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Effect of Irrigation Regimes on Biochemical Studies of Red Cabbage (*Brassica oleracea* L. var. *capitata f. rubra*) under Mulch and Non-Mulch Condition

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ABSTRACT

A field experiment was conducted at College of Horticulture and Forestry, Central Agriculture University, Pasighat, Arunachal Pradesh during 2019-20 to assess the "Effect of Irrigation Regimes on Biochemical Studies of Red Cabbage (*Brassica oleracea* L. var. *capitata f. rubra*) under Mulch and Non-mulch Condition". The experiment was done in a Randomized Block Design (RBD) with seven treatments and three replications as control, 100% CPE with drip irrigation, 80% CPE with drip irrigation, 60% CPE with drip irrigation, 100% CPE with drip irrigation under mulch, 80% CPE with drip irrigation under mulch, 60% CPE with drip irrigation under mulch. From the present investigation, it was observed that biochemical parameters like TSS (6.75 °B), total carbohydrates (3.30 g/100g) and anthocyanin (23.66 mg/100g) were maximum at control. While total protein content (2.84 g/100g) and ascorbic acid (102 mg/100g) were recorded higher in 60% CPE with drip irrigation. The findings demonstrated that using irrigation water at a lower rate than full drip irrigation rate can assist increase in TSS, total carbohydrate, anthocyanin, total protein and ascorbic acid concentrations in red cabbage.

Keywords CPE, Drip irrigation, Quality, Red cabbage, TSS, Total protein.

INTRODUCTION

Red cabbage (*Brassica oleracea* L. var. *capitata f. rubr*wf) is a cruciferous vegetable crop that is high in nutrients. It is high in dietary fiber, antioxidants and anthocyanin (a color component responsible for the red-purple coloration), is low in calories and prevents cancer and inflammation. It also has a high concentration of vitamins (C, E, A and K) and minerals (calcium, manganese, magnesium, iron and potassium), as well as a low saturated fat and cholesterol level. This crop also contains B vitamins such as thiamine (B_1), riboflavin (B_2) and folate (B_8). Cabbage contains a tiny quantity of protein in addition to vitamins and minerals (Hasan and Solaiman 2012). Antioxidant capabilities of red cabbage are superior to those of spinach, broccoli, onion or tomato (Proteggente *et al.*

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2002). Raw red cabbage is frequently used in salads and coleslaw. This vegetable can be consumed raw or cooked. It is the classic side dish served with many German dinners, particularly meat dishes such as Sauerbraten or Döner. It can be seasoned, braised, and eaten as a complement to seasonal roast goose or turkey during Christmas. Apples are frequently added to give it a sweet-sour flavor.

Freshwater scarcity, as well as contamination of ground and surface water, is becoming a major source of worry for agriculture. Drip irrigation is the most efficient water application technology (Mangrio *et al*. 2013) because it applies irrigation water to the plant's root zone, reducing crop water application and increasing applied water use efficiency. Generally, being a cool season crop, it yields less under reduced irrigation regimes, although several quality characteristics, such as TSS and total protein content, tend to rise when a stressed situation is generated.

With these considerations in mind, this study was done to determine the influence of various irrigation regimes on red cabbage TSS, total protein concentration, total carbohydrate, ascorbic acid and anthocyanin content.

MATERIALS AND METHODS

The experiment was conducted at Vegetable Research Farm of College of Horticulture and Forestry, Central Agriculture University, Pasighat, Arunachal Pradesh during 2019-20 in *rabi* season. The experimental site located at 28.07º N latitude and 95.33º E longitude and is 155 meters above mean sea level. The site lies in the "Eastern Himalaya region" of the planning commission's agro-climatic zones, with an average annual temperature of 22.8°C to 23.96°C with a sub-tropical and humid climate. The soil of the experimental field was sandy loam in texture, with a pH of 6.4, a moisture content of 26.15 % and a water holding capacity of 27.69%. The experiment consists of seven treatments and three replications in a Randomized Block Design with three level of irrigation (viz., 100%, 80% and 60% CPE) with and without mulch. The detail of treatments is as follows:

T_1 = Control
T_2 = 100% CPE with drip irrigation
T_3 = 80% CPE with drip irrigation
T_4 = 60% CPE with drip irrigation
T_5 = 100% CPE with drip irrigation under mulch
T_6 = 80% CPE with drip irrigation under mulch
T_7 = 60% CPE with drip irrigation under mulch

Seedlings were replanted in a paired row at 60×45 cm spacing after 30 days. The recommended fertilizer dose, together with manure, has been applied to meet the nutritional needs of red cabbage for optimum growth and development.

Estimation of irrigation water requirement

The water requirement of red cabbage was calculated using daily reference pen evaporation data collected from a class. A evaporation pen at the college's meteorological station (as mention in Table 1). The irrigation amount was then calculated using the Doorenbos and Pruitt (1977) formula.

$$V = IW \times A \times Wa \times Kc$$

Where,

V = Net depth of water required, liters/day/plant
IW = Irrigation water, mm
A = Area allocated to a plant (row to row x plant to plant), m^2
Wa = Wetted area factor
Kc = Crop coefficient

Irrigation Water (IW) was computed using a cumulative pan evaporation (CPE) reading and the

Table 1. Meteorological data recorded during crop period of the year 2019-20.

Month	Temp (°C) FN Max	AN Max	RH (%) FN	AN	Rainfall (mm)	No. of rainy days	Evaporation (mm/day)
October	24.1	28.3	86.6	87.1	132.00	9	3.30
November	22.7	27.9	84.9	80.8	22.00	3	3.00
December	17.9	23.1	87.2	80.5	7.00	2	3.90
January	15.8	20.9	91.0	86.2	97.25	3	3.47
February	18.4	24.7	95.9	95.0	48.85	3	3.72
March	21.9	24.5	91.6	90.6	377.04	5	4.50
Average			**89.53**	**86.70**	**114.02**		**3.65**
Total					**684.14**	**25**	

IW/CPE = 1 formula, with an 80% wetted area factor (for close growing crops). For the initial, development and mid stages, the reference crop coefficients were 0.45, 0.75 and 1.05, respectively. For better seedling establishment, the experimental plots were irrigated with a uniform volume of irrigation water at first, then irrigation was scheduled at three-day intervals.

Total soluble solids

The selected red cabbage head were cut into small pieces and crushed with mortar and pestle. The juice was extracted and collected in a small beaker after passing through a double layer of muslin fabric. Total soluble solids were measured using a hand refractometer. After each sample, the refractometer was cleaned.

Total protein

Total protein content in red cabbage for each treatment was analyzed by the method described by Lowry *et al*. (1951).

Reagent (A): 2% sodium carbonate (Na_2CO_3) in 0.1N sodium hydroxide (NaOH).

Reagent (B): 0.5% copper sulphate ($CuSO_4 .5H_2O$) in 1% potassium sodium tartrate.

Reagent (C): Alkaline copper solution- mixing of 50 ml of reagent (A) and 1 ml of reagent (B).

Reagent (D): Folin- ciocalteau reagent

Procedure: 200 mg (0.2 g) of sample was grinded with 5 ml of buffer solution and centrifuged. Separated 0.2 ml of supernatant in test tubes and made up the volume to 1 ml in each. Added 5 ml of reagent (C) and allowed to stand for 10 minutes. Then added 0.5 ml of reagent (D) and incubated in dark for 30 minutes at ambient temperature. Blue color developed and the OD value was taken at 660 nm.

$$\text{Total protein}\left(\frac{g}{100}\right) = \frac{\text{OD values } (\mu g) \times \text{Total vol (ml)} \times 100}{\text{Vol of extract used (ml)} \times \text{Wt of sample (g)} \times 1000}$$

Ascorbic acid

Ascorbic acid content of fresh head from the representative plants was estimated by using 2, 6- dichlorophenol indophenols titration method and expressed in mg/100g of fresh weight.

Total carbohydrates

Total carbohydrates content of fresh heads of red cabbage was estimated from the selected plant samples by using anthrone method.

Reagent: 2.5 N HCl and anthrone reagent (prepared by mixing 200 mg of anthrone in 600 ml of ice cold 95% HCl).

Procedure: 0.1 g of sample bland with 5 ml of 2.5 N HCl and transferred to test tubes. Test tubes were kept on hot plates for 3 hours and cooled. Samples were neutralized with Na_2CO_3 till the effervescence, shifted to centrifuge tubes, made up volume to 10 ml and centrifuged. 0.5 ml of supernatant was collected and made up vol to 1 ml with distilled water then volume made to 5 ml by adding anthrone reagent in test tubes. Again kept on hot plate for 8 minutes and cooled it. Color changed from green to dark green then recorded OD values at 630 nm.

$$\text{Carbohydrates}\left(\frac{mg}{100g}\right) = \frac{\text{OD values } (\mu g) \times \text{total vol. (ml)} \times 100}{\text{Vol of extract used (ml)} \times \text{Wt of sample (g)} \times 1000}$$

Anthocyanin

Anthocyanin content of fresh heads of representative plants was estimated by the method given by Ranganna (1986).

Reagent: Ethanolic HCl, prepared by mixing of 99.9% pure ethanol and 1.5 N HCl in a ratio of 85:15.

Procedure: 0.5 g of sample crushed with 10 ml of Ethanolic HCl and kept overnight in refrigerator at 4ºC. 0.2 ml of volume was taken in test tube and made up the volume to 5ml with ethanolic HCl and recorded OD value at 535 nm.

$$\text{Total OD per 100 g} = \frac{\text{OD} \times \text{vol made up of extract} \times \text{total vol (ml)} \times 100}{\text{Vol of extract used (ml)} \times \text{wt of sample (g)}}$$

$$\text{Total anthocyanin (mg/100 g)} = \frac{\text{Total OD per 100 g}}{98.2}$$

Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significance difference of different irrigation regimes and mulch- non mulch condition on the growth, yield and yield attributes of red cabbage. Field and laboratory data was then subjected to analysis of variance by Randomized Block Design. Significance and non-significance of the variance due to the different treatments were determined by calculating the respective 'F' values as given by Gomez and Gomez (1984). The statistical analysis of the data on the mean values of individual parameters was analyzed by using OPSTAT online software, developed by Department of Mathematics and Statistics, HAU, Hisar, Haryana.

RESULTS AND DISCUSSION

Total soluble solids

Red cabbage produced under different levels of drip irrigation with and without mulch condition was found statistically significant for total soluble solid (TSS). TSS in freshly harvested heads was ranged from 6.75 to 4.90°B as presented in Fig. 1 and Table 2. T_1 (control) had the highest TSS level (6.75 °B), which was on par with T_4 (60% CPE with drip irrigation) 6.35 °B and T_7 (60% CPE with drip irrigation under mulch) 6.30 °B. The treatment T_2, on the other hand, had the lowest TSS (5.13°B).

Table 2. Effect of different regimes of drip irrigation on TSS and total protein concentration.

Treatments	TSS (°B)	Total protein (g/ 100g)
T_1	6.75	1.70
T_2	5.13	2.25
T_3	6.04	2.34
T_4	6.35	2.84
T_5	6.00	2.57
T_6	5.90	2.39
T_7	6.30	2.37
SE (d)	0.26	0.19
CD at 5%	0.57	0.45

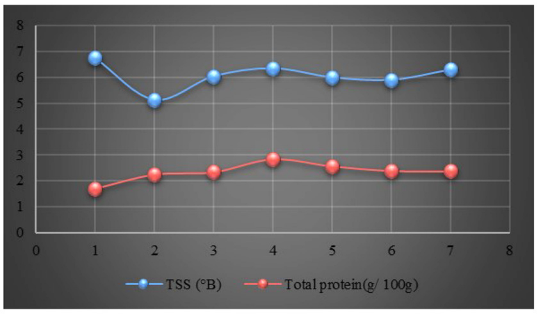

Fig. 1. Effect of different regimes of drip irrigation on TSS and total protein concentration.

Plants have been shown to accumulate total soluble solids (TSS) as a key adaptation mechanism in response to low moisture levels (Babita *et al*. 2010). The TSS concentration increased with decreased irrigation levels in our study, while the maximum TSS concentration was found in the control. Low irrigation water increases the activity of sucrose synthesis and sucrose phosphate synthesis, which transports more assimilates into the head and increases the rate and amount of fructose and glucose transformation from sucrose, resulting in higher TSS (Zegbe Dominguez *et al*. 2003) and (Chen *et al*. 2013).

Total protein

The influence of different drip irrigation regimes under mulch and non-mulch conditions on total protein content in red cabbage was found to be statistically significant Table 2. T_4 (60% CPE with drip irrigation) had the highest total protein content of 2.84 g/100g which was on par with T_5 (100% CPE with drip irrigation under mulch) 2.57 g/100g followed by treatment T_6 (80% CPE with drip irrigation under mulch) 2.39 g/100g. In red cabbage, treatment T_1 (control) produced the lowest total protein (1.70 g/100g).

The total protein content of red cabbage is dramatically affected by different drip irrigation regimes with and without mulch. T_4 (60 % CPE with drip irrigation under mulch) had the highest total protein content, which was on par with T_5 (100 % CPE with drip irrigation). The total protein content of non-mulched treatments increased when irrigation levels decreased, whereas mulched treatments did not display the same pattern. It is possible that the mulch condition made enough moisture available to the plant root zone by reducing evaporation and percolation losses, allowing for better growth and photosynthetic activity in plants, as well as better nitrogen assimilation in plants, which may be responsible for protein synthesis. Kumar and Imtiyaz (2007) reported increase in total protein content of onion bulb with decreasing irrigation levels.

Ascorbic acid (mg/100g)

Data presented in Table 3 and Fig. 2 indicated significant influence of drip irrigation levels on ascorbic acid content of red cabbage. The maximum value manifested for treatment T_4 (60% CPE with drip irrigation) 102 mg/100g which was on par with treatment T_7 (60% CPE with drip irrigation under mulch) 94 mg/100g and T_5 (100% CPE with drip irrigation) 91 mg/100g. Treatment T_1 (control) manifested minimum ascorbic acid content 61.75 mg/100g.

The concentration of ascorbic acid was found to be increase for treatment T_4 and T_7 with lower level of irrigation. However, treatment T_5 interestingly exhibited higher concentration of ascorbic acid in red cabbage. Kuscu *et al*. (2014) and Chen *et al*. (2013) were also reported the similar result where the concentration of ascorbic acid increased with the decrease of irrigation water as they stated that increased irrigation level negatively affected the ascorbic acid concentration in tomato. It may be attributed to a decrease in water accumulation, which resulted in a decrease in water content of the head and, as a result, an increase in ascorbic acid concentration in red cabbage. This result is in agreement with Zhang *et al*. (2017).

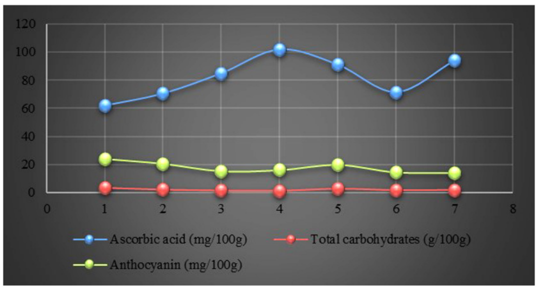

Fig. 2. Effect of different regimes of drip irrigation on ascorbic acid, total carbohydrates and anthocyanin concentration.

Total carbohydrate (g/100g)

The data presented in Table 3 and Fig. 2 depicted that effect of different irrigation regimes with and without mulch significantly affects the total carbohydrates content in red cabbage. However, the highest total carbohydrate was manifested in T_1 (control) 3.30 g/100g which was at par with T_5 (100% CPE with drip irrigation under mulch) 2.65 g/100g followed by T_2 (100% CPE with drip irrigation) 2.02 g/100g. The lowest value was obtained for treatment T_4 (60% CPE with drip irrigation) which was 1.28 g/100g.

Data presented in Table 3 shown significant influence of different irrigation regimes on total carbohydrate content of red cabbage. The higher amount of total carbohydrate was attributed for T_1 (control). The total carbohydrates concentration in treatments under water deficit and non-deficit condition along with and without mulch were not significantly different but there was a decrease in total carbohydrate content with decrease in irrigation regimes. Interestingly, treatment under 100% of irrigation along with mulch (T_5) showed a higher amount of total carbohydrate for red cabbage.

The highest concentration of total carbohydrate in T_1 that may be attributed due to the decrease in starch content within the cell as well as fall in photosynthetic activity that reduces the cellular growth,

Table 3. Effect of different regimes of drip irrigation on ascorbic acid, total carbohydrates and anthocyanin concentration.

Treatments	Ascorbic acid (mg/100g)	Total carbohydrates (g/100g)	Anthocyanin (mg/100g)
T_1	61.75	3.30	23.66
T_2	70.50	2.02	20.33
T_3	85.00	1.40	15.24
T_4	102.00	1.28	15.99
T_5	91.00	2.65	19.54
T_6	71.50	1.72	14.44
T_7	94.00	1.88	14.01
SE(d)	86.25	1.05	14.06
CD at 5%	1.52	0.49	1.04

and reduces the synthesis of sucrose for export, may attributed for higher synthesis of total carbohydrate content in T_1 (Rossiello *et el*. 198 Vassey and Sharkey 1989) were also reported. Furthermore, the decrease in total carbohydrate content with decreasing water supply may be attributed to depletion of polysaccharides such as starch and their utilization to combat with the water deficit condition according to Patakas and Noitsakis (2001).

Anthocyanin (mg/100g)

Data pertained in Table 3 and Fig. 2. demonstrated that the effect of different irrigation regimes under mulch and non-mulch was found significant for anthocyanin content in red cabbage. Treatment T_1 (control) perceived the highest amount of anthocyanin 23.66 mg/100g followed by T_2 (100% irrigation with drip irrigation) 20.33 mg/100g while treatment T_7 (60% irrigation with drip irrigation under mulch) resulted in the lowest anthocyanin content 14.01 mg/100g.

The influence on anthocyanin content in red cabbage had been observed due to the effect of different irrigation regimes under mulch and non-mulch condition. Data obtained, revealed that the concentration of anthocyanin did not vary much for different irrigation levels but the anthocyanin content in heads of red cabbage was decreased as per the stress increased to the plants. This may be due to deficit soil moisture, produced poor plant growth in respect to plant height and number of leaves per plant that may be attributed to decreased photosynthetic activity, causing reduction in head size and circumference that may lead to decrease in anthocyanin content as decreasing the irrigation levels.

CONCLUSION

The findings demonstrated that using irrigation water at a lower rate than full drip irrigation rate can assist increase in TSS, total carbohydrate, anthocyanin, total protein and ascorbic acid concentrations in red cabbage.

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