RESEARCH ARTICLE

Effect of dripper discharge rates and irrigation schedules on yield of cabbage (*Brassica oleracea L var capitata*)

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ABSTRACT

The field experiment was conducted during rabi season, 2015-16 in split plot design with three replications. Two irrigation levels namely 0.6 ETc (I_1)and 0.8 ETc (I_2) as Main plot treatments and four discharge rates 1.6 lph (D_1), 2.2 lph (D_2), 3.0 lph (D_3) and 4.0 lph (D_4) were planned as Sub treatments with a total of 24 plots. The cabbage yield (t/ha) was maximum when the crop was irrigated with the drip at 0.8 ETc (29.85 t/ha) which was significantly superior over the crop irrigated with drip at 0.6 ETc (28.35 t/ha). The crop which was irrigated at 1.6 lph (Lowest discharge rate) has recorded significantly highest yield (32.43 t/ha) followed by 2.2 lph (30.08 t/ha), 3.0 lph (28.12 t/ha) and the lowest yield was recorded at the discharge rate of 4 lph (25.75 t/ha). Among two irrigation levels (0.8 ETc and 0.6 ETc), crop irrigated at 0.8 ETc gave higher yield but water use efficiency was higher for crop irrigated at 0.6 ETc. Hence irrigation water could be saved by irrigating the cabbage crop at 0.6 ETc without compromising for the yield.

Key words: Discharge rates and Irrigation schedules

INTRODUCTION

Water scarcity and lack of water resource management technologies are common challenges faced by majority of small and marginal farmers in fast developing countries like India. In order to solve the problem of water shortage in agriculture, it is necessary to develop water-saving management technologies. The efficient utilization of irrigation water is possible by the adoption of high efficient irrigation system, such as, micro irrigation system. Drip irrigation method is one of the best water application methods that have been used in the world among the other irrigation methods because of its good and high uniformity and high water use efficiency.

Cabbage is a popular crop of the species *Brassica oleracea Linn.* of the family Brassicaceae (or Cruciferae) and one of the important cole crops in India. It is a leafy green vegetable grown as an annual vegetable crop for its dense-leaved heads. It is a herbaceous, biennial, dicotyledonous flowering plant distinguished by a short stem upon which a crowded mass of leaves, usually green but in some varieties red or purplish, which while immature form a characteristic compact, globular cluster (cabbage head). The origin of cabbage is the Western Europe and north shores of Mediterranean Sea. It is widely grown both in the tropical and temperate countries. Cabbage is a good source of vitamin K, vitamin C and dietary fiber. It is cultivated in 0.245 M ha in India with average productivity of 22.9 mt/ha. The productivity can be improved further by cultivating under drip irrigation as the production depends on availability of soil moisture during crop growth.

In drip irrigation the water movement and its distribution in the soil depends upon many parameters like soil type, crop cultivars, crop planting pattern, discharge rate of emitters, amount of water applied, and climatic factors, etc. While planning drip irrigation system for a crop it is imperative to select: (i) emitters of size that discharge water at a desired rate, (ii) irrigation supplies that render a wetted soil-volume sufficient to fulfill plant's evaporative demands and (iii) a planting pattern that reduces the cost of initial investment without adversely affecting crop yield. Keeping in view, the importance of water management in vegetable crops the present study undertaken to "Evaluate the effect of dripper discharge rates and irrigation schedules on yield of cabbage crop".

MATERIAL AND METHODS

A field experiment was conducted at college farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University(PJTSAU), Rajendranagar, Hyderabad during *Rabi* (Oct-Feb) season of 2015-16, evaluate the effect of dripper discharge rates on yield of cabbage crop. The Farm is geographically situated in the southern part of Telangana at 17° 50' N latitude and 80° 00' E longitude with an altitude of 542.6 m above mean sea level. The geographical area of Hyderabad comes under dry tropical and semi-arid region. Winter is generally milder at Hyderabad.The experimental soil was sandy clay loam in texture, moderately alkaline in reaction and non-saline.

Mean weekly maximum temperatures ranged from 28.6 to 32.79 ^{0}C, while mean weekly minimum temperatures varied from 11.1 to 20.71^{0}C during crop growth period.With respect to pan evaporation, mean pan evaporation ranged 3.5 to 4.69 mm/day. The treatments were laid out in split plot design with two irrigation levels namely 0.6 ETc (I_1)and 0.8 ETc (I_2) as main plot treatments and four discharge rates 1.6 lph (D_1), 2.2 lph (D_2), 3.0 lph (D_3) and 4.0 lph (D_4) were as sub-plot treatments.

Twenty five day old cabbage seedlings were transplanted on 15th October 2015, maintaining crop geometry of 40 x 40 cm with lateral spacing of 120 cm with paired row planting. Water requirement of cabbage was estimated on the basis of reference crop evapotranspiration (ETo) on the daily basis by using Pan evaporation method. The crop evapotranspiration (ETc) was estimated by multiplying reference evapotranspiration (ETo) with crop coefficient (Kc), i.e. ETc = ETo × Kc. Total growing period of cabbage was 120 days and may be divided into four growth stages namely, Initial: 35 days, Development stage: 30 days, Mid-season stage: 40 days and Maturity stage: 15 days. The single crop coefficients adapted for initial, development, mid-season and maturity stages were 0.70, 0.88, 1.05 and 0.95, respectively (FAO-56). The application rate and irrigation time were calculated by using following formulae.

$$\text{Application rate (mm/h)} = \frac{Q}{Sl \times Se} \quad \text{-------------- (1)}$$

$$\text{Irrigation time (in hours)} = \frac{ETC \times W.P \times 6o}{\text{Application rate}} \quad \text{----- (2)}$$

Where,
Q = Emitter flow rate (lph)
Sl = Spacing between laterals (mm)
Se = Spacing between emitters (mm)
ETc = Crop evapotranspiration (mm)
W. P = Wetting percentage (%)

Plot wise cabbageswere harvested at different dates after attaining maturity. The crop was harvested from 27th January to 12th February 2016. Statistical analysis has been conducted to obtain the effect of different irrigation levels and dripper discharge on plant growth parameters like dry matter production (g/plant), root length (cm) and yield attributes like cabbage head weight (kg) and diameter (cm) and yield (t/ha).

RESULTS AND DISCUSSION

Plant growth in terms of its rate, vigor and stand of the crop provide an index of productivity of the crop. Water was one of the major constituents of plant, which helps in cell division, cell elongation and ultimately the growth of the plant, due to the favorable soil moisture conditions by maintaining balanced microclimate around the root zone towards it throughout the growth, which in turn helps in better meristamatic activity of the plant in terms of growth. The results on growth parameters and yield attributes of cabbage viz., root length, dry matter content, head diameter and weight were influenced by different discharge rates and irrigation schedules discussed here under.

Dry matter production:

The observations recorded on dry matter production of cabbage at 30,45, 60 days after transplanting, and at harvest were presented in Table 1 and depicted in Figure 1 respectively. The dry matter production increased progressively with advance in age of the cabbage crop.

Dry matter production showed significant improvement with decrease in discharge rate from 4.0 lph to 1.6 lph at 30, 45, 60 days after transplanting, and at harvest stages. Similarly among the two irrigation levels, crop irrigated at 0.8 ETc has recorded significantly high dry matter production than crop irrigated at 0.6ETc.

Higher dry matter production with discharge rate of 1.6 lph irrigated at 0.8 ETc irrigation level might be due to better crop growth, more number of leaves as a result of maintenance of favorable soil moisture and microclimate in the root zone level and effective absorption of water and nutrients by plants. More number of leaves and higher leaf area could have been maintained at all the growth stages resulted in enhanced carbohydrate synthesis which ultimately led to higher dry matter accumulation. These results corroborate with finding of sunder singh (2001).

Table 1: Dry matter production(g/plant) as influenced by different irrigation schedules and dripper discharge (lph) at different stages during *rabi* 2015-16

Treatments		**DRY MATTER (g/plant) at**			
Main Plot Treatments		**30 DAP**	**45 DAP**	**60 DAP**	**At harvest**
0.6 ETc		2.08	8.91	13.44	27.05
0.8 ETc		0.30	9.51	14.12	28.00
SEm±		0.04	0.10	0.09	0.15
CD(0.05)		NS	0.59	0.51	0.93
Sub Plot Treatments					
1.6 lph		2.38	10.57	15.30	30.85
2.2 lph		2.20	9.72	14.20	28.89
3.0 lph		1.97	8.70	13.32	25.94
4.0 lph		1.98	7.85	12.30	24.42
SEm±		0.13	0.47	0.46	0.97
CD(0.05)		NS	1.45	1.40	2.98
0.6 ETc	**1.6 lph**	2.34	10.33	14.94	30.35
	2.2 lph	2.16	9.42	13.85	28.34
	3.0 lph	1.85	8.41	13.06	25.53
	4.0 lph	1.97	7.48	11.90	23.96
0.8 ETc	**1.6 lph**	2.42	10.80	15.65	31.35
	2.2 lph	2.23	10.01	14.55	29.44
	3.0 lph	2.08	8.98	13.57	26.35
	4.0 lph	1.99	8.22	12.70	24.87
Interaction					
SEm±		0.18	0.67	0.65	1.37
CD(0.05)		NS	NS	NS	NS

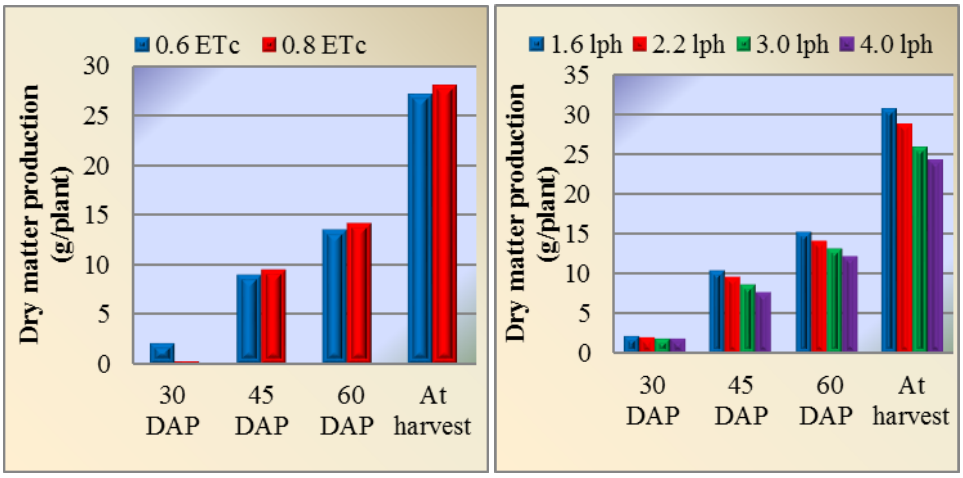

Figure 1: Dry matter production (g/plant) at different stages as influenced by different irrigation levels and different dripper discharge rates

Root Length:

The data on root length as influenced by different discharge rates was presented in Table 2 and was depicted in the Figure 2.The results indicated that the root length (cm) was maximum when the crop was irrigated through drip at 0.8 ETc which was significantly superior over the crop irrigated with drip at 0.6 ETc.

Similarly among the four dripper discharge levels, significantly averagemaximum root length of 23.73 cm was recorded with the crop irrigated at 1.6lph(lowest discharge) than 2.2 lph (21.08 cm), followed by 3.0 lph (19.05 cm). The lowest root length of 17.23 cm was recorded at 4.0 lph and was significantly lower with 1.6, 2.2 and at par with 3.0lph. Root length at discharge levels of 2.2 lph and 3.0lph were at par with each other.

The effect of interaction was non-significant, however the crop irrigated with drip at 0.8 ETc at 1.6 lph discharge level has recorded the maximum root length(24.1 cm) followed by the crop irrigated at 0.6 ETc with 1.6 lph discharge rate(23.35 cm).

The explanation of this phenomenon could be that with lower discharge drippers, the rate of vertical water movement below the emitters was higher than the rate of lateral movement, which may be due to fact that emitter's relatively slower rate of discharge than the intake rate of the soil. As the emitter discharge rate increases the lateral spread of water was dominant over the vertical spread. Hence increase of dripper discharge and growth period of cabbage affects the root system to cover a wider range of horizontal extension growth. The results were in accordance with the experiment conducted by Shrivastava *et al* (2012) in vegetable crop of tomato.

Table 2: Root length (cm)as influenced by different irrigation schedules and dripper discharge rates during *rabi* 2015-16

Discharge rates (lph)	Root length (cm)		
	0.6 ETc	0.8 ETc	Mean
1.6	23.35	24.1	23.73
2.2	20.39	21.76	21.08
3.0	18.34	19.76	19.05
4.0	17.15	17.32	17.23
Mean	19.81	20.74	
Comparision between		**SEm (±)**	**CD (0.05)**
Irrigation levels		0.07	0.43
Discharge rates		0.69	2.11
Discharge rates at same irrigation level		0.97	NS
Irrigation level at same or different discharge rates		0.84	NS

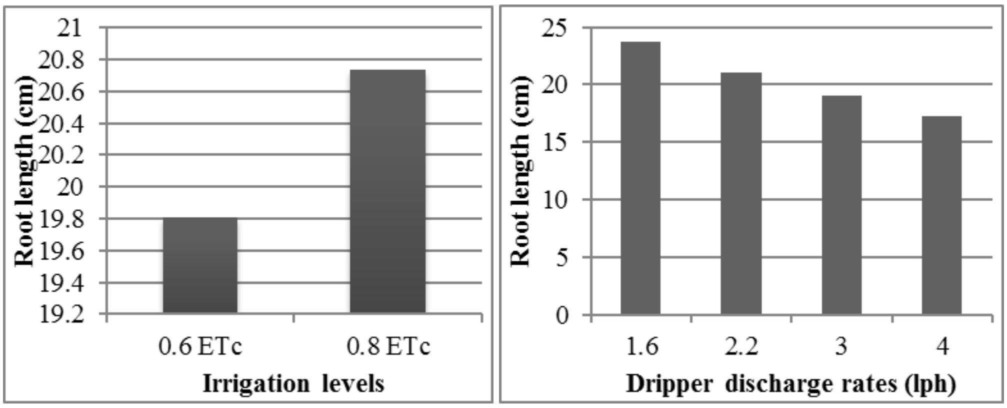

Figure 2: Root length(cm) as influenced by different irrigation levels and dripper discharge rates

Diameter of head (cm)

Diameter of head as an indicator of size of cabbage was an important yield contributing character of cabbage. From the present study it was observed that head diameter was maximum when the crop was irrigated through drip at 0.8 ETc which was significantly superior over the crop irrigated with drip at 0.6 ETc Similarly among the four discharge levels i.e., 1.6 lph, 2.2 lph, 3.0 lph and 4.0 lph, the crop which was irrigated at 1.6 lph has recorded significantly maximum head diameter (20.6 cm), followed by 2.2 lph (17.8 cm), 3.0 lph (15.14 cm) and the lowest head diameter was recorded at discharge rate of 4.0 lph (13.29 cm) and significantly lower under discharge levels of 2.2 lph and 1.6 lph, and was at par with 3.0 lph discharge level.

The effect of interaction was non-significant. However the irrigation with drip at 0.8 ETc at 1.6 lph discharge level has recorded the maximum head diameter (24.1 cm) followed by the crop irrigated at 0.6 ETc with 1.6 lph discharge rate(23.35 cm).

Table 3:Head diameter(cm) as influenced by different irrigation levels and dripper discharge rates during *rabi* 2015-16

Discharge rates (lph)	**Head diameter(cm)**		
	0.6 ETc	**0.8 ETc**	**Mean**
1.6	20.02	21.18	20.60
2.2	16.27	19.34	17.80
3.0	14.94	15.35	15.14
4.0	12.49	14.10	13.29
Mean	15.93	17.49	
Comparision between		**SEm (±)**	**CD (0.05)**
Irrigation levels		0.22	1.37
Discharge rates		0.67	2.08
Discharge rates at same irrigation level		0.96	NS
Irrigation level at same or different discharge rates		0.85	NS

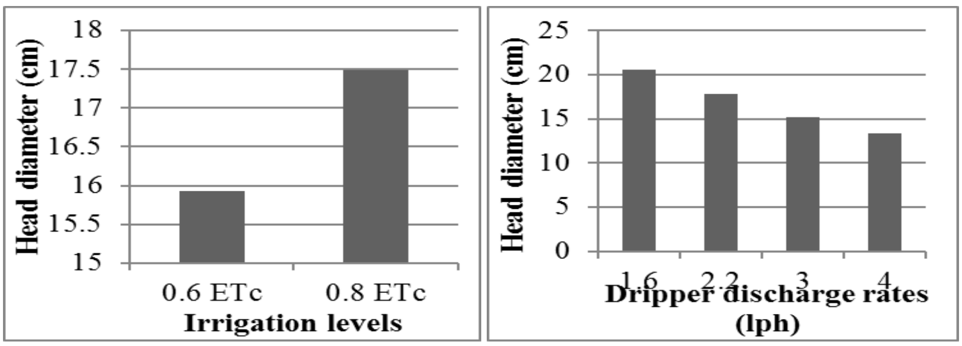

Figure 3: Head diameter(cm) as influenced by different irrigation levels and dripper discharge rates

Head weight(kg):

The data of head weight (kg) in the experimentwere presented in Table 4 indicates that the head weight was maximum when the crop was irrigated with drip at 0.8 ETcwhich was significantly superior over crop irrigated with drip at 0.6 ETc.

Similarly among the four discharge levels i.e., 1.6, 2.2, 3.0 and 4.0 lph, the crop which was irrigated at 1.6 lph has recorded significantly highest head weight (1.078 kg), followed by 2.2 lph (0.88 kg), 3.0 lph (0.748 kg) and the lowest head diameter was recorded at discharge rate of 4.0 lph (0.595 kg) which was significantly lower. Head weight at discharge levels of 2.2 lph and 3.0 lph were at par with each other

The interaction effect on the head weight was non-significant. However the irrigation with drip at 0.8 ETc at 1.6 lph discharge level has recorded the maximum head weight (1.13 kg) followed by the crop irrigated at 0.6 ETc with 1.6 lph discharge rate(1.03 kg).

Table 4: Head weight(kg) as influenced by different irrigation levels and dripper discharge rates during *rabi*2015-16.

Discharge rates (lph)	**Head weight (kg)**		
	0.6 ETc	**0.8 ETc**	**Means**
1.6	1.03	1.13	1.08
2.2	0.84	0.94	0.89
3.0	0.71	0.78	0.75
4.0	0.55	0.64	0.60
Mean	0.78	0.87	
Comparision between		**SEm (±)**	**CD (0.05)**
Irrigation levels		0.01	0.07
Discharge rates		0.05	0.14
Discharge rates at same irrigation level		0.07	NS
Irrigation level at same or different discharge rates		0.05	NS

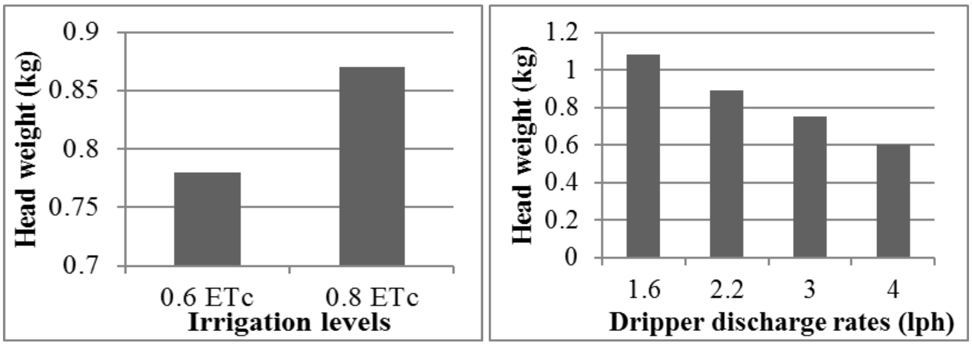

Figure 4: Head weight (kg)as influenced by different irrigation schedules and dripper discharge rates

YIELD(t/ha):

The results of the experiment are presented in Table 5 indicated that though the irrigation levels on the yield of cabbage were non-significant the cabbage yield(t/ha) was maximum when the crop was irrigated with the drip at 0.8 ETc (29.85 t/ha) which was significantly superior over the crop irrigated with drip at 0.6 ETc(28.35 t/ha).

Similarly among the four discharge levels of 1.6, 2.2, 3.0 and 4.0 lph the crop which was irrigated at 1.6 lph (Lowest discharge rate) has recorded significantly the highest yield (32.43 t/ha) followed by 2.2 lph (30.08 t/ha), 3.0 lph (28.12 t/ha) and the lowest yield was recorded at the discharge rate of 4.0 lph (25.75 t/ha) and significantly lower over the other three discharge levels. The yields under discharge levels of 2.2 lph and 3.0 lph were at par with each other (Figure 5).

There was no significant difference on the cabbage yields between the interaction levels. However the crop irrigated with drip at 0.8 ETc at 1.6 lph discharge level has recorded the maximum yield (33.32 t/ha) followed by the crop irrigated with drip at 0.6 ETc with 1.6 lph discharge rate(31.537 t/ha).

Favorable soil water balance under the crop irrigated at 1.6 lph dripper discharge and 0.8 ETc aided the plants in better root penetration and root mass due to more wetted depth because slow and continuous irrigation throughout the crop growth. The better root growth might have facilitated the crop plants to extract adequate soil moisture to meet the evapotranspiration demand, thus in turn helped the crop plants to increase their height vigour which in turn might have put forth more photosynthetic surface, thus contributed to more yield. The increase in cabbage yield was mainly attributed by greater and soil consistent availability of soil moisture under 1.6 lph dripper discharge rate. The results were similar to the findings of Sulitan*et al.,* (2013) who has reported that higher yield was obtained moderate emitter discharge rates, lower discharge rates facilitates the availability of water for longer duration at right place. Higher discharge rate leads to evaporation losses along with percolation losses i.e., beyond the root zone which was not useful for the crop. Lower discharge rates with increased irrigation duration improve the yield. Similar results were observed by Badr and Talab (2007) in vegetable crop tomato. The results were similar to the findings of Rajurkar *et al.,* (2015) in cabbage crop who has reported that the dripper discharge and amount of water applied determines the variation in soil water potential consequently root distribution and plant water uptake which ultimately affects the yield.

Table 5: Yield(t/ha) as influenced by different irrigation levels and dripper discharge rates during *rabi* 2015-16

Discharge rates (lph)	**Yield (t/ha)**		
	0.6 ETc	**0.8 ETc**	**Mean**
1.6	31.54	33.32	32.43
2.2	29.50	30.67	30.08
3.0	27.55	28.70	28.12
4.0	24.80	26.71	25.76
Mean	28.35	29.86	
Comparision between		**SEm (±)**	**CD (0.05)**
Irrigation levels		0.25	1.51
Discharge rates		0.49	1.50
Discharge rates at same irrigation level		0.69	NS
Irrigation level at same or different discharge rates		0.64	NS

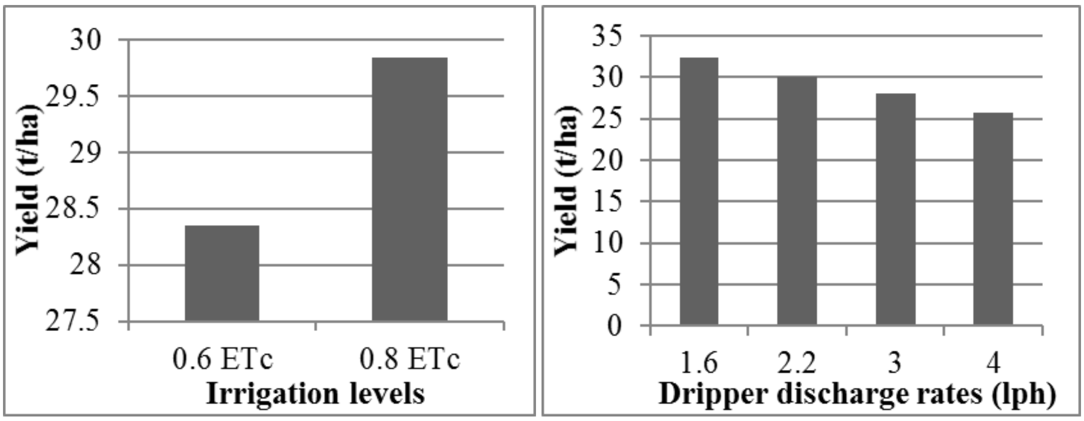

Figure 5: Yield (t/ha) as influenced by different irrigation levels and dripper discharge rates

Water Use Efficiency (kg/ha-mm):

Water Use Efficiency(kg/ha-mm)helps to assess the productivity of a crop per unit water used. It was computed by taking economic yield of crop and total water used (including effective rainfall) into consideration. It can be increased either by increasing the yield or by reducing the quantity of water applied. The results WUE under different irrigation levels and dripper discharge rate is presented in Table 6.

Total volume of water applied for different discharge rates ranged from 263.65 mm to 371.55 mm throughout the crop period. The results of the experiment indicated that the water use efficiency was maximum when the crop was irrigated with the drip at 0.6 ETc (119.6 kg/m^3) which was significantly superior over the crop irrigated with drip at 0.8 ETc (102.8 kg/m^3).

Similarly among the four discharge levels of 1.6 lph, 2.2 ph, 3.0 lph and 4.0 lph the crop which was irrigated at 1.6 lph (Lowest discharge rate) has recorded maximum water use efficiency followed by 2.2 lph, 3.0 lph, respectively. Lower water use efficiency was observed in 4.0 lph dripper discharge.

Higher discharge rates can reduce water use efficiency by increasing the evaporation losses and it might have reduced the yield. Similar results were observed by Badr and Talab (2007) in vegetable crop tomato that with increase in dripper discharge rate from 2 to 8 lph, water use efficiency will be decreased and also reported that increase in soil moisture regime could increase the water productivity up to a certain level, but tends to decline thereafter.

Table 6:Water Use Efficiency (kg/ha-mm)as influenced by different irrigation levels and dripper discharge rates during *rabi* 2015-16

Treatment		Yield (t/ha)	Total water applied (mm)	Water Use Efficiency (kg/ha-mm)
0.6 ETc	1.6 lph	31.54	263.65	119.6
	2.2 lph	29.50	273.33	107.9
	3.0 lph	27.55	281.86	97.8
	4.0 lph	24.80	290.42	85.4
0.8 ETc	1.6 lph	33.32	323.97	102.8
	2.2 lph	30.66	335.86	91.3
	3.0 lph	28.69	348.77	82.3
	4.0 lph	26.71	371.55	71.9

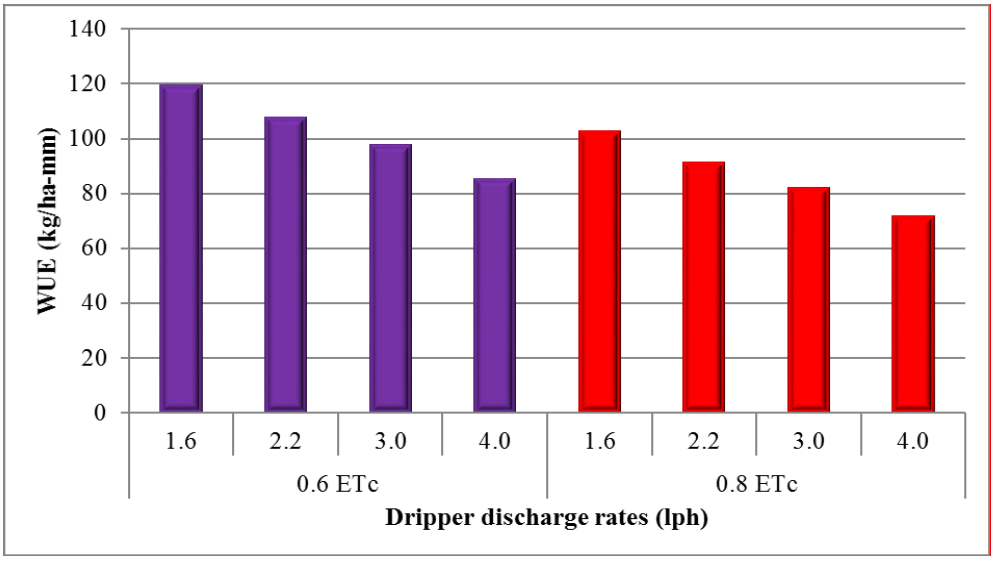

Figure 6:Water Use Efficiency (kg/ha-mm) as influenced by different irrigation levels and dripper discharge rate

No significant difference in cabbage yield was observed for the irrigation levels with 0.6 ETc and 0.8 ETc. Consequently, irrigation water could be saved by irrigating the cabbage crop at 0.6ETc without compromising the yield. Thus, indicating a definitive benefit in adopting irrigation at 0.6 Etc for cabbage production in areas with water shortage condition. Deficit irrigation has potential in enhancing the water use efficiency for various crops without causing severe decline in yield (Geerts and Raes 2009). The results were similar with XU *et al.* (2014) studied on cabbage under deficit irrigation and revealed that implementing deficit irrigation (75% ETc) could save water (16%) although a moderate decrease in yield (12%) and head size was expected.

CONCLUSION

Among four levels of dripper discharge rates, 1.6 lph significantly gave higher dry matter production (g/plant), root length (cm), head weight (g) and diameter (cm) and yield(t/ha). Among two irrigation levels (0.8 ETc and 0.6 ETc), crop irrigated at 0.8 ETc gave higher yield but water use efficiency (t/ha-mm) is higher for crop irrigated at 0.6 ETc. Hence irrigation water could be saved by irrigating the cabbage crop at 0.6 ETc without compromising for the yield. Thus, in areas with water shortage condition, adopting irrigation at 0.6 ETc for cabbage production would give beneficiary results. The interaction effect of dripper discharge and irrigation levels was non-significant for all parameters.

Conflicts of interest: The authors stated that no conflicts of interest.

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