SUSTAINABILITY OF THE WATER REQUIREMENT OF TWO CULTIVARS OF OKRA UNDER THE USE OF COVER CROP AND MINIMUM TILLAGE SYSTEM

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ABSTRACT

An experiment was carried out at one of the fields located south of Baghdad during the 2024 agricultural season to study the water requirements of two cultivars of okra, a local cultivar (Batra) and an Egyptian cultivar (Lahloba) under the effect of the previous crop compared with the absence of residues. The factorial experiment included the crop cultivar and the presence or absence of previous crop residues. The characteristics studied for these two factors and their interactions were the water requirement of the okra crop, water productivity, germination speed, plant height, number of leaves, and fresh pod yield. The presence of crop residues led to a decrease in water consumption by the crop (mm) and consequently a decrease in the amount of water used (m^3) per hectare by 19.26% and an increase in both water productivity by 64.15%, the germination by about 7.3%, plant height (cm) by 22.7%, and the number of leaves per plant 13.6%, and the yield of fresh pods (kg/ha) is approximately 32.5%. The Egyptian cultivar (Lahloba) exceeded the local cultivar Batra in achieving the lowest water consumption and therefore the least amount of water used by 4.5% and the highest percentage of water productivity (10.5%), germination speed (7.3%), number of leaves per plant (4.2%) and fresh pod yield (kg/ ha) (5.9%), while the local cultivar Batra exceeded in achieving the highest average plant height reaching 143 cm compared to the average height of the Lahloba plant (142 cm), with an increase of 0.7%.

Keywords: Batra, Lahloba, water consumptive use, water productivity

إستدامة الأحتياجات المائية لصنفين من الباميا تحت أستعمال محصول الغطاء ونظام الحراثة الصغرى

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المستخلص

نفذت تجربة في أحد الحقول الواقعة جنوبي بغداد خلال الموسم الزراعي 2024 لدراسة الأحتياجات المائية لصنفين من الباميا (صنف محلي (بتره) وصنف مصري (لهلوبة)) تحت تأثير وجود بقايا المحصول السابق من عدم وجود البقايا. تضمنت التجربة العاملية عاملان هما صنف المحصول وبقايا الحاصل السابق من عدمه. كانت الصفات المدروسة الأحتياج المائي لمحصول الباميا، أنتاجية المياه، سرعة الأنبات، أرتفاع النبات، عدد الأوراق، حاصل القرنات الطازج لمحصول الباميا. أدى وجود بقايا المحصول إلى أنخفاض الأستهلاك المائي من قبل المحصول (مم) وبالتالي أنخفاض كمية الماء المُستخدم (م^3) لكل هكتار بنسبة 19.26% وزيادة كل من أنتاجية المياه بنسبة 64.15% ونسبة الأنبات بحدود 7.3% وأرتفاع النبات (سم) بنسبة 22.7% وعدد الأوراق لكل نبات بحدود 13.6% وحاصل القرنات الطازج (كغم /هكتار) بحدود 32.5%. تفوق الصنف المصري لهلوبة على الصنف المحلي بتره في تحقيقه أقل أستهلاك مائي وبالتالي أقل ماء مُستخدم بنسبة 4.5% وأعلى نسبة لكل من أنتاجية المياه (10.5%) وسرعة الأنبات (7.3%) وعدد أوراق لكل نبات (4.2%) وحاصل القرنات الطازج (كغم /هكتار) (5.9%) أما الصنف المحلي بترة فقد تفوق في تحقيقه أعلى معدل لأرتفاع للنبات (سم) بلغ 143 سم مقارنة بمعدل ارتفاع نبات لهلوبة (142 سم) وبزيادة مقدارها 0.7%.

الكلمات المفتاحية: البترة، لهلوبة، الاستهلاك المائي، انتاجية المياه

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INTRODUCTION

The water crisis in the Arab world and Iraq is mainly linked to several factors, including its geographical location within the arid and semi-arid regions, and recent climate changes. Moreover, the policies of some countries to reduce water supplies were another factor that caused a severe shortage in the agricultural share of that water for several countries, including Iraq in particular. To overcome these challenges facing agricultural production, specialists in the agricultural sector need to find solutions and ways to reduce the negative impact of climate and state policies on agricultural production. The use of the cover crop system, or the residue of the previous main crop after harvest, is an important practice that regulates much of the water drainage and meets the crop's water requirements. Also, the introduction of this system has a positive impact in the short term in reducing water and wind erosion, reducing soil temperature, and increasing water yield, and thus it works to create a more suitable environment for crop growth. In the long term, this system works to increase the soil’s organic matter content, improve its structure, enhance its biological activity, and recycle nutrients, which will undoubtedly reduce the use of chemical fertilizers. This means saving costs and creating a healthy environment. The cover crop can be applied by leaving part of the previous crop residues after harvest, which is represented by the stems, leaves, and roots, and proceeding with planting the subsequent season’s crop. However, the success of this system requires the use of correct management by following specific types of tillage, including minimum tillage, which leaves the harvest residues on the surface of the soil without burying them. Furthermore, increasing the chances of being able to plant crops at specified times, especially in the rainy seasons, and reducing the compaction of soil by machines can also be achieved when applying this practice (8, 10, 24, 29). Minimum tillage leaves a portion of the previous plant residues, at a rate of 15-30%, on the surface of the plowed soil without burying it. The most important feature of this system is that it maintains soil moisture and its organic matter content. It also preserves the soil from wind and water erosion, maintains soil fertility, improves its quality, as well as reduces production costs (9, 20). Moreover, minimum tillage has been described as sustainable agricultural practices that enhance land productivity. Jena (18) stated that the application of minimum tillage has achieved an increase in plant production and improved germination conditions and seedling emergence, in addition to improving the physical, chemical, and biological characteristics of the soil, which contributed to creating better conditions for growth and production. Applying cover crops is a good practice for climate change adaptation and mitigation (13). Reducing evaporation from the soil is considered one of the means of water management, and this can be achieved using various methods, including applying a cover crop, which aims to leave the previous plant residues at a rate of 30%, as it works to change the thermal and moisture regime of the soil. It also works to change the conditions surrounding the plant by preserving its water reserves and reducing the amount of irrigation water used to reduce evaporation rates from the soil surface (19). This system is widely applied in the production of vegetable crops because the abundance of water and the provision of organic soil are important in the productivity of these crops, including okra. India is considered one of the world's largest producers of okra, with an annual production of about 5,507,000 tons. India plants approximately 485,000 ha of okra plants annually. Nigeria ranks second globally after India in okra production, with its production reaching approximately 1,978,286 tons annually. On the Arab level, Egypt is considered one of the Arab countries that produces the most okra, with its annual production reaching approximately 57,721 tons, and the Kingdom of Saudi Arabia is ranked 11th in okra production, with its annual production reaching approximately 46,478 tons (15). In Iraq, okra is one of the summer vegetable crops (*Abelmoschus esculentu*) widely cultivated in most of its regions. Okra plants are susceptible to low temperatures, as this leads to the formation of skinny plants with a weak ability to form leaves and flowers, and the resulting pods become irregular in shape, thus reducing the yield in quantity and quality. Young pods contain some proteins, some carbohydrates, and vitamins A and C, with a little vitamin B, but they are a good source of calcium (Ca), phosphorus (P), and iron (Fe). As for its seeds, they are rich in protein and fats with some starch, and they are high in potassium (K), calcium, and phosphorus (11). Okra production is associated with different practices from zero tillage to conventional tillage. However, minimum tillage will help maintain soil health, which helps maintain the natural balance of nutrients and microorganisms in the soil. Thus, farmers can provide ideal conditions for the growth of the okra crop with less labor, fertilizers, fuel, and equipment compared to conventional tillage methods, this has the effect of saving farmers' costs without reducing returns. Therefore, soil and water management in okra cultivation is crucial to ensure optimal growth of the crop (6). This research was aimed at studying the sustainability of the water requirement of two cultivars of okra under the use of cover crop and minimum-tillage system.

MATERIALS AND METHODS

A field experiment was conducted in one of the farmers' fields in the Al-Bu Amer area - Yusufiyah district - Baghdad (44 °18'75" E and 33°07'84" N). The field soil was described morphologically and then classified based on the American Soil Classification System, Typic Torrifluvent. Preliminary measurements and analyses of the field soil were carried out by taking soil samples at a depth of 0.00 - 0.30 m to study the physical and chemical properties of the soil (Table 1) according to the methods mentioned in (12).

Experimental treatments and statistical design: The experiment included the following treatments:

1- **Cover crop treatment**

The presence of the previous crop residues T_1

Absence of the previous crop residues T_2

2- **Cultivars**

Batra (local cultivar) C_1

Lahloba (locally produced Egyptian cultivar) C_2

Table 1. Physical and chemical characteristics of field soil and its separates before planting

Characteristic	Value	Unit
Bulk density	1.38	µg.m^{-3}
Particle density	2.65	
Porosity	48	%
Volumetric moisture content at 33 kPa	0.281	cm^3 cm^{-3}
Volumetric moisture content at 1500 kPa	0.141	
Electrical conductivity EC $_{1:1}$	1.71	dS m^{-1}
pH	7.22	
Organic matter	11.0	
Carbonate minerals	552	
Sand	310	g kg^{-1}
Silt	294	
Clay	396	
Soil texture	Clay Loam	

The experiment was carried out on a land area of 1000 square meters. Minimum tillage was carried out according to the principle of minimum soil disturbance, using a spike tooth harrow machine, one of the secondary tillage machines, to a depth of 0.10 m. Turkey, origin, year of manufacture 2020, number of stems 50 distributed over five lines, each line number of stems ten. Within the same area of the experimental field, two separate experiments were applied that included the presence or absence of cover crop residues for each site as a factorial experiment. Within the design of factorial experiments, the cultivar factor was distributed at two levels on the main plots and with four replicates, so the number of experimental units was (2 (cover crop) × 2 (cultivar) x 4 (replicates) = 16 experimental units). The means were compared to Duncan's Multiple Range test at a probability level of 0.05, and the results were analyzed using SAS (2018) programming. The cover crop treatment was an alfalfa crop grown in the previous winter season (grown as a cover crop and as green manure) and harvested before the experiment was implemented. Alfalfa crop residues (cover crops) were removed from the soil surface manually and carefully. Okra seeds were planted on 10/3/2024 for both cultivars after soaking them for 24 hours in warm water to accelerate germination, especially early planting, with a distance of

0.30 m between one seed and another. After germination, the plants were fertilized with the fertilizer recommended for okra (21). The irrigation process was carried out using water with an electrical conductivity of 1.33 dS/m after depletion of 55% of available water for the plant in the 0.00-0.30 m layer from planting until the end of the vegetative growth stage. The depth of the irrigation water for the layer was increased (0.00-0.40 m) from the beginning of the flowering stage until harvest. The furrow irrigation system consisted of a gasoline-powered pump that drew water from the water source (adjacent to the field) and pumped it through the main pipe with a diameter of 3 inches (0.077 m) to the experimental units through secondary pipes with a diameter of 1.5 inches (0.038 m). Locks were placed on the secondary pipes to control the opening and closing of the water flow to each furrow in the experimental unit. The distance between one furrow and another was 0.6 m, and the furrow was V-shaped, 0.4 m wide, and 0.2 m deep. To determine the volume of water flowing into the treatments, place a water gauge at the beginning of each secondary pipe. The system was calibrated in advance by testing several operating pressures, including (100, 200, and 300) kPa. The best operational pressure was chosen based on efficiency, consistency, and irrigation efficiency. The operational pressure (200) kPa was chosen for this experiment. To control the amount of water added to compensate for moisture deficiency for each treatment, the depth of water that must be added to compensate for moisture depletion was calculated using (Equation 1) (4).

$$d = (\theta_{fc} - \theta_w) \times D \quad \dots\dots\dots \quad (1)$$

Where: d = added water (mm).

θ_{fc} = volumetric moisture at field capacity ($cm^3.cm^{-3}$).

θ_w = volumetric moisture before irrigation ($cm^3.cm^{-3}$) according to gravimetric method (28)

D = soil depth, which is equal to the depth of the effective root (mm) of the plant.=

The quantities of added water were used to calculate the Actual Evapotranspiration (ETa) values through the equation (Equation 2), taking into account that the deep groundwater is approximately 2 m:

$$I + P = ET_a + \Delta S \dots\dots\dots\dots (2)$$

Where:

I = irrigation water added (mm)

P = rain (mm).

ET_a = actual evapotranspiration (mm).

ΔS = change in soil water storage.

As for field water use efficiency (WUE_f), it was calculated according to the equation mentioned in (4):

$$WUE_f = \frac{Yield}{ETa} \dots\dots\dots\dots\dots\dots \quad (3)$$

Where:

WUE_f = field water uses efficiency (kg m^{-3}).

Yield = total yield (kg ha^{-1}).

ETa = actual evapotranspiration (m^3 ha^{-1}).

The germination speed on day 1 and the plant height (cm) of the longest stem from the area where the stem connects to the soil until the growing point was measured for twenty plants, and then the average was calculated. The number of leaves for the 20 plants was also calculated and then their average was found. To calculate the total yield of fresh okra pods (kg. ha^{-1}), the harvesting process continued until 2/8/2024.

RESULTS AND DISSCUTION

Water requirement of okra crop

Table 2 shows the depth of irrigation water added for the cover crop treatments with/or without previous crop residues. The treatments with previous crop residues decreased in the depth of irrigation water compared to the treatment without cover for both okra cultivars (Batra and Lahloba). From the table, it is clear that the highest water consumption was in the absence of crop residue treatment, where it reached 583 mm and an average irrigation water depth of 498 mm for the Batra, while the water consumption for the Lahloba was 558 mm and an average irrigation water depth of 473 mm. The decrease in the amount of irrigation water added to the field in the cover crop treatments compared to the treatment without soil cover was 22.29 and 27.55% for the Batra and Lahloba cultivars, respectively. The reason for this may be due to the role of the minimum tillage system in that it greatly reduced the amount of water added due to its role in improving the physical properties of the soil. All of these will contribute to increasing soil water conservation in times of scarcity (3, 7, 14). The second reason is the role of the cover crop in reducing the amount of water added because the cover crop works to reduce the transfer of heat to the soil surface as a result of absorbing solar radiation energy and reflecting it to the atmosphere. Thus, the thermal energy transferred to the soil decreases, which leads to a reduction in evaporation. This leads to the soil remaining appropriately moist and its temperature is regulated, thus reducing soil temperatures under the cover crop, and improving the soils physical properties, which in turn contributes to preserving soil moisture for a more extended period. This difference between the amounts of irrigation water added is essential in adding and exploiting new agricultural areas.

Table 2. Water balance factors for cover crop and without cover treatments for okra crop

Cultivar	Treatments	Rainwater depth (mm)	Irrigation water depth (mm)	Water consumption ETa (mm)	Amount of water used (m^3/ha)
Batra	Presence of cover crop residue	85	387	472	4720
	Without covering crop residue	85	498	583	5830
	Mean	85	443	528	5280
Lahloba	Presence of cover crop residue	85	365	450	4500
	Without covering crop residue	85	473	558	5590
	Mean	85	419	504	5040
	CV			0.21	

As for conventional tillage, which is represented by a treatment without a cover crop, as used by Iraqi farmers in all agricultural applications, its results showed an increase in water losses due to the role of deep tillage by increasing water infiltration, and thus losing quantities of water quickly, especially at the effective area of the roots of the okra crop, as mentioned in other research showed that water consumption values reached more than 800 mm.

Germination speed, some growth characteristics, and yield of two cultivars of okra: The results of the statistical analysis (Table 3) showed that there were significant differences in the average height of the two okra cultivars for the cover crop treatments, as well as the interaction between them. The cover crop treatments affected the average plant height, as the cover crop treatment gave the highest average plant height of 158 and 156 cm for the Batra and Lahloba cultivars, respectively. The average plant height in the absence of vegetation cover was 128 cm for the two cultivars: Batra and Lahloba. The reason for the superior average plant height can be attributed to the effect of minimum tillage on some soil physical properties, which was indirectly reflected in the plant height trait under study (27). As for the treatment of the cover crop, it also had a significant effect on the plant's height. The increase in plant height is attributed to the cover crops providing suitable environmental conditions for plant growth by preserving soil moisture, reducing the evaporation of its surface water, and improving its ventilation. Together, these factors increase the biological activity of microorganisms in the soil and encourage the roots growth, leading to increased plant height. This is consistent with (1, 2).

Table 3. Effect of cover crops on germination speed, plant height, number of leaves per plant, and fresh pod yield for the two okra cultivars Batra and Lahloba

Cultivar	Treatments	Germination speed day^{-1}	Plant height cm	Number of leaves $plant^{-1}$	Yield of fresh pods kg ha^{-1}
Batra	Presence of cover crop residue	21a	158a	252a	3850b
	Without covering crop residue	20b	128b	225b	2970c
	Mean	20.5	143	239	3410a
Lahloba	Presence of cover crop residue	23a	156a	266a	4150a
	Without covering crop residue	21b	128b	231b	3070c
	Mean	22	142	249	3610 b

***Values that share the same letter and for each characteristic separately within one column do not differ significantly according to Duncan's Multiple Range test at a probability level of 0.05.**

Table 3 shows the germination speed day^{-1} for the crop cover treatments for the two okra cultivars, Batra and Lahloba. The highest germination speed was achieved at the cover treatment, and it reached 21 and 23 days for the cultivars of Batra and Lahloba, respectively. The lowest percentage of germination was 20 and 21 days for the Batra and Lahloba cultivars, respectively, at treatment without a cover crop. The results of Table 3 showed the effect of the cover crop treatments and the okra cultivar on the values of the number of leaves. plant^{-1}, as the results of the statistical analysis showed that there were significant differences in the values of the number of leaves. plant^{-1}, as the values of the number of leaves. plant^{-1}, ranged from 252 to 266 at the cover crop treatments, and between 225 - 231 at treatments without cover crops. The highest number of leaves, plant^{-1} reached 266 at Lahloba cultivar and treatment with the cover crop, and the lowest number of leave reached 225 at treatment without the cover crop and the cultivar Batra. This decrease in the number of leave, can be attributed to the effect of the different stages of plant growth. Thus, all the physiological processes of the plant will be affected by the moisture content, amount and timing of adding water, and thus the number of leave is affected. Additionally, to the role of the cover crop in increasing the soil's ability to retain water by reducing evaporation from the soil surface, it also works to change the thermal regime of the soil in addition to improving soil health, which increases the efficiency of nutrients and water absorption. This is consistent with the results of (5, 25, 26). Table 3 shows the effect of cover crop treatments on the yield of fresh pods for two okra cultivars. The highest fresh pod yield was 4150 kg ha^{-1} for the Lahloba and at the cover crop treatment, and the lowest value was for Batra and the treatment without cover crop residue (2970 kg ha^{-1}). The reason for the increase in this may be attributed to the positive role of minimum tillage in improving the physical, chemical, and biological characteristics of the soil, in addition to its decomposition by soil microorganisms and providing plants with the necessary nutrients, especially nitrogen, and potassium, which are credited with increasing the strength and activity of vegetative growth, which was reflected positively in increasing the yield of pods. Cover crops also play an influential role in increasing the total yield compared to treatment without a crop cover by weed control and not competing with the economic crop for water and nutrients. This in turn increases the effectiveness of carbon fixation, and provides the necessary nutrients for the plant, especially organic nitrogen, which works to increase vegetative growth characteristics, reflected positively in the yield of the two cultivars of okra.

Water productivity: Table 4 shows the water productivity of the crop cover treatments for the okra cultivars Batra and Lahloba. It was observed that the highest water productivity was achieved at the cover treatment and reached 0.82 and 0.92 kg.m^{-3} for Batra and Lahloba cultivars, respectively. The lowest water productivity was 0.51 and 0.55 kg m^{-3} for Batra and Lahloba cultivars, respectively, at treatment without cover. This could be attributed to the fact that minimum tillage increases soil water storage by maintaining high moisture levels for a longer period, especially within the effective root zone of plant, while at the same time reducing water consumption and increasing productivity, which is in line with what (17). In addition to the role of the cover crop in reducing evaporation rates from the soil surface, which provided an opportunity to spacing irrigations (irrigation periods) and thus reduce water consumption, in addition to increasing the average fresh okra pods due to its positive role in improving the physical and chemical properties of the soil as a result of the decomposition of the organic matter of the cover crop by soil microorganisms and then providing the plants with the necessary nutrients, especially nitrogen and potassium, which are credited with increasing the strength and activity of vegetative growth. This is consistent with the modern trends of sustainable development by the United Nations, one of whose goals is the importance of preserving the soil from degradation and depletion of nutrients due to erosion. For this reason, the cover crop system is widely used as sustainable crop management that reduces soil and water losses, restores organic matter, increases biodiversity, and increases the fertility of degraded agricultural soil. Surface runoff and soil water storage are two significant processes that determine plant productivity, health, and sustainability, so cover crops contribute positively to reducing surface runoff and enhancing soil water storage (16, 22, 23).

Table 4. Effect of crop cover treatments on water productivity (kg m^{-3}) of two okra cultivars

Treatment	Batra	Lahloba
With crop residues	0.82	0.92
Without crop residues	0.51	0.55
LSD 0.05	0.173	

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