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Estimation of Water Productivity of Cucumber and Potato Crops for Water Management in Palestine

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: The aim of this study was to survey the agronomic practices that practiced by the farmers for potato and cucumber crops, and to estimate the water productivity of these crops.
Study Design: A questionnaire was designed to collect data about the agronomic practices that practiced by the farmers during the growing period of cucumber cultivated in open field and potato crops.
Place and Duration of Study: A field survey was carried out at Al-Bqaia'h and Kashda areas located at Tubas governorate of the West Bank, Palestine between December 2021 and July 2022.
Methodology: The questionnaire includes several parts: soil characteristics, crop cultivation, crop development, crop fertilization, yield production, type of irrigation systems used, irrigation water management, and amount of applied irrigation water. Crop evapotranspiration (ETc) was estimated using AQWACROP program. Soil samples were collected from the selected field to evaluate the soil fertility status.
Results: It is indicated that the crop evapotranspiration of potato (378 mm), higher than that of cucumber crop (343 mm). Huge amount of water (754 and 689 mm) were applied by the farmer during the growing period of potato and cucumber, respectively compared to calculated actual water requirement. The water productivity of cucumber crop varies among different farmers and varies from (3.56 – 6.82 kg/m^3) in Al-Bqaia'h area, and (3.7 – 7.5 kg/m^3) in Kashda area. The water productivity of potato crop varies from (4.29 – 8.10 kg/m^3) in Al-Bqaia'h area, and (5.1 – 8.1 kg/m^3) in Kashda area. It is found that the dripper discharge of 2 L/hr enhanced the water productivity compared to the dripper discharge of 4 and 8 L/hr.

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Conclusion: The field survey found that the water productivity of cucumber and potato crops was mainly affected by the performance of individual farmers, the amount of water applied, method of water application and the crop verity.

Keywords: Water productivity; evapotranspiration; yield production; water management.

1. INTRODUCTION

Water is the most important component in the earth and constitutes more than 80% of the growing tissue [1]. Because it is essential for most plant functions, the amount of water applied during irrigation, the time and method of water application and the quality of the irrigation water are important in plant growth and yield production. The water resources are limited worldwide for all sectors and it becomes more and more scare for irrigation; therefore, there is a need for irrigation water-saving and management practices to be explored and necessitates to be utilized in a scientific manner.

Palestine, as many areas of the Middle East is suffering from severe water scarcity. Groundwater is the main source of water for the Palestinians in the West Bank and Gaza Strip and provides more than 90% of all water supplies. The average water use of Palestinians in the West Bank is about 50 m^3 per person per year. This water is used for domestic, industrial and agricultural purposes [2]. Agriculture consumes about 65% of available water resources in the West Bank of Palestine [3]. However, management of irrigation water is needed to maximize the benefit from scarce water resources [4]. Improving water use efficiency is so important in order to secure water for agricultural production and increasing the crop productivity [5]. Drip irrigation considered an important practice which improves a water uniformity and enhances water use efficiency in a wide range of crops especially where water is limited [6,7]. Scheduling of irrigation is very important as excessive or inadequate water application is very critical for yield production [5]. Water saving may be achieved with drip irrigation, and even improved results seem to be possible [8].

It is important to determine the actual amounts of water needed for plants during the growth periods, and to develop the most suitable irrigation schedule to produce the optimum plant yield. Such schedules are developed for different ecological regions, as plant water consumption during the growth period depends mostly on plant growth, soil and climatic conditions [9]. Optimum irrigation scheduling based on water use patterns and crop response to water deficit can potentially improve the water productivity which is the ratio of the crop yield to seasonal water use [10].

Water Productivity plays an important role in modern agriculture which aims to increase yield production per unit of water used mainly under irrigation conditions. Water productivity with dimensions of kg/m^3 is used exclusively to indicate the amount or value of the product over volume of water applied to the crop. The value of the product might be expressed in different terms biomass, grain or money [11]. The reduction in the water productivity was due to the huge quantities of water applied by the irrigation systems during the season [12].

Production of vegetable crops enhances the economic benefits of the farmers but improper irrigation scheduling or high losses of irrigation water increases the production costs. To reduce the production costs and to optimize the benefits, farmers should apply well practices for water management at farm level [13,14]. The production of more food under a water-scarce situation can be achieved by maximizing crop yield per unit of water consumption [15,16]. Several scientists recommended to add more attention on improving water productivity mainly in water-scarce regions [17,18,19].

Cucumber (*Cucumis sativus* L.) is among the most popular vegetable crops grown worldwide [20]. The growing period of cucumber estimated between 80-100 days. It grows successfully under conditions of high light, high humidity, high soil moisture, temperature and fertilizers. The plants have higher demand for moisture during pollination and fruit development [21]. When cucumber is water-stressed, fruits can become misshapen and develop an unpleasant bitter flavor.

Potato is a water-stress-sensitive crop, and produces higher quality tubers when irrigation water is used precisely than if they are under-or over irrigation. Potato grows well in well-drained and sandy soil. Adding organic matter (compost, cover crops, well-rotted manure or leaves) is a good way to improve soil before growing potato. Recent studies for developing countries show an expected annual growth rate in potato production of 2.7% during the period 1993–2020 [22]. For global potato production, [22] estimated that 80% of the estimated increase will come from developing countries, with 64% coming from Asia alone. Early studies have shown that water is a limiting factor for potato and cucumber production and it is possible to increase production levels by applying well agronomic practices and well-scheduled irrigation programs throughout the growing period [23,24,25].

The main objectives of this study were to estimate the crop evapotranspiration of cucumber and potato crops based on climatic data. Furthermore, to survey the agronomic practices that applied by the farmers during the growing season of cucumber and potato crops and to estimate the water productivity of these crops for management of irrigation water in the surveyed areas.

2. MATERIALS AND METHODS

2.1 Site Description

Afield survey was carried out at two locations named as Al-Bqaia'h and Kashda areas which are located at Tubas Governorate, West Bank, Palestine (Fig. 1). Al-Bqaia'h is located 50 meters above mean sea level, with an area around 29250 dunums. The total cultivated area is a round 11495 dunums cultivated with orchards, field crops, open field vegetables and protected agriculture. Kashda is located at south of Tubas near Wadi Al-Fara'a. The area is considered an extensive agricultural area cultivated mainly with vegetables and field crops, with 360 du protected agriculture and 120 du as open field.

2.2 Questionnaire Design

A questionnaire was designed to survey the agronomic practices that carried out by each individual farmer during the growing season of cucumber crop cultivated in open field and potato crop. The questionnaire was designed based on the following parameters: soil characteristics, crop cultivation, crop development, crop fertilization, yield production, type of irrigation systems used, irrigation water management, and amount of applied irrigation water. The questionnaire was surveyed at least from nine farmers per crop in the selected areas through a personal interview with the farmers.

2.3 Calculating Water Productivity

Water productivity and economic analysis combined for physical accounting of water with yield or economic output to assess how much value is being obtained from the use of water [26]. Mathematically, water productivity can be calculated as described in (equation 1) as follows:

$$\mathrm{WP} = \mathrm{Output}/\mathrm{Q} \qquad (1)$$

Where, WP is the productivity of water in (kg/m^3), $Output$ is the productivity of the crop in (kg/du) and Q is the water applied to the crop in (m^3/du).

Fig. 1. Map of the study areas (The red color)

2.4 Estimating Crop Evapotranspiration (ETc)

The reference evapotranspiration (ETo) was estimated during the growing periods of cucumber and potato crops using AQWACROP program. The values of Kc for the selected crops were obtained from FAO drainage paper No. 56. The crop evapotranspiration was calculated from (equation 2).

$$\mathrm{ETc} = \mathrm{Kc} * \mathrm{ETo} \quad (2)$$

Where, ETc is crop evapotranspiration (mm), Kc is crop coefficient and ETo is reference evapotranspiration (mm).

2.5 Soil Analysis

Soil samples were collected from the selected fields to evaluate the soil fertility status. Soil samples were analyzed for total Nitrogen, Phosphorous, Potassium, organic matter, pH, ECe, Na^+, Ca^{+2}, Mg^{+2} and Cl.

3. RESULTS AND DISCUSSION

3.1 Climatic Data

The climatic data were collected during the year 2021/2022 from a meteorological station located at Jenin city which is closed to the study areas. The average minimum and maximum daily temperature during the year 2021/2022 were range between 17 to 26.6°C (Fig. 2). The highest temperature was recorded during July month. The average daily relative humidity was 67% (Fig. 3). The total amount of rainfall recorded was 569 mm during year 2021/2022. The extensive rainfall was distributed from December to March (Fig. 4).

3.2 Crop Coefficient (Kc)

To find out the Kc values of cucumber and potato crops, the duration of each growth period must be known. The observed duration of the selected crops are given in Table 1. The Kc values of cucumber and potato crops at different growth stages named initial, development, midseason and late stage are shown in (Figs. 5 and 6), respectively. It is found that the Kc values of these crops are higher for the mid-season stage because of fully grown and maximum coverage of the ground surface.

3.3 Crop Evapotranspiration (ETc)

The crop evapotranspiration (ETc) was measured using the meteorological data which was collected during the year 2021/2022. The ETc was estimated using AQWACROP program. The program estimated the daily reference evapotranspiration (ETo). The results indicated that the maximum ETo value was observed during July month while the minimum value was observed during January month (Table 2). The ETc of cucumber and potato crops was measured in a daily basis and given in (Figs. 7 and 8), respectively.

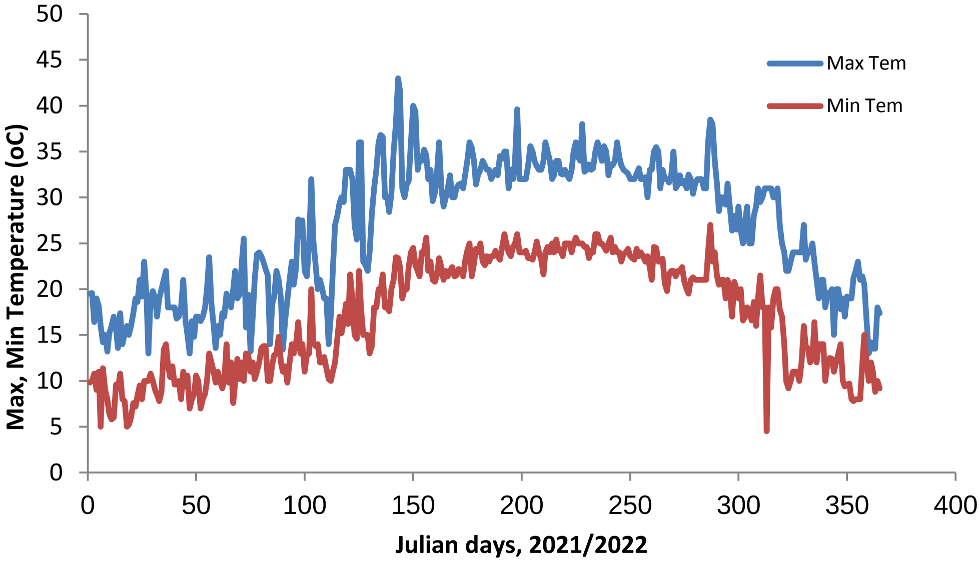

Fig. 2. The daily maximum and minimum temperature of the study area

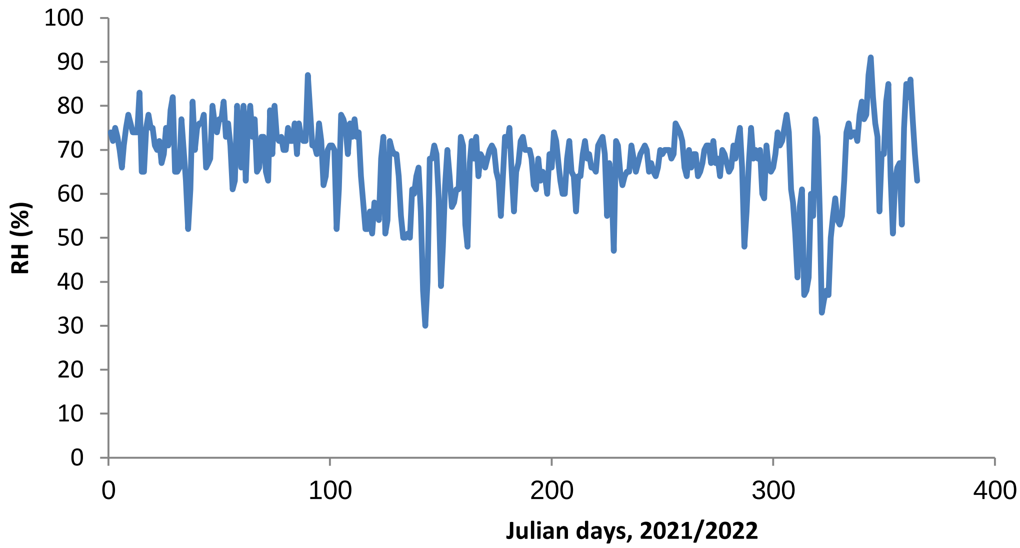

Fig. 3. The daily relative humidity of the study area

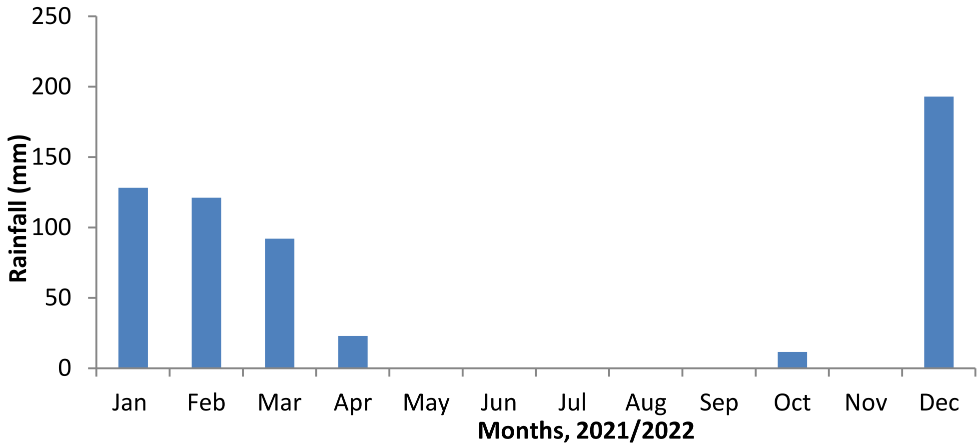

Fig. 4. The monthly rainfall distribution of the study area

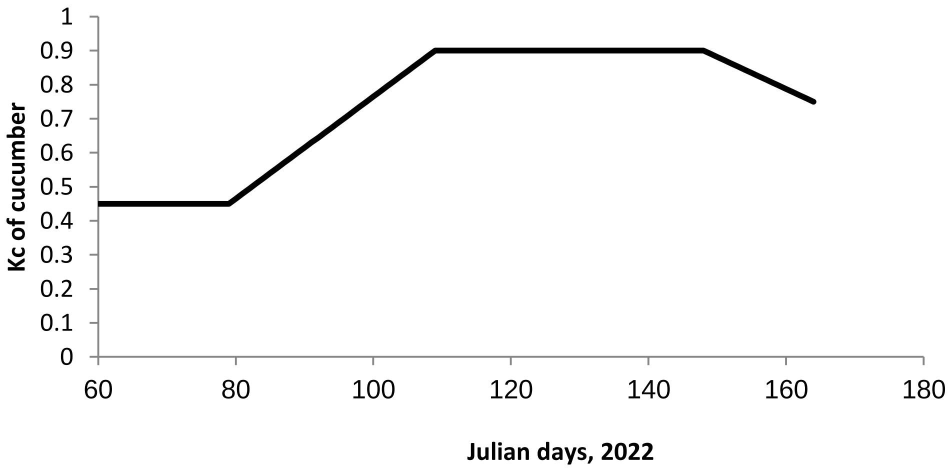

Fig. 5. Daily crop coefficient (Kc) of cucumber crop

Table 1. Length of different growth stages of the selected crops

Crops	Growth stages				Duration (days)
	Initial	Development	Mid-season	Late stage	
Cucumber	20	30	40	15	105
Potatoes	25	30	45	30	130

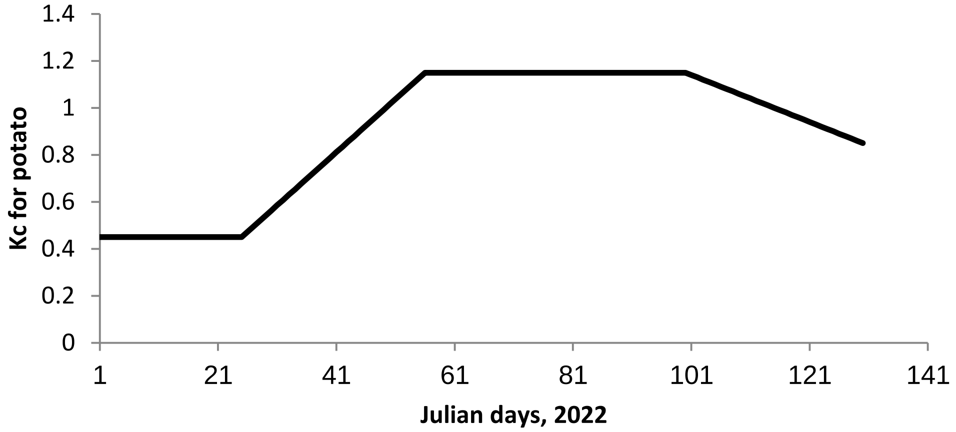

Fig. 6. Daily crop coefficient (Kc) of potato crop

Table 2. Daily reference evapotranspiration (ETo) of the study area

Month	ETo (mm/day)	Days	ETo (mm/month)
January	1.10	31	34.10
February	1.72	28	48.16
March	2.31	31	71.61
April	3.65	30	109.50
May	4.72	31	146.32
June	5.13	30	153.90
July	5.34	31	165.54
August	5.00	31	155.00
September	4.13	30	123.90
October	3.12	31	96.72
November	1.70	30	51.00
December	1.15	31	35.65

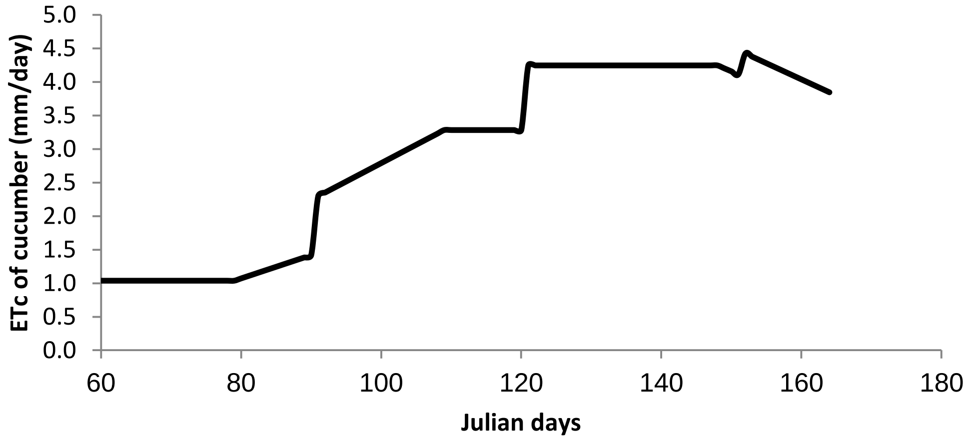

Fig. 7. Daily crop evapotranspiration (ETc) of cucumber crop

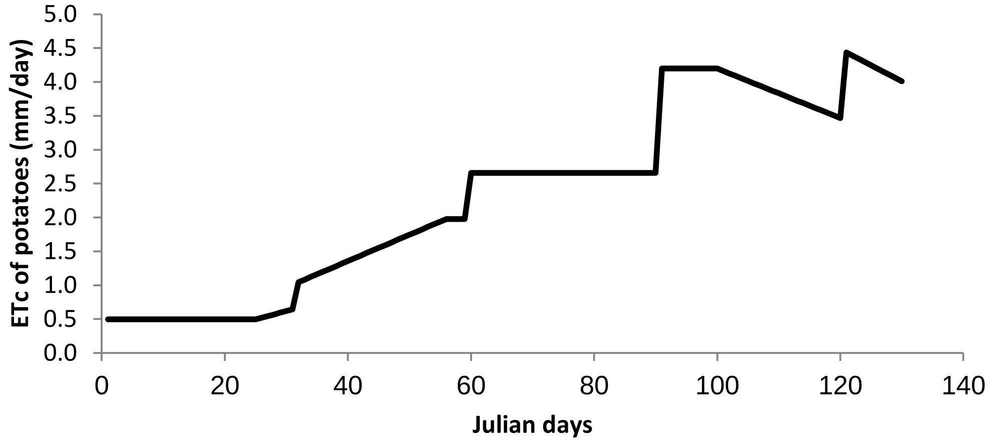

Fig. 8. Daily crop evapotranspiration (ETc) of potato crop

It is found that the crop evapotranspiration of potato crop (378 mm) was higher than that of cucumber crop (343 mm). Moreover, the applied irrigation water by the farmers during the growing periods of cucumber and potato crops was (754 mm) and (689 mm), respectively (Table 3). This means that huge amount of irrigation water was applied to the field by the farmers during the growing season of potato and cucumber crops compared to the calculated actual water requirements.

3.4 Water Productivity of Cucumber

Results of this study showed that the water productivity of cucumber crop cultivated in open field vary among individual farmers and vary from 3.56 – 6.82 kg/m^3 in Al-Bqaia'h area, and 3.7 – 7.5 kg/m^3 in Kashda area (Figs. 9 and 10). This may be affected by the agronomic practices that usually carried out by the individual farmer during the growing period like amount of applied water, crop variety, sowing date, planting density, type of irrigation system used, dripper discharge and others (Table 4). Furthermore, the average water productivity of cucumber crop was higher in Kashda area comparing to that in in Al-Bqaia'h area (Fig. 11). This may be explained by the performance of the farmers in this area from one point; and to the higher content of N, P, K and organic matter of the soil in Kashda area (Table 6); which improves the soil fertility and soil productivity compared to Al-Bqaia'h area.

Table 3. Amount of seasonal irrigation water of selected crops

Crop type	Farmer irrigation (mm)	ETc (mm)
Cucumber	754	343
Potatoes	689	378

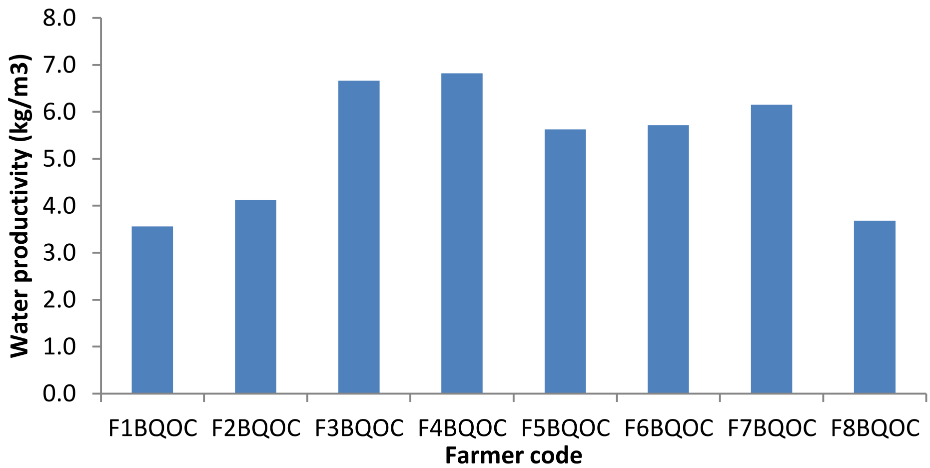

Fig. 9. Water productivity of cucumber among different farmers in Al-Bqaia'h area

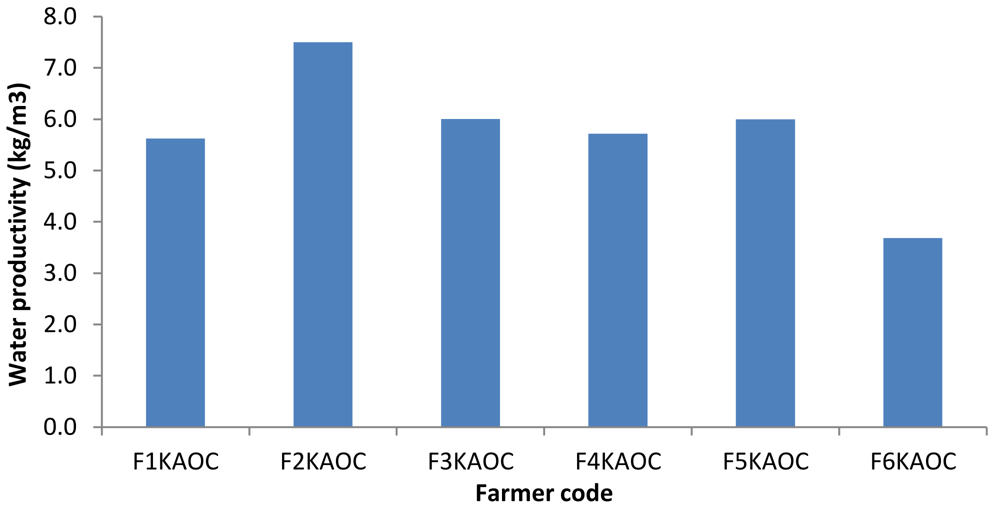

Fig. 10. Water productivity of cucumber among different farmers in Kashda area

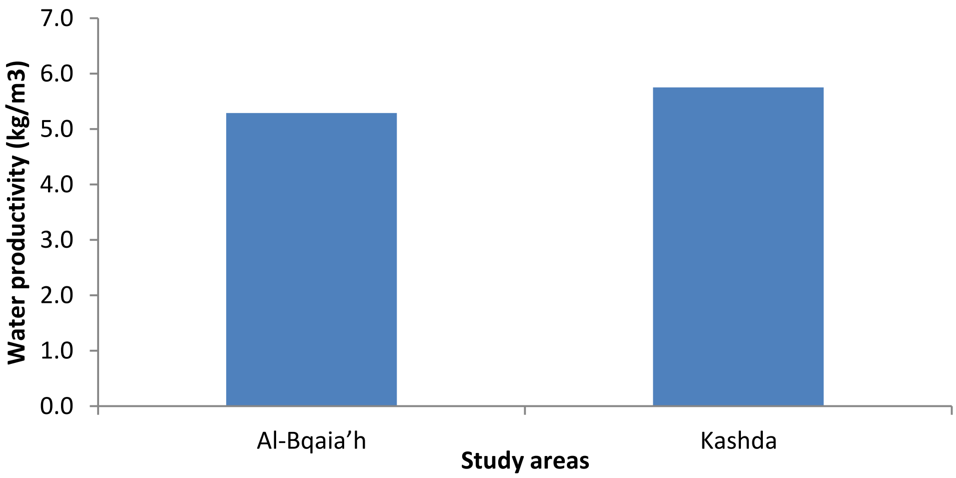

Fig. 11. Average water productivity of cucumber in the study areas

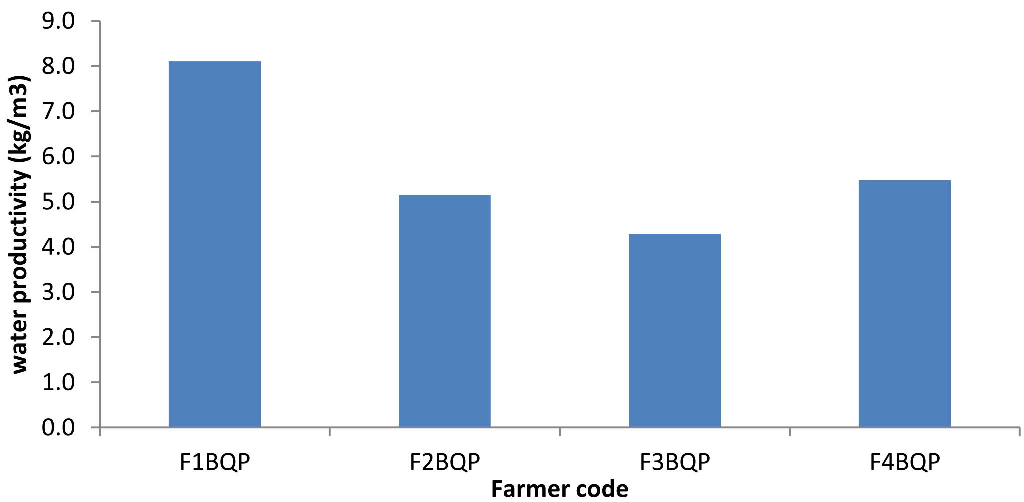

Fig. 12. Water productivity of potato crop among different farmers in Al-Bqaia'h area

Table 4. Agronomic practices that applied by the farmers for cucumber crop in Al-Bqaia'h area

Agricultural practice	Farmer code							
	F1BQP	**F2BQP**	**F3BQP**	**F4BQP**	**F5BQP**	**F6BQP**	**F7BQP**	**F8BQP**
Soil type	Medium	Heavy	Heavy	heavy	Heavy	Heavy	Heavy	Heavy
Variety	Yamama	Yamama	Yamama	Yamama	Yamama	Yamama	Yamama	Max-plus
Sowing date	20/2/2022	28/2/2022	1/3/2022	20/2/2002	5/3/2022	1/3/2022	5/3/2022	1/3/2022
Growing period (days)	90	120	100	90-100	90-100	90	100	90
Time to reach maximum crop canopy (days	40-50	50	50	30	50	50	45	45
Time to reach physiological maturity (days)	40	60	60	40-45	40	30	45	50
Plant density (kg/du)	2500	2500	2900	2600	1500	2600	2500	2400
Sprinkler flow (L/hr)	8	8	2	2	4	4	4	8
Amount of applied water (m^3/du)	1265	850	600	660	800	700	650	950
Average Yield production (kg/du)	4500	3500	4000	4500	4500	4000	4000	3500
Water productivity (kg/m^3)	3.56	4.12	6.67	6.82	5.63	5.71	6.15	3.68

3.5 Water Productivity of Potato

The results of this study observed that the water productivity of potato crop varies from (4.29 – 8.10 kg/m^3) in Al-Bqaia'h area, and (5.1 – 8.1 kg/m^3) in Kashda area (Figs. 12 and 13). This may be explained by the variance in agronomic practices that usually applied by the individual farmer like type of sprinkler irrigation system used, planting density, amount of applied water, amount of potato tubers and others (Table 5). The results also observed that the water productivity of potato cultivated in Kashda area was higher than that cultivated in Al-Bqaia'h area (Fig. 14).

3.6 Impact of Irrigation System on Water Productivity

The field survey found that all the farmers in the study area used a drip irrigation system in cucumber cultivation. Furthermore, it is found that the farmers usually used a dripper discharge of 2, 4 or 8 L/hr in Al-Bqaia'h area. It is indicted that the dripper discharge played an important role in the water productivity. The farmers who used a dripper discharge of 2 L/hr produced more water productivity of cucumber than the farmers who used a dripper flow of 4 and 8 L/hr (Fig. 15). Low water flow in drip irrigation system ensures that there are less water losses than when the flow as high as 8 L/hr.

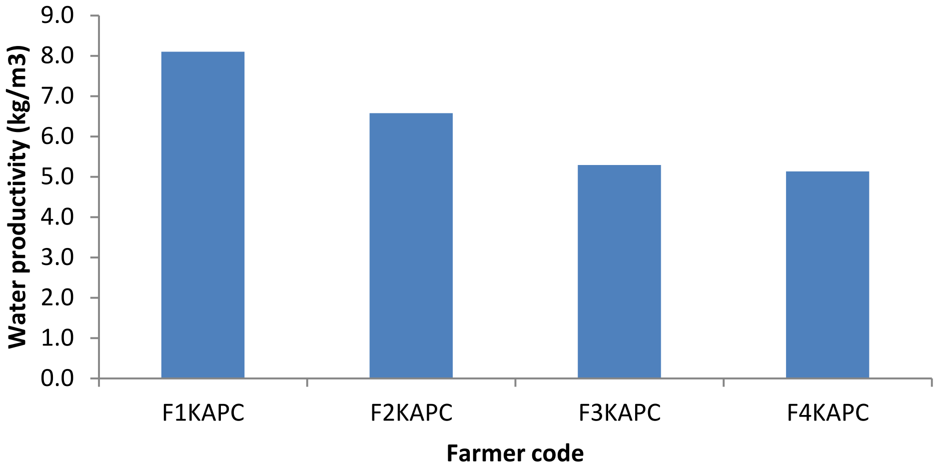

Fig. 13. Water productivity of potato crop among different farmers in Kashda area

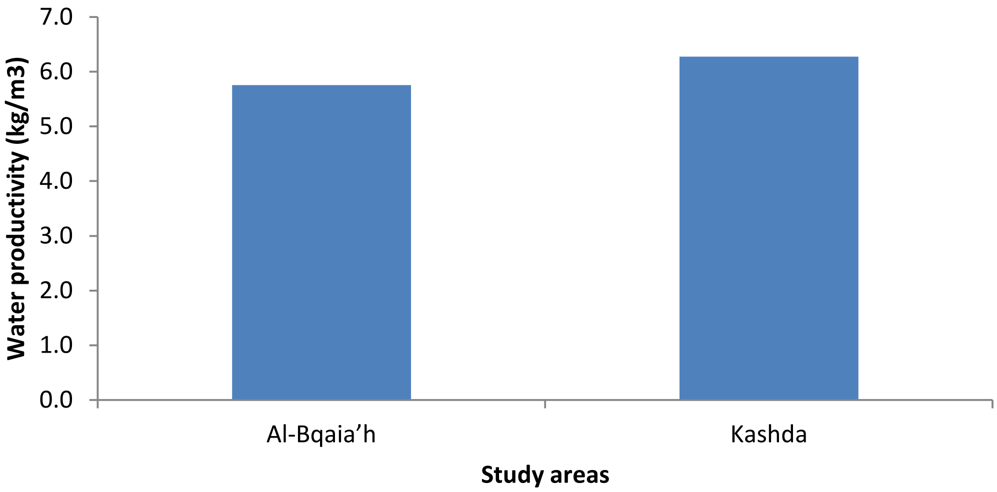

Fig. 14. Average water productivity of potato crop in the study areas

Table 5. Agronomic practices applied by the farmers for potato crop in Al-Bqaia'h area

Agricultural practice	Farmer code			
	F1BQP	F2BQP	F3BQP	F4BQP
Soil type	Medium	Heavy	Heavy	Heavy
Variety	Sponta	Sponta	Sponta	Sponta
Sowing date	20/12/2021	15/12/2021	15/12/2021	20/12/2021
Growing period (days)	120	130	120	125
Time to reach maximum crop canopy (days	50	45-50	60	55
Time to reach physiological maturity (days)	120	130	120	125
Plant density (kg/du)	350	300	300	350
Sprinkler flow (L/hr)	540	750	500	500
Amount of applied water (m^3/du)	617	680	700	730
Average Yield production (kg/du)	5000	3500	3000	4000
Water productivity (kg/m^3)	8.10	5.15	4.29	5.48

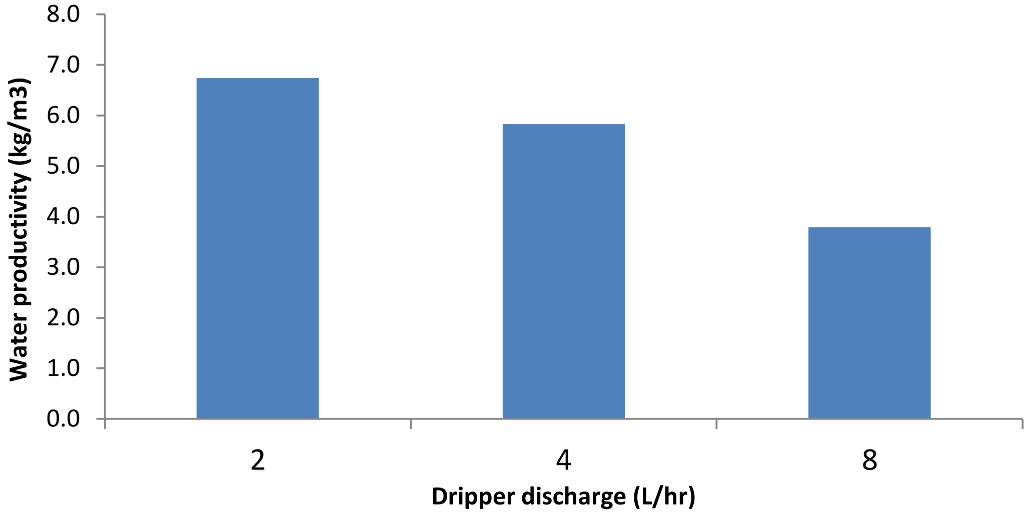

Fig. 15. Water productivity of cucumber crop under different dripper discharge in Al-Bqaia'h area

3.7 Impact of Crop Variety on Water Productivity

The field survey showed that the Yamama and Max-Plus are the major cucumber varieties that are cultivated in open fields in the investigated study areas. Results also showed that the average water productivity of Yamama variety (5.5 kg/m^3) was higher than that of Max-Plus variety (3.7 kg/m^3) in Al-Bqaia'h area. The same results were indicated in Kashda area with average water productivity of (6.2 kg/m^3) for Yamama and (3.7 kg/m^3) for Max-Plus (Fig. 16). This indicated that the water productivity might be affected by the crop variety.

3.8 Impact of Plant Density on Water Productivity

The field survey observed that the farmers cultivated different plant densities of potato tubers and cucumber seedlings in open field. It is found that the farmers who cultivated higher plant density of cucumber (2900 seedlings/du) produced higher water productivity compared to the other farmers who cultivated lower plant density (2400 seedlings/du) (Fig. 17). The same investigation was also observed for potato crop for the farmers who cultivated more tubers (350 kg tubers/du) compared with the farmers who cultivated (270 kg tubers/du) (Fig. 18).

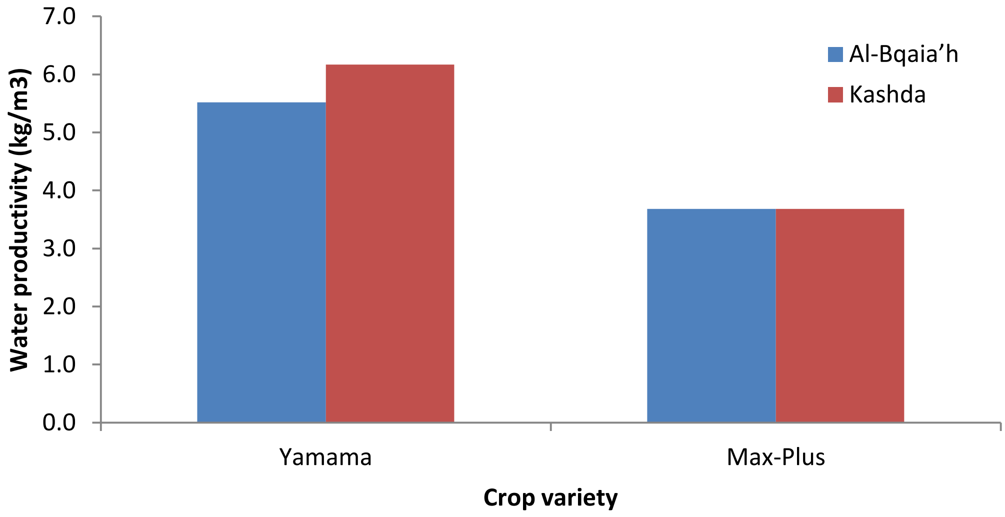

Fig. 16. Water productivity of cucumber in open field based on crop variety

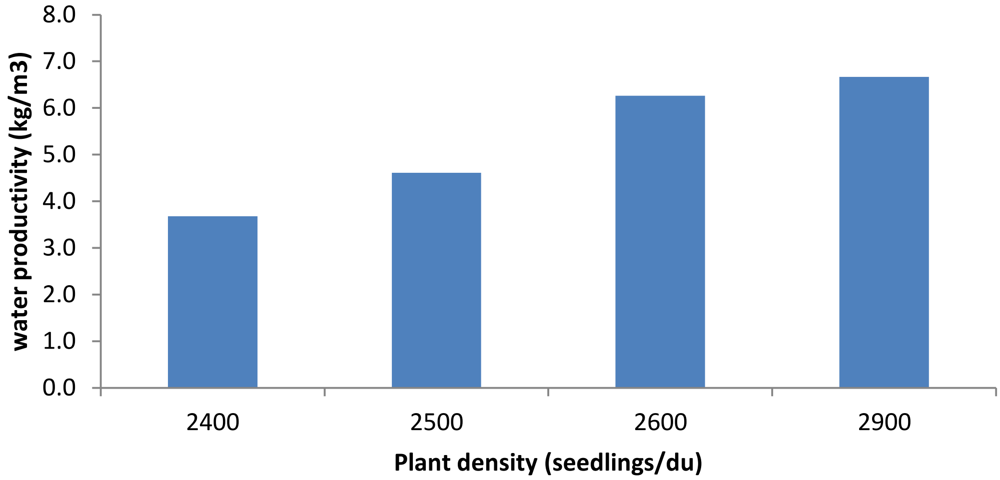

Fig. 17. Water productivity of cucumber crop based on plant density

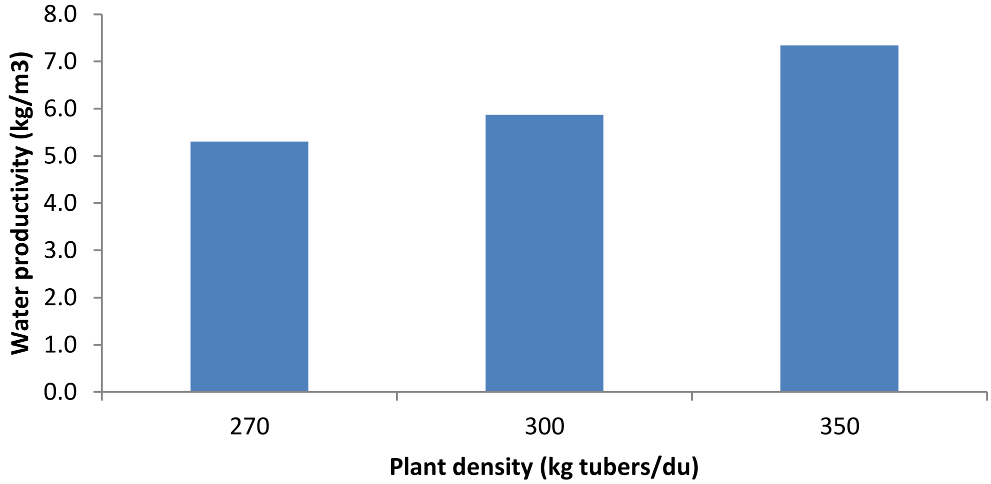

Fig. 18. Water productivity of potato crop based on plant density

Table 6. Physicochemical properties of the soil in the investigated areas

Study area	Soil depth	TN %	PO4 ppm	K ppm	Ca ppm	Mg ppm	Na ppm	Cl ppm	OM %	pH	ECe dS/m
Al-Bqaia'h	0-20	0.42	14.4	14	98	67.4	38	233.6	0.74	7.7	2.3
	20-40	0.49	14.9	13	88	22.2	41	212.4	0.8	7.76	1.8
Kashda	0-20	0.7	26.4	54	60	26.5	78	177	1.24	8.16	2.3
	20-40	0.56	28.1	70	50	88.75	23	191.2	1.19	7.68	2.4

3.9 Soil Properties

The results of soil analysis showed that the N, P, K concentrations, and the organic matter content were higher in Kashda area compared to Al-Bqaia'h area (Table 6). This improves the soil fertility status of these fields.

4. CONCLUSION

A field survey was carried out in Al-Bqaia'h and Kajda areas located at Tubas governorate in the West Bank of Palestine, for estimating water productivity of cucumber and potato crops. The selected areas considered extensive agricultural areas for vegetable crops mainly cucumber and potato. The field survey observed that the agronomic practices which carried out by the farmers played an important role in water productivity of cucumber and potato crops. Water productivity was affected by several factors and mainly affected by the performance of individual farmer, amount of water applied, method of application, the dripper or sprinkler discharge, the crop variety and the planting density. Estimating crop evapotranspiration of cucumber and potato crops based on climatic data considered an important tool for water management. It is recommended to use a dripper discharge of 2 L/hr instead of 4 or 8 L/hr for enhancing the water productivity of cucumber. Increasing the planting density up to 2900 seedlings/du improved the water productivity of cucumber crop. Water productivity considered an important parameter in water management issues mainly in the water scares regions like Palestine.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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