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IMPACT OF URBAN CONDITION ON BRASSICACEAE DEVELOPMENT

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Abstract

Urban agriculture refers to the practice of cultivating plants within city environments. It faces challenges such as accessing resources, soil, water, and air quality in urban environment. Field experiments were carried out in 2023 on alluvial-meadow soil located in Sofia city, focusing on growing cabbage and kohlrabi. Biometric analysis, absolute dry matter, and crop yields were conducted for both crops. Soil analyses were performed at the beginning of the experiment. The soil showed weak humus content, ranging 1.5% to 1.82%. The data obtained for kohlrabi yields and total available water, along with the correlation coefficient R2-0.77, indicate that an increase in irrigation rate results in decreased yield. Yields obtained in urban conditions ranged between 14-15 t/ha for kohlrabi and 34-47 t/ha for cabbage.

Key words: *urban agriculture, drip irrigation, yield, soil condition.*

INTRODUCTION

In an era marked by rapid urbanization and environmental concerns, the concept of urban gardening has emerged as a promising avenue for sustainable living and resilient communities (Eigenbrod, C. & Gruda, N., 2015; Saha, M. & Eckelman, M. J., 2017). Urban gardening leads to sustainability and community resilience in the face of rapid urbanization and environmental degradation. However, its realization is not without hurdles, particularly in the realm of resource access and environmental quality. Access to resources forms the bedrock of successful urban gardening endeavours. Furthermore, the quality of soil in urban environments poses a significant challenge to successful gardening practices (Dobson, M. C. et al., 2021). Soil contamination, resulting from industrial activities, vehicular emissions, and improper waste disposal, jeopardizes plant health and compromises food safety. Water scarcity and quality issues also loom large in urban gardening pursuits (Bediakoh, A. W. et al., 2024). Competition for water resources, coupled with erratic precipitation patterns exacerbated by climate change, underscores the importance of efficient water management strategies. Rainwater harvesting, drip irrigation systems, and grey water recycling techniques offer promising avenues for conserving water and reducing reliance on municipal water supplies. The ability of drip irrigation to save water is unparalleled, making it a crucial tool in addressing water scarcity while ensuring food security and agricultural sustainability. The irrigation of late cabbage and kohlrabi holds significant importance in determining both the quantity and quality of the yield. Cultivating Brassicaceae can be effectively managed even under conditions of deficit irrigation. Moreover, employing a deficit irrigation approach enables crops to sustain a certain level of water deficit with minimal impact on yield, as noted by Abdelkhalik (2019). This strategy holds promise for enhancing water use efficiency and conserving water resources. Moreover, alert monitoring of water quality parameters is imperative to safeguarding plants from contaminants and ensuring the safety of harvested produce (Orsini, F. et al., 2013). In conclusion, navigating the complex challenges of resource access and environmental quality is paramount to the success and sustainability of urban gardening initiatives. Through collaborative efforts and innovative solutions, urban gardening holds immense potential to transform our cities into greener, healthier, and more equitable spaces for generations to come.

The aim of study is to establish the influence of urban condition and deficit irrigation regimes on cabbage and kohlrabi quality of yield for the conditions of Sofia city region.

MATERIALS AND METHODS

The experiment was conducted in 2023 in the suburban area of Sofia city. The soil type is alluvial-meadow. The tested crops are late cabbage and purple kohlrabi. The study was carried out on long plot method in four replicates, featuring harvest plots measuring 12 square meters each. Sowing followed a two-row strip pattern with an inter-row spacing of 70 by 50 centimetres.

To assess the impact of the irrigation regimen on the growth, development, and yield of cabbage and kohlrabi, the vegetation period is segmented into two distinct sub-periods: "vegetative" and "reproductive".

Different variants of the irrigation regime (IR) were tested as follows:

IR 1. Irrigation with 40% of the irrigation rate determined in the optimal variant.

IR 2. Irrigation with 70% of the irrigation rate determined in the optimal variant.

IR 3. Irrigation with full irrigation rate (100% m) - optimal irrigation (control).

IR 4. Irrigation with an increased irrigation rate (130% m) - determined in the optimal variant.

IR 5. Without irrigation during the "planting-vegetative growth" period.

IR 6. Without irrigation during the "head formatting" period.

In the optimal variant (IR3), irrigation will be conduct when soil moisture reaches 80% of the field capacity (FC) within the 0-40 cm layer. The irrigation rate will be adjusted to ensure adequate moisture throughout the active soil layer (0-60 cm). To achieve this, soil moisture dynamics will be monitored over a period of 7 days using the Gravimetric Soil Moisture Detection method (S.G. Reynolds, 1970).

GWC (%) = [(mass of moist soil (g) − mass of dry soil (g))/mass of dry soil (g)] × 100

The irrigation rate in the control variant will be calculated based on the water balance equation. (Z. Stoyanov et al., 1981).

Drip hoses will be used to irrigate the experimental plots, allowing for precise control over the dosage of irrigation water. The water supplied to each irrigated plot will be measured based on an hourly flow rate.

The water source is a borehole near a livestock farm. Fertilizer is not applied during the crop's vegetation period to stimulate growth.

Precipitation levels are recorded each morning using a rain gauge. The average daily temperature during the crop’s vegetation was recorded.

Soil and water analyses were conducted in a certified laboratory according to approved methodology.

The quantity and quality of the yield was evaluated from 10 plants of each replication.

RESULTS AND DISCUSSIONS

The average annual air temperature in Sofia city for the period 1956-1995 was 9.8°C. The coldest is January (-1.3°C), and the warmest is July (20.0°C). The average annual temperature in the centre of the capital is 10.2°C. Differences in air temperatures between the centre and peripheral urban areas indicate the presence of a heat "island" in the ground part of the atmosphere, which is a specific feature of the urban climate. This "heat island" has been particularly pronounced in the last three decades.

The average annual rainfall in the city and its adjacent territory is about 550-600 mm.

A curve of precipitation availability has been drawn for a 37-year period. According to the obtained results, the year 2023 is characterized by a precipitation availability of 45.9%, which defines it as a wet year. The annual precipitation amount is 638.3 mm, which is about 30 mm more than the previous year.

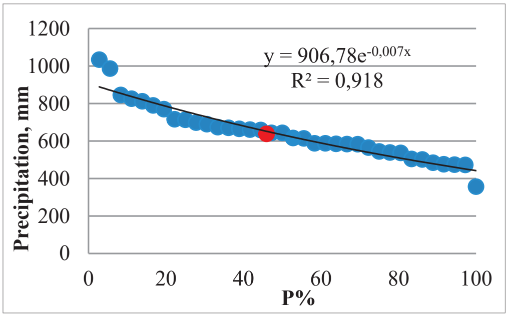

Figure 1. Curve of precipitation availability for the period 1987-2023

Brassicaceae crops typically prefer cooler temperatures for optimal growth. They thrive in temperatures ranging from around 15°C to 25°C during the growing season. Extreme heat can cause bolting (premature flowering), which negatively affects the quality of the crop. Temperatures exceeding 25-30°C can induce heat stress, negatively impacting cabbage head formation and yield (Červenski, J. et al., 2022).

In terms of water requirement of the crops moderate amount of rainfall or irrigation is sufficient, but it's important to avoid both drought stress and waterlogging.

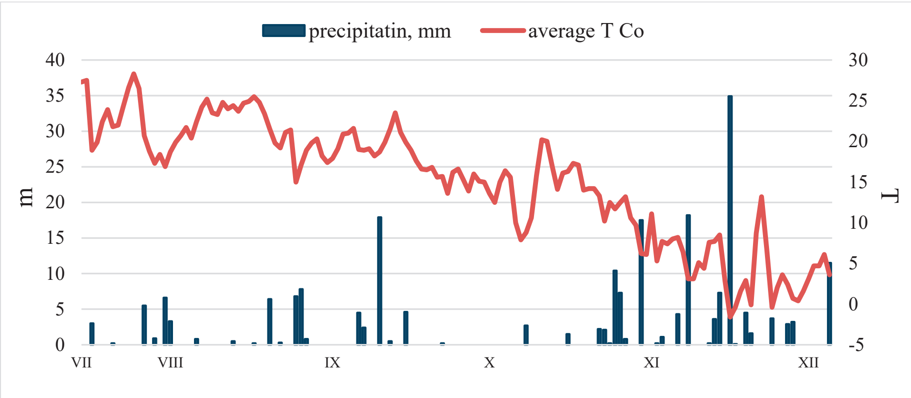

Figure 2. Precipitation and average daily temperatures during the growing season of cabbage and kohlrabi in 2023

There is an even distribution of precipitation during the growing season of both crops. However, the recorded precipitation until the beginning of November rarely exceeds 10 mm. At the beginning of the vegetable crop development period, the average daily temperatures reach 28.3°C, while at the end of the period before harvesting, negative values are recorded.

After the recorded temperature peak, a significant decrease in temperatures was noted during the second ten days of August. Towards the completion of head formation, the average daily temperatures fall within the optimal range for crop development.

Soil condition is the other important factor for successful cabbage and kohlrabi growth in urban condition.

Table 1. Agrochemical characteristics of the soil

Depth	Humus	pH	NH_4^+-N	NO_3^--N	P_2O_5	K_2O
cm	%	H2O	mg/kg	mg/kg	mg/100 g	mg/100 g
0-40	1.68	7.25	46.75	9.07	48.09	23.1

The NH_4 content of 67.75 mg/kg soil, as obtained from soil probe data, suggests a moderate level of ammonium in the soil. Ammonium is an essential source of nitrogen for plant growth, but excessive levels can potentially lead to nutrient imbalances or toxicity issues, particularly for sensitive plants. The NH_3 content of 9.07 mg/kg soil, as obtained from soil probe data, indicates the presence of ammonia in the soil. Ammonia can serve as a source of nitrogen for plant growth, although it's typically found in lower concentrations compared to other forms of nitrogen such as nitrate (NO_3^-) and ammonium (NH_4^+). Soil data obtained before vegetables planting, show a good degree of storage of K_2O, a very high content of available P_2O_5. The soil reaction is slightly alkaline. The soil is poorly humus with humus content for the arable soil layer.

This high content of NH_4 and P_2O_5 is probably due to unprepared storage of manure from keeping a few cows nearby. Thera is some evidence for spreading the manure in the area.

The samples of water used for irrigation on the experimental plots have been taken and analyzed. The boreholes are located near the experimental site, and the well-used to supply the drip irrigation system has a flow rate of 2 l/sec. The data from the water analyses conducted in an independent certified laboratory are presented in Table 2. The analysis conducted is fully compliant with

Regulation No. 18 of May 27, 2009, regarding the quality of water for irrigation of agricultural crops.

Table 2. Water quality analysis

Name of index	Unit	Results	MAC
Solids	mg/dm^3	216	-
Total hardness	mg eqv/dm^3	3.75	12
pH		7.18	6.5-9.5
Electro conductivity	µS/cm	311	2000
Voidability, permanganate	mg O_2/dm^2	0.82	5
Florida/F	mg/dm^3	0.25	1.5
Chlorides/Cl	mg/dm^3	10.59	250
NO2	mg/dm^3	<0.05	0.5
NO3	mg/dm^3	69.77	50
PO4	mg/dm^3	<0.1	0.5
SO4	mg/dm^3	50.75	250
HCO3	mg/dm^3	102	-
CO3	mg/dm^3	<5	-
NH4	mg/dm^3	<0.005	0.5
Ca	mg/dm^3	52.72	150
K	mg/dm^3	2.08	-
Mg	mg/dm^3	13.55	80
Na	mg/dm^3	11.3	200
Al	mg/dm^3	<0.005	0.2
As	mg/dm^3	<0.001	0.01
Cd	mg/dm^3	<0.001	0.005
Cr	mg/dm^3	<0.001	0.05
Cu	mg/dm^3	<0.001	2
Fe	mg/dm^3	0.077	0.2
Mn	mg/dm^3	<0.001	0.05
Ni	mg/dm^3	0.0031	0.2
Pb	mg/dm^3	<0.001	0.01
Zn	mg/dm^3	0.0112	5

The electrical conductivity of water for drinking and household needs should not exceed 2000 µS/cm, which is approximately equal to a total mineralization of 1000 mg/l. In the borehole used for drip irrigation, the conductivity is only 311 µS/cm, indicating a low content of soluble salts.
The water has a weakly alkaline pH. Elevated levels of nitrate forms are observed, which are 1.4 times higher than the norm. Nitrates in underground water mainly occur due to excessive use of fertilizers, animal waste, and the proximity of underground water sources to irrigation water.
High nitrate content in underground water can often be attributed to improper manure storage practices. When manure is not stored properly, such as in uncovered or inadequately sealed facilities, it can lead to the leaching of nitrates into the soil and eventually into groundwater. This is because manure contains nitrogen compounds that can break down into nitrate through microbial processes.
Excessive nitrates in the soil are most commonly found in agricultural areas. Boreholes constructed in shallow sandy soils are more vulnerable to nitrate contamination due to their increased mobility. Improper disposal of manure has led to groundwater pollution.
Cabbage and kohlrabi plants are relatively sensitive to water stress, particularly during the head formation stage. Severe water stress during this critical period can lead to reduced head size, uneven head formation, and decreased yield. However, moderate water stress during early growth stages may stimulate root development and enhance water use efficiency without significantly compromising yield.
The largest cabbage heads in terms of diameter were observed in the variants with 70% of the irrigation rate and in the variant with skip irrigation during the vegetative phase. The smallest diameter was reported for the variant with 130% of the irrigation rate, resembling the size of a rosette. This is likely due to restricts oxygen availability to plant roots and leads to root suffocation, nutrient leaching, and increased susceptibility to diseases.
Similar results were observed in the tuber of the kohlrabi, with approximately the same widths, lengths, and heights across variants. There is a directly proportional tendency of average weight increase relative to the irrigation rate for the variants at 40%, 70%, 100%, and 130%.
While deficit irrigation may reduce cabbage yield under severe water stress conditions, it can also improve yield quality in some cases. Moderate water stress may result in firmer heads with higher dry matter content and increased resistance to diseases such as tip burn.
Obtained yield of cabbage and kohlrabi is reported by variants and is equated in tons per hectare.
It is clear that skipping the irrigation during the vegetative phase does not lead to a significant decrease in yield, with only about a 10% reduction observed.
Reduced irrigation at 70% of the norm and canceling irrigation during the vegetative phase of cabbage development provide grounds for the successful implementation of deficit irrigation regimes in late-season cabbage production.

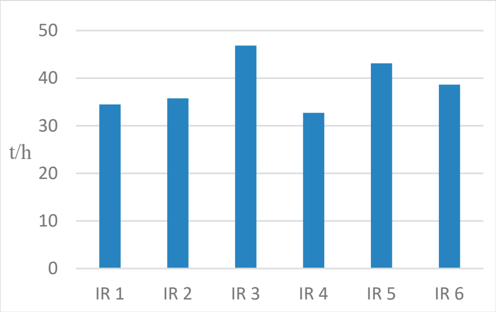

Figure 3. Cabbage yield 2023

From the data, we can observe some variation in kohlrabi yield among the different irrigation condition conditions. The average yield appears to be around 15.5 tons per hectare, with individual conditions ranging from approximately 14.7 to 16.6 tons per hectare.

In variants whit high irrigation rate 130% the lowest yield is observed, which defines kohlrabi as sensitive to waterlogging. Kadiri, L. et al. (2017) obtain a similar result according to authors Waterlogging can have significant effects on the yield of kohlrabi, as it can adversely affect plant growth, nutrient uptake, and overall productivity.

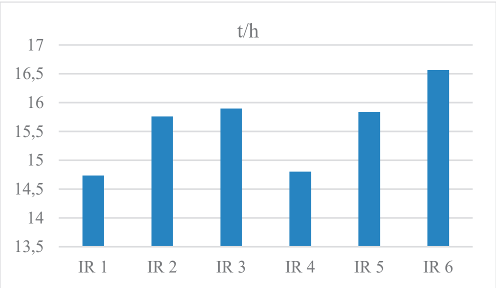

Figure 4. Kohlrabi yield 2023

The statistical processing of the data for the yield of the two crops with ANOVA. Shows statistically proven differences between irrigation variants with $P < 0.01$.

Total Available Water (TAW) refers to the amount of water present in the soil that is available for plant use.

The obtained data for kohlrabi yield, as well as the derived dependency, indicate that increasing the irrigation rate results in a decrease in kohlrabi yield. This is due to the low amount of air in the soil pores, resulting from their filling with water. The good results obtained with reduced irrigation rates show that kohlrabi is a crop that does not tolerate overwatering and can be successfully grown under conditions of disrupted irrigation regimes.

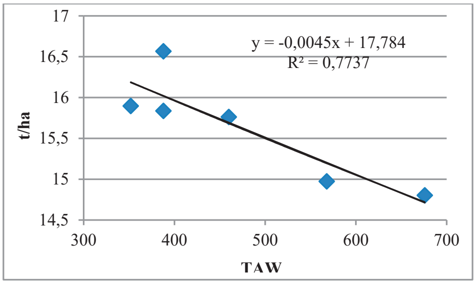

Figure 5. Dependency between yield and irrigation rate for kohlrabi 2023

Monitoring the quality of vegetables, particularly regarding nitrate content, is crucial for ensuring consumer safety and health. Vegetables such as cabbage and kohlrabi are known to have the propensity to accumulate nitrates, which can have implications for human health if consumed in excess.

Nitrate accumulation in vegetables can occur from various natural sources, as highlighted by Putnik-Delić, M. et al. (2023). These sources may include nitrogen-containing fertilizers, organic matter decomposition in soil, and environmental factors such as temperature and moisture levels. Understanding and managing these factors are essential for mitigating nitrate accumulation and ensuring the production of high-quality vegetables.

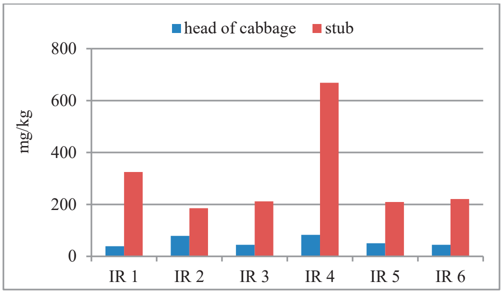

Figure 6. Nitrate content in heads and cobs of cabbage 2023

There is variation in nitrate content across different irrigation conditions for both the head and stub of cabbage. Variant IR 4 has significantly higher nitrate content compared to the other conditions in stub. Interestingly, there are differences in nitrate content between the head and stub of cabbage within each condition. This suggests that nitrate accumulation may vary between different parts of the cabbage plant. The data suggests that different irrigation regimes may influence nitrate accumulation in cabbage. For example, IR 4 shows notably high nitrate levels compared to other variants, indicating a potential correlation between irrigation practices and nitrate content.

The measured levels of nitrates in the edible part of the cabbage do not exceed the maximum permissible concentration of 500 mg/kg.

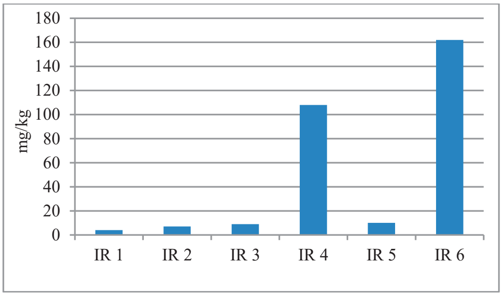

Figure 7. Nitrate content in the productive part of kohlrabi 2023

The data shows variations in nitrate content across different experimental conditions. Particularly, IR 4 and IR 6 exhibit significantly higher nitrate levels compared to other conditions.

Water stress conditions caused by over watering can alter plant metabolism, including the assimilation of nitrates. Under water stress, plants may prioritize the assimilation of nitrates over other metabolic processes, leading to increased nitrate accumulation in plant tissues. Morard, P. et al. (2000) obtain similar result for tomato plants. The authors report that 12 hours after the onset of oxygen deprivation could be attributed to the reduction of nitrates by the root system of tomato plants. This reduction process might utilize oxygen, derived from the reaction, to facilitate essential processes like water and nitrate uptake, which are pivotal for plant nutrition. Consequently, it appears that under conditions of root asphyxia, the plant may acclimate by resorting to a metabolism akin to "nitrate respiration".

CONCLUSIONS

Based on the research findings, it can be concluded that the climatic conditions within the Sofia city region are conducive to the cultivation of cabbage and kohlrabi crops. However, the presence of nearby livestock may have adverse effects on soil and water quality, posing a risk of potential contamination. Nevertheless, current assessments indicate that the quality of both soil and water remains satisfactory and does not pose any immediate threat to human health.

The irregular distribution of rainfall throughout the growing season necessitates regular irrigation practices. Cabbage crops exhibit positive responses to controlled irrigation deficits, with the most promising outcomes observed when watering is withheld during the vegetative phase. However, it's crucial to note that excessive soil moisture resulting from over-irrigation can induce stress in plants, adversely affecting both yield and nutrient absorption. The data obtained regarding kohlrabi yield, along with the derived dependencies, suggest that an increase in irrigation rates correlates with a decrease in kohlrabi yield.

Under conditions of water stress, plants may prioritize the assimilation of nitrates over other metabolic processes, leading to heightened nitrate accumulation in plant tissues. However, it's worth noting that measured levels of nitrates in the edible portion of cabbage and kohlrabi do not surpass the maximum permissible concentration of 500 mg/kg, indicating compliance with safety standards.

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