Indian Journal of Agricultural Sciences **85** (2): 189–93, February 2015/Article

Effect of deficit irrigation on growth and yield of drip irrigated cabbage

G B RAJURKAR[1], NEELAM PATEL[2], T B S RAJPUT[3] and CINI VARGHESE[4]

Indian Agricultural Research Institute, New Delhi 110 012

Received: 19 August 2013; Revised accepted: 11 August 2014

ABSTRACT

A field experiment was conducted on cabbage crop (var. Indo-American Hybrid Ramakrishna) during the winter season of 2010-11 in loamy soil of Water Technology Centre, Indian Agricultural Research Institute, New Delhi. The objective of the study was to evaluate the effect of three levels of irrigation, i.e. 60, 80 and 100% of crop evapotranspiration (ET_c) and two types of drip irrigation systems, viz. pressure compensating (PC) and non-pressure compensating (NPC) drippers on the cabbage growth and yield. Rated discharge of PC and NPC drippers were 1.0 and 2.1 litres per hour (lph). Cabbage crop was sown in November 2013 at the spacing of 30cm (plant to plant) and 60cm (row to row). Leaf Area Index (LAI) was recorded at initial, developmental, mid-season and maturity stages while the root volume was determined at the maturity stage of crop growth. Under PC system, the LAI values of 0.59, 0.90 and 2.07 were recorded at initial, developmental and middle stage of crop, respectively. During maturity stage, NPC dripper showed higher LAI (2.61) as compared to PC drippers (2.57). Increased wetting depth under NPC system resulted in higher root depth (70 cm) and higher root volume. The maximum and minimum yields obtained in PC drippers were 91.2 and 83.33 t/ha, whereas in the plot having NPC drippers, maximum and minimum yields obtained were 61.48 and 53.70 t/ha, respectively. Yield obtained under 80 and 100 % ET_c was not significantly different, however full application of water (100%) resulted in better yield. Thus, Pressure compensating drippers with discharge matching to crop water needs (1.0 lph) and irrigation at 80 % ET_c is recommended as optimum practice for cabbage cultivation in loamy soils of northern India.

Key words: Cabbage yield and growth, Drip irigation system performance, Irrigation levels; Non-pressure compensating drippers, Pressure compensating drippers

Efficient use of water by irrigation is becoming increasingly important, and drip irrigation may contribute substantially to the best use of water for agriculture, improving irrigation efficiency (Sezen *et al.* 2006). Dripper is the most important component of drip system which regulates the rate of water application. Two kinds of drippers (alternately called emitters), namely pressure compensating (PC) and non-pressure compensating (NPC), are available in the market. PC drippers for drip irrigation systems are designed and constructed to obtain nearly uniform discharge from each dripper, in spite of varying operating pressures. Water can be applied uniformly on long rows and on uneven slopes with PC drippers. In NPC dripper, discharge tends to vary widely with the operating pressure, as compared to PC. Water distribution in the soil profile is different for both the system as their discharge varies. Westarp *et al.* (2004) suggested that low cost drip irrigation was viable option for increasing food production in water scarce area with long-term economic and labour benefits. Previous research shows that the yields and quality of cabbage crop can be enhanced with application of water using micro-irrigation systems (Tiwari *et al*. 2003, Imtiyaz *et al*. 2000).

Deficit irrigation has potential in enhancing the water productivity for various crops without causing severe decline in yield (Geerts and Raes 2009). In other words, Deficit Irrigation aims at stabilizing yields and obtaining maximum water productivity rather than maximum yields (Zhang *et al*. 1999). Hence many researchers recommended deficit irrigation instead of full irrigation (Zhang *et al.* 2003, Tavakkoli and Oweis 2004).

Review suggests that deficit irrigation (DI) is emerging as promising management option to reduce the agricultural water use without severe yield reduction. Few studies are available to investigate the effect of water deficit and irrigation system (PC and NPC dripper) on growth, and yield of cabbage crop. The aim of the present study was to study the response of cabbage crop under different types of dripper systems and varying levels of deficit irrigation.

MATERIALS AND METHODS

The experiment was conducted during the winter season of 2010-11 at the research farm of Precision Farming Development Centre, Water Technology Centre, Indian Agricultural Research Institute (IARI), New Delhi. The soil

[1]Ph D Scholar (rajurkargb@gmail.com), [2,3]Principal Scientist, Water Technology Centre; [4]Senior Scientist, Division of Agricultural Statistics, IASRI, New Delhi 110 012

of experimental site was loamy and had a pH of 7.3 and EC of 0.12 dS/m.The available nitrogen, phosphorous and potassium in experimental plot were 108.5, 15.80 and 143.86 kg/ha respectively. The soil texture was loamy with 48.28% sand, 32.22% silt and 19.5% clay. The mean hydraulic conductivity and bulk density of soil was 1.345 cm/h and 1.52 gm/cm^3, respectively. The percent moisture content at field capacity (FC) and permanent wilting point (PWP) of soil was determined using pressure plate apparatus on gravimetric basis. The moisture content at FC and PWP was 18.36% and 9.49%, respectively. The irrigation treatment consisted of three levels, i.e. 100% of ET_c (no deficit-control treatment), 80% of ET_c (20% deficit) and 60% of ET_c (40% deficit). Two irrigation systems with pressure compensating (PC) and non-pressure compensating (NPC) drippers were installed. The experiment comprised six treatments and each treatment was replicated three times as shown in Table 1. Six week old cabbage seedlings were transplanted at a plant to plant and row to row spacing of 30 cm × 60 cm. Drip laterals of 16 mm diameter and dripper to dripper spacing of 30 cm, were placed at the spacing of 60 cm to cover each row of crop. The rated discharge of PC and NPC drippers was 1.0 lph and 2.1 lph respectively.

Uniformity tests for water distribution were carried out during crop growing period. Discharge data from 108 drippers uniformly distributed throughout the experimental plot was collected and analysed to estimate the drip system performance in terms of uniformity coefficient (UC), emission uniformity (EU), statistical uniformity (SU) and coefficient of variation (CV). Standard equations were used to calculate UC, EU, CV and SU. Christiansen's Uniformity Coefficient (UC) is used to describe uniformity of irrigation application and is defined as;

$$UC = 100\left[1.0 - \frac{\sum_{i=1}^{n}|(X_i - m)|}{\sum_{i=1}^{n} X_i}\right]$$

where, X_i, Measured depth of water in individual catch can, cm; n, number of the catch can; m, mean depth of water of the catch in all cans, cm; Σ, indicates that all measured depths are summed.

Another most important parameter for evaluating performance of micro-irrigation system is Emission uniformity (EU) which is given by the equation as follows;

Table 1 Treatment details

Treat-ment	Under PC dripper system	Treat-ment	Under NPC dripper system
T1	100% of ET_c (Control, No deficit)	T4	100% of ET_c (No deficit)
T2	80% of ET_c (20% Deficit)	T5	80% of ET_c (20% Deficit)
T3	60% of ET_c (40 Deficit)	T6	60% of ET_c (40 Deficit)

$$EU = \left(\frac{q_{lq}}{q}\right) \times 100$$

where, EU, Emission uniformity, %; q_{lq} = Mean of lowest one fourth of dripper discharge, lph; q = Mean dripper discharge, lph.

Coefficient of manufacturing variation (CV) is the quotient between the standard deviation and average discharge of dripper, lph (Keller and Karmeli, 1974) and is mathematically expressed as;

$$CV = \left(\frac{s}{q}\right)$$

Statistical uniformity (SU) is simple parameter to describe the performance of micro-irrigation system and is given by the following equation as;

$$SU = \left(1 - \frac{s}{q}\right) \times 100$$

where, CV, Coefficient of manufacturing variation, Fraction; SU, statistical uniformity (%); s, standard deviation; q, mean dripper discharge, lph.

Water requirement of cabbage was estimated on the basis of reference crop evapotranspiration (ET_0) on the daily basis by using Penman-Monteith's semi-empirical formula (Smith 1991). The required weather data (minimum and maximum temperature, rainfall, sunshine hours, wind speed etc.) was collected from the automatic weather station, located near the experimental site.

The crop evapotranspiration (ET_c) was estimated by multiplying reference evapotranspiration (ET_0) with crop coefficient (K_c), i.e. $ET_c = ET_0 \times K_c$ (Allen *et al.* 1998). Irrigation was applied on daily basis. 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). Under the climatic conditions of the study area, the total amount of water required to irrigate cabbage crop was estimated as 36 cm.

Thus, water applied in case of no deficit treatment (i.e 100% of ET_c: T1 and T4) was 36 cm whereas under the treatment T2 and T5 (80% of ET_c) it was 28.8 cm and for the remaining treatment T3 and T6 (60% of ET_c), water applied was 21.6 cm.

The recommended dose of fertilizer for cabbage (N, P and K in the ratio of 180:100:150 kg/ha) was applied during the growing period using urea (46% N), phosphoric acid (85% P) and muriate of potash (60% K), respectively. Equal amount of fertilizer were applied to the each treatment. Venturi pump was used to inject fertilizer in precise amount. Fertilizers were applied on weekly basis.

Leaf area index (LAI) was recorded during initial, mid-season and maturity stage of crop was monitored using canopy analyser (LAI-2000). Root volume was determined at maturity stage of crop using root scanner (Epson expression). Cabbage yield during each picking was recorded using electronic weighing balance and was summed to get the yield/plot. The recorded data of cabbage yield was analysed using one way analysis of variance (ANOVA) (at α=0.05) to test the significance of difference between treatment means. Statistical analysis was performed using SPSS statistical program (v. 16.0).

RESULTS AND DISSUSSION

Water requirement of crop

The water requirement of cabbage varied from 1.4 to 5.5 mm/day from initial to maturity stage, respectively. The daily irrigation water requirement for total growing period of cabbage is shown in Fig 1. The water requirement of cabbage crop increased from initial stage to maturity stage (i.e. from 16 Nov-2010 to 16 March 2011) due to increased evapotranspiration owing to beginning of summer season. Water was applied under each treatment on daily basis based on water requirement of the crop.

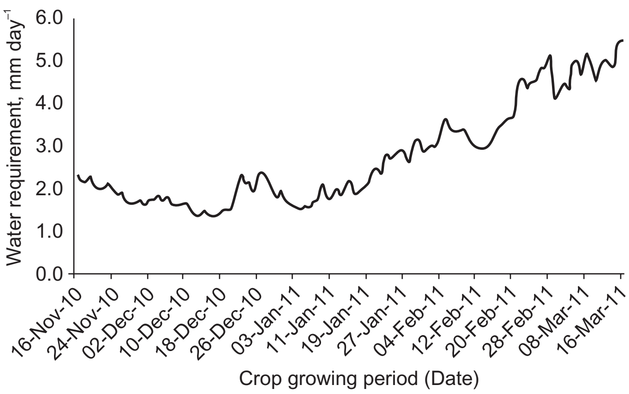

Fig 1 Water requirement of cabbage

Performance of drip irrigation system

Values of different statistical parameters were compared with the standard criteria (Pitts 1997) for rating the performance of irrigation system (Table 2).

The acceptable dripper flow variation was considered to be less than 20% (Wu *et al.* 1979). The discharge variation in PC was 6% which was within the acceptable limit (Fig 2). The discharge variation of 12% under NPC was also within acceptable limit, this might be due to the good quality products and small length of the laterals used in the test system (Fig 3).The lower variation in dripper discharge for the PC dripper over NPC dripper indicated good performance of the PC dripper system. Both the systems, PC and NPC, recorded UC values above 95%. Dasberg and Or (1999) stated that modern drippers should have CV less than 0.05 and UC of more than 96%. But NPC dripper was not fulfilling this criterion. The SU and EU were above 90 and 87%, respectively (Table 3), which justifies the excellent rating for the performance of irrigation systems as per the criteria outlined by Pitts (1997) (Table 2).

Table 2 Criteria for rating the performance of the irrigation systems

Statistical uniformity, % (SU)	Emission uniformity, % (EU)	System rating
> 90	>87	Excellent
80-90	75-87	Good
70-80	62-75	Fair
<70	<62	Poor

(Source: Pitts 1997)

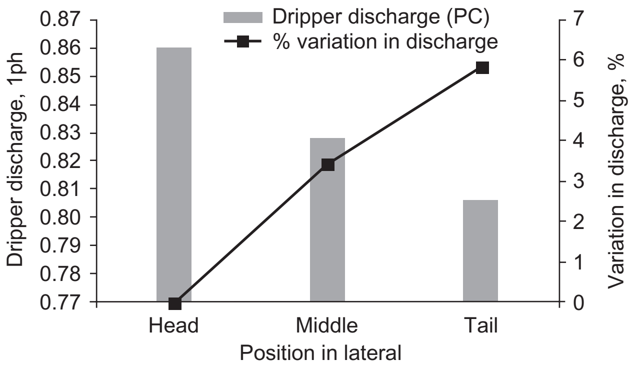

Fig 2 Variation in PC dripper discharge along the laterals

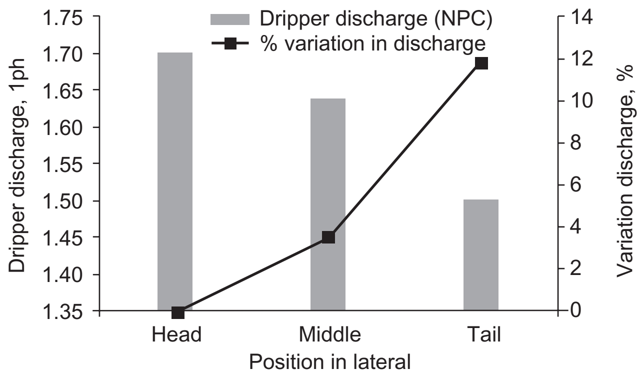

Fig 3 Variation in NPC dripper discharge along the laterals

Effect of irrigation systems and irrigation levels on Leaf Area Index (LAI)

Leaf area index increased successively from initial to maturity stage of crop growth (Fig. 4). In case of no deficit treatment, LAI value of 0.59, 0.90, 2.07 and 2.57 was recorded at initial, developmental, mid-season stage and maturity stage of crop, respectively under plot with PC dripper system. At maturity stage of crop, LAI in NPC dripper (2.61) was more than PC dripper (2.57). The value of LAI at initial, developmental, and mid-season stages of crop decreased by 15.3, 6.0 and 1.3 % in NPC dripper as compared to PC dripper (Table 4). At maturity stage of crop, LAI in PC dripper was decreased by 1.7 % in comparison to NPC dripper (Table 4). But difference in LAI at maturity stage of crop was not considerable under both the systems. LAI was found maximum under full irrigation treatment followed by deficit irrigation of 80% ET_c at all the growth stages of crop. The least LAI values were obtained under deficit irrigation level of 60% ET_c at all growth stages of crop.

Table 3 Performance indicators showing the performance of the irrigation systems

Type of drip Systems	Rated dripper discharge (lph)	Observed dripper discharge (lph)	UC (%)	DU (%)	CV	SU (%)
PC drippers	1.0	0.82	96.02	92.68	0.048	95.2
NPC drippers	2.1	1.65	95.44	92.12	0.058	94.2

Table 4 Effect of dripper type on LAI at different crop growth stages

Treatment	Percent LAI variation under PC & NPC dripper system			
	Crop growth stages			
	Initial	Developmental	Mid-season	Maturity
No deficit	–15.91*	–8.70*	–1.40*	+1.50**
20 % deficit	–13.50*	–7.20*	–0.80*	+0.27**
40 % deficit	–16.56*	–2.00*	–1.60*	+3.20**

*-ve sign indicate percent decrease in LAI under plot with NPC dripper over PC dripper. **+ve sign indicate percent increase in LAI under plot with NPC dripper over PC dripper.

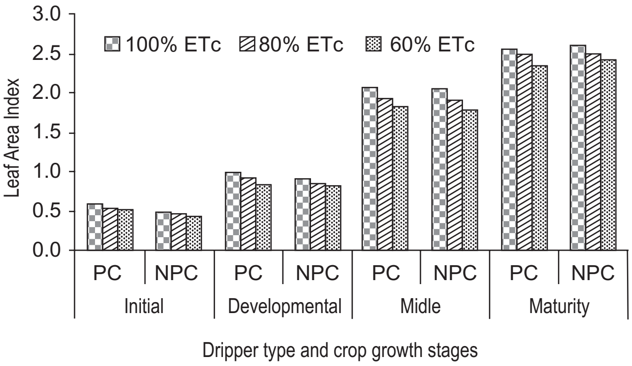

Fig 4 Effect of irrigation system and irrigation levels on LAI

Effect of irrigation system and irrigation levels on the root volume

Lower infiltration depth under lower dripper discharge through PC dripper resulted in lesser wetting depth; consequently, cabbage roots were concentrated in top 40 to 50 cm of the soil profile. However, in case of NPC system, higher infiltration rate under higher dripper discharge caused wetting of soil profile to greater depth, consequently the roots were extended in lower soil profile (up to 70 cm). As compared to PC dripper system, increased wetting depth under NPC system resulted in higher root volume.

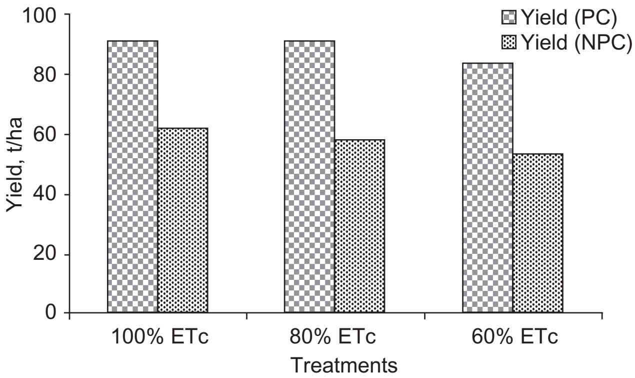

Fig 5 Effect of irrigation system and irrigation levels on yield

Effect of irrigation system and irrigation levels on the yield of cabbage crop

The maximum and minimum yield obtained in the plot with PC dripper system was 91.2 and 83.33 tonnes/ha whereas in the plot with NPC dripper system was 61.48 and 53.70 tonnes/ha, respectively.

High uniformity of water application and less dripper discharge variation under PC system resulted in higher cabbage yield. The effect of irrigation levels and irrigation system on cabbage yield is shown in the Fig 5.The maximum cabbage yield was obtained under 100 % ET_c level in both the systems. However, statistical analysis (Table 5) showed that there was no significant difference in the average yields obtained under 100 % ET_c and 80 % ET_c irrigation levels in plot with PC dripper systems. This may be due to more effective use of irrigation water and increased use of stored water in plot with deficit irrigation (80% of ET_c). PC dripper system has high irrigation uniformity with less dripper flow rate which restricts water movement beyond effective root zone and canopy area. Whereas, higher flow rate through NPC dripper enthused water beyond the root zone which was not available for plants at any stage of growth consequently affected the yield. The cabbage yield obtained under 60 % of ET_c irrigation treatment was significantly lower from other two levels of water application

Table 5 One way ANOVA to show the effect of irrigation levels on cabbage yield

Source of variation		Sum of squares	Degree of freedom	Mean square	Computed F	Significant
Yield (PC)	Treatments	122.26	2	61.13	131.96	<0.001
	Exp. error	2.78	6	0.463		
	Total	125.04	8			
Yield (NPC)	Treatments	91.44	2	45.72	50.61	<0.001
	Exp. error	5.42	6	0.903		
	Total	96.86	8			

in both plots with PC and NPC dripper systems. Less uniformity of water distribution under plot with NPC drippers resulted in significant difference in average yield under all the treatments (irrigation levels) with maximum yield (61.43 tonnes/ha) in 100% ET_c. Analogous marginal effect of deficit irrigation (80% ET_c) on yield reduction were reported by earlier investigators (Tiwari *et al.* 2003; Wahb-Allah *et al.* 2014). In summary, 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.

CONCLUSIONS

The present study was carried out to evaluate the impact of PC and NPC drip irrigation systems and three levels of irrigation on growth and yield of cabbage crop. PC dripper system performed better than NPC dripper system in terms of irrigation uniformity parameters. Therefore, PC dripper system could be suggested where high irrigation uniformity is crucial. PC dripper with low dripper flow rate has potential for increasing yield of cabbage as compared to NPC drippers. Moreover, under PC drip systems, no significant difference in cabbage yield was observed for the irrigation levels with 100 and 80 % ET_c. Consequently, about 20% irrigation water could be saved in PC drip system by irrigating the cabbage crop at 80% ET_c without compromising the yield. Thus, indicating a definitive benefit in adopting deficit irrigation with PC drip irrigation system for cabbage production in areas with water shortage condition.

REFERENCES

Allen R G, Pereira L S, Raes D and Smith M. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. Irrigation and Drainage Paper No. 56, FAO, Rome, Italy, p 300.

Central Water Commission (CWC). 2000. Report of the Standing Sub-Committee for Assessment of availability and requirement of water for diverse uses in the country. (Available at: http://www.cwc.nic.in).

Central Water Commission (CWC). 2011. Water Resources at a Glance, New Delhi. (Available at: http://www.cwc.nic.in).

Dasberg S and Or D. 1999. *Applied Agriculture: Drip Irrigation.* p 162. Springer-Verlag, New York, NY.

Geerts, Sam and Raes, Dirk, 2009. Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management.* **96**(9):1 275–84.

Imtiyaz M, Mgadla N P, Chepete B and Manase S K. 2000. Response of six vegetable crops to irrigation schedules. *Agricultural Water Management*, **45:** 331–42.

Keller J and Karmaeli D. 1974. Trickle irrigation design. Rain Bird Sprinkler Manufacturing Corporation, Glendora, California.

Pitts D J. 1997. Evaluation of micro irrigation systems. South West Florida Research and Education Centre, University of Florida.

Sezen SM, Yazar A and Eker S. 2006. Effect of drip irrigation regimes on yield and quality of field grown bell pepper. *Agricultural. Water Management* **81**: 115–31.

Smith M (Eds.).1991. Report on the expert consultation on procedures for revision of FAO guidelines for prediction of crop water requirements. FAO, Rome, p 45.

Tavakkoli A R, and Oweis T Y. 2004. The role of supplemental irrigation and nitrogen in producing bread wheat in the highlands of Iran. *Agricultural Water Management*. **65:** 225–36.

Tiwari K N, Singh A and Mal P K. 2003. Effect of drip irrigation on yield of cabbage under mulch and non-mulch conditions. *Agricultural Water Management* **58:**19–28.

Wahb-Allah M, Abdel-Razzak H, Alsadon A and Ibrahim A. 2014. Growth, yield, fruit quality and water use efficiency of tomato under arbuscular mycorrhizal inoculation and irrigation level treatments. *Life Science Journal* **11**(2):109–17.

Westarp S V, 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**:143–60.

Wu I P, Howell T A and Hiler E A. 1979. Hydraulic design of drip irrigation systems. Hawaii Agric Exp Stn, Tech. Bull. 105, Honolulu.

Zhang, Heping and Oweis, Theib. 1999. Water-yield relations and optimal irrigation scheduling of wheat in the Mediterranean region, *Agricultural Water Management* **38**(3): 195–211.

Zhang Y, Kendy E, Qiang Y, Changming L, Yanjun S and Hongyong, S. 2003. Effect of soil water deûcit on evapotranspiration, crop yield, and water use efficiency in the North China Plain. *Agricultural Water Management* **64**:107–22.