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Effect of Different Irrigation Methods on Red Cabbage (*Brassica oleraceae* L. var. *capitata* Subvar. *F. rubra*) Yield and Some Plant Characteristics

[1]Bilal Acar and [2]Mustafa Paksoy
[1]Department of Irrigation and Drainage Engineering, Faculty of Agriculture,
University of Selcuk, 42031 Konya, Turkey
[2]Department of Horticulture, Faculty of Agriculture,
University of Selcuk, 42031 Konya, Turkey

Abstract: This study was conducted to investigate the effects of trickle (T), sprinkler (S) and furrow (F) irrigation methods on yield and some plant characteristics of two different red cabbage varieties namely ACN-33 F_1 and Royale F_1. Irrigation water was applied to the plants when the water depletion of 25, 50 and 60% from available water capacity of soil for trickle, sprinkler and furrow irrigation methods, respectively. The research results showed that there was not found significant difference between ACN-33 F_1 and Royal F_1 varieties according to the yield and some plant characteristics. Irrigation methods and amount of applied water significantly affected red cabbage yield. The highest yield with 28.32 t ha^{-1} was obtained by using trickle followed by sprinkler (20.85 t ha^{-1}) and furrow (16.04 t ha^{-1}) irrigation methods. The effect of different irrigation methods on mean head weight, mean head diameter and plant height was found significant.

Key words: Irrigation, irrigation methods, red cabbage, yield

INTRODUCTION

Red cabbage (*Brassica oleraceae* L. var. *capitata* Subvar. *F. rubra*) belongs to the family Brassicaceae and is one of the most popular, palatable and nutritious vegetable crops. It is widely grown in USA and Europe but very low in Turkey and is consumed as salad, pickling or brine. Brassicaceae vegetables are consumed through the year in Europe and Turkey. Fresh 100 g red cabbage contains 92% water and 8% dry matter which of 1.3% protein, 0.2% oil, 3.8% carbohydrate and other minerals with low calorie (Vural *et al*., 2000; Günay, 1984).

Turkey is situated in 36-42° Northern latitude and 26-45° Eastern longitude so that it has a unique geographical and cultural position at the cross-road between Asia and Europe. Turkey has a total land area of 77.8 million hectares of which about 35.6% arable areas, 28% pasture-meadow, 30.2% forest and woodland and remaining surface water and residential area. Economically and physically irrigable arable land is almost 8.5 million hectares (Kara, 2005).

The study area, Konya plain, is a closed basin both surface and groundwater resources are limited. Total water potential of Konya plain is 5.84 billion m^3/year (Anonymous, 2002).

Deep and loam-clay, sandy or sandy-clay soils are suitable for red cabbage growing (Günay, 1984; Çaylak, 1996).

Soil water content should be optimum for increasing the crop yield and quality in vegetable productions. In arid and semi-arid areas of the world, because of the insufficient rainfall, moisture deficit in soil root zone depth is met by irrigation practices.

In Konya Region of Turkey where the study was conducted, total annual rainfall is almost 300 mm and only 130 mm of it precipitates during the crop growth period. Thus, irrigation is vital important in especially summer season. Sprinkler irrigation system is mostly used (75%) and is followed by furrow, border, basin and trickle irrigation methods, respectively (Çiftçi *et al*., 1994).

Ideally, irrigation water should be applied completely uniform manner, but it is impossible to over come this in practice. Even naturally rainfall is non-uniform. Under the non-uniform water application conditions, some crops uptakes more water while the others less.

The losses in surface irrigation methods are direct evaporation from the soil surface, run off and leakage in water delivery systems. The run off losses may be minimized by diverting the water stored lower end of field to the upper part. The leakage losses in unlined delivery

Corresponding Author: Bilal Acar, Department of Irrigation and Drainage Engineering, Faculty of Agriculture, University of Selcuk, 42031 Konya, Turkey

systems or open fields' canals depend on the soil texture of canals, length of canal network and average of 10-15% (Solomon, 1988).

The primary losses associated with sprinkler irrigation (other than those due to over watering) are evaporation from droplets and wet soil surfaces, transpiration from unwanted vegetation, wind drift, field border losses, leaks and system drainage (Keller and Bleisner, 1990; Li, 1998).

In absence of excess water application, the losses are very low in trickle irrigation system. The reason that water is delivered through the pipe systems and only small part of the soil volume is wetted. The conveyance losses are very low under good management conditions.

Surface and pressurized irrigation methods are commonly used for irrigation of vegetable crops in Konya. Topak *et al.* (2003) reported that the average application efficiencies of sprinkler irrigation systems for two different areas of Konya-Çumra Province were 76.17 and 76.40%. These values were almost same the value of previous studies by Topak (1996) and Çakmak (1994).

Prabhat *et al.* (1999) studies about the effect of trickle, micro sprinkler and surface irrigation methods on yield of cabbage in India. The yields were found 38.97, 40.23 and 33.76 t ha^{-1} for trickle, micro sprinkler and surface irrigation methods, respectively. The lowest yield with 33.76 t ha^{-1} was obtained from surface but very close to trickle and mini sprinkler methods.

None study was reported in literatures about effect of irrigation methods on red cabbage production. Thus, the effects of trickle, sprinkler and furrow irrigation methods on red cabbage yield and some plant characteristics were studied.

MATERIALS AND METHODS

The study was carried out during the period from June 2004 to September 2004 in Konya- Sarayönü province.

Some soil physical and chemical properties of study area for irrigation were determined and represented in Table 1. Red cabbage is a shallow rooted vegetable (45-60 cm). The soil is loam so soil is favorable for vegetable growing (Babuççu *et al.*, 2005).

In Table 1, salt content of study area varies between the 1.77-2.27 mmhos cm^{-1}. The red cabbage is tolerant to the salt content of 4-8 mmhos cm^{-1}. so salt content of study area is not hazardous red cabbage growing (Anonymous, 1984).

As plant material, two different red cabbage varieties (ACN-33 F_1 and Royale F_1) were used. Seeds were sown in 06 June 2004 and transplanted to field in 15 July 2004. Seedlings were planted to the field 60×50 cm (Çaylak, 1996; Babuççu *et al.*, 2005).

Table 1: Some soil physical and chemical properties of research area

	Soil depth (cm)	
Soil properties	0-30	30-60
Texture	Loam	Loam
Bulk Density (g cm^{-3})	1.40	1.39
Available Water Capacity, AWC (mm)	44.00	46.80
Electrical Conductivity EC (mmhos cm^{-1})	2.27	1.77
pH	7.15	7.34
$CaCO_3$ (%)	32.50	51.90

Plants were irrigated by trickle (T), sprinkler (S) and furrow (F) irrigation methods. Irrigation water was applied to the plants when the water depletion of 25, 50 and 60% from available water capacity of soil in T, S, F irrigation methods, respectively. Amounts of mean seasonal water application of red cabbage were 325.50, 336.87 and 380.00 mm for T, S, F irrigation methods, respectively. Soil water content in soil root zone depth was controlled by gravimetrically.

Furrows were leveled until the slope is in the range of between 0.2 to 2% as suggested by Walker (1989).

Irrigation water was applied to the furrows by using the calibrated small 60° V-notch flume (Walker and Skogerboe, 1987).

In this research, yield (t ha^{-1}), mean head weight (g), mean head diameter (cm) and mean head height (cm) of red cabbage were determined.

The study was designed as Randomized Complete Blocks with four replications. The data obtained were analyzed by using Costat Packed Program ANOVA Statistically differences were compared by Tukey's Test.

RESULTS AND DISCUSSION

There was not found significant difference between ACN-33 F_1 and Royal F_1 varieties according to the yield and some plant characteristics (Table 2). The yields of ACN-33 F_1 and Royal F_1 were 20.86 and 22.62 t ha^{-1}, respectively. These were higher than the results from Babuççu *et al.* (2005) and lower than Padem and Güvenç (1997) and Üner (1991). The reasons may be differences in ecological conditions and varieties. The other results were given in Table 2.

The effects of T, S, F irrigation methods on red cabbage yield were found significant ($p<0.05$). The yield of red cabbage varieties at different irrigation methods was found between 16.04 and 28.32 t ha^{-1} (Table 3). The highest yield with 28.32 t ha^{-1} was obtained by using T irrigation and followed by sprinkler (20.85 t ha^{-1}) and furrow (16.04 t ha^{-1}) irrigation methods. The use of T irrigation method resulted in 76.55% yield increase comparison to F irrigation method. The yield was about 30% higher in using S than F irrigation method.

Table 2: Yield and some plant characteristics according to varieties.

Varieties	Yield (t ha^{-1})	Mean head weight (g)	Mean head diameter (cm)	Mean head height (cm)	Plant height (cm)	Root length (cm)	Fresh root weight (g)
ACN-33 F_1	20.86	625.8	14.58	14.29	25.02	24.96	212.17
Royal F_1	22.62	678.5	14.32	14.13	24.99	24.21	199.08
Tukey's, 5%	NS	NS	NS	NS	NS	NS	NS

NS: Not Significant. There are no differences statistically between means indicated same letters ($p<0.05$)

Table 3: Yield and some plant characteristics according to different irrigation methods

Irrigation methods	Yield (t ha^{-1})	Mean head weight (g)	Mean head diameter (cm)	Mean head height (cm)	Plant height (cm)	Root length (cm)	Total fresh root weight (g)
Trickle, T	28.32a	849.60a	15.29a	15.03a	27.99a	25.00	213.13
Sprinkler, S	20.85b	625.50b	14.24b	14.01b	24.46b	24.94	204.50
Furrow, F	16.04c	481.40c	13.82b	13.59b	22.56c	23.81	200.25
Tukey's, 5%	2.20	66.03	0.65	0.40	1.01	NS	NS

NS: Not significant. There are no differences statistically between means indicated same letters ($p<0.05$)

The effect of different irrigation methods on mean head weight was found significant ($p<0.05$). The highest mean head weight was found 849.6 g by using T but lowest in F irrigation method (481.4 g). The mean head weight increased as 76.49% in T irrigation comparison to F irrigation method. The mean head weight was about 30% higher in S irrigated parcel than F irrigation method. The increments were similar to yield percentage data (Table 3).

The effect of different irrigation methods on mean head diameter was found statistically significant ($p<0.05$). The highest mean head diameter was measured as 15.29 cm from T irrigation. This was followed by S (14.24 cm) and F (13.82 cm) irrigation methods (Table 3).

As represented in the Table 3, effect of different irrigation methods on mean head height was found significant ($p<0.05$). The highest mean head height was measured as 15.03 cm from T irrigation and followed by S (14.01 cm) and F (13.59 cm) irrigation methods (Table 3).

The plant heights were affected statistically significant from irrigation methods ($p<0.05$). The highest plant height was measured as 27.99 cm from T irrigation, but the lowest with 22.56 cm in F irrigation method. The plant height measured from S irrigation (24.46 cm) was in the range of between T and F irrigation methods.

The results of root lengths and total fresh root weights were not affected significantly from the irrigation methods (Table 3).

It may be concluded from the present study that there was not found significant difference between ACN-33 F_1 and Royal F_1 varieties according to the yield and some plant characteristics. It is suggested that irrigation methods significantly affected red cabbage yield. The highest yield with 28.32 t ha^{-1} was obtained by using T irrigation and followed by S (20.85 t ha^{-1}) and F (16.04 t ha^{-1}) irrigation methods. The possible reason of obtaining highest yield in T irrigation may be that irrigation water was applied almost uniform and controlled for all plants and plants were taken water from the root zone depths equally. The other reason may be that unlike the surface irrigation methods, irrigation water was applied frequently to the plants in T irrigation so soil moisture content was remained as field capacity. Thus, plants received water from soil profile without any stress. Therefore, optimum plant growth was supplied and yield was higher in T irrigation comparison to surface irrigation. In research region, water resources are limited and annual rainfall is almost 300 mm. Efficient water use is vital important in sustainable irrigation especially in arid regions. In present study, although applied irrigation water was lower in T irrigation, yield was found highest. The irrigation efficiency is higher in T irrigation than S and F irrigation. Thus, it is possible to irrigate more area in using T irrigation than S and F irrigation with same amount of irrigation water. Therefore, to increase the irrigable area in arid and semi arid areas of the world, T irrigation method should be used widely. The T irrigation resulted in highest mean head weight with 849.6 g but lowest in F irrigation as 481.4 g. None study was demonstrated in literatures about effect of different irrigation methods on red cabbage yield or yield components. Therefore, it is impossible to compare the results relate to previous findings. Further research is needed to be carried out to find its beneficial effects of irrigation methods on red cabbage and other vegetables. This study is original and will be guide for future relevant studies.

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