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# Effect of Environment, Irrigation and Fertigation on Growth, Yield and Water Use Efficiency in Red Cabbage

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## ABSTRACT

A study was conducted on red cabbage at the Precision Farming Development Centre, Mahatma Phule Krishi Vidyapeeth in Rahuri, Maharashtra, India. The research compared two growing environments: inside a polyhouse and in an open field. It also tested three different irrigation levels (0.90 ETc, 0.75 ETc, and 0.60 ETc) and three fertilizer application rates (125% of the recommended dose (RD), 100% RD, and 75% RD). The results showed that red cabbage yielded the best under polyhouse conditions with the highest irrigation level (0.90 ETc) and the highest fertilizer rate (125% RD). Additionally, the highest water use efficiency was achieved with a slightly lower irrigation level (0.75 ETc) but still with the highest fertilizer rate (125% RD) inside the polyhouse.

**Key Words:** Environment condition, Fertigation regimes, Irrigation regimes, Polyhouse, Red cabbage

## INTRODUCTION

Indian Government is promoting exotic vegetables, of which market value and nutrient content is quite higher than traditional vegetables. In this situation, to acquire proper knowledge of a particular vegetable, i.e. how the variety of that vegetable is responding to Indian climate and to the irrigation and fertigation regimes as well. A research experiment of red cabbage was under taken at Precision Farming Development Centre, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. Red cabbage is new crop recently introduced in India. The native of this crop is Southern Europe, which requires cooler climate for its well development. It is proved by several researchers that there is significant role of environment, irrigation and fertigation on the growth and yield of crop. (Harel et al, 2014; Ojha et al, 2016; Umesha et al, 2011) Bhosale and Sonawane (2016) and (Santosh et al, 2017) reported similar results for different vegetables. (Paksoy, 2006) conducted a research experiment on different varieties of red cabbage with different methods of irrigation and reported that highest yield was obtained under drip irrigation, followed by sprinkler and furrow irrigation. (Kumar *et al* 2010), and (Gopala Reddy et al, 2017) also specified that drip irrigation was the most efficient and profitable method among all irrigation methods.

## MATERIALS AND METHODS

The site of experiment was situated at $19^0$ 47' N latitude and $74^0$ 37' E longitudes at 657 m above mean sea level, in the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The experiment was carried out in polyhouse and open field in split-split plot design with 18 treatments comprising of two environmental conditions i.e. polyhouse ($E_1$) and open field ($E_2$), three irrigation regimes 0.90 ($I_1$), 0.75 ($I_2$) and 0.60 ($I_3$) of crop evapo-transpiration and three fertigation regimes 125 ($F_1$), 100 ($F_2$) and 75 ($F_3$) % of RDF (recommended dose of fertilizer) with three replications. The size of the polyhouse was 25 × 20 m and open field was 20 x 18 m. The size of each raised beds in polyhouse and open field were 2.7 x 0.75 m and 4.5 × 0.75 m, respectively, with 0.3 m height and 0.5 m buffer strip was provided between two beds. Silver colour at top and black colour at bottom polyethylene mulch was used commonly in all the treatments. The width of mulch and thickness

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**Table 1. Effect of different environmental condition, irrigation regimes and fertigation regimes on plant height, stem girth, E-W spread and N-S spread at harvest (120 DAT) of red cabbage plant**

| Treatment | At harvest, 120 DAT | | | |
|---|---|---|---|---|
| | Plant Height, cm | Stem girth, mm | E-W spread, cm | N-S spread, cm |
| A. Environmental factor | | | | |
| $E_1$: Polyhouse | 33.46 | 14.76 | 46.43 | 50.30 |
| $E_2$: Open field | 29.13 | 16.40 | 38.55 | 43.03 |
| S.E.m± | 0.13 | 0.26 | 0.15 | 0.26 |
| C.D. at 5% | 0.81 | 1.57 | 0.92 | 1.60 |
| B. Irrigation level (I) | | | | |
| $I_1$: 90% ETc | 31.87 | 18.07 | 43.26 | 47.68 |
| $I_2$: 75% ETc | 31.55 | 15.40 | 42.55 | 46.88 |
| $I_3$: 60% ETc | 30.47 | 13.26 | 41.65 | 45.44 |
| S.E.m± | 0.06 | 0.14 | 0.36 | 0.39 |
| C.D. at 5% | 0.21 | 0.44 | 1.18 | 1.26 |
| C. Fertigation level (F) | | | | |
| $F_1$: 125% RD | 32.63 | 16.67 | 43.29 | 48.54 |
| $F_2$: 100% RD | 31.19 | 15.32 | 42.68 | 46.65 |
| $F_3$: 75% RD | 30.08 | 14.74 | 41.49 | 44.81 |
| S.E.m± | 0.11 | 0.06 | 0.49 | 0.63 |
| C.D. at 5% | 0.33 | 0.18 | 1.44 | 1.84 |
| C. Interaction (E X I) | | | | |
| S.E.m± | 0.09 | 0.19 | 0.51 | 0.55 |
| C.D. at 5% | 0.29 | 0.63 | NS | NS |
| D. Interaction (E X F) | | | | |
| S.E.m± | 0.16 | 0.09 | 0.70 | 0.89 |
| C.D. at 5% | NS | 0.26 | NS | NS |
| E. Interaction (I X F) | | | | |
| S.E.m± | 0.19 | 0.11 | 0.86 | 1.09 |
| C.D. at 5% | 0.57 | 0.32 | NS | NS |
| F. Interaction (E X I X F ) | | | | |
| S.E.m± | 0.28 | 0.15 | 1.21 | 1.55 |
| C.D. at 5% | 0.80 | 0.45 | NS | NS |

were 1.20 m and 25 micron respectively. The recommended dose of fertilizers of red cabbage in open field cultivation was 80:40:40 kg/ha (N: P: K). In the experiment, drip irrigation system was used for daily irrigation. Average emission uniformity of drip irrigation system was observed in the range of 89.16 % to 93.12 %.

## RESULTS AND DISCUSSION

The maximum plant height (35.87 cm) was observed under $T_1 = E_1I_1F_1$ (Polyhouse x 0.90 ETc x 125 % RDF), which was significantly superior over other treatments. However, the minimum plant height was (25.91 cm) under $T_{18} = E_2I_3F_3$ (Open field x 0.60 ETc x 75 % RDF) treatment (Table 1). The effect of different factors i.e. environment, irrigation and fertigation are depicted in Fig. 1(a), (b) and (c) respectively and interaction of all three factor is depicted in Fig. 1(d) (Table 2). The maximum stem girth (20.66 mm) was observed under $T_1 = E_2I_1F_1$ (Open field x 0.90 ETc x 125 % RDF), which was significantly

**Table 2. Interaction effect of different environmental condition, irrigation regimes and fertigation regimes on plant height (cm) at harvest (120 DAT) of red cabbage plant**

| Treatment | $E_1$: Polyhouse | | | $E_2$: Open field | | |
|---|---|---|---|---|---|---|
| | $I_1$:0.9 ETc | $I_2$:0.75 ETc | $I_3$:0.6 ETc | $I_1$:0.9 ETc | $I_2$:0.75 ETc | $I_3$:0.6 ETc |
| | ( cm ) | ( cm ) | ( cm ) | ( cm ) | ( cm ) | ( cm ) |
| $F_1$: 125% RDF | 35.87 | 34.33 | 33.99 | 31.01 | 30.79 | 29.79 |
| $F_2$: 100% RDF | 33.27 | 33.85 | 32.44 | 29.58 | 29.21 | 28.78 |
| $F_3$: 75% RDF | 32.87 | 32.61 | 31.93 | 28.64 | 28.51 | 25.91 |
| S.E.± = 0.28 | | | | CD at 5 % = 0.80 | | |

**Table 3. Interaction effect of different environmental condition, irrigation regimes and fertigation regimes on stem girth (mm) at 120 DAT (at harvest) of red cabbage plant**

| Treatment | $E_1$: Polyhouse | | | $E_2$: Open field | | |
|---|---|---|---|---|---|---|
| | $I_1$:0.9 ETc | $I_2$:0.75 ETc | $I_3$:0.6 ETc | $I_1$:0.9 ETc | $I_2$:0.75 ETc | $I_3$:0.6 ETc |
| | ( mm ) | ( mm ) | ( mm ) | ( mm ) | ( mm ) | ( mm ) |
| $F_1$: 125% RDF | 18.78 | 15.10 | 13.45 | 20.66 | 17.11 | 14.92 |
| $F_2$: 100% RDF | 16.78 | 14.18 | 12.29 | 18.56 | 16.49 | 13.65 |
| $F_3$: 75% RDF | 15.89 | 13.77 | 12.58 | 17.78 | 15.72 | 12.68 |
| S.E.± = 0.15 | | | | CD at 5 % = 0.45 | | |

**Table 4. Effect of environmental condition, irrigation regimes and fertigation regimes on the yield, equatorial and polar diameter of red cabbage**

| Treatments | q/1008 $m^2$ | Equatorial diameter | Polar diameter |
|---|---|---|---|
| A. Environment Condition (E) | | | |
| $E_1$: Polyhouse | 32.65 | 201.13 | 278.73 |
| $E_2$: Open field | 18.95 | 128.38 | 90.18 |
| S.E.m± | 0.31 | 2.65 | 1.89 |
| C.D. at 5% | 1.88 | 16.11 | 11.53 |
| B. Irrigation level (I) | | | |
| $I_1$: 90% ETc | 31.88 | 197.91 | 227.66 |
| $I_2$: 75% ETc | 27.70 | 168.44 | 186.30 |
| $I_3$: 60% ETc | 17.83 | 127.92 | 139.41 |
| S.E.m± | 0.36 | 0.61 | 1.45 |
| C.D. at 5% | 1.18 | 1.97 | 4.73 |
| C. Fertigation level (F) | | | |
| $F_1$: 125% RD | 28.18 | 174.96 | 199.03 |
| $F_2$: 100% RD | 25.96 | 165.72 | 189.68 |
| $F_3$: 75% RD | 23.27 | 153.58 | 164.65 |
| S.E.m± | 0.28 | 1.14 | 1.21 |
| C.D. at 5% | 0.81 | 3.33 | 3.53 |

| Treatments | q/1008 m$^2$ | Equatorial diameter | Polar diameter |
|---|---|---|---|
| D. Interaction (E X I) | | | |
| S.E.m± | 0.51 | 0.86 | 2.05 |
| C.D. at 5% | 1.68 | 2.79 | 6.69 |
| E. Interaction (E X F) | | | |
| S.E.m± | 0.39 | 1.61 | 1.71 |
| C.D. at 5% | 1.14 | NS | 4.99 |
| F. Interaction (I X F) | | | |
| S.E.m± | 0.48 | 1.97 | 2.10 |
| C.D. at 5% | 1.40 | 5.76 | 6.12 |
| G. Interaction (E X I X F ) | | | |
| S.E.m± | 0.68 | 2.79 | 2.96 |
| C.D. at 5% | 1.98 | 8.14 | 8.65 |

**Table 5. Interaction effect of different environmental condition, irrigation regimes and fertigation regimes on yield (q/1008 m$^2$), head diameter (equatorial diameter in mm) and head diameter (polar diameter in mm), of red cabbage plant**

| Treatment | $E_1$: Polyhouse | | | $E_2$: Open field | | |
|---|---|---|---|---|---|---|
| | $I_1$:0.9 ETc | $I_2$:0.75 ETc | $I_3$:0.6 ETc | $I_1$:0.9 ETc | $I_2$:0.75 ETc | $I_3$:0.6 ETc |
| | Yield, q/1008 m$^2$ | | | | | |
| $F_1$: 125% RDF | 43.74 | 36.74 | 26.09 | 25.95 | 22.18 | 14.39 |
| $F_2$: 100% RDF | 37.92 | 36.22 | 24.56 | 24.12 | 20.41 | 12.52 |
| $F_3$: 75% RDF | 37.18 | 32.48 | 18.94 | 22.37 | 18.15 | 10.49 |
| S.E.± = 0.68 | | | | CD at 5 % = 1.98 | | |
| Equatorial head diameter, mm | | | | | | |
| $F_1$: 125% RDF | 243.33 | 221.65 | 172.23 | 165.77 | 138.54 | 108.24 |
| $F_2$: 100% RDF | 235.36 | 202.36 | 165.89 | 161.43 | 131.17 | 98.14 |
| $F_3$: 75% RDF | 232.19 | 190.82 | 146.34 | 149.38 | 126.09 | 76.68 |
| S.E. ± = 2.79 | | | | CD at 5 % = 8.14 | | |
| Polar head diameter, mm | | | | | | |
| $F_1$: 125% RDF | 332.18 | 308.55 | 255.34 | 136.31 | 88.28 | 73.50 |
| $F_2$: 100% RDF | 331.45 | 293.03 | 238.91 | 129.53 | 85.65 | 59.52 |
| $F_3$: 75% RDF | 309.31 | 256.82 | 182.96 | 127.16 | 85.45 | 26.22 |
| S.E.± = 2.96 | | | | CD at 5 % = 8.65 | | |

superior over other treatments. However, the minimum stem girth was (12.58 mm) under $T_9$= $E_1I_3F_3$ (Polyhouse x 0.60 ETc x 75 % RDF) treatment (Table 1). The effect of different factors i.e. environment, irrigation and fertigation are depicted in Fig. 2(a), (b) and (c) respectively and interaction of all three factor is depicted in Fig. 2(d) (Table 3). There was no significant difference was noticed in plant spread in N-S and E-W direction under different treatments (Table 1).

The maximum yield per 1008 m$^2$ area of polyhouse was 43.74 q was observed under $T_1$= $E_1I_1F_1$ (Polyhouse x 0.90 ETc x 125 % RDF), which was significantly superior over other treatments. However, the minimum yield per 1008 m$^2$ area of polyhouse was 10.49 q under $T_{18}$= $E_2I_3F_3$ (i.e. open

**Table 6. Total depth of irrigation water applied over the growth period of red cabbage**

| Treatment No. | Treatment | Total water required, mm | Water use efficiency, kg/m$^3$ |
|---|---|---|---|
| $T_1$ | Polyhouse x 90 % ETc x 125% RDF | 356.47 | 20.11 |
| $T_2$ | Polyhouse x 90 % ETc x 100% RDF | 356.47 | 17.44 |
| $T_3$ | Polyhouse x 90 % ETc x 75% RDF | 356.47 | 17.10 |
| $T_4$ | Polyhouse x 75 % ETc x 125% RDF | 297.05 | 20.28 |
| $T_5$ | Polyhouse x 75 % ETc x 100% RDF | 297.05 | 19.99 |
| $T_6$ | Polyhouse x 75 % ETc x 75% RDF | 297.05 | 17.93 |
| $T_7$ | Polyhouse x 60 % ETc x 125% RDF | 237.64 | 17.995 |
| $T_8$ | Polyhouse x 60 % ETc x 100% RDF | 237.64 | 16.94 |
| $T_9$ | Polyhouse x 60 % ETc x 75% RDF | 237.64 | 13.06 |
| $T_{10}$ | Open Field x 90 % ETc x 125% RDF | 362.29 | 11.74 |
| $T_{11}$ | Open Field x 90 % ETc x 100% RDF | 362.29 | 10.91 |
| $T_{12}$ | Open Field x 90 % ETc x 75% RDF | 362.29 | 10.12 |
| $T_{13}$ | Open Field x 75 % ETc x 125% RDF | 311.60 | 11.67 |
| $T_{14}$ | Open Field x 75 % ETc x 100% RDF | 311.60 | 10.74 |
| $T_{15}$ | Open Field x 75 % ETc x 75% RDF | 311.60 | 9.55 |
| $T_{16}$ | Open Field x 60 % ETc x 125% RDF | 260.91 | 9.04 |
| $T_{17}$ | Open Field x 60 % ETc x 100% RDF | 260.91 | 7.87 |
| $T_{18}$ | Open Field x 60 % ETc x 75% RDF | 260.91 | 6.59 |

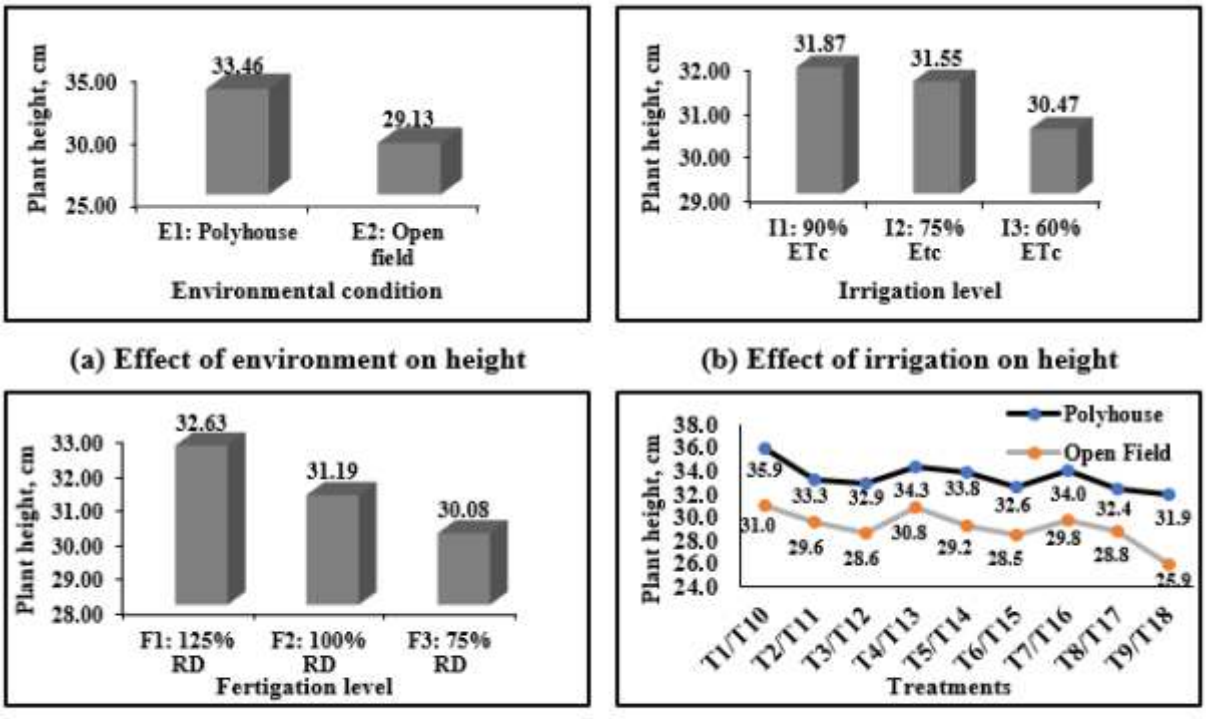
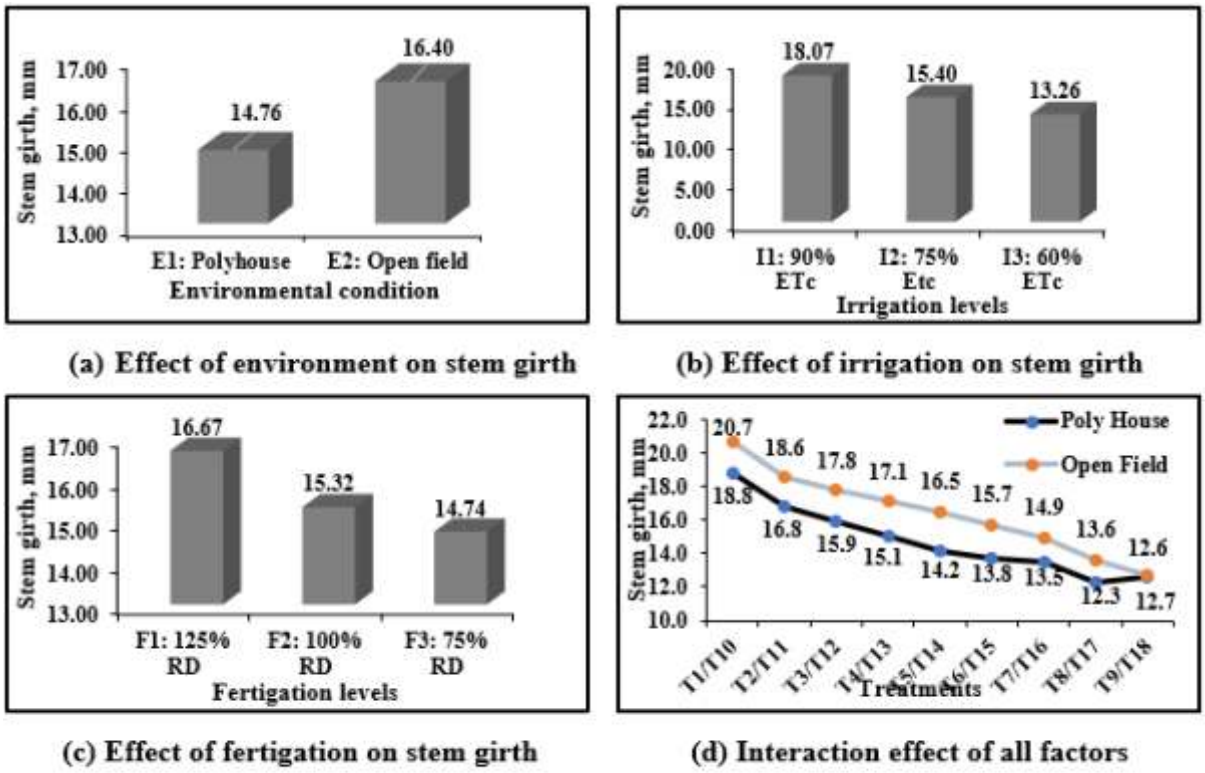



**Fig. 1 Effect of treatments on an average height of red cabbage plant at harvest**



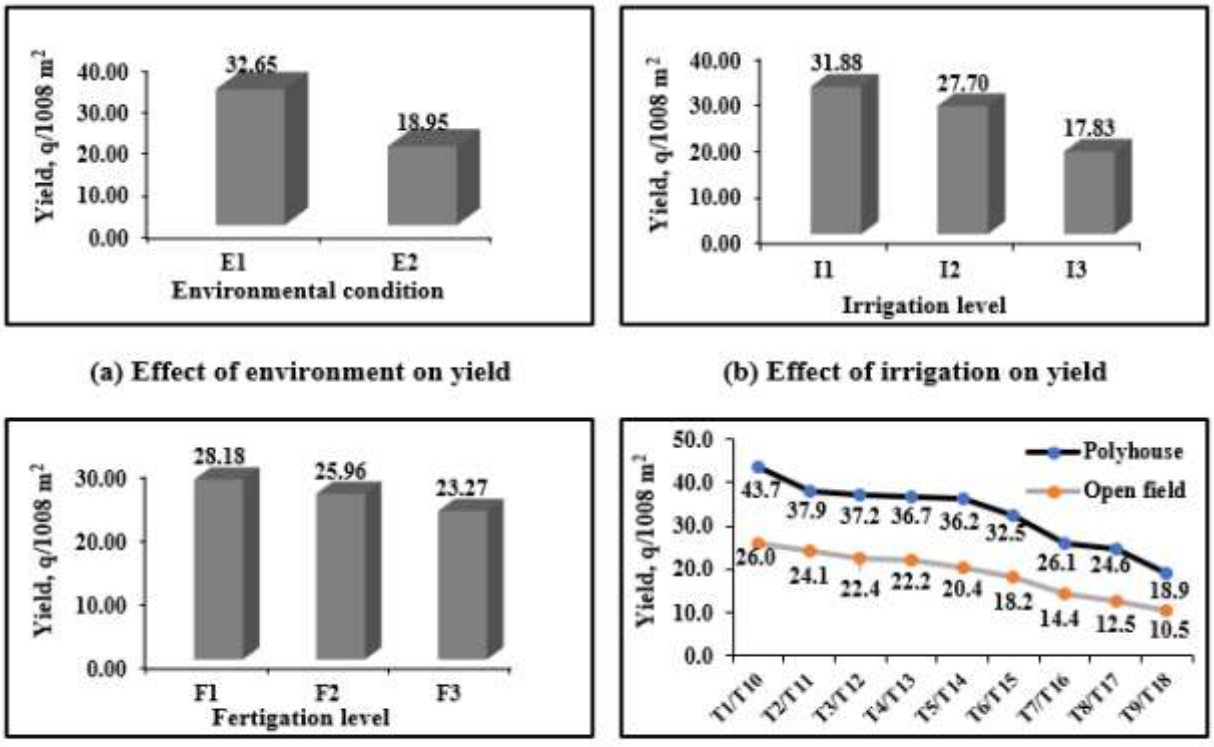

(a) Effect of environment on stem girth

(b) Effect of irrigation on stem girth

(c) Effect of fertigation on stem girth

(d) Interaction effect of all factors

**Fig. 2 Effect of treatments on an average stem girth of red cabbage plant at harvest**




(a) Effect of environment on yield

(b) Effect of irrigation on yield

(c) Effect of fertigation on yield

(d) Interaction effect of all factors

**Fig. 3 Effect of treatments on an average yield of red cabbage plant**

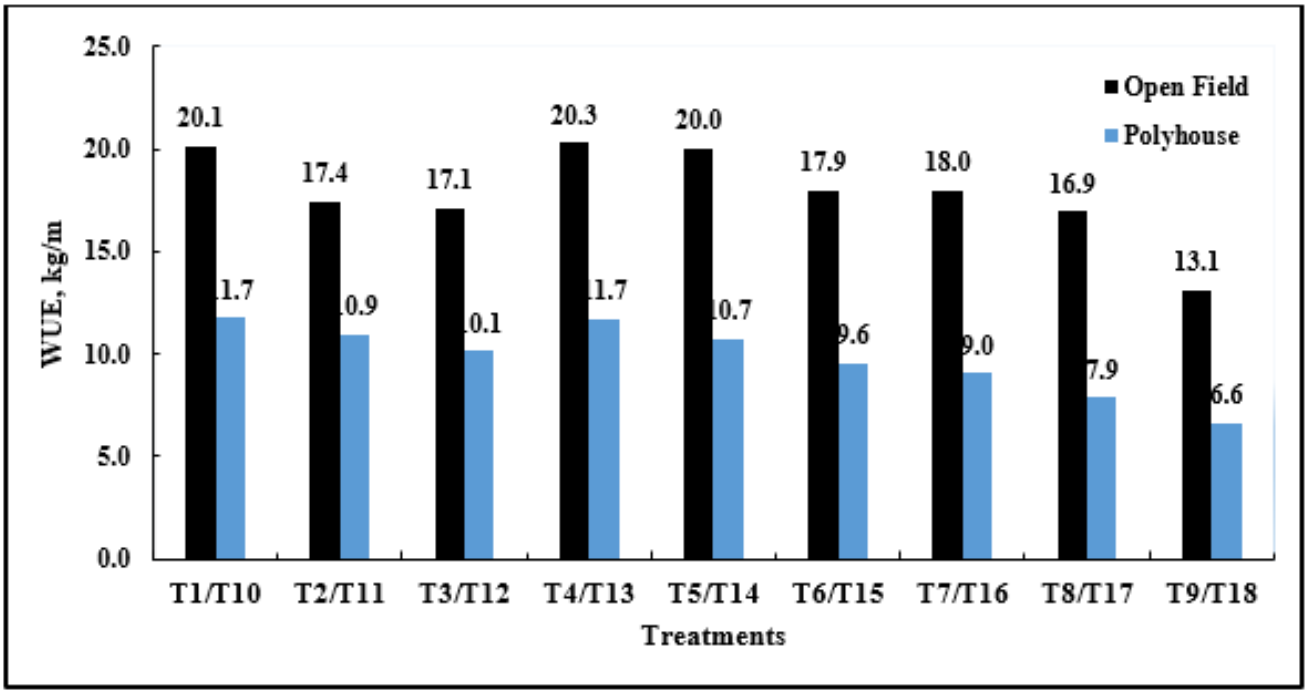



**Fig. 4 Water use efficiency (WUE) of red cabbage as affected by treatments**

field x 0.60 ETc x 75 % RDF) (Fig. 3) (Table 4). The maximum equatorial diameter (243.33 mm) was observed under $T_1$= $E_1I_1F_1$ (Polyhouse x 0.90 ETc x 125 % RDF), which was significantly superior over other treatments and the minimum (76.68 mm) was noticed under $T_{18}$= $E_2I_3F_3$ (Open field x 0.60 ETc x 75 % RDF) treatment (Table 4). The maximum polar diameter (332.18 mm) was observed under $T_1$= $E_1I_1F_1$ (Polyhouse x 0.90 ETc x 125 % RDF), which was significantly superior over other treatments while the minimum was (26.22 mm) under $T_{18}$= $E_2I_3F_3$ (Open field x 0.60 ETc x 75 % RDF) (Table 4).The maximum depth of water (362.29 mm) was applied in treatment $I_1$ (0.90 ETc) in open field and minimum (237.64 mm) in treatment $I_3$ (0.60 ETc) in polyhouse (Table 6). The highest water use efficiency (20.28 kg/m) was found in treatment $T_4$= $E_1$ x $I_2$ x $F_1$ (Polyhouse x 0.75 ETc x 125 % RDF) whereas the lowest water use efficiency (6.59 kg/$m^3$) in treatment $T_{18}$= $E_2I_3F_3$ (Open field x 0.60 ETc x 75 % RDF) (Table 6). The water use efficiency of red cabbage due to different treatment is depicted in Fig.(4).

## CONCLUSION

The study revealed that, there was significant effect of environment, irrigation and fertigation on the yield and some growth factors, on the red cabbage. Cultivation of red cabbage under polyhouse with drip irrigation at 0.90 ETc and fertigation at 125 % RDF resulted in 59.50 % higher yield and 57.63 % higher water use efficiency was resulted under polyhouse with drip irrigation at 0.75 ETc and fertigation at 125 % RDF, over that of best treatment of open field cultivation. However, in case of open field condition with drip irrigation of 0.90 ETc and fertigation at 125 % RDF resulted in maximum yield and water use efficiency of red cabbage.

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