0.20 m is slightly stocked with humus 1.88%, and in the depth 0.20-0.40 m it increases to 2.51%.

The recommended nitrogen fertilizer rate for producers from this soil and climate region is 10 kg dka^{-1} active substance nitrogen. The results of the agrochemical analysis of the soil show that the soil's availability of mobile forms of potassium is high, with phosphorus - average, and there is no need for phosphorus and potassium fertilization.

The planting of garlic in the experimental plots during the considered experimental years was done manually at the end of March or the beginning of April. After the late sowing of garlic in 2023. is due to the rains that have fallen and the impossibility of cultivating the soil. Seven days after application of the inter-storing catch irrigations, the garlic emerged at a height of 1-2 cm. After about two months, the garlic is ready to sell for green. The beginning of the ripening of the bulb occurred around 10.07. The mass laying of the false stem is observed around 15.07.2023 (Table 3.). Garlic harvested when the false stems soften and 15-20% of the plants have laid down on the soil (Fig. 2). Figure 2 shows the main phases

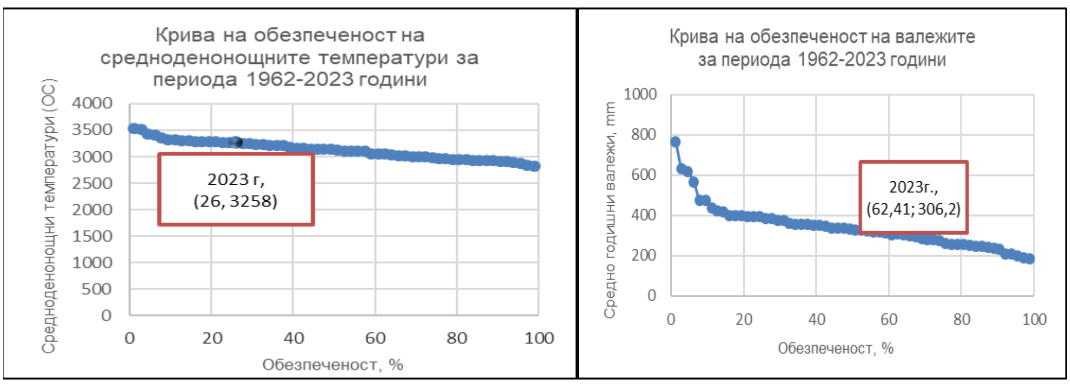

Figure 1. Curves of collateral of the average day-night temperatures and the fallen precipitation for the period 1962 – 2023

Table 1. Monthly sums of daily mean air temperatures in °C in the experimental field Chelopechene for the period April - September 2023

Month/Year	IV	V	VI	VII	VIII	IX	Total
2023	255.25	432.5	550.75	727.25	716.75	575.5	3 258.0
1963-2023	-	-	-	-	-	-	3 136.54

Table 2. Monthly rainfall totals (mm) in the experimental field in Chelopechene for the period April - September 2023

Month/Year	IV	V	VI	VII	VIII	IX	Total
2023	63.1	58.3	96.8	39.0	44.2	4.8	306.2
1963-2023	-	-	-	-	-	-	342.76

of culture development. The period from planting to harvest is 125 days.

The growing season of garlic is about 125 days on average.

The crop irrigation regime is determined by the weather conditions of the year and, more precisely, by the amount of precipitation during the growing season. The other factors that influence the irrigation regime are the biological requirements of the crop, the type of soil and its water-physical properties.

Two types of irrigation are applied to vegetable crops:

◊ for interception, immediately after planting, irrigation is done with an irrigation rate of 10-15 mm and after 5-7 days, if necessary, a second one.

◊ basic irrigations throughout the growing season, as the size of the irrigation rates depends on the current soil moisture (with drip irrigation, they vary from 5-20mm, at pre-irrigation humidity 85-90%, during germination and vigorous growth and 60% - 70% during the ripening phase of garlic).

In the case of summer garlic, the plants have intensive growth, greater water consumption, and need more frequent irrigation, maintaining optimal humidity. The culture‘s need for moisture changes during the vegetation process. The irrigation period for active garlic vegetation in the Sofia region covers the period from April, which period coincides with the formation and growth of new leaves and bulbs, until the heads ripen - mid-July.

Variants with different irrigation techniques were studied at an optimal and reduced garlic irrigation regime: V_1 - subsoil drip irrigation - 100% irrigation rate, V_2 - subsoil drip irrigation - 50% irrigation rate; V_3 - surface drip irrigation - 100% irrigation rate; V_4 - surface drip irrigation - 50% irrigation rate; V_5 - non-irrigated variant. To maintain the soil moisture between 80-100% of the FC, 10 main irrigations with an average irrigation rate are needed: V_1 – 16.89 mm; V_2 – 8.44 mm, V_3 – 26 mm; V_4 – 13mm.; V5 – 0 mm; which are realized at different intervals depend-

Table 3. Characteristics of the phenophases of garlic for the area of the Sofia field

Year	Sowing	Germination	Intense growth	Garlic for green	Bulb ripening	
				Beginning	Beginning of head thickening/Mass lodging of false stem	Harvesting the yield
2023	26.03	5.04	20.04	10.06	10.06/15.07	25.07

Figure 2. Main phases of culture development
(sprouting, garlic for greening and mass laying of the false stem)

ing on the development of culture and weather conditions. Their difference is due to the way of water supply. In both methods of drip irrigation, it is concentrated around the root system. With surface drip irrigation, it was established with the help of soil samples that the evaporation of water from the surface is about 20-30% compared to an underground location of the irrigation wings. (Table 4)

The established parameters of the irrigation regime and the water consumption of garlic make it possible to optimize irrigation, but they are not sufficient for a more complete solution to the country‘s water deficit problem. For this purpose, we conducted experiments to optimize these parameters when applying a „disturbed irrigation regime“, in which a significant saving of irrigation water is realized without drastically reducing the yield and deteriorating the quality of the bulbs.

The coefficient of reduction of the irrigation rate was determined analytically and is 0.44 for drip irrigation. This factor accounts for the water savings when using drip irrigation.

The amount of yield from the tested variants irrigated by drip irrigation with surface and underground location of the irrigation wings are different. In the variants irrigated with subsoil drip irrigation with a planting scheme of 0.20/0.10m and paths 0.50m. The different irrigation regimes affect crop production respectively: V_1 -750 kg dka^{-1}; V_2 – 580 kg dka^{-1}, V_3 – 650 kg dka-^{1}; V_4 -435 kg dka^{-1}; V_5 -230 kg dka^{-1}. The reduction in the size of the irrigation rates by 50% for surface and underground placement of the irrigation wings leads to a reduction in yield by 34 and 23% and can be applied in water deficit.

The method of placing the experiment in the year 2023 in the experimental field of Chelopechene district with different irrigation technologies for growing garlic is by the method of long plots in four repetitions. To prove the influence of the different rates of irrigation on the yield, the results obtained from the four repetitions of a variant were subjected to variance analysis. The significance of the obtained differences and the interaction of the factors were proved. From the correct statistical evaluations based on the experience with different irrigation technologies and different water security, it can be seen that:

Variants V_1 - sub. 100% and V_3 – surface. 100% is significantly different from the non-irrigated variant V5 - non-irrigated with a reliability index of P=0.1% and marked with three pluses, the difference is very well proven. Variant V_3 – surface. 50% and V_4 – surface. 50% have very good evidence (++) at P=1. In all four irrigation methods, increased yields are obtained compared to the non-irrigated option. The yield at 100% water supply in both ways of laying the irrigation wings is higher and differs from the non-irrigated option, which proves that garlic is a moisture-loving crop and, in our climate, needs irrigation for better quality and quantity.

Table 4. Elements of the irrigation regime for 2023

Year	2023		
Variant	Number depth N.	Irrigat. dept mm	Irrigation rate, Mm
Subsoil drip irrigation			
100 %	10	17.0	170
50 % Irrig. rate	10	8.5	85
Surface drip irrigation			
100% irrig rate	10	26.0	260
50% irrig rate	10	13.0	130
Nonirrigation	0	0	0

CONCLUSIOS

✓ During the growing season of the crop from April to July, depending on the soil moisture indicators, 10 main waterings were implemented for both irrigation methods and one/two at the beginning after sowing the garlic for moisture storage. The average irrigation rate for surface, subsoil drip irrigation at 100% water supply is 26 and 17m^{3}dka^{-1}, respectively.

✓ The difference in soil moisture in the 0-0.30m layer with subsoil drip irrigation compared to surface drip irrigation is of the order of 20-30%.

✓ The highest yields under the soil-meteorological conditions for the Sofia field area were obtained with the option irrigated with 100% implementation of the irrigation rate with subsoil drip irrigation. Its yield is 750 kg dka^{-1}, followed by the variant with 100% irrigation rate when the irrigation wings are placed on the surface 650 kg dka^{-1}. In the non-irrigated variant, a yield of 230 kg dka^{-1} was obtained.

✓ The increase in yields as a result of the implemented irrigations for both irrigation technologies (underground drip and surface drip) is 25%, 55% compared to the non-irrigated version.

✓ The reduction of the irrigation rate by 50% and in different ways of laying the irrigation wings for drip irrigation leads to a decrease in yield (23% in subsoil drip irrigation and 34% in surface drip irrigation) and can be applied in water deficit.

REFERENCES

Astapati, A. D., & Nath, S. (2023). The complex interplay between plant-microbe and virus interactions in sustainable agriculture: Harnessing phytomicrobiomes for enhanced soil health, designer plants, resource use efficiency, and food security. *Crop Design*, *2*(1), 100028.

Bachmann, J. (2001). Organic Garlic Production. National sustainable agriculture information service. Davis, California, USA. (http://attra.ncat.org/attra- Pub/PDF/garlic.pdf)

Brewster, J. L. (1994). Onions and other vegetable Alliums. CAB International, Wallingford, UK. Pp 236.

Bu, R., Ren, T., Lei, M., Liu, B., Li, X., Cong, R., ... & Lu, J. (2020). Tillage and straw-returning practices effect on soil dissolved organic matter, aggregate fraction and bacteria community under rice-rice-rapeseed rotation system. *Agriculture, Ecosystems & Environment*, *287*, 106681.

Cheruth, A.J., Gopi, R., Sankar, B., Gomathinayagam, M., & Panneerselvam, R. (2008). Differential responses in water use efficiency in two varieties of Catharanthus roseus under drought stress. Comptes rendus, Biologies, 331(1), 42-47.

Diriba-Shiferaw, G., Nigussie-Dechassa, R., Woldetsadik, K., Tabor, G., & Sharma, J. J. (2014). Bulb quality of Garlic (*Allium sativum* L.) as influenced by the application of inorganic fertilizers. Afr. J. Agric. Res., 9(8), 778-790. http://dx.doi.org/10.5897/AJAR2013.7723

Diriba-Shiferaw, G., Nigussie-Dechassa, R., Woldetsadik, K., Tabor, G., & Sharma, J. J. (2015). Effect of Nitrogen, Phosphorus, and Sulphur Fertilizers on Growth, Yield, and Economic Returns of Garlic (*Allium sativum* L.). African Journal of Agricultural Research. 4(2), 10-22.

Cabrera-Pérez, C., Llorens, J., Escola, A., Royo-Esnal, A., & Recasens, J. (2023). Organic mulches as an alternative for under-vine weed management in Mediterranean irrigated vineyards: Impact on agronomic performance. *European Journal of Agronomy*, *145*, 126798.

Jaleel, C.A., Manivannan, P., Sankar, B., Kishorekumar, A., Gopi, R., Somasundaram, R., & Panneerselvam, R. (2007). Water deficit stress mitigation by calcium chloride in Catharanthus roseus; effects on oxidative stress, proline metabolism and indole alkaloidaccumulation. Colloids Surf. B: Biointerfaces, 60, 110–116.

Tisdale, S. L., & Nelson, W. L. (1985). Soil fertility and fertilizers, 3rd Ed. Macmillan Publishing Co. Inc., New York and Collico-Macmillan Publishers, London.

Tisdale, S. L., Nelson, W. L., Beaton, J. D., & Halvin, J. L. (1993). Soil Fertility and Fertilizers (5th Ed), Macmillan Publishing Company, New York.

Hamma, I. L., Ibrahim, U., & Mohammed, A. B. (2013). Growth, yield and economic performance of garlic (Allium sativum L.) as influenced by farmyard manure and spacing in Zaria, Nigeria. Journal of Agricultural Economics and Development, 2(1), 001-005.

Hashimi, R., Huang, Q., Dewi, R. K., Nishiwaki, J., & Komatsuzaki, M. (2023). No-tillage and rye cover crop systems improve soil water retention by increasing soil organic carbon in Andosols under humid subtropical climate. *Soil and Tillage Research*, *234*, 105861.

Hassan, A. H. (2015). Improving Growth and Productivity of two Garlic Cultivars (Allium sativum L.) Grown under Sandy Soil Conditions. Middle East Journal of Agriculture Research. 4(2), 332-346.

Lal, R. (2016). Soil health and carbon management. *Food and energy security*, *5*(4), 212-222.

Liu, Y., Chen, S., Yu, Q., Cai, Z., Zhou, Q., Bellingrath-Kimura, S. D., & Wu, W. (2023). Improving digital mapping of soil organic matter in cropland by incorporating crop rotation. *Geoderma*, *438*, 116620.

Rice, R. P., Rice, L. W., & Tindall, H. D. (1990). Fruit and vegetable production in warm climates. Macmillan Education Ltd. Hong Kong. Pp 486.

Six, J., Calleja-Cabrera, H.S., Helmisaari, D.S., Powlson, A., Russell, E., & Kumar, S. (2022). The role of soil organic matter in sustaining soil structure. *Soil Discussions* (2022), pp. 1-29.

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