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Effect of furrow and drip surface irrigation on growth and yield of broccoli (Brassica oleracea) grown under mulch and non-mulch conditions

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Abstract:

Adopting low-input and water-efficient technologies is crucial for crop production and agricultural sustainability, particularly in semi-arid regions, as the country's growing water demand highlights. The goal of the current study was to assess how well plastic mulch works at the field level to enhance surface irrigation performance. The combined effects of drip and furrow irrigation lengths, with and without plastic mulching, on broccoli productivity were evaluated in a field experiment. According to the study's findings, mulching produced the most flowers overall, with surface irrigation producing 20.67 Mg ha^{-1} and drip irrigation 18.26 Mg ha^{-1}, Additionally, under furrow irrigation, broccoli flowers with mulching had larger average sizes (35.22 cm) than those without mulching (26.76 cm).

Key word: *Plastic mulch, Drip and Furrow irrigation, Broccoli.*

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تأثير الري بالمروز والتنقيط السطحي في نمو وحاصل نبات القرنابيط المزروع تحت ظروف التغطية البلاستيكية وبدونها

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الخلاصة

يؤكد الطلب المتزايد على المياه في الدولة على ضرورة اعتماد تقنيات منخفضة المدخلات وموفرة للمياه لإنتاج المحاصيل والاستدامة الزراعية، وخاصة في المناطق شبه القاحلة. يهدف البحث الحالي إلى تقييم فعالية التغطية البلاستيكية في تحسين أداء الري السطحي على نطاق الحقل. أجريت تجربة ميدانية لتقييم الآثار المشتركة لأطوال المروز والري بالتنقيط، سواء مع أو بدون التغطية البلاستيكية، على إنتاجية البروكلي. أشارت نتائج الدراسة إلى أن التغطية البلاستيكية أدت إلى أعلى إنتاج إجمالي للزهور، حيث بلغ إنتاج الري بالتنقيط 18.26 ميكاغرام للهكتار والري السطحي 20.67 ميكاغرام للهكتار. كما أدت التغطية في الحصول على أحجام أكبر لزهور البروكلي تحت الري بالمروز، بمتوسط 35.22 سم، مقارنة بـ 26.76 سم مقارنة بعدم استخدام التغطية. في نظام الري بالتنقيط السطحي، كان قطر زهرة البروكلي 44.78 سم مع التغطية البلاستيكية و39.67 سم بدونها. وأظهرت النتائج أن أزهار البروكلي المزروعة باستخدام الري بالتنقيط السطحي، سواء كانت مغطاة بالغطاء البلاستيكي أم لا، كان متوسط قطرها أكبر من تلك المزروعة باستخدام الري بالمروز.

الكلمات المفتاحية: *الملش البلاستيكي، الري بالتنقيط والري بالأثلام، البروكلي.*

Introduction

There are major environmental barriers to agricultural productivity due to climate change and global warming. Global consumers, including urban, industrial, agricultural, and environmental users, are increasing their water consumption and demand despite the limited supply of water resources (Simsek, 2012; Liu, *et al.,* 2013; Xia *et al.,* 2017; Peters-Lidard *et al.,* 2021; Roy *et al.,* 2022). Both domestically and internationally, agriculture is a significant user of water resources (Khan and Abbas, 2007; Pfister *et al.,* 2009; FAO, 2011; Levintal *et al.,* 2023). Agriculture is the most water-intensive industry, using 87% of freshwater for irrigation (Dalin *et al.,* 2015; Aivazidou *et al.,* 2016; Wu *et al.,* 2022). Even worse, water shortage significantly limits agricultural development in dry locations, underscoring the need to conserve water for sustainable agricultural and economic growth (Karthe *et al*, 2015). In order to lessen the risks that drought circumstances bring to agricultural productivity, research has been done on agricultural water-saving systems. Consequently, it is essential to conduct research aimed at creating and applying methods that minimize excessive water consumption and degradation of freshwater resources within the supply chain stages that significantly contribute to local water scarcity, whether directly or indirectly, as noted by Aivazidou *et al.* (2016); Quinteiro *et al.* (2014) and Ati et al. (2025c). Additionally, Petruzzello (2023) highlighted that improving irrigation technologies is a crucial approach to mitigating water scarcity in agriculture.

The amount of irrigated cropland is predicted to keep growing as the population and food demand increase (UN. World population prospects 2019; Mayanja *et al*., 2020; Rosa *et al*., 2020). Without a doubt, this will put further strain on agricultural water supplies. The conflict between growing irrigation demand and water shortages will worsen in arid regions due to global climate change, underscoring the pressing need to increase crop water use efficiency. In order to reconcile the conflict between food production and water resources, the transformation of irrigation techniques has emerged as a key avenue. One of the most effective techniques is drip irrigation. Drip irrigation involves the delivery of water to the soil at minimal rates (2-20 L hr^{-1}) through a network of small-diameter plastic pipes equipped with outlets. Water is introduced near the plants, ensuring that only a portion of the soil (15-60%) becomes moist. This method of irrigation allows for more frequent water applications (typically every 1-3 days) compared to other techniques, thereby maintaining an ideal moisture level in the soil to promote healthy plant growth (Brouwer *et al*., 1988).

Li *et al*. (2021) illustrated the advantages of drip irrigation in enhancing water use efficiency by supplying water directly to the root zone. These systems have the potential to increase the homogeneity of irrigation water distribution in the field (Al-Lami *et al*., 2023; Ati *et al*., 2025a, b; Dawod *et al*., 2024). Numerous studies have observed a substantial decrease in water usage (ranging from 35% to 80%) with drip irrigation when compared to surface irrigation. Additional advantages of drip irrigation may encompass enhanced crop survival, reduced yield variability, and superior crop quality (Kadasiddappa and Rao, 2018; Fuentes *et al*., 2018; Neima *et al*., 2020). Plastic mulch alters the environmental conditions and energy balance at the soil surface, fostering more advantageous conditions for plant development (Parmar *et al.,* 2013; Cao *et al.,* 2021). One water-saving strategy that may have contributed to the increase is the adoption of plastic mulching technology that is most commonly used worldwide (Daryanto *et al.,* 2017). This technique has a significant impact on agriculture; it helps retain soil moisture and temperature. Ingman *et al.* (2015) confirmed that farmers estimate water savings of 24% to 26% when using plastic mulch. In addition to retaining soil moisture, it plays a very effective role in inhibiting weed growth in the field (Zhao *et al.*, 2023; Jones *et al.*, 2021; Biswas *et al.*, 2022). Furthermore, plastic mulches can be employed alongside drip irrigation to improve crop yield and quality. Therefore, mulched drip irrigation is an effective technology for saving water and increasing crop yields (Sui *et al.,* 2018; Li *et al.,* 2021; Wang *et al.,* 2021). Integrating drip irrigation with plastic mulch can greatly enhance water conservation in agricultural practices.

Both Iraq and the Kurdistan Region of Iraq (KRI) are characterized by the suitable conditions for its cultivation, and for numerous years, the KRI has been recognized for its cultivation of various types of vegetables. (Hammed and Al-Jbari, 2019; Abou El-Maged *et al.,* 2015). Although the two rivers (Tigris and Euphrates) and their tributaries are present in Iraq, agricultural lands, especially in Iraqi Kurdistan, suffer from a scarcity of water for irrigation. The scarcity of water caused by dams constructed by upstream nations and the effects of climate change is emerging as a significant threat to the agricultural sector in the region. Approximately 80% of the water resources in Iraq and 40% of those in the Kurdistan Region of Iraq (KRI) are regulated by neighboring countries. Additionally, the Kurdistan region is categorized as semi-arid due to low and erratic rainfall, which presents difficulties for managing water resources and promoting sustainable agriculture (Al-Ansari *et al.,* 2018; Yousuf *et al.,* 2018). Furthermore, climate changes such as drought, desertification, heightened evapotranspiration, and increasing temperatures are placing additional strain on the region's water resources (Sissakian *et al.,* 2013). In response to these challenges, farmers in Kurdistan have transitioned over the past ten years from conventional farming methods that utilized surface irrigation on bare soil to more advanced techniques like drip irrigation combined with mulch.

In Kurdistan's hilly terrain, mulching also reduces soil erosion and weed growth, which is particularly advantageous (Kumar & Singh, 2019). The overall irrigation efficiency is decreased by drip irrigation without mulching, which tends to increase moisture loss through evaporation (Sharma *et al.,* 2020). Mulching also helps with furrow irrigation, which is popular because it is easy to use. Mulching reduces runoff and water loss, increasing infiltration and crop yields (Singh & Patel, 2017). Nevertheless, furrow irrigation without. However, especially in regions with uneven topography, furrow irrigation without mulching leads to increased water waste and soil deterioration (Qureshi *et al.,* 2015). In order to solve the issues of water scarcity and soil conservation in Kurdistan's agriculture, it is advised to combine mulching with any irrigation technique (Al-Karaghouli *et al.*, 2016).

The Brassicaceae family includes many important vegetable crops, one of which is broccoli, whose scientific name is *Brassica oleracea Italica var.* A functional food, according to Villarreal-García *et al. (*2016). It is grown for its inflorescences, which are edible when they are in the flower bud stage with their thick, tender stalks. It is an annual herbaceous plant native to the Mediterranean basin. Meena *et al. (*2018) examine this relationship by comparing the growth and yield of broccoli grown with and without mulch under drip surface irrigation and furrow irrigation. The overall objective of the study was to investigate and determine the effect of different levels and types of irrigation water quantities, as well as the effect of using mulch on the quantitative and qualitative yield of broccoli.

MATERIALS AND METHODS

Experiment layout and design

The experiment was conducted out at the University of Sulaimani's College of Agricultural Engineering Sciences research field station in Bakrajo district, Sulaymaniyah governorate, Kurdistan Region of Iraq (35°32'40.9"N 45°21'55.2"E) during the growing seasons, from mid-September to the end of February 2024-2025.

As shown in table (1), the experiment was set up in a furrow and drip irrigation system with two primary treatments: plastic-mulched furrows (MF) and non-mulched furrows (NMF), and plastic-mulched drip irrigation (MDI) and non-mulched drip irrigation (NDI) (as control). In all treatments, the distance between furrows was 0.4 meters. At an operating in-line emitter, discharge was 2 L h^{-1}. Water from two types of furrow irrigation was distributed via a network of pipes. To prevent water from moving laterally between the plots, a 0.75-meter-wide trench was dug. A system of pipes carried surface irrigation water. Using the gravimetric method, a meter was used to estimate the amount of applied irrigation water for each experimental plot. Three replications and a Randomized Complete Block Design (RCBD) were used to set up the experiment. Throughout the whole growing season, use tap water sources for irrigation. A share-plow was used to plow the ground, and a rotating plow was used to soften it. The seedlings of broccoli (Brassica oleracea var. Agassi RZ) were moved to the open field plots.

Table 1: The experiment treatment and the irrigation types

MF	MF	MF	NMF	NMF	NMF
Plot interval to go (1 meter)					
MDI	MDI	MDI	NDI	NDI	NDI

Samples of soil were taken from the experimental site between 0 and 30 cm below the surface, and their physicochemical characteristics were examined using standard procedures (Black *et al.*, 1965) table (2). Irrigation was carried out when 35% of the available water in the soil was depletion and completed to the field capacity (Allen et al., 1998).

Parameters	**Soil Texture**			**Bulk density**	**Partical density**	**CaCO$_3$ (gm kg^{-1})**	**EC dS m^{-1}**	**pH**	**water content at**		**Available water**
	Sand	**Silt**	**Clay**						**KPa 33**	**KPa 1500**	

	(gm kg^{-1})	(mg cm^{-3})					
Soil test values	66.0 512 422 **Silty clay**	1.25 2.5	280	0.45	7.3	30.0 % 19.40 %	10.7 %

Table 2: Physiochemical parameters of studied soil

In mid-February 2025, the broccoli crops were harvested. Measurements of plant height (cm), number of leaves, leaf area (cm²), number of branches, flower diameter (cm), moist weight of plant (gm plant^{-1}), and total yield (Mg ha^{-1}) were made on nine plants from each experimental unit. The SAS 2012 program was used to statistically evaluate the collected data for all parameters and measurements. The means were compared based on the least significant difference (LSD) ($p \leq 0.05$). To assess and contrast how broccoli grown in a semi-arid climate grows, yields, and uses water when watered using furrow and drip irrigation methods, with and without mulching.

Results and Discussion

Plant Height (cm)

Table 3 shows significant differences in plant height between broccoli plants grown under drip and surface irrigation systems. The results indicated that the irrigation system used significantly affected plant height. Plants grown under surface drip irrigation achieved the highest plant height compared to drip irrigation, reaching 63 and 59 cm, respectively. Broccoli plants also achieved the highest plant height under mulch treatments, reaching 61.55 and 66.67 cm, respectively, under drip and surface irrigation systems. Drip and surface irrigation, together with mulch treatments, had a substantial impact on the development and production contributing characteristics of broccoli, including plant height, number of leaves per plant, leaf size index, plant spread, curd diameter, and curd yield (Thentu *et al.*, 2016).

Number of lateral branches (vegetative branch/plant^{-1})

Table 3 shows significant differences between broccoli plants grown under drip and surface irrigation systems in the number of lateral branches. The results showed that the irrigation system used significantly affected the number of lateral branches. Plants grown under drip irrigation systems achieved the highest plant height compared to the drip irrigation treatment, reaching 63 and 59 cm, respectively. Broccoli plants also achieved the highest height under mulching treatments, reaching 61.55 and 66.67 cm under the drip and surface irrigation systems, respectively.

Leaf area (cm²)

Table 3 shows significant differences between broccoli plants grown under drip and surface irrigation systems in the leaf area (cm²). The results showed that the irrigation system used significantly affected leaf area. Plants grown under drip irrigation systems achieved the highest leaf area compared to the drip irrigation treatment, reaching 63 and 59 cm. 40,604 and 28,684 cm^2, respectively. The highest leaf area for broccoli plants under mulching treatments was 31,456 and 42,443 cm^2 under the drip and surface irrigation systems, respectively.

Number of leaves

Table 3 shows significant differences between broccoli plants grown under the drip and surface irrigation systems in terms of the number of leaves per plant. The results indicated that the irrigation system used significantly affected the number of leaves per plant. Plants grown under the drip and surface irrigation systems produced the highest number of leaves per plant, compared to the mulching irrigation treatment, which reached 20 and 15, respectively. The highest number of leaves per plant for broccoli plants under mulching treatments was 16 and 21 under the drip and surface irrigation systems, respectively.

Table 3: Plant height (cm), number of lateral branches (vegetative branch per plant), leaf area (cm^2), and number of leaves.

Irrigation system	mulching	Plant height (cm)	Number of branches	Leaf Area (cm^2)	Number of Leaves
Furrow	With mulch	61.55	4.26	31456	16
	Without mulch	56.32	3.21	25912	13
Mean		59	3.7	28684	15
Drip surfaces	With mulch	66.67	4.65	42443	21
	Without mulch	60.27	3.87	38765	18
Mean		63	4.3	40604	20
LSD 0.05		1.35	0.26	389	0.86

Fresh vegetative weight (gm plant^{-1})

The results of Table 4 show significant differences between irrigation systems in plant fresh weight. The surface drip irrigation system yielded the highest fresh vegetative weight, reaching 1477 g plant^{-1}, while the drip irrigation system yielded 1281 g plant^{-1}. The results of the same table also show significant differences in the application of mulching technology, which yielded the highest fresh vegetative weight values for broccoli under the two irrigation systems used in the experiment. The average fresh vegetative weight reached 1336 and 1225 g plant^{-1} under mulching and without mulching, respectively, under the mulching system. It reached 1488 and 1465 g plant^{-1} under mulching and without mulching, respectively, under the surface drip irrigation system.

Flower Head Diameter (cm)

The results of Table 4 show significant differences between irrigation systems in broccoli flower head diameter. The surface drip irrigation system yielded the highest average flower diameter of 42 cm, decreasing to 31 cm under the drip irrigation system. The results of the same table also show significant differences in the application of mulching technology, which yielded the highest values in broccoli flower head diameter under the two irrigation systems used in the experiment. The average broccoli flower diameter was 35.22 and 26.76 cm under mulching and no mulching, respectively, under the furrow irrigation. It was 44.78 and 39.67 cm under mulching and no mulching, respectively, under the surface drip irrigation system. When mulch was used, the yield under a furrow irrigation system increased significantly. Broccoli production: Farmers may find that using mulching with a gravity-fed drip irrigation system is a technically feasible solution that will increase yields (Patle *et al.*, 2018).

Total yield of main flower discs (Mg ha^{-1})

The results shown in Table 4 showed significant differences between irrigation systems in total yield. The surface drip irrigation system produced the highest average total yield of main flower heads, reaching 19 Mg ha^{-1}, decreasing to 17 Mg ha^{-1}, a decrease of 11%. When compared to surface watering, the output of broccoli was greatly boosted by drip irrigation combined with mulch (Ravish Chandra *et al*.,2015). Mulching treatments also achieved the highest total yield of flower discs, reaching 18.26 and 20.67 Mg ha^{-1}under the drip and surface irrigation systems, respectively (DT et al.,2025) discovered that drip irrigation with plastic mulch at 100% irrigation water supply for yield resulted in the highest net seasonal revenue.

The increase in total yield and total yield indicators of broccoli may be due to the role of surface drip irrigation and mulching in improving the physical and chemical properties of the soil by increasing soil moisture retention and aeration. The drip irrigation system also provided a balanced and sufficient supply of nutrients for plant growth and plant readiness, retaining them in the effective root zone and preventing them from being washed away from that area, as occurs with mulch irrigation (Jabbar and Ati, 2025).

Table 4: Wet vegetative weight (gm plant^{-1}), flower head diameter (cm), and total yield of main flower heads (mg ha^{-1}).

Irrigation system	mulching	wet weight of plant (gm plant^{-1})	Flower Diameter (cm)	Total yield (Mg ha^{-1})
Furrow	With mulch	1336	35.22	18.26
	Without mulch	1225	26.76	16.45
Mean		1281	31	17
Drip surfaces	With mulch	1488	44.78	20.67
	Without mulch	1465	39.67	18.19
Mean		1477	42	19

LSD 0.05	8.29	2.11	1.36

Conclusion

1. In comparison to furrow irrigation and non-mulch circumstances, broccoli (Brassica oleracea) grows and yields much more when drip surface irrigation and mulching are used together. By lowering soil evaporation and supplying water straight to the root zone, these combinations increase water usage efficiency and encourages larger leaf area, larger blossom diameter, and higher yield overall, Mulching also supports plant development by preserving ideal soil temperature and moisture levels. Thus, using mulch with drip irrigation is a good way to manage water and increase broccoli yield, particularly in areas where water is scarce.

2. Farmers in Sulaymaniyah Governorate are recommended to adopt mulching with a surface drip irrigation system, which yields better yields and vegetative growth characteristics, as well as a lower water depth compared to furrow irrigation. This study is among a new study in Sulaymaniyah Governorate on horticultural vegetables grown in good areas there.

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