Journal of Applied Horticulture, 25(1): 74-78, 2023
https://doi.org/10.37855/jah.2023.v25i01.13
Journal of Applied Horticulture
ISSN: 0972-1045

Water productivity of drip irrigated melon in semi-arid climate

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Abstract

Water productivity refers to the yield produced per cubic meter of fresh water for a given crop. It is not recorded for most crops in Iraq and the Kurdistan Region of Iraq (KRI), where water shortages have recently forced farmers to switch from conventional farming methods like surface irrigation on bare soil to modern farming methods like drip irrigation and mulching. This study is the first effort in Iraq and KRI to determine and report the water productivity for melons (*Cucumis melo* L.) grown on farms using drip irrigation and plastic mulch. Data on the production, the number of irrigations, the length of each irrigation, as well as the cost and benefit of production were collected from 24 farmers who produced melons in 2022 on an area of 56 ha. Then, the yield, the amount of water applied, and the water productivity were determined. The mean value was 37.4 tons ha^{-1} for yield, 5,486 m^3 ha^{-1} for water applied, and 7.1 kg m^{-3} water for productivity. Hence, 140 litres of water were applied to produce 1 kilogram of melon. A cost-benefit analysis showed that water applied accounted for 18% of the overall production benefits, production expenses for 37%, and net benefits for 45%. Therefore, melon production is a profitable rising business in the region. In light of the present water shortage in the area, it is concluded that the recent switch from bare soil surface irrigation to drip irrigation and mulching is a successful adaptation approach.

Key words: Farm-scale, agricultural water, mulch, Kurdistan Region of Iraq, adaptation approach

Introduction

The world's population reached 8.0 billion individuals in mid-November 2022 and is expected to reach 9.7 billion in 2050 around the world (UN, 2022). Therefore, food production must be boosted by 60% in developed nations and by up to 100% in developing countries (Alexandratos and Bruinsma, 2012). 60% to 90% (Bastiaanssen and Steduto, 2017) or on average, 70% of the world's freshwater withdrawals are used for agriculture, mostly for irrigation (WorldBank, 2022).

Irrigation methods include surface, sprinkler, and drip irrigation. In surface irrigation, water is applied by gravity flow to the surface of the field. Drip irrigation is the delivery of water to the soil at low rates (2–20 L hr^{-1}) using a network of outlets-equipped, small-diameter plastic pipes. Close to the plants, water is applied so that just a portion of the soil (15–60%) is wetted. Unlike other irrigation methods, drip irrigation applies water more often (usually every 1-3 days), ensuring the soil has the ideal moisture content for healthy plant development (Brouwer *et al.*, 1988). Studies have shown drip irrigation uses significantly less water than surface irrigation, ranging from 35 to 80% less (Darouich *et al.*, 2014; Fuentes *et al.*, 2018; Kadasiddappa and Rao, 2018; Boutheina *et al.,* 2022). Other advantages of drip irrigation include improved crop quality, reduced yield variability, and increased crop survival (Kadasiddappa and Rao, 2018).

Plastic mulch improves the environment for plant growth through energy balance at the soil surface and prevents weed development, retains heat, and conserves soil moisture (Shah *et al.,* 2022; Parmar *et al.*, 2013; Ibarra-Jimenez *et al.*, 2006). Farmers believe that plastic mulch results in water savings of between 24 and 26%, according to surveys by Ingman *et al.* (2015). Plastic mulches can be used with drip irrigation to increase crop quality and yield (Preet *et al.,* 2022; Akbari and Farhadi, 2022; Yaghi *et al.*, 2013; Romic *et al.*, 2003). Therefore, using plastic mulch in addition to drip irrigation can greatly reduce the amount of water used in agriculture.

The Kurdistan Region of Iraq (KRI) has a long history of growing a wide range of grains, fruits, and vegetables, earning it the moniker "breadbasket of Iraq". Due to the existence of the Tigris and Euphrates Rivers and their tributaries, both Iraq and KRI are regarded as being wealthy. However, this water resource is under great threats posed by dams constructed by upstream countries and climate changes. The neighbours control about 80% of the water in Iraq and 40% of the water in KRI. More than 30 dams have been constructed on the Euphrates River by Turkey and Syria, resulting in just half of the river's typical flow reaching Iraq. Iran has also constructed many dams on Tigris River tributaries that mostly flow through KRI (Al-Ansari *et al.*, 2018; Yousuf *et al.*, 2018). Water flow to the KRI would be completely cut when all the planned dams and their diversion tunnels are constructed (Chomani and Bijnens, 2016). Additionally, water resources in the area are being put under additional stress due to climate change, including drought, desertification, and rising temperatures (Hama-Aziz, 2022). Farmers in KRI have changed their agricultural practices over the past ten years to adapt to this water scarcity, moving away from traditional methods like surface irrigation on bare soil and toward more contemporary ones like drip irrigation with mulch.

Melon is one of KRI's most important vegetable crops. It ranks fourth in cultivated area and production after tomato, cucumber and watermelon, with annual yield production of 115,298 tons in 2020 (KRSO, 2021). It is often grown in open areas throughout the summer. Since the KRI experiences dry summers, irrigation water often comes from streams and wells.

Water productivity (kg m^{-3}) is defined as crop yield (kg ha^{-1}) per water supply to the crop (m^3 ha^{-1}). The water supply includes water for rain-fed areas (effective rainfall) and water (diverted from water systems) for irrigated areas (Cai and Rosegrant, 2003). Water productivity, then, shows how much water is applied to cultivate a given crop. As far as we know, no study calculated the water productivity of melon on a farm scale in Iraq and KRI.

Furthermore, most studies on water productivity have used controlled plot scale research, which frequently does not accurately reflect actual values of yield, water applied, and water productivity on large and commercial farms. Although water use for agricultural production is a highly imposing environmental concern, the only study conducted by Hama-Aziz *et al.* (2022) has reported water use and productivity on a farm scale for tomato production in KRI and Iraq.

As a result, more farm-scale research is needed to educate farmers and government decision-makers about agri-environmental policies. This study addresses the deficiencies mentioned above and is the first in Iraq and the KRI to quantify and report farm-scale water productivity for an intensive agricultural region that produces melons using drip irrigation and plastic mulch.

Materials and methods

The study area was in Penjwen district, east of Sulaimaniyah province in KRI in northeastern Iraq (Fig.1). The region has a semiarid climate with an average total annual precipitation of 1032 mm and mean annual temperature of 14 ^{o}C (Mustafa *et al.*, 2018). However, the country and the entire area experienced a remarkable decline in precipitation in 2022. Only 855 mm of precipitation fell on Penjwen overall in 2022.

In the last decade, the region has witnessed extraordinary production of numerous crops and vegetables, including melon, using mulch and drip irrigation. Twenty-four farmers who grew melons on 24 fields covering 56 ha provided the raw data for this study in 2022. Cantaloupe melons can be grown with both ways of seeding and seedling, but mostly by direct seeding. Seeds of melon (*Cucumis melo* L.) were sown from May or June and they grew until harvest in October (Fig. 2). Fertilizers of 13-32-13, 20-20-20, 15-5-35, and 15.5-0-0+26.5(Ca) were applied as sources of nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and calcium (Ca) by all farmers. Fertilizer application rates were 62.1 kg ha^{-1} for Nitrogen, 52.7 kg ha^{-1} for Phosphorus, 61.6 kg ha^{-1} for Potassium, 70.4 kg ha^{-1} for Sulfur, and 67.8 kg ha^{-1} for Calcium. It was noted that the application amount of these fertilizers increases every year, perhaps because farmers do not practice crop rotation.

Each farm's yield output (in tons) and applied water (in m^3) are required to calculate water productivity. Farmers provided data on yield production, duration of initial irrigation, number of irrigations, and routine irrigation length (Table 1). The following is the calculation for applied water. Mulch and drip tapes were laid 1.5 m apart (1 drip tape was 1,000 m long). One hectare had 6.4 drip tapes. One drip tape had 5,000 holes to water the melon's roots. 2.95 L hr^{-1} was the computed average flow from one hole. Melons are only grown with water diverted from wells, streams, canals, and ponds; thus, rainfall water was excluded from the applied water calculation of water productivity because it does not rain during the summer months when melons are grown.

Table 2 provides the cost of producing melons. All expenses were in Iraqi Dinar (IQD), and the 2022 exchange rate was used to convert them to US dollars (1 USD= 1,480 IQD). Some expenses, such as farm startup costs, well drilling costs, and the cost of creating pumps and tubing, are not included.

Results and discussion

Yield and water applied: All 24 farms had a combined cultivable area of 56 ha, and they produced 2,278 tons of melons, or around 2% of the 115,289 tons of melons produced in KRI overall

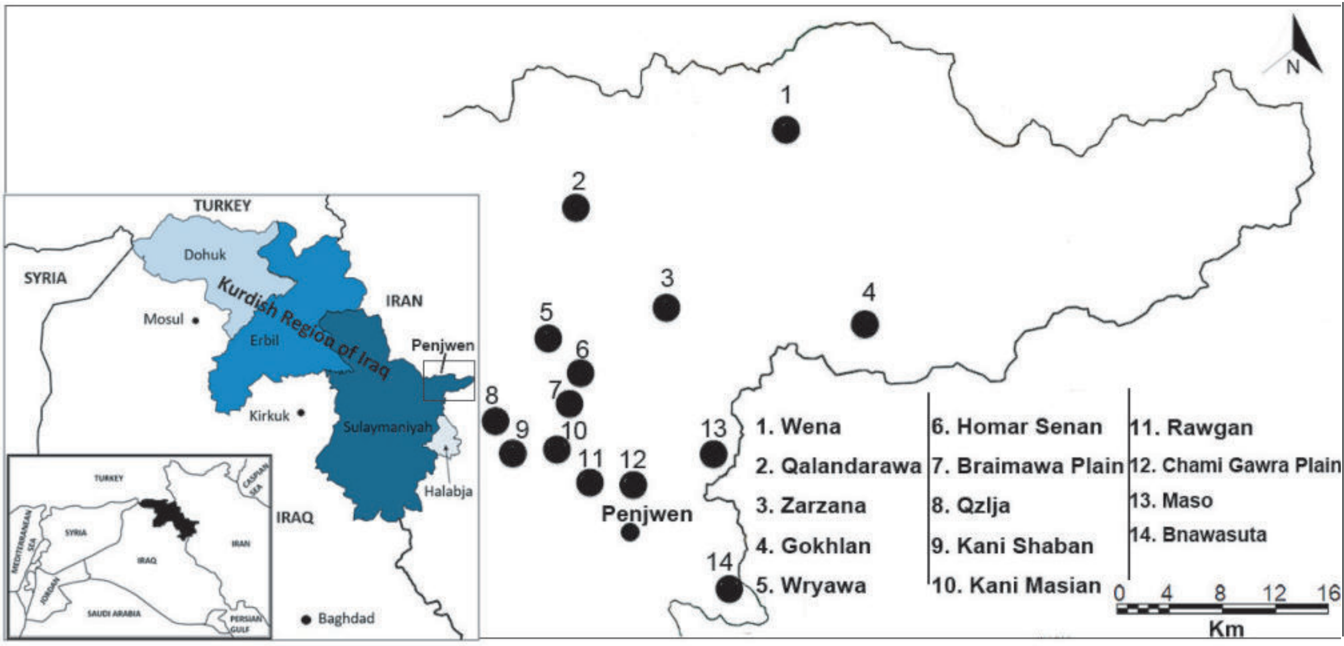

Fig. 1. Displays the map of the research area and the farm locations (*Administrative map of the Kurdistan region was adapted from Mohammed *et al.*, (2019) and the sampling locations from Google map).

Table 1. Number of drip tapes installed and area of cultivation, irrigation-related parameters, calculated amount of water applied, and harvested weight

Code of farmers	Location	Number of drip tapes	Cultivated area (ha)	First irrigation duration (hr)	Number of irrigation (n)	Duration of irrigation (hr)	Water applied (m^3)	Yield production (ton)	Water Productivity (Kg m^{-3})
1	Chami Gawra	17	82.7	3	30	1.5	12,036	93	7.7
2	Maso	13	2.0	2.5	31	1.25	7,910	102	12.9
3	Braimawa	8	1.3	2.5	33	1.75	7,110	42	5.9
4	Braimawa	7	1.1	2.25	31	1.5	5,033	46	9.0
5	Qzlja	7	1.1	1.5	28	2	5,937	44	7.4
6	Qzlja	18	2.8	1.5	31	1.75	14,802	113	7.6
7	Homara Senan	60	9.4	3	34	2	62,835	450	7.2
8	Kani Shaban	6	0.9	4	34	2	6,372	30	4.7
9	Bnawasuta	6	0.9	2.5	31	1.75	5,022	24	4.8
10	Wryawa	20	3.1	3	35	2	21,535	110	5.1
11	Qalandarawa	6	0.9	4	31	1.5	4,469	40	9.0
12	Gokhlan	45	7.0	2.5	38	1.75	45,799	360	7.9
13	Maso	23	3.6	3.25	34	1.75	21,288	143	6.7
14	Rawgan	9	1.4	2	30	1.5	6,239	48	7.7
15	Wryawa	10	1.6	3.25	33	2	10,214	61	6.0
16	Gokhlan	35	5.5	4	35	2	38,203	193	5.1
17	Wena	5	0.8	3	32	1.75	4,351	28	6.4
18	Narzana	6	0.9	2	30	1.25	3,496	34	9.7
19	Braimawa	7	1.1	2	29	2	6,195	37	6.0
20	Qzlja	8	1.3	2.5	35	1.75	7,523	44	5.8
21	Homar Senan	6	0.9	3.25	33	1.6	4,960	26	5.2
22	Rawgan	12	1.9	2.5	32	1.75	10,355	60	5.8
23	Narzana	12	1.9	3	35	1.75	11,372	62	5.5
24	Kani Masian	14	2.2	3	34	1	7,641	88	11.5

Table 2. List of the materials used for producing melons and their costs

Items	Cost	Unit
Drip tape cost	18	USD/tape
Mulch cost	26	USD/km
Mulch & tapes install labor	13	USD for installing one tape and mulch
Plowing cost	106	USD/ha
Seed cost	640	USD/ha
Seeding labor	53	USD/ha
Fertilizer& pesticide cost	826	USD/ha
Fuel	651	USD/ha
Harvesting & Loading labor	6.25	USD/ton
Farmland renting	1,333	USD/ha

(KRSO, 2021). Between the farms, the yield ranged from 26 to 51 ton ha^{-1}, with a mean of 37.4 ton ha^{-1} (Fig. 3). It was not possible to compare the results of this study to those from other studies since, as was previously indicated, there has been no research on yield and water productivity for melons in the country. However, a few investigations have been conducted globally and nearby. Rashidi and Keshavarzpour (2011) reported a yield of 27 tons ha^{-1} under drip irrigation in combination with plastic mulch in Iran. Al-Mefleh *et al.* (2012) observed (15-23 ton ha^{-1}) in a field experiment in Jordan. Cabello *et al.* (2009) noticed a 29-43 ton ha^{-1} yield in a plot scale study in Spain. The mean value of 37.4 ton ha^{-1} for the yield of melon determined in this study is within the normal range or even higher than the average compared to the studies mentioned above.

Fig. 2. Photographs of melon production in Homar Senan farm in the study area (A) on 3 June 2022 and (B) on 23 August 2022.

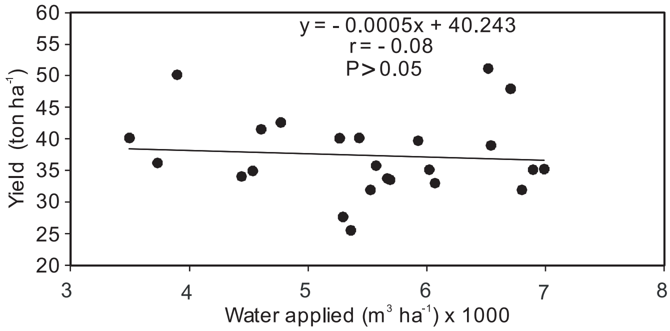

Fig. 3. Yield and water applied of melon production

The melon plants were irrigated 32 times on average, with a mean of 1.7 hours duration of irrigation. Among the farms, the amount of water applied significantly fluctuated from 3,493 to 6,986 m^3 ha^{-1} with a mean value of 5,486 m^3 ha^{-1} (Fig. 3). This calculated value of water applied was close to 4,975 m^3 ha^{-1} which was reported by Al-Said *et al.* (2012) for drip irrigation on a farm scale in Oman. Although it was not statistically significant ($P > 0.05$), a negative relationship (r = -0.08) was observed between water applied and yield, meaning that applied water may be more than required. Farmers, therefore, are recommended to reduce applied water to increase the yield of melon further.

Water productivity: The calculated water productivity had a mean value of 7.1 kg m^{-3} and a range of (4.7-12.9 kg m^{-3}, Table 1). This indicates that 140 litres of water produced 1 kilogram of melon. This value exceeded the water productivity reported in the literature for surface irrigation (Table 3). For instance, in a pilot study in Iran, Rashidi and Gholami (2008) reported water productivity of 5.3 kg m^{-3} for surface irrigation. Fan *et al.* (2014) recorded a mean value of 3.3 kg m^{-3} for surface irrigation on a farm scale in China. Therefore, this result confirms the fact that compared to surface irrigation, drip irrigation achieves high water productivity while using less water.

The result here is somewhat comparable to drip irrigation results from the literature. Seyfi and Rashidi (2007) reported water productivity of 9.1 kg m^{-3} of cantaloupe under the combination of drip irrigation and plastic mulch in a plot scale study in Iran. Al-Mefleh *et al.* (2012) observed 7-13 kg m^{-3} in a pilot study in Jordan, and Al-Said *et al.* (2012) calculated 5.7 kg m^{-3} in a farm study in Oman. It is observed that the estimated water productivity value here is lower than most values in plot studies. This is because, in contrast to plot research where irrigation water is tightly regulated, this study was conducted on a large farm where there may be significant water waste during irrigation. It is also observed that the number of farm studies in the literature is far less than that of plot study, highlighting a need for additional farm-scale studies to assist farmers and government decision-making on agri-environmental policies.

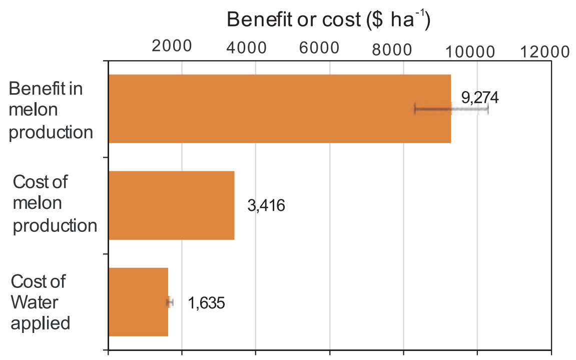

Fig. 4. The cost and benefit of melon production in the study area and the cost of water applied. The numbers are displayed as means, and the error bar represents standard error.

Table 3. The water productivity (WP) values for melons given in several publications and the WP value calculated in this study. The values are presented as the mean or the range

PW value kg m^{-3}	Irrigation method	Type of study	Country	Source
5.3	Surface	Plot	Iran	Rashidi and Gholami, 2008
3.3	Surface	Farm	China	Fan *et al.*, 2014
9.1	Drip+Mulch	Plot	Iran	Seyfi and Rashidi, 2007
4.7-5.6	Drip	Plot	Brazil	Silva *et al.*, 2007
13.8	Drip	Plot	Turkey	Kuşçu, 2017
5.7	Drip	Farm	Oman	Al-Said *et al.*, 2012
5.9-11.5	Drip	Plot	Spain	Cabello *et al.*, 2009
6.25	Drip	Farm	Brazil	Frizzone *et al.*, 2021
5-11	-	Plot	Turkey	Yavuz, 2021
7-13	Drip	Plot	Jordan	Al-Mefleh *et al.*, 2012
7.1	Drip + Mulch	Farm	Kurdistan Region, Iraq	This study

Melon and water economy: An economic analysis of the benefits of producing melons, their costs, and the cost of the water used was carried out (Fig. 4). The mean selling price was 0.248 USD for 1 kilogram of melon. Considering the average yield of 37.4 tons ha^{-1}, the total production value is 9,274 USD ha^{-1}. The overall cost of production was 3,416 USD ha^{-1}. Regarding the cost of water applied, some farmers were required to pay well owners 20% of their production profits, while others did not have to pay since they obtained their water from streams and canals. However, the cost of water applied was computed in this case to compare the cost and production benefit. The Kurdistan Regional Government of Iraq estimates that one cubic meter of water costs 0.298 USD (Rudaw, 2021; GOV.KRD, 2022). The average water applied was 5,486 m^3 ha^{-1} in this study, which makes the cost of water applied of 1,635 USD ha^{-1}. Hence, 18% of production benefits were spent on the water applied and 37% on production cost, and the remaining 45% was a net benefit. It is worth noting that in this study, the cost of water represented 18% of the production benefit. This was remarkably similar to the 20% that farmers who do not own water were required to pay well owners. Despite consuming a significant quantity of water, melon production is a successful business in the region.

The area produced a high yield, but the amount of water applied was also high, resulting in a moderate value for water productivity. 140 litres of water were used to produce 1 kilogram of melon. Perhaps more water was used than was required. As a result, farmers are advised to reduce the amount of water applied by improving irrigation schedules. According to the analysis of cost-benefit in this study, it was revealed that water applied accounted for 18% of the overall production benefits, production expenses for 37 and 45% of net benefits. As a result, melon production is a thriving rising industry in the region. More research is needed to determine and report the country's water productivity of melon and other crops.

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Received: March, 2023; Revised: March, 2023; Accepted: March, 2023