Shahid Chamran University of Ahvaz

Irrigation Sciences and Engineering (JISE)
Vol. 45, No. 2, Summer 2022, p. 31-48

Original Paper

Journal homepage: https://jise.scu.ac.ir

Comparison of furrow, drip tape irrigation, 2- hole bottle and sub-surface tape irrigation on the yield and yield component of (Raphanus sativus var. longipinnatus) radish

K. Baharloo[1], M. Albaji[2*], M. Golabi[3] and P. Tishehzan[4]

1- MSc Student of Irrigation and Drainage, Department of Irrigation and Drainage, Faculty of Water and Environmental Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.
2- Corresponding Author, Associate Professor, Department of Irrigation and Drainage, Faculty of Water and Environmental Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.*
3- Associate Professor, Department of Irrigation and Drainage, Faculty of Water and Environmental Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.
4- Assistance Professor, Environmental Engineering Department, Faculty of Water and Environmental Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.

ARTICLE INFO

Artlcle history:
Received: 10 June 2022
Revised: 20 July 2022
Accepted: 23 July 2022

Keywords:
Arid areas, Irrigation, Radish, Treatment, Water productivity, Yield.

TO CITE THIS ARTICLE:

Baharloo, K., Albaji, M., Golabi, M., Tishehzan, P. (2022). 'Comparison of furrow, drip tape irrigation, 2- hole bottle and sub-surface tape irrigation on the yield and yield component of (Raphanus sativus var. longipinnatus) radish', Irrigation Sciences and Engineering, 45(2), pp. 31-48.

Abstract

The purpose of this experiment is the comparison between four different method of irrigation which include: furrow irrigation, drip tape irrigation, sub-surface (t-tape 5 cm under soil) drip irrigation, and 2-hole bottle irrigation. This experiment was carried out in 2 continuous sowing season first was from November to January and the second one was from January to March of 2020-2021. In the first experiment, it is observed no significant difference in any components of radish which may be due to mild weather condition and sufficient rain fall. However, the best treatment for arid areas like Ahvaz, was bottle irrigation treatment with yield of 680.6 kg. ha^{-1} and water productivity of 0.3 $kg.m^{-3}$ and the least irrigated water. In this second experiment due to the lack of rainfall and abundance of sunlight the amount of water consumed for treatments increased. In the experiment bottle irrigation yield was 298.24 kg. ha^{-1} and water productivity was 0.105 $kg.m^{-3}$. In conclusion bottle irrigation for poor countries with limited water supply, areas where the cost of assembling a drip system is high or in counties or arid areas which suffer from lack of rainfall can be efficient in producing vegetable for household consumption. For better performance this form of irrigation can be automated which increase system's productivity. Bottle irrigation is low-cost, easy to operated and doesn't require manpower which makes it the ideal irrigation for poor countries like Africa and arid areas same as Ahvaz.

Highlights

- Plastic bottles collected from the environment can be used in bottle irrigation and reduce environmental pollution.
- In areas with limited water supply like rural areas bottle irrigation can be very effective.

 DOI: 10.22055/JISE.2022.41094.2034

- Among different irrigation methods in mild weather conditions bottle irrigation used lowest amount of irrigated water.
- Bottle irrigation method is recommended for rural people who cannot afford to buy drip system for the production of vegetables for household consumption.

Introduction

Radish (Raphanus sativus var. Longipinnatus) is an edible member of the Brassicaceae family. This vegetable has various different skin color root that ranges from white to pink and mostly is used in salads (Da Silva et al., 2020). In addition to its nutritional properties radish also have some health benefits which include: reduction of cancer risk, improvement of blood flow, and enhanced liver function due to being rich in vitamin C and antioxidant properties (Wagner et al., 2013). China and Mediterranean have been growing and consuming radish for thousands of years. In ancient Egypt even before the construction of the pyramids, they were a common food and radish is considered to be one of our most ancient cultivated plants. Generally commercial radishes are approximately 2 cm in diameter and are either red or white. They reach market size in 21 to 28 days (or longer in cool weather). Radish is cool season plant and in a proper soil temperature which is 18 to 30 °C it will take 3 to 4 days to germinate and the minimum and maximum temperature is 3 and 35 °C respectively, but the optimum temperature is 30 °C (Anonymous, 1988). The nutritional value of radish is related to the high amount of dietary soluble fiber and its antioxidant glucosinolide and isothiocyanate compounds (Peyvast, 2005). Roots remain in marketable condition only a short time before becoming pithy. Growth must be continuous and rapid for good quality. This crop requires good source of organic matter supply for good quality. Rocky or gravelly soils are not appropriate; Peat soils are also suitable for production of radish (Anonymous, 1988). Radish can grow in almost any weather condition and the best type of soil is sandy and loose soil. But in warm weather it cannot tolerate the heat and rapidly grow to seed and its quality is decreased and become more pungent in hot weather (Hassani et al., 2015).

Water resources in the world are being decreased by rapid growth of population, pollution of natural resources, global warming, and climate change. Quantity and quality of water in both arid and rainy areas have declined. Water scarcity and water demand have increased with population growth; therefore, the need to store water and sustain agriculture for pressurized irrigation methods has escalated. Surface drip irrigation and sub-surface drip irrigation are the most effective methods for water and food transfer, water storage, salinity management, and uniform water distribution (Odhiambo and Irmak, 2015). Applying these methods can decrease water loss, which is caused by evaporation, infiltration, deep percolation, and weed growth. These methods can lead to a suitable agriculture. Drip irrigation system includes drippers which can be put either on the soil or under it for discharging water on controlled area. A proper irrigation system must be able to discharge water uniformly. Inadequate water causes plant stress and yield reduction. Excessive irrigation can be problematic as well due to the fact that, it increases disease incidence and disturbs the natural growth of important parts of the plant (Solomon, 1993).

One the advance form of irrigation is sub-surface irrigation which applies water in small amounts to the soil through drippers which are placed beneath the soil and discharge water at same range of surface irrigation (ASAE std, 1999). SDI (Subsurface drip irrigation) has many benefits that surface drip irrigation doesn't have such as reduction in evaporation and deep percolation losses and removal of surface runoff (Camp, 1998). Drip irrigation has some advantage that other irrigation methods don't have such as water usage reduction. Decrees in evaporation loss, effective water use in plant roots zone, applying water with fertilizer, applying water with lower quality (Brown et al., 1981). Success of drip tape irrigation relies on choosing the proper irrigation tape and its hydraulic characteristics such as physical, chemical. Biological system pressure variation, irrigation water temperature, and manufacturing of coefficient of variation (CV_m) of emitters may change uniformity of water distribution and reduce the efficiency of irrigation (Abdel-Mawgoud et al., 2009; Bracy et al., 2003).

In the drip tape irrigation design the outflow discharge must be equal (Thokai et al., 2001). However, in the field a maximum of 10 differences is allowed (Brown et al., 1981). The main reason of this difference in emitter discharge (non-uniform water distribution in the field) is the fluctuation in farm operating pressure (Mostafa and Sultan, 2018). Another vital reason that changes the emitter discharge is the temperature. Variations in temperature in different times of the day, days of the week, and different seasons of the year (Thokai et al., 2001). Efficiency in drip irrigation can go up to 90% since water and nutrients are directly delivered to the crop root zone, however most farmers can't afford the cost of drip irrigation system. The benefits of drip irrigation are due to its uniform water application (Sandhu et. al., 2019), controlled root zone development, and better management since only the soil is wetted (Holmer and Schnitzler, 1997). Most rural farmers can't afford the expanses of drip irrigation; therefore, bottle irrigation offers a more modest option for economic production in areas with low rainfall or during times of water scarcity (Von Westarp et al., 2004). Drip irrigation is simply a system which delivers water to the root zone of each plant individually (Bajracharya and Sharma, 2005).

These new methods used in this study are drip tape irrigation and new irrigation methods such as drip irrigation with bottle that are effective in reducing surface evaporation, deep percolation, and water loss. Drip tape irrigation is one the forms of drip irrigation which was introduce by Davis Alpert and was first used in 1979 as t-tape; in this method water slowly exist through orifices (holes) in t-tape stripe. These t-tape stripes ate placed near the plant roots; these stripes are diverse in forms of thickness, inside diameter, and orifice flow (Burt and Barreras, 2000).

Bottle irrigation is one of the cheapest forms of drip irrigation since there is no need for to buy bottles because old bottle is useful, no need for powers to supply water and it is easy to make (Darouich et al., 2014). Bottle irrigation which is combination of traditional pitcher irrigation and modern drip irrigation is designed for irrigation pots and seedling of 1- to 3-year-old in Iran, in other countries different methods were implemented but they all had the same result which was water was gradually given to the plants (Zanganeh, 2009). Bottle irrigation is also the most inexpensive form of drip irrigation; water bottles can be used in this system which reduces the plastic pollution in some areas. In the Lowveld region of Eswatini (country in South Africa) which is an ideal place to grow vegetable farmers struggle to make ends meet that due to the low annual rainfall (about 450mm). Bottle irrigation in areas like this region can prove to be very productive (Darouich et al., 2014.) Bottle irrigation can also be used in mountainous areas where their terrain makes it hard to access them with vehicles in order to irrigated them and make the cost of assembling drip irrigation system to increase (Zanganeh, 2009). In poor countries like Africa or places with limited water supply and low rainfall and regions where farmers have hard time to irrigate them.

Drip irrigation can be an ideal form of irrigation for rural farmers and more efficient than sprinkler and furrow irrigation since only the root zone of the cropped area is irrigated. Since the cost of micro irrigation systems like sprinkler irrigation and drip irrigation is high, bottle irrigation offers a cheap system for farmer in poor countries to maximize their vegetable production for household consumption (Darouich et al., 2014). Bottle irrigation can be designed to irrigated larger farms and grow not only crops but trees. This system can be modified and also be automated for better performance and reduce water loss. Another benefit of this system is that it can be operated by anyone so the need for professional manpower is reduced (Zanganeh, 2009) and also because of the huge hole that can be priced into the bottler blockage happens infrequently (Darouich et al., 2014.).

The purpose of this experiment is the comparison between four different method of irrigation which include: furrow irrigation, drip tape irrigation, sub-surface (t-tape 5 cm under soil) drip irrigation, and 2-hole bottle irrigation. This experiment was carried out in 2 sowing seasons autumn and winter.

Materials and Methods

This experiment was carried out in 2 sowing season first was from November to January and the second one was from January to March of 2020-2021, on the Irrigation Research Station of Ahvaz Shahid Chamran University, in the Khuzestan Province, located in the south-west of Iran, latitude 31°18´18´´ N, longitude 48°39´68´´ E, and altitude 18 m above sea level. The local climate is arid, summers are hot and dry, and winters are sub mild.

The Karun River supplies all of the water demand of this region and also was used for this area water demand. The type of soil in this area is loam. Some physical and chemical properties of the experimental soil are given in Table (1).

WC was determined by the difference between the water content at field capacity (FC) and at permanent wilting point (PWP).

The irrigation methods used in this experiment are furrow irrigation, bottle irrigation (with 2 holes at the bottom for water to exit), drip tape irrigation, and sub-surface (t-tape 5 cm under soil) drip irrigation. In this experiment the both plots were same size 24 m^2 (8×3 m). For the first sowing the crops were hand sown on 19 November 2020 and on 13 December 2020 for the second sowing, row spacing was 0.25 m, plant spacing was 0.5 m, and the first plot hand sown on 30 January 2021 and second plot were also hand sown on 9 March 2021(Figure 1). At the sowing we used manure as fertilizer to help the crops sprout and after several weeks to help the plants 25 kg ha^{-1} of organic fertilizer were used which consisted of 12.5 kg ha^{-1} superphosphate and 12.5 kg ha^{-1} leonardite. Weed control was realized manually at monthly basis without any chemical input.

Table 1. physical and chemical properties of the experimental soil

BD (g cm^{-3})	depth									
1.59	(0-30)									
1.57	(30-60)									
1.50	(60-90)									
characteristics	Sand%	Clay %	Silt %	Nitrogen %	Wp (g g^{-1})	Ec (dS m^{-1})	pH	K_2O (kg ha^{-1})	P_2O_5 (kg ha^{-1})	OM
value	44	24	35	0.07	133.1	3.4	7.79	0.11	1.26	1.1

Fig.1-Exprimental Field

Fig. 2- A fully grown radish blub

Forty plants were randomly selected from each plot (treatment) (at maturity period of the plants) for measurement of fresh and dry biomass, fresh and dry bulb weight, fresh and dry leaf weight width, number of leaves on single plant, sowing index, and water productivity (Figure 2).

Biomass was estimated by weighing the total fresh matter at sowing and for dry biomass obtaining its water content from a sub-sample that was oven-dried at 70°C until constant weight.

Measured variables

Yield compounds

Yield compounds include fresh and dry fruit (bulb) weight, leaf weight, biomass weight, leaf length, bulb length, number of leaves, bulb width.

Water productivity

Agriculture is the largest water user therefore one of the challenges in modern worlds is to increase food production by using smaller amount of water which means an increase in water productivity. WP is defined as crop yield to water use ratio. The water supplied includes rainwater, irrigation or a combination of the two. WP is calculated by the fowling equation (Albaji et al., 2011).

$$WP_y = \frac{\text{Yield}}{\text{Irrigatation}} \quad (1)$$

Where:

WP_y = Yield water productivity (kg m^{-3})

Yield = Bulb (kg)

Irrigation = Total water given to treatments (m^3)

$$WP_b = \frac{\text{Biomass}}{\text{Irrigation}} \quad (2)$$

WP_b = Biomass water productivity (kg m^{-3})

Biomass = Weight of leaves and stems (kg)

Irrigation = Total water given to treatments (m^3)

Volume of irrigated water

Table (2) presents the meteorological data during sowing season, according to this data an arid climate prevails in the region according to mean rainfall amount, and rainfall amounts are low in the winter period.

The depth of irrigation for furrow irrigation was the determined by equation (3), in this experiment the ρb was 1.59 g cm^{-3}, root depth was 200 mm and θ_{fc} and θpwp were 19.39% and 8.30% respectively, so therefore as shown in the following calculation the depth of irrigation was 35.26 mm. the volume of irrigated water was calculated using Equation (4):

$$dn = (\theta fc - \theta pw) \times Zr \times \rho b \quad (3)$$

dn = Depth of irrigation (mm or m)

 DOI: 10.22055/JISE.2022.41094.2034

θ_{fc} = Soil moisture at field capacity level (percentage %)

θ_{pw} = Soil moisture before irrigation (percentage %)

Zr = Root depth (mm)

pb = Bulk density of soil (g cm^{-3})

$$V = dn \times A \quad (4)$$

V= Volume of irrigation water (m^3)

A= area of furrow irrigation treatment rows (m^2)

For drip (tape) and sub-surface (tape) irrigation treatment a 1000 lit water tank was used water was distributed through drippers that were installed on the main pipe which was attached to the water tank (Figure 3 and 4).

Table 2- Mean air temperature, relative humidity and total monthly rainfall during harvest season at Ahvaz

Month	Nov	Dec	Jan	Feb	March	Average
Temperature (°C)	20.50	19.80	18.70	20.70	21.40	20.22
Relative humidity (%)	65	76	60	53	41	56
Rainfall (mm)	2.46	1.47	0.001	0.94	0.10	Total rainfall (mm) 4.97

Fig. 3- drip irrigation treatment

Fig.4- Sub-surface drip tape irrigation

Fig. 5- Bottle irrigation treatment

Water tank was place 10 m above the ground so the water in the tank would distribute the gravity so there was no need for water pump. Since the diameter and the water pressure in the pipe was even and the water loss was at the minimum. Therefore, water was distributed evenly among each of 8 pipes that were used for drip and sub-surfaced drip tape irrigation. Each pipe irrigated almost 125 lit of water to each row.

For bottle irrigation treatment bottles were filled with water using watering can (Figure 5). Each bottle had the volume of 1 lit and 48 bottles were used so ultimately 48 lit water was used for irrigation each time for the bottle irrigation treatment.

Irrigation water for furrow irrigation was delivered by 32 mm polyethylene pipes and the water was distributed in this pipe by a pumping station which its source was the Karun River, required irrigation water was applied to the plots by short blocked-end furrows (Figure 6). Therefore, runoff and was assumed as zero because the plots had earthen embankments. Deep percolation was assumed as zero in practice (Hanks et al., 1978).

Drip and sub-surface drip tape irrigation tape and emitters were affected by water quality which causes problems like clogging and blockage. Prior to each irrigation (Each 1 days before irrigation) using the gravimetric method (Black, 1965) FC and PWP were measured then these values were converted to volumetric water contents using bulk density. According to the soil water contents measured, the plots of the treatments were irrigated from deficit moisture content (60% depletion of available water) of 0-30 cm soil layer to FC at each irrigation (Albaji et al., 2010).

In Table (3) amount water which was given to the plant in each irrigation period has been reported. This amount is consisted of water which was provided for the plant by irrigation and the amount of rainfall.

In bottle irrigation treatment bottles were filled by water and put between two plants, and in drip tape irrigation, and sub-surface (t-tape 5 cm under soil) drip irrigation treatment water was applied to the plot by drippers. The layout of the experiments was a completely randomized block design with four replications.

Statistical analysis

All statistical analyses were carried out using SAS 9.4, to determine significance among irrigation treatments. Duncan Multiple Range Test (α=0.01 and α=0.05) was used for mean separation. EXCEL (2016) was used to drawing the figures.

Results and Discussion

The following tables repent the data analysis which was carried out by the Duncan test as 1% and 5% probability level. Most of the data gathered from the first sowing season were not significant (Table 4). However, the data gathered from the second season show significant difference at 1% and 5% probability level (Table 5).

 DOI: 10.22055/JISE.2022.41094.2034

Fig. 6- Furrow irrigation treatment

Table 3- Irrigation scheduling

Treatments / Irrigation interval	Furrow (lit)	Bottle (lit)	Sub-surface drip (t-tape) irrigation (lit)	Drip (t-tape) irrigation (lit)
1st irrigation	320	48	125	125
2nd irrigation	-	48	125	125
3rd irrigation	-	48	125	125
4th irrigation	320	-	-	-
5th irrigation	-	48	125	125
6th irrigation	-	48	125	125
7th irrigation	320	-	-	-
8h irrigation	-	48	125	125
9th irrigation	320	48	125	125
10th irrigation	-	48	125	125
11th irrigation	320	48	125	125
12th irrigation	320	48	125	125
Total Irrigated water First sowing season (lit)	1923.93	483.93	1253.93	1253.93
		2nd sowing season		
1st irrigation	320	48	125	125
2nd irrigation	-	48	125	125
3rd irrigation	320	48	125	125
4th irrigation	-	48	125	125
5th irrigation	320	48	125	125
6th irrigation	-	48	125	125
7th irrigation	320	48	125	125
8h irrigation	-	48	125	125
9th irrigation	320	48	125	125
10th irrigation	-	48	125	125
11th irrigation	320	48	125	125
12th irrigation	-	48	125	125
13th irrigation	320	48	125	125
14th irrigation	-	48	125	125
15th irrigation	320	48	125	125
16th irrigation	320	48	125	125
Total Irrigated water second sowing season(lit)	2881.041	769.041	2000.041	2000.041

Table 4- Results of variance of radish Anatomical characteristics (first sowing season)

Source	DF	Fresh bulb	Dry blub	Fresh leaf	Dry leaf	Fresh biomass	Dry Biomass	Bulb length	Leaf Length	Width	No.leaves	Wp_y	Wp_b
Block	3	47.01ns	9.9ns	33.05ns	0.009ns	638.07ns	8.032ns	7.04ns	49.87ns	0.368ns	1.386ns	0.0159ns	0.0629ns
Treatment	3	254.37ns	211.32**	670.85**	0.823ns	6523.89**	4.97ns	10.15ns	56.28ns	0.072ns	2.716ns	0.35**	0.89**
Error	9	2033.62	48.97	330.5	2.18	950.18	11.95	16.95	137.67	0.805	3.97	0.4526	1.07
Coeff Var	-	22.72	26.1	27.29	20.69	12.84	20	10.20	10.03	8.8	8.6	21	28.49

ns: Not significant
*and**Significant at P<0.05 and P<0.01 level, respectively.

Table 5- Results of variance of radish Anatomical characteristics (second sowing season)

Source	DF	Fresh bulb	Dry blub	Fresh leaf	Dry Leaf	Fresh biomass	Dry Biomass	Bulb length	Leaf Length	Width	No.leaves	Wp_y	Wp_b
Block	3	56.72ns	1.001ns	5.92ns	0.059ns	542.05ns	1.32ns	3.93ns	38.64ns	0.2217ns	0.835ns	0.0008ns	0.038ns
Treatment	3	3336.24**	32.80**	122.44*	1.58*	2236.10**	16.02**	22.33**	102.67*	2.15**	50.980ns	0.003**	0.0589**
Error	9	381.43	12.51	81.38	1.31	1121.96	8.093	22.08	76.83	0.37	2.13	0.044	0.113
Coeff Var	-	13.69	20.88	17.05	20	20.45	22	9.98	9.75	8.01	8.45	21.5	16.28

*and**Significant at P<0.05 and P<0.01 level, respectively.
ns: Not significant

Weight of fresh Bulb

According to the result analysis of variance in the first experiment there are no significant differences between weights of fresh bulb in first sowing season. The maximum fresh weight 86.48 g was associated with furrow irrigation treatment and the minimum fresh weight 77 g belonged to drip tape irrigation treatment, (Table 6). However, in the second sowing season Test results showed that a significant difference was found at the 1% probability level between treatments (Table 7). According to our results furrow irrigation treatment with 73.5 g had the maximum fresh bulb weight and bottle irrigation with 37.28 g had the minimum amount fresh bulb weight. According to the results furrow irrigation treatment had the highest bulb weight among other treatments in both experiments because the treatment was provided with an adequate amount of water mild weather condition, and proper fertilizer. Based on horticultural science, growing and forming bulb is the most important part of radish growth (Dhaliwal and Klair. 2008). Temperatures above 32 degrees in the middle of the growing season cause the blub to lose weight and increases the amount of hollow and woody radish gland and in the cells of the root center with increase Temperature occurs lignin formation (Kano and Fukuoka, 1995). Howell et al. (1999) experimented with eggplant and concluded that the use of the furrow irrigation increased the fresh weight of the bulb (fruit) but reduced water productivity. They also concluded that if the plant is exposed to dehydration, its fresh weight will be reduced, which is corresponds with the results of this study.

Weight of dry Bulb

The analysis of variance results for dry weight of bulb showed significant difference at the 1% probability level (Table 4). The maximum dry weight belonged to furrow irrigation treatment at 19.43 g and the minimum amount belongs to drip tape irrigation treatment at 7.73 g (Table 6). In the second sowing season analysis of variance showed us a significant difference at 1% probability level between furrow and drip tape treatments (Table 5). The maximum dry bulb weight belonged to furrow irrigation treatment at 9.59 g and minimum belonged to drip tape irrigation treatment at 4.6 g (Table 7). The results showed a nearly identical bulb size in different treatments, but the difference in dry weight bulb may indicate a better transfer rate of photosynthesis and partitioning that resulted in the packing bulb and bulb density is higher. (Lashgari ,2014). Sobrado and Turner (1987) concluded that if the plant is exposed to water stress, the dry weight of different parts of the plant will be reduced. And slow down plant growth.

Weight of fresh leaf

Based on the results of the Duncan test, there was significant difference between bottle and drip tape irrigation at the 1% probability level (Table 4). The bottle irrigation treatment with 37.65 g had the maximum fresh leaf weight and the drip tape irrigation treatment with 12.5 g minimum fresh leaf weight (Table 6). In the second sowing season, the test showed a significant difference at 5% probability(Table 5). Based on the results most significant different was between furrow and bottle irrigation treatment with maximum of 24.63 g for furrow irrigation treatment and minimum of 17.56 g for bottle irrigation treatment (Table 7). However, in the second season furrow had the highest fresh leaf weight because of receiving more water than bottle irrigation treatment and also in high temperature growth of bulb is higher than leaf, hence bottle irrigation treatment has the lowest leaf weight (Camejo et al., 2005). Albaji et al. (2011) in their research also concluded that water causes the Turgor pressure, which increases cell division, which in turn increases the number and volume of plant leaves. This phenomenon has increased the weight of the leaves.

Weight of dry leaf

Base on the results of the Duncan test, the effect of different irrigation treatments on weight of dry leaf in the first experiment was not significant (Table 4). The furrow irrigation treatment with 3.23 g had the maximum fresh leaf weight and the sub-surface tape irrigation treatment with 2.58 g minimum fresh leaf weight (Table 6). In the second sowing season, the test showed a significant difference at 5% probability (Table 5). According to the test results most significant different was between furrow irrigation treatments with maximum of 2.74 g and sub-surface tape irrigation treatment with minimum of 1.8 g (Table 7). Dry leaves can be caused by disease, lack of moisture, excessive fertilizer, and in some case even excessive moisture. In this study lack of moisture cause the leaf to dry more than usual due the high temperature and this often happens during hot, dry weather when moisture evaporates before the plant can absorb it through the roots. Sometimes just like in our experiment in the second season when the plants haven't grown properly too may be to blame; too much can scorch the roots and burn the plant (Xiangyang et al., 2010) Sobrado and Turner (1987), and Jovzi and Zare Abyaneh (2015) also concluded in their research that lack of water in the plant reduces the dry weight of leaves, stems and tubers and reduces the total weight of the plant.

Weight of fresh biomass

In the first sowing season there was significant difference between treatments at 1% probability level (Table 4). The maximum amount which was 125.46 g was associated with bottle irrigation treatment and the minimum amount which was 67.62 g belonged to sub-surface tape treatment (Table 6) in the second sowing, there was significant difference in weight of fresh biomass at 1% probability level. According to the results obtained from furrow and bottle treatments (Table 5), The maximum amount of 86.09 g was associated with furrow irrigation treatment and the minimum amount of 49.92 g belonged to bottle irrigation treatment (Table 7). The weight if fresh biomass is mostly related to the weight of stem, size of stem, and amount water store in the plant. In this first experiment which was carried out in the mild weather condition rate of evaporation was low therefore most of the water was sort in the plant which increased the fresh biomass. In the second experiment which was carried out in warmer weather and the rate of evaporation increased, the size and weight of stem was lower than the first experiment hence the difference in biomass between the two experiments.

Weight of dry biomass

According to the variance analysis there was no significant difference among irrigation treatment in the first experiment (Table 4). The maximum amount of dry biomass weight belonged to bottle irrigation treatment at 8.13 g and the minimum belonged to sub-surface tape irrigation treatment at 6.12 g (Table 6). In the second sowing season the test results indicated that a significant difference was found at 1%probability level between different irrigation treatments in the terms Weight of dry biomass (Table 5). According to the result of the test the furrow and drip tape irrigation treatment had maximum and minimum of 6.15 and 3.31 g weight, respectively (Table 7). The conventional means of determining dry weight of biomass is the measurement of oven-dried samples. In the second experiment plants difference between the fresh and dry biomass was more than the first experiment that may be due the low amount of water which was store in the plants.

Bulb length

Based on the result of the Duncan test there were no significant difference in bulb length among irrigation treatments in the first experiment (Table 4). The maximum amount of bulb length was observed in drip tape irrigation treatment with amount of 16.45 cm and the minimum amount was observed in furrow irrigation treatment which was 13.83 cm (Table 6). In the second sowing season based on the test results there were significant difference was found at 1%probability level in bulb length among irrigation treatments (Table 5). The maximum amount was 13.16 cm which belonged to drip tape irrigation treatment and the minimum amount which was 9.25 belonged to sub-surface drip tape irrigation treatment (Table 7). Dlamini and Khumalo (2019) also observed in their studies that weight decreases with the increase of bulb length. These observations were in line with the results in this first sowing season. In the second season, due to the intensification of water stress by air temperature, the drip irrigation treatment caused narrow and long bulb.

Leaf length

According to the Duncan test result there no significant leaf length among irrigation treatments in the first experiment (Table 4). The maximum leaf length was 47.99 cm which belong to bottle irrigation treatment and minimum leaf length was 39.85 cm which belonged to drip tape irrigation treatment (Table 6). In the second sowing season based on the Duncan test there were some significant differences in 5% probability among treatments (Figure 3). The maximum leaf length was related to furrow treatment averaged 36.58 cm and the minimum one was associated with sub-surface drip tape irrigation treatment averaged 28.23 cm (Table 7). If radishes are planted in too much shade—or even where neighboring vegetable plants shade them—they will put all their energy into producing larger leaves.

They need to be large enough to absorb lots of sunlight for photosynthesis, but not so big they use up a lot of water to cool down themselves through evaporation. Main driver of leaf size for plants in most places is actually the difference between the temperature of the leaf itself and the air around it (Wright, 2017). Dlamini and Khumalo (2019) in their research concluded that in suitable climatic conditions, bottle irrigation increases the length of the plant leaves compared to other irrigations. The results are consistent with the results of this study.

Width

Based on the result of the test there were no significant difference in width among irrigation treatments in the first experiment (Table 4). The maximum amount of width was observed in furrow irrigation treatment with amount of 4.17 cm and the minimum amount was observed in drip tape irrigation treatment which was 3.45 cm (Table 6). In the second sowing season the test results indicated that a significant difference was found at 1% probability level between different irrigation treatments in the terms width (Table 5). According to the result of the test the furrow and drip tape irrigation treatment had maximum and minimum of 3.54 and 2.21 cm width, respectively (Table 7).Water stress is one of the factors that has reduced tuber drop in dehydration treatments. Lack of water reduces cell division and thus reduces the number of cells. As a result, it reduces drop growth (Soriano et al., 2004).

Number of leaves per plant

The results of the tests, the effect of different irrigation treatments on number of leaves were not significant and did not show significant effect treatments in the first experiment (Table 4). The drip tape irrigation treatment had the maximum average number of leaves per plant which was 8.8 and bottle irrigation treatment with 7.7 had the minimum leaves per plant. (Table 6). In the second sowing season the test results indicated no significant difference (Table 5). According to the result of the test the drip tape and bottle irrigation treatment had maximum and minimum of 7 and 6, respectively (Table 7). The number of leaves depends on genetic factors, but in some cases the planting date and growing period and suitable weather conditions increase the number of leaves (Ameri et al., 2009).

Yield

In the first experiment as shown figure (7) the maximum bulb yield which is 694.72 kg ha^{-1} belonged to bottle irrigation treatment and the minimum which was 680.6 kg ha^{-1}. However according to table (3) bottle irrigation treatment used smaller amount of water and there was no significant difference among treatment which makes the bottle irrigation the ideal treatment. In the second experiment based on the data shown in figure (8 furrow irrigation treatment with 588 kg ha^{-1} had the maximum amount bulb yield and the bottle irrigation treatment with 298.24 kg ha^{-1} had the minimum amount and the data was significant at 1% probability level. but in the second experiment based on table (3) more amount of water was used for other treatment except furrow treatment because of the high temperature and evaporation which in the second experiment makes the furrow irrigation treatment the ideal treatment.

In this study the different treatments yield could be a result of differences in photosynthetic capacity, reservoir strength or limb capacity (Usuda, 2004). Radish as a product of the cool season has the best conditions for growth and development in mild climates. Growing it in warm seasons or in areas with hot climates can disturb the natural growth of it, when the plant is disturbed. Decreased bulb growth, shrinkage of the bulb, and is the result of weather-related problems (Camejo et al., 2005).

Yield Water productivity (WP_y)

In the first experiment bottle irrigation treatment with 0.30 kg m^{-3} has the maximum water productivity and the minimum belonged to furrow irrigation treatment with 0.092 kg m^{-3}(Table 6). In the second sowing season the bottle irrigation with 0.105 kg.m^{-3} has the maximum water productivity and the minimum belonged to furrow irrigation treatment with 0.06 kg m^{-3}(Table 7).

The effect of different irrigation treatment on WP in the first and second season was significant at 1% probability level (Table 4 and 5). In the second experiment the bottle irrigation treatment which is also a type of drip irrigation had better performance due to the lower evaporation rate. The results indicate that bottle irrigation treatment had higher yield for lesser amount of water which makes it the best treatment for areas with mild weather condition and areas with limited water supply Sasani et al. (2004) also concluded that consumption efficiency has increased with low irrigation. Deficit irrigation to the extent of moderate stress increases the water use efficiency significantly compared to non-stress treatment. Dalamini and Khumalo (2019) also observed that bottle irrigation performed better than drip tape irrigation.

Biomass Water Pproductivity (WP_b)

The effect of different irrigation treatment on WP_b in the first and second season was significant (Table 4 and 5). Bottle irrigation treatment with 0.44 kg m^{-3}had the maximum WP_b and furrow irrigation treatment with 0.15 kg m^{-3}had the minimum WP_b (Table 6). In the second season the effects were also significant (Table 7). Bottle irrigation treatment with 0.14 kg.m^{-3}had the maximum WP_b and furrow tape irrigation treatment with 0.095 kg m^{-3} had the minimum WP_b

The effect of different irrigation treatment on WP_b in the first and second season was significant at 1% probability level (Table 4 and 5). Oyonarte (1992) concluded that non-stress irrigation treatment caused a significant difference in water productivity due to higher water consumption than other medium or low stress treatments. This result was in line with the findings of this experiment.

Table 6- The effect of irrigation treatments on radish characteristics at Ahvaz Region (First sowing season)

Irrigation treatment	Fresh bulb weight (g)	Weight of dry bulb(g)	Weight of fresh leaf(g)	Weight of dry leaf(g)	Weight of fresh biomass (g)	Weight of dry biomass (g)	Blub length (cm)	Leaf length(cm)	Width (cm)	No.leves	WPy (Kg m^{-3})	WPb (Kg m^{-3})
Furrow	86.48^{a}	19.43^{a}	28.89^{ab}	3.23^{a}	104.79^{a}	7.24^{a}	13.83^{a}	45.39^{a}	4.17^{a}	8.7^{a}	0.092^{b}	0.15^{b}
Bottle	83.84^{a}	8.17^{b}	37.65^{a}	2.87^{a}	125.46^{a}	8.13^{a}	15.06^{a}	47.99^{a}	3.75^{a}	7.7^{a}	0.3^{a}	0.44^{a}
Sub-surface drip(T-Tape) irrigation	84.86^{a}	8.36^{b}	30.52^{ab}	2.58^{a}	67.62^{b}	6.12^{a}	14.67^{a}	40.46^{a}	3.61^{a}	8.6^{a}	0.11^{b}	0.19^{b}
Drip (t-tape) irrigation	77^{a}	7.73^{b}	12.5^{b}	3.11^{a}	78.8^{b}	6.81^{a}	16.45^{a}	39.85^{a}	3.45^{a}	8.8^{a}	0.1^{b}	0.16^{b}

The values with the same letter are statistically homogeneous in Duncan test at 1% probability test.

Table 7- The effect of irrigation treatments on radish characteristics at Ahvaz Region (Second sowing season)

Irrigation treatment	Fresh bulb weight (g)	Weight of dry bulb(g)	Weight of fresh leaf(g)	Weight of dry leaf(g)	Weight of fresh biomass	Weight of dry biomass (g)	Leaf length(cm)	Blub length (cm)	Width(cm)	No.leves	WPy (Kg m^{-3})	WPb (Kg m^{-3})
Furrow	73.59^{a}	9.59^{a}	24.63^{a}	2.74^{a}	86.09^{a}	6.15^{a}	36.58^{a}	11.75^{ab}	3.54^{a}	6.2^{a}	0.06^{ab}	0.095^{b}
Bottle	37.28^{b}	6.12^{ab}	17.56^{b}	2.15^{ab}	49.22^{b}	6.09^{ab}	35.99^{a}	11.29^{ab}	2.81^{b}	6^{a}	0.105^{a}	0.14^{b}
Sub-surface drip(t-tape) irrigation	39.6^{b}	4.6^{sb}	21.36^{ab}	1.8^{b}	64.88^{b}	4.49^{ab}	28.23^{b}	9.26^{b}	2.52^{b}	6.1^{a}	0.083^{b}	0.1^{a}
Drip (t-tape) irrigation	61.52^{a}	5.82^{b}	21.31^{ab}	2.48^{a}	63.03^{b}	3.31^{b}	31.88^{b}	13.16^{a}	2.21^{b}	7^{a}	0.093^{ab}	0.097^{b}

The values with the same letter are statistically homogeneous in Duncan test at 1% probability test

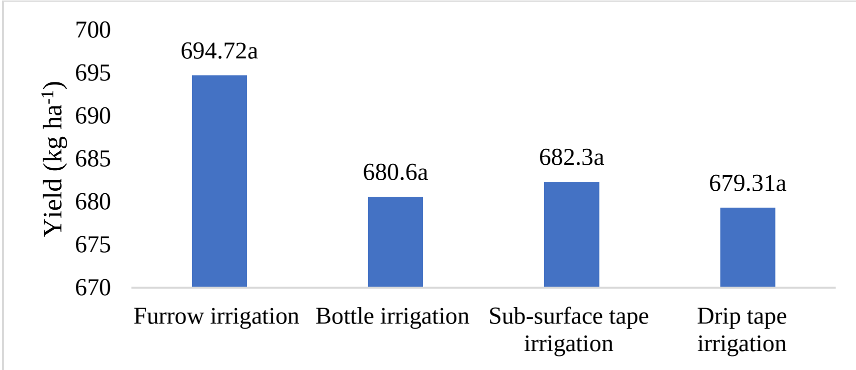

Fig. 7- The effect of treatment on bulb season (First sowing season)

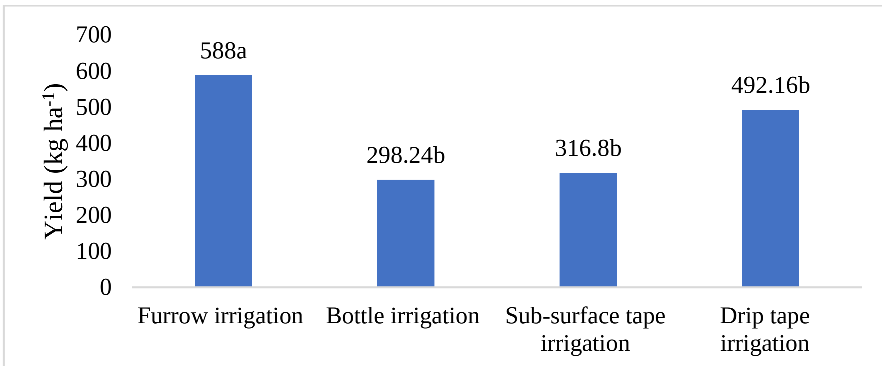

Fig. 8- The effect of treatments on bulb season (Second sowing season)

Conclusion

The purpose of this study was to determine the best treatment for deficit irrigation program, bottle irrigation treatment which used the least amount of water was chosen as the best treatment for both sowing seasons. In both semi-arid and arid areas with mild weather condition with sufficient rainfall and for areas with hot weather condition with insufficient rainfall bottle irrigation is the best choice because this method used the least amount of water for irrigation among other treatments. Bottle irrigation is also one of the low-cost forms of drip irrigation and farmers in rural areas can use this system to grow vegetable. Farmers in poor countries and different region of the world can use bottle irrigation to irrigated their farms and grow vegetable for household consumption. Bottle irrigation is mostly used to irrigated rural farms but if the bottle irrigation is properly designed in larger scales, it can be used to grow trees. Bottle irrigation is easy to operated so any farmer around the world with any level of education can use this method to produce crop with minimum water consumption. Bottle irrigation can be enhanced and improved by being automated which can save reduced the bottle refilling time and help maximize the production rate.

Acknowledgment

We are grateful to the Research Council of Shahid Chamran University of Ahvaz for financial support (GN: SCU.WI98.280).

References

1- Abdel-Mawgoud, A.S.A., Gameh, M.A., Abd-Elaziz, S.H. and El-Sayed, M.M., 2009, March. Sunflower water relations at various irrigation regimes with modern irrigation systems under climatic conditions of Assiut Governorate, Upper Egypt. In *13th International Water Technology Conference (IWTC 2009), Hurghada, Egypt* (pp. 12-15).

2- Albaji, M., Behzad, M., Nasab, S.B., Naseri, A.A., Shahnazari, A., Meskarbashee, M., Judy, F. and Jovzi, M., 2011. Investigation on the effects of conventional irrigation (CI), regulated deficit irrigation (RDI) and partial root zone drying (PRD) on yield and yield components of sunflower (Helianthus annuus L.). *Research on Crops*, *12*(1), pp.142-154.

3- Albaji, M., Nasab, S.B., Behzad, M., Naseri, A., Shahnazari, A., Meskarbashee, M., Judy, F., Jovzi, M. and Shokoohfar, A.R., 2011. Water productivity and water use efficiency of sunflower under conventional and limited irrigation. *J. Food, Agric. Environ*, *9*(1), pp.202-209.

4- Ameri, A.A. and NASIRI, M.M., 2009. Effects of nitrogen application and plant densities on flower yield, essential oils, and radiation use efficiency of Marigold (Calendula officinalis L.).

5- Anonymous. 1988. Advisory committee on vegetable crops. Published by authority of the Atlantic Provinces agriculture services coordinating committee.

6- ASAE Std. 1999. Soil and Water Terminology. S 526.1. ASAE Standards. Amer. Soc. Agric. Engr., St. Joseph, MI.

7- Bajracharya, R.M. and Sharma, S., 2005. Influence of drip-irrigation method on performance and yields of cucumber and tomato. *Int J. Appl Sci Eng Tech*, *1*(1) pp. 1-7.

8- Black, C. H. 1965. Methods of Soil Analysis. American Society of Agronomy, Madison,WI. pp. 63-66.

9- Bracy, R.P., Parish, R.L. and Rosendale, R.M., 2003. Fertigation uniformity affected by injector type. *HortTechnology*, *13*(1), pp.103-105.

10- Brown, M.J., Bondurant, J.A. and Brockway, C.E., 1981. Subsurface trickle irrigation management with multiple cropping. *Transactions of the ASAE*, *24*(6), pp.1482-1489.

11- Barreras, J.T., 2000. *Drip tape retrieval: A study of distribution uniformity on multiple use drip tape*. California Polytechnic State University.

12- Dlamini, M.V. and Khumalo, T., 2019. Comparing the performance of a home-made bottle drip to a commercial drip system in the production of lettuce (Lactuca sativa L.). *International Journal of Environmental & Agriculture Research*, *5*(9), pp.1-4.

13- Camejo, D., Rodríguez, P., Morales, M.A., Dell'Amico, J.M., Torrecillas, A. and Alarcón, J.J., 2005. High temperature effects on photosynthetic activity of two tomato cultivars with different heat susceptibility. *Journal of plant physiology*, *162*(3), pp.281-289.

14- Camp, C.R., 1998. Subsurface drip irrigation: A review. *Transactions of the ASAE*, *41*(5), p.1353.

15- Da Silva, D.F., Cipriano, P.E., de Souza, R.R., Júnior, M.S., da Silva, R.F., Faquin, V., de Souza Silva, M.L. and Guilherme, L.R.G., 2020. Anatomical and physiological characteristics of Raphanus sativus L. submitted to different selenium sources and forms application. *Scientia Horticulturae*, *260*, p.108839.

16- Darouich, H.M., Pedras, C.M., Gonçalves, J.M. and Pereira, L.S., 2014. Drip vs. surface irrigation: A comparison focussing on water saving and economic returns using multicriteria analysis applied to cotton. *Biosystems engineering*, *122*, pp.74-90.

17- Dhaliwal, M.S. and Klair, J.S., 2008. Sowing date affects development and root yield of radish. *International journal of vegetable science*, *13*(3), pp.75-93.

18- Hanks, R.J., Ashcroft, G.L., Rasmussen, V.P. and Wilson, G.D., 1978. Corn production as influenced by irrigation and salinity—Utah studies. *Irrigation Science*, *1*(1), pp.47-59.

19- Hassani, D.B., Abedini, M., Hemmati, I., Falahati, S. 2015, Radish plant and its medicinal properties, Third National Conference on Medicinal Plants and Sustainable Agriculture.

20- Holmer, R.J. and Schnitzler, W.H., 1997. Drip irrigation for small-scale tomato production in the tropics. *Kasetsart J.(Nat. Sci.)*, *32*(5), pp.56-60.

21- Howell, T.A., Dusek, D.A. and Copeland, K.S., 1999. Evaluation of crop water stress index for LEPA irrigated corn. *Irrigation science*, *18*(4), pp.171-180.

22- Jovzi, M. and Zare Abyaneh, H., 2015. Water productivity and water use efficiency indexes of Sugar beet under different levels of water and nitrogen fertilizer. *Journal of Water and Soil Conservation*, *22*(5), pp.117-133.

23- Kano, Y. and Fukuoka, N., 1995. Effects of soil temperature on hollowness in Japanese radish (Raphanus sativus L. cv.'Gensuke'). *Scientia Horticulturae*, *61*(3-4), pp.157-166.

24- Lashkari Zadeh, A., Souri, M.K. and Naieji, M., 2016. Investigation of Growth Yield and Nutritional Value of Five Radish Cultivars in Bam Region. *Journal of Vegetables Sciences*, *2*(1), pp.1-12.

25- Mostafa, H. and Sultan, W., 2018. Hydraulic evaluation of locally modified emitter under laboratory conditions. *Journal of Water Supply: Research and Technology—AQUA*, *67*(3), pp.291-296.

26- Odhiambo, L.O. and Irmak, S., 2015. Relative evaporative losses and water balance in subsurface drip and center pivot–irrigated soybean fields. *Journal of Irrigation and Drainage Engineering*, *141*(11), p.04015020.

27- Oyonarte, N.A. and Mateos, L., 2003. Accounting for soil variability in the evaluation of furrow irrigation. *Transactions of the ASAE*, *46*(1), p.85.

28- Peyvast, G. H. (2005). Vegetable Culture. 3rd Edition, DaneshPazir Press, Rasht (in Farsi).

29- Sandhu, O.S., Gupta, R.K., Thind, H.S., Jat, M.L. and Sidhu, H.S., 2019. Drip irrigation and nitrogen management for improving crop yields, nitrogen use efficiency and water productivity of maize-wheat system on permanent beds in north-west India. *Agricultural Water Management*, *219*, pp.19-26.

30- Sasani, S., Jahansooz, M.R. and Ahmadi, A., 2004, September. The effects of deficit irrigation on water-use efficiency, yield, and quality of forage pearl millet. In *Proceedings of the 4th International Crop Science Congress Brisbane, Australia* (Vol. 26).

31- Sobrado, M.A. and Turner, N.C., 1986. Photosynthesis, dry matter accumulation and distribution in the wild sunflower Helianthus petiolaris and the cultivated sunflower Helianthus annuus as influenced by water deficits. *Oecologia*, *69*(2), pp.181-187.

32- Solomon, K., 1993. Subsurface drip irrigation: product selection and performance. *Subsurface drip irrigation: theory, practices and applications*, pp.3-25.

33- Soriano, M.A., Orgaz, F., Villalobos, F.J. and Fereres, E., 2004. Efficiency of water use of early plantings of sunflower. *European Journal of Agronomy*, *21*(4), pp.465-476.

34- Thokai, R.T., Mokashi, A.K., Kumar, S.R. and Shindhe, Y.R., 2001. Emitter discharge sensitivity to water temperature. *Annals of Arid Zone*, *40*(1).

35- Usuda, H., 2004. Effects of growth under elevated CO2 on the capacity of photosynthesis in two radish cultivars differing in capacity of storage root. *Plant production science*, *7*(4), pp.377-385.

36- Wagner, A.E., Terschluesen, A.M., Rimbach, G. 2013. Health promoting effects of Brassica-derived phytochemicals: from chemo preventive and anti-inflammatory activities to epigenetic regulation. *Oxid. Med. Cell*. Longev. 2013, 964539.

37- Von Westarp, S., Chieng, S. and Schreier, H., 2004. A comparison between low-cost drip irrigation, conventional drip irrigation, and hand watering in Nepal. *Agricultural Water Management*, *64*(2), pp.143-160.

38- Wright, I.J., Dong, N., Maire, V., Prentice, I.C., Westoby, M., Díaz, S., Gallagher, R.V., Jacobs, B.F., Kooyman, R., Law, E.A. and Leishman, M.R., 2017. Global climatic drivers of leaf size. *Science*, *357*(6354), pp.917-921.

39- Xiangyang, L., Zhang, L., Lei, H., Zhang, H., Cheng, Y., Zhu, R. and Ruan, R., 2010. Effect of drying technologies on quality of green tea. *Int Agric Eng J*, *19*(3), pp.30-37.

40- Zanganeh, H. 2009. Bottles of drip irrigation systems, national conference on sustainable development patterns in water management, Mashhad Engineers Mahab Samen.