Water productivity of mulched and drip irrigated watermelon in Kurdistan Region of Iraq

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Abstract

Water productivity is the amount of yield produced for a specific crop per cubic meter of fresh water. It is not determined for majority of crops in Iraq and Kurdistan region of Iraq (KRI) where water shortage compelled farmers to practice modern techniques like drip irrigation and plastic mulch. This study aims to calculate and report the water productivity of watermelon produced using drip irrigation and plastic mulch at a farm scale. Data on the yield, the number of irrigations, the length of each irrigation, as well as the cost and benefit of production were gathered in 2019 from 32 farmers who produced watermelons in a 119 ha area. The mean value was 62 ton ha^{-1} for yield, 4,675 m^3 ha^{-1} for water applied, and 15 kg m^{-3} for water productivity. Approximately, 66 liter of water was applied to produce one kilogram of watermelon. A cost-benefit analysis showed that water applied accounted for 11% of the overall production benefits, production expenses for 31%, and net benefits for 58%. It is concluded that the later move from surface irrigation on uncovered soil to drip irrigation and mulching is an important adaptation strategy given the current water shortage in the area.

1. Introduction

By 2050, there will be about 9.7 billion people on the planet, up from an anticipated 8 billion in 2022 (UN 2022). Therefore, food production must rise by 60–100% (Alexandratos and Bruinsma 2012). 60–90% of the world's freshwater withdrawals are used for agriculture, mostly for irrigation (Bastiaanssen and Steduto 2017). Water is either applied through surface or drip irrigation methods. In surface irrigation, water is applied by gravity flow to the surface of the field. Either the entire field is flooded or the water is fed into small channels or strips of land. In the drip irrigation system, amount of applied water is controlled at approximate rate of 2 to 20 L hr^{-1} using a network tubes that controllably deliver water to each individual plant’s root zone area. The frequency of providing water is more often (typically every 1 to 3 days) in the drip irrigation system with ensuring the soil has the right amount of moisture for strong plant growth in comparison to other irrigation methods (Brouwer et al. 1988). Studies like (Darouich et al. 2014; Fuentes et al. 2018; Kadasiddappa and Rao 2018) shown that drip irrigation consumes 35–80% less water than surface irrigation. Additionally, drip irrigation has also minimized yield variability, improved survival of crops,, and crop quality (Kadasiddappa and Rao 2018).

Plastic mulch amends the environmental conditions and the energy balance of soil for plant growth (Ibarra-Jimenez et al. 2006). It helps in preserving soil moisture and temperature, and preventing weed from growing (Parmar et al. 2013). According to Ingman et al. (2015), using plastic mulch results in water savings of 24–26% for farmers. Therefore, the combination of drip irrigation system and plastic mulch can significantly reduce amount of water consumption in agriculture (Romic et al. 2003; Yaghi et al. 2013).

The Kurdistan Region of Iraq (KRI), where a wide range of cereals, fruits, and vegetables have been farmed, was referred as the breadbasket of entire Iraq for a longtime. Iraq was considered water rich country in the middle east for having Tigris and Euphrates rivers flow through it. The water resources, however, are now under great threat caused by dams constructed by upstream countries and climate change. The source of water is mostly (about 80% of water in Iraq and 40% of water in KRI) controlled by the neighbor countries. The construction of dams on the Euphrates River by Turkey and Syria has resulted in just half of the river's typical flow reaching Iraq. Meanwhile, many dams has been built by Iran on Tigris River tributaries that mostly flow through the 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). Water resources in the area are being put under additional stress due to climate change including drought, desertification, and rising temperatures (Hama-Aziz 2022). To adapt to this water shortage, farmers in KRI have modified their agricultural practices during the past 10 years, switching from conventional surface irrigation method to modern drip irrigation system combined with mulch.

Watermelon is an important vegetable, widely cultivated throughout the world. According to the previous studies, watermelon crop production require a high amount of water (Erdem et al. 2001; Kuşçu et al. 2015), varying from 240 to 660 mm depending on the climatic condition and the length of the growing season. Within the last decade, watermelon production in KRI has significantly increased from 56,257 tonne in 2014 to 160,289 tonne in 2019. The production in 2020 rose to 397,838 tonne from 13,640 ha (KRSO 2021). It is often grown in open fields throughout the summer. Since the KRI has dry summers, streams and wells are frequently used to supply irrigation water.

Water productivity is defined as crop yield per cubic meter water applied to the crop, which either sourced from effective rainfalls and/or any other diverted from water systems (Cai and Rosegrant 2003). So, water productivity reveals the amount of water applied to grow a specific crop. No study that we are aware of has estimated the farm-scale water productivity of watermelons in Iraq and KRI.

Additionally, the majority of water productivity studies have relied on controlled plot scale research, which do not adequately reflect actual values of the crop yield, water use, and water productivity on large-scale farms. Therefore, more farm-scale research is required to aid in improving farmer and government decision-making about agri-environmental policies. This study, which addresses the deficiencies mentioned above, is the first of its kind in Iraq and the KRI to determine water productivity of watermelon crop cultivated under the use of drip irrigation system combined with plastic mulch.

2. Materials and methods

This study was conducted in the Penjwen district, east of Sulaimani governorate in KRI in northeastern Iraq (Fig. 1). The region has a semi-arid climate with a total annual precipitation of 1032 mm and a mean annual temperature of 14 ^{0}C (Mustafa et al. 2018).

The Penjwen region has witnessed incredible progress in producing several crops and vegetables in the last decade, including watermelon by using mulch and drip irrigation. More than 3,750 ha of watermelon are grown in Penjwen every year, producing a total of approximately 100,000 tonne. In this study, the data were collected from 32 watermelon crop farmers in 2019 with a total cultivated area of 119 ha. The farmers were started sowing watermelon seeds from mid-May to mid-June and it grew until mid-July to mid-August when they were harvested (Fig. 2). The length of the growing period depends on the seed type. Seven types of seeds were used, namely, Zenon, Laredo, Tango, Faraw, Mirage, Heed, and Canned which had a length growing (60, 70, 70, 70, 75, 90, and 90 days), respectively. The fertilizers applied were Nitrogen, Phosphorus and Potassium (N-P-K) within the ratios of 21-0-0, 12-61-0, 10-15-35, and 20-20-20. The application rates of the fertilizers in average were 15.7 kg ha^{-1} Nitrogen, 28.8 kg ha^{-1} Phosphorus, 18.6 kg ha^{-1} Potassium, and 38.4 kg ha^{-1} Calcium. In addition, 160 kg ha^{-1} of poultry manure was applied with some other micronutrients.

Yield output (in tonnes) and water applied (in m^3) for each farm are required to calculate water productivity. Farmers provided data on yield production, initial irrigation duration, 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 watermelon's roots. 2.95 L hr^{-1} was the computed average flow from one hole. The watermelons are only produced using water that has been diverted from wells, streams, canals, and ponds.

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

Code of farmers	Location	Number of drip tapes	Cultivated area (ha)	Type of seed	First Irrigation (hr)	Number of irrigation (n)	Period of Irrigation (hr)	Water applied (m^3)	Biomass produced (tonne)
1	Chamigawra	20	3.1	Laredo	2	32	2	19,470	145
2	Braimawa	24	3.8	Zenon	2	23	0.67	6,163	240
3	Braimawa	20	3.1	Laredo	1	19	2.5	14,308	145
4	Braimawa	8	1.3	Zenon	3.5	22	2	5,605	80
5	Braimawa	6	0.9	Tango	3.5	28	2	5,266	54
6	Wiryawa	2.5	0.4	Zenon	5	28	2.67	2,941	25
7	Wiryawa	13.5	2.1	Zenon	3	26	2.67	14,421	135
8	Wiryawa	14	2.2	Zenon	3	26	2.5	14,042	140
9	Hargina	12	1.9	Mirage	3.3	35	1	6,779	126
10	Qizilja	9	1.4	Zenon	2.5	39	0.67	3,801	90
11	Qizilja	4	0.6	Mirage	2.5	45	0.67	1,926	42
12	mirmam	5	0.8	Faraw	3	36	1.25	3,540	45
13	mirmam	11	1.7	Zenon	3	28	1.25	6,166	110
14	Gokhlan	200	31.3	Zenon	3	28	2	174,050	2000
15	Bistan	20	3.1	Zenon	3	32	1.5	15,045	200
16	Chamigawra	27	4.2	Zenon	3.5	28	1	12,545	270
17	Kanishaban	30	4.7	Zenon	4	28	1	14,160	300
18	Gokhlan	30	4.7	Zenon	3.5	28	1.5	20,134	300
19	Nzaraiy	36	5.6	Mirage	3	27	1.67	25,536	378
20	Nzaraiy	9	1.4	Mirage	3	26	1.5	5,576	95
21	Rawgan	4	0.6	Zenon	4	28	1	1,888	40
22	Kani-Sif	20	3.1	Heed	6	34	1.5	16,815	180
23	Bnawasuta	9.5	1.5	Zenon	2.5	39	0.67	4,012	95
24	Wiryawa	11	1.7	Zenon	2	28	2	9,411	110
25	Penjwen	68	10.6	Zenon	5.3	28	1.5	47,442	680
26	Penjwen	10	1.6	Tango	5.3	32	1.5	7,862	90
27	Qalandarawa	10	1.6	Canned	5	42	1	6,933	85
28	Qalandarawa	12	1.9	Zenon	4	28	1	5,664	120
29	Tatan	46	7.2	Canned	4	39	1.5	42,406	391
30	Bimawa	12	1.9	Zenon	3	28	1.5	7,965	120

Code of farmers	Location	Number of drip tapes	Cultivated area (ha)	Type of seed	First Irrigation (hr)	Number of irrigation (n)	Period of Irrigation (hr)	Water applied (m^3)	Biomass produced (tonne)
31	Bimawa	30	4.7	Canned	3	41	2.25	42,148	255
32	Penjwen	25	3.9	Mirage	3	35	2	26,919	263

Table (2) provides the cost of producing watermelons. All expenses were in Iraqi Dinar (IQD), and the 2019 exchange rate was used to convert them to US dollars (1 USD = 1,200 IQD). The start-up costs for farms, the cost of drilling wells, and the cost of generating pumps and tubes, are not included in this calculation of expenses. The Statistical Package for Social Sciences (SPSS) software (ver. 20.0) were used for statistical analyses of the collected data. The significance levels (with p-value of 0.05) among the treatments were compared using a one-way analysis of variance (ANOVA) and Post-hoc tests (LSD) with an approximate normality assumption of the data.

Table 2
Watermelon production needs and costs

Needs	Unit	Cost
Tilling	USD ha^{-1}	106
Drip irrigation tapes	USD $tape^{-1}$	18.3
Plastic mulch	USD km^{-1}	26
Labors for installation of the tapes and mulch	USD tape and mulch $roll^{-1}$	12.5
Seed	USD ha^{-1}	435–652
labor for seeding and transplantation	USD ha^{-1}	53
Fertilizers and pesticides	USD ha^{-1}	704
Fuel	USD ha^{-1}	320
Labor for harvesting and loading	USD $tonne^{-1}$	6.25
Transportation and unloading	USD $tonne^{-1}$	18.3
Rent a farmland	USD ha^{-1} $season^{-1}$	1,333

3. Results and discussion

3.1. Yield

The total yield of all 32 farms combined was 7,348 ton which represents for about 4.5% of total watermelon production in KRI of 160,289 ton. Figures (3) illustrated that the watermelon yields were varied between 46 to 67 tonne ha^{-1} with a mean value of 62 tonne ha^{-1}. 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 watermelons in the country. However, there are some studies conducted in nearby countries and globally. Alizadeh et al. (2016) reported a yield of 40 tonne ha^{-1} watermelon with drip irrigation in Bushehr province in Iran. Rolbiecki et al. (2011) observed (29–30 tonne ha^{-1}) on Turkish soil. A decent commercial yield under irrigation is between 25 and 35 tonne ha^{-1}, according to FAO (2021). The mean value of 62 tonne ha^{-}

^{1} for the watermelon yield determined in this study was within the usual range or even above the average when compared to the studies mentioned above.

3.2. Water applied

The watermelon plants received irrigation 31 times on average, with a mean irrigation time of 1.5 hours. With a mean value of 4,675 m^3 ha^{-1}, the amount of water applied significantly varied across the farms, ranging from 1,644 to 8,992 m^3 ha^{-1} (Fig. 3). The amount of water applied in this study was remarkably higher than 2,078 – 2,916 m^3 ha^{-1} reported by Khalifa (2020) and 2,330 m^3 ha^{-1} noted by Pereira et al. (2019). Applied water, therefore, maybe was more than required. Another indication of the excessive irrigation was the presence of a negative relationship (r= -0.34) between applied water and yield. It is generally expected to have a positive relationship between these two figures as illustrated by (Erdem et al. 2001; Kuşçu et al. 2015; Sánchez et al. 2015). This means that over-irrigation in this study causes a slight decrease in the yield. Hence, farmers are highly recommended to improve irrigation scheduling so that water applied is reduced and yield is further increased.

3.3. Water productivity

The calculated mean value of water productivity was 15 kg m^{-3} (Table 3), with a range of (6–39 kg m^{-3}). This figure was greater than many other values for surface irrigation published in the literature. Rashidi and Gholami (2008), for instance, found a range of 2–14 kg m^{-3} in a review work in Iranian literature. Another study in Iran was by Alizadeh et al. (2016) who calculated a water productivity value of 3 kg m^{-3}. Also, Enyew et al. (2020) reported 0.94 kg m^{-3} in Ethiopia. The high value of water productivity calculated in this study might be because of the combination of plastic mulch with drip irrigation which was observed to give a high yield with less applied water (Kadasiddappa and Rao 2018; Yaghi et al. 2013).

However, the water productivity value in this study was found to be lower than several reported values in the literature for drip irrigation. Khalifa (2020), for instance, reported 37–57 kg m^{-3}, and Sánchez et al. (2015) calculated 23–30 kg m^{-3}. Fuentes et al. (2018) calculated 27 kg m^{-3} from a plot study of drip irrigation with plastic mulch. The low value of water productivity calculated in this study is likely to be related to the excessive irrigation mentioned earlier. Additionally, a considerable quantity of water may be lost during irrigation because this study was conducted on a large and commercial farm as opposed to a plot study where irrigation water is tightly managed. According to the finding of this study, approximately 66 liter of water was applied to produce 1 kilogram of watermelon.

Table 3
The given watermelons water productivity values in some previous studies worldwide and that calculated in this study. (Note: the values are presented either as mean or range).

Water productivity Kg m^{-3}	Irrigation method	Type of study	Country	Source
0.94	Surface	Plot	Ethiopia	(Enyew et al. 2020)
3	Surface	Farm	Iran	(Alizadeh et al. 2016)
2–14	Surface	Plot	Iran	(Rashidi and Gholami 2008)
6	Surface	Farm	Egypt	(M El-Marsafawy et al. 2018)
15 ± 0.1	Surface	Plot	USA	(Fuentes et al. 2018)
8	Drip	Farm	Iran	(Alizadeh et al. 2016)
23 ± 0.1	Drip	Plot	USA	(Fuentes et al. 2018)
23–30	Drip	Plot	Spain	(Sánchez et al. 2015)
27 ± 0.3	Drip + plastic mulch	Plot	USA	(Fuentes et al. 2018)
37–57	Drip	Plot	Egypt	(Khalifa 2020)
15 ± 7	Drip + plastic mulch	Farm	Kurdistan Region, Iraq	This study

3.4. Types of seed

Seed types showed differences in yield, water applied, and water productivity (Fig. 4). Crop yields in Mirage (67 tonne ha^{-1}), and Zenon (64 tonne ha^{-1}) were the highest, and crop yields in Laredo (46 tonne ha^{-1}), and Canned (54 tonne ha^{-1}) were the lowest, and the other types were in between. However, these differences in yield were not statistically significant ($P > 0.05$). Unlike crop yield, water applied showed significant differences among different types of seed. Water applied in Zenon (4,267 m^3 ha^{-1}) and Mirage (4,419 m^3 ha^{-1}) were significantly ($P \leq 0.05$) lower than that in Canned (6,443 m^3 ha^{-1}). Consequently, the water productivity value in Zenon (17 kg m^{-3}) was significantly higher than in Canned (9 kg m^{-3}). This means that, in comparison with other seed types, the Zenon seed type had the best performance as it gave a slightly higher yield with less water applied. This is probably because the length of the growing period of Zenon (60 days) was the shortest of all the seed types. This result perhaps was already known by some of the farmers because the Zenon type was used most in the area. However, there were still some farmers who used only low-performing seed type (i.e. canned), so they may be encouraged to switch to using Zenon and Mirage seed types.

3.5. Watermelon and water economy

An economic analysis of the benefits of producing watermelons, their costs, and the cost of the water applied was carried out (Fig. 5). The mean farm price of selling watermelon was 250 USD $tonne^{-1}$ during the study. The value of total watermelon production for that season was 15,500 USD ha^{-1}, as the average yield was about 62 tonne ha^{-1}. The total calculated cost of the watermelon production was 4,845 USD ha^{-1}. Although farmers did not have to directly pay for irrigation water as the water comes from streams and wells, the cost of irrigation water was calculated in this study in order to show the hidden value of applied irrigation water for watermelon production in the region. The general directorate of agriculture and water of KRI estimation for 1 cubic meter of water cost was 0.298 USD. The mean of water applied was approximately 4,675 m^3 ha^{-1} which prove that the cost of water applied could be about 1,719 USD ha^{-1}. Hence, 11% of production benefits were counted on the water applied and 31% on production cost, and the remaining 58% was a net benefit. According to this, one watermelon with 10 kg was worth 2.5 USD, from this 0.78 USD was the cost of production and 0.28 USD was the cost of applied water, so 1.44 USD was the net margin. Keeping in mind that the cost of water was even augmented in 2021 and 2022 when farmers with no irrigation water had to pay 20% of their total margin to the water owners. From the results of this study it was resolved that though the use of irrigation was noticeably high amount, still production of watermelon is considered as a profitable business.

4. Conclusions

For the majority of crops in Iraq and KRI, water productivity was not recorded. This study was aimed to determine water productivity of watermelon grown under plastic mulch and drip irrigation system on farm-scale. A relatively high yield was observed, the amount of the irrigation water applied was also high, resulting in a moderate rate of water productivity. It was observed that the combination of plastic mulch and drip irrigation has made the watermelon production a successful rising industry in the region. Further studies are recommended to determine water productivity of other crops in the country.

Declarations

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Conflict of interest: The authors have no relevant financial or non-financial interests to disclose.

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Figures

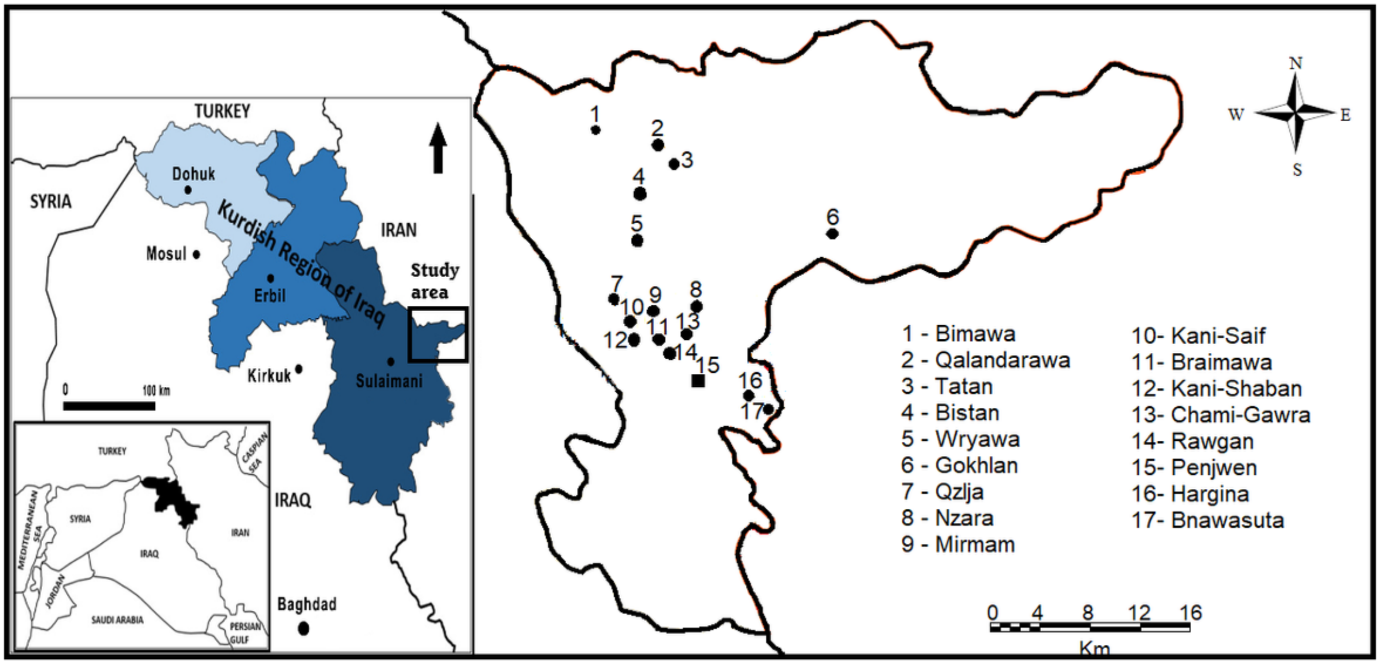

Figure 1

The map of study area showing the 17 studies sites and villages

Figure 2

Photographs of watermelon production in a study area; (A) Plant vining stage on13 June 2019, and (B) Harvesting time on 31 August 2019.

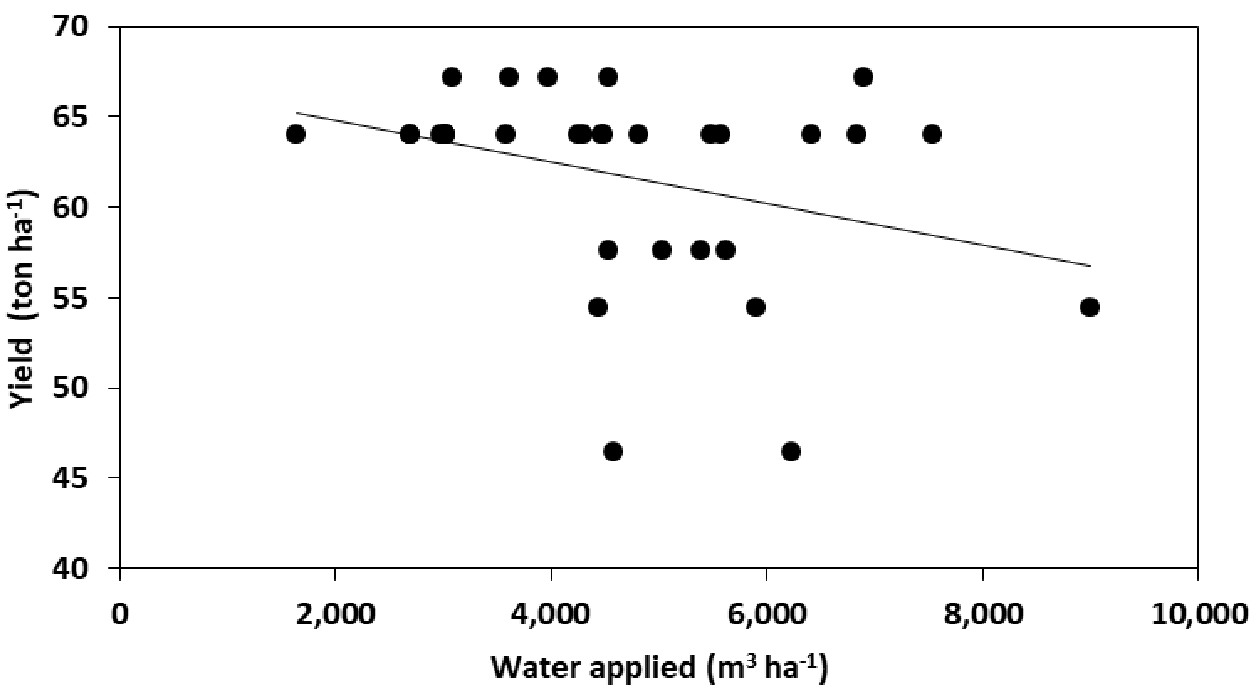

Figure 3

Yield and water applied

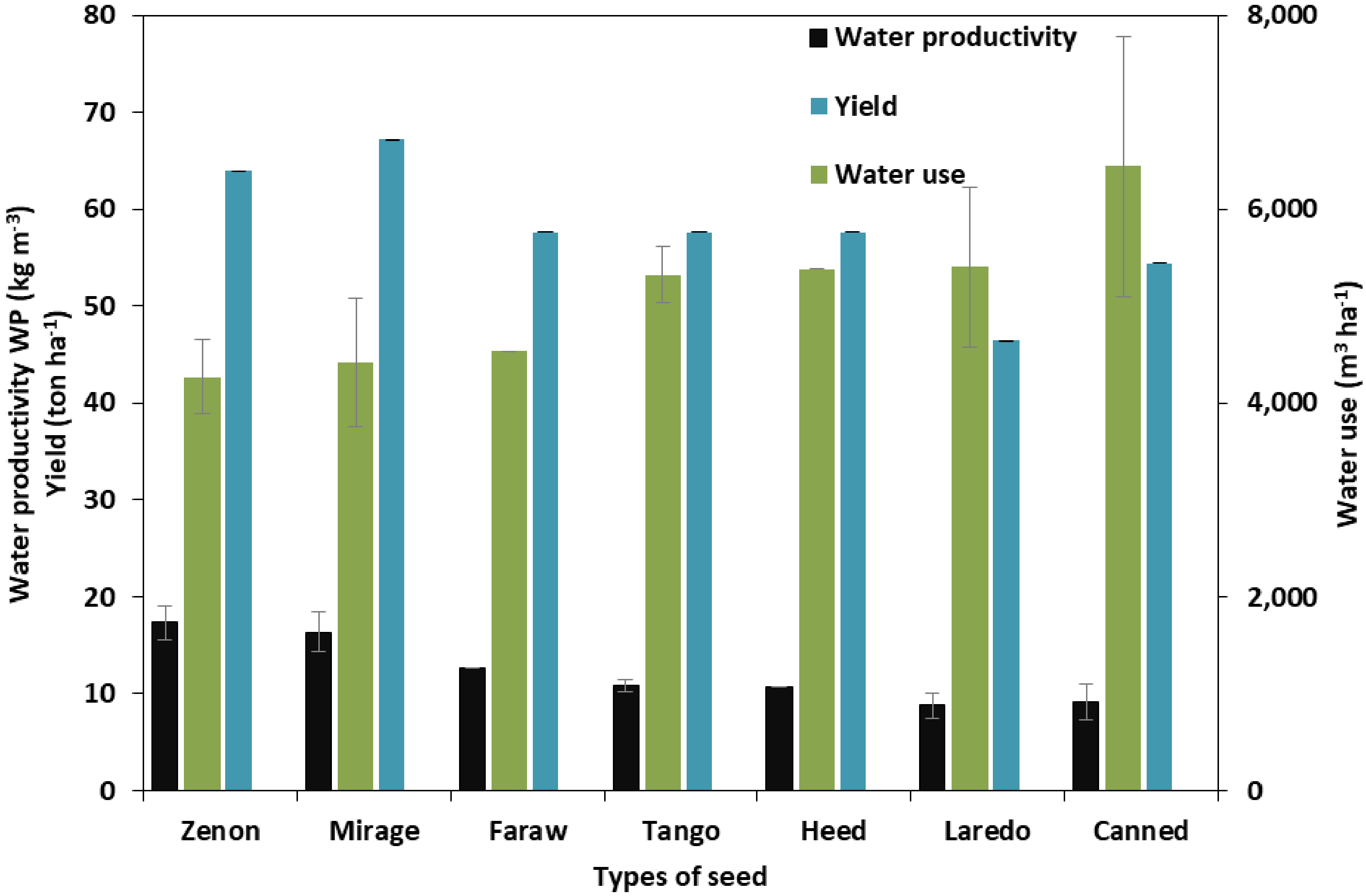

Figure 4

Water productivity, yield, and water applied for different types of seeds used in the study area. (Note: The mean values are presented with their standard error bars).

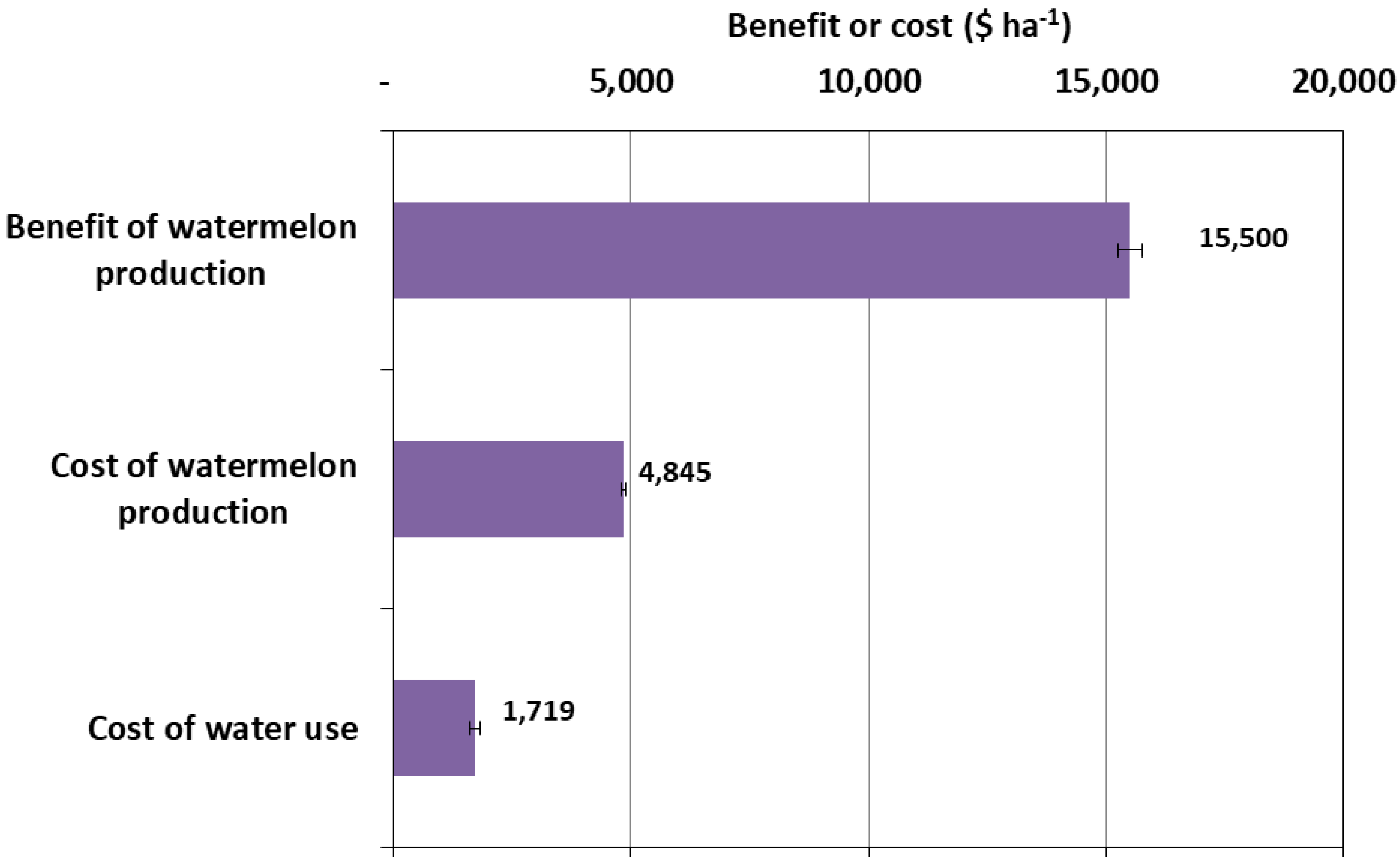

Figure 5

The cost and margin ($ ha^{-1}) of watermelon production in the study area. (Note: The mean values are presented with their standard error bars).