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EFFECT OF HUMIC ACID, BORON AND POTASSIUM ON GROWTH, YIELD AND QUALITY ATTRIBUTES OF CAULIFLOWER

Aparnna Rani Swain, Vishal Tripathi*, Deven Verma, Etalesh Goutam, Diksha Choudhary and Yaman Kumar

Department of Horticulture, School of Agriculture, Lovely Professional University, Jalandhar - 144 411, Punjab, India.
*Corresponding author E-mail : vishal.ambro@gmail.com
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ABSTRACT

Background : Prior research has demonstrated the critical roles that potassium, humic acid and boron play in stimulating plant development, increasing production and affecting the qualitative characteristics of cauliflower. To evaluate the crop's overall performance, more thorough research is still required to clarify the precise impacts and interactions of these nutrients.

Methods: An experiment was conducted at the Vegetable Research Farm of Department of Horticulture of Lovely Professional University, Punjab in 2023-24. This study was laid out in a randomized block design in triplicates to analyze the effect of foliar application of humic acid @5mLL^{-1}, boron @30gL^{-1}, potassium @1.5gL^{-1} and their combinations including humic acid @5mLL^{-1} + boron @30gL^{-1} and humic acid @5mLL^{-1} + potassium @1.5gL^{-1} on different growth [plant height (cm), number of leaves, leaf length (cm), leaf width (cm), chlorophyll index (SPAD value), stem diameter (cm)], yield [days to 50% curd initiation, days to curd maturity, curd weight (g), curd diameter (cm), curd size (cm^2), curd compactness (gcm^{-3}), curd yield per plot (kg), curd yield per hectare (q) and qualitative traits [total soluble solids (^{0}Brix), vitamin C content (mg per 100 g of fresh weight of curd), dry matter content of leaves (%)and shelf life (days)] of cauliflower at an interval of 40, 50 and 60 days after transplanting.

Results : From the obtained results treatment humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) showed a significant effect on various growth, yield and qualitative traits. However, some traits like number of leaves, curd compactness (gcm^{-3}) and shelf life (days) were found the best with boron @30gL^{-1} (T_4). While, the treatment with humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3) was found good for the traits including chlorophyll index (SPAD unit).

Key words : Cauliflower, *Brassica oleracea* var. *botrytis* L., Humic acid, Boron, Potassium.

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis* L.; 2n = 18) is one of the prime members of Cruciferae family, grown in cool-season. It requires a balanced dose of nutrients for its optimum growth and development (Hazra and Som, 2009). It is a nutrient rich crop that provides good amount of protein, vitamins and minerals (Thamburaj and Singh, 2001; Mahmood *et al.*,2019). The consumable part of cauliflower is curd. China and India account for roughly similar portions of the world's cauliflower production- 34.6% and 37.4%, respectively (Singh *et al.*,2022). Cauliflower production mainly depends on the heavy application of fertilizers, also it needs potassium for the development of its pre-floral apical meristem. The application of balanced dosages of fertilizers resulted into increased yield and productivity of a crop (Lahari *et al.*,2022). Studies revealed that humic acid, boron and potassium play an essential role for the improvement of various traits of cauliflower and strengthen it against various abiotic and biotic challenges (Meena *et al.*,2018; Moharmand Jawad, 2019; Abdel Nabi*et al.*,2020; Obaid *et al.*,2020; Hassan and Bader, 2023).

Materials and Methods

This experiment was carried out at the Vegetable farm (situated at 31°14´46´´N latitude, 75°42´12´´E longitude with an altitude of 245.98m from mean sea level), of Lovely Professional University, Punjab, in *rabi* season (2023-2024). The experiment was laid out in randomized block design (RBD) with six treatments in triplicates. The field soil was brought to fine tilth and recommended dose of fertilizer (RDF) @ 50:25:25 NPK kg/acre (Thindand Mahal, 2021) was applied at the time of land preparation excluding T_1 (control). Healthy seedlings with a height of 15-20cm and 3-4 true leaves of F_1 hybrid Bioseed SW 65 (Shriram Bioseed Genetics) cauliflower were transplanted at 45cm × 30cm distance in the prepared field. 10-plants/plot were tagged for recording various observations. The foliar application of treatments (stated in Table 1) including humic acid (5mLL^{-1}), boron (30gL^{-1}) and potassium (1.5gL^{-1}) and their combinations was applied at 40, 50 and 60 days after transplanting (DAT).

Growth parameters

To evaluate the impact of the various treatments, a random sample of ten plants from each plot was chosen at 30 DAT, 50 DAT and final harvest and the average was recorded for statistical analysis. Plant height (cm) was measured from the base of the plant to the longest leaf using a metric scale. The total number of leaves was counted except the small jacket leaves inside the whorl. Leaf length was measured from the distance from the base of the leaf blade where it joins the stem to the tip of the leaf and leaf width was measured from the same selected leaf. The chlorophyll content within the leaves was assessed using a specialized instrument called a SPAD-502 plus chlorophyll meter (SPAD-502, Minolta Co, ltd., Japan). Stem diameter was measured using vernier calliper during harvest (Hawall *et al.*, 2018).

Table 1 : Treatment details.

S. no.	Treatments	Concentration
T_1	Control	-
T_2	Humic acid	5 mL L^{-1}
T_3	Humic acid + boron	5 mL L^{-1} + 30 g L^{-1}
T_4	Boron	30 g L^{-1}
T_5	Humic acid + potassium	5 mL L^{-1} + 1.5 g L^{-1}
T_6	Potassium	1.5 g L^{-1}

Yield attributes

Yield related attributes *viz.* days to 50% curd initiation was recorded by counting the number of days taken from transplanting till half the plants in each plot develop visible curds. Days to curd maturity was calculated by counting the number of days taken from transplanting till fully matured marketable curds were formed. Curd weight (g) was measured using weighing balance after removal of leaves and stalks. Curd diameter (cm) was obtained by cutting the curd in two equal halves and measure the equatorial diameter using metric scale. Curd size (cm^2) was measured by multiplying polar and equatorial diameter of curd. Curd compactness (gcm^{-3}) was measured using the formula suggested by Pearson (1931), $Z= C/W^3 \times 100$ [where, Z= curd compactness, C= curd weight, W= average between polar and equatorial diameter] (Kumar, 2018). Curd yield per plot was calculated by taking the average of curd weight multiplied to total number of plants in each plot. Curd yield per hectare was calculated using the formula,

Yield per hectare = MF × Yield per plot (kg) [Multiple factor (MF) = 10,000 m^2/ area of net plot (m^2)].

Quality attributes

Quality attributes *viz.* total soluble solids (TSS) (^{0}Brix), vitamin C content (mg per 100 g of fresh weight of curd), dry matter content of leaves (%)and shelf life (days) were observed.

Total soluble solids (^{0} Brix)

The TSS of cauliflower was measured by using digital hand refractometer. This instrument, a handheld Erma (Japan) model with a range of 0-32° Brix, determines the concentration of TSS in the liquid portion of the curd (Chauhan, 2023).

Vitamin C content (mg per 100 g of fresh weight of curd)

To estimate the vitamin C content of fresh curds 2,6-dichlorophenol-indophenol visual titration method (A.O.A.C., 1990) using formula,

$$\text{Vitamin C content} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Volume of sample taken}}$$

Dry matter content of leaves (%)

The cauliflower leaves were dried in an oven at a higher temperature of 70°C for 48 hours to remove moisture more efficiently, then weight of leaves were measured using electric weighing balance. The average was calculated using formula,

$$\text{Dry matter content of leaves} = \frac{\text{Dry weight} \times 100}{\text{Fresh weight}}$$

Shelf life (days)

Cauliflower curds from each treatment were stored at room temperature. The days were recorded until it became unmarketable due to factors like shrinking, shape changes, or discoloration. This storage time was averaged for each treatment to determine shelf life.

Statistical analysis

Data analysis was done at 5% ($P<0.05$) level of significance using Duncan's Multiple Range Test.

Results and Discussion

Vegetative traits

Plant height (cm)

Results stated in Table 2 and Fig. 1 showed that at 30 DAT most of the treatments were found not significant for plant height except T_1 (control) which was lowest and significant to T_5 (18.88cm) and T_6 (18.70cm). At 50 DAT treatment with humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) was observed with the highest (27.45cm) plant height over control (20.91cm). Whereas, at the final harvest treatment with humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) and treatment containing potassium @1.5gL^{-1} (T_6) had the highest height (35.70cm and 35.75cm, respectively). However, both T_5 and T_6 were not found statistically different, while T_1 (control) was the lowest and inferior among the treatments. Foliar application of humic acid improved the plant metabolism and potassium boosted the plant growth. Similar results were reported by Kazemi (2013), Burhan and Al-Taey (2018)and De Moura *et al.* (2023).

Number of leaves

Results depicted in Table 2 and Fig. 1 stated that at 30 DAT application of humic acid 5mLL^{-1} + potassium 1.5gL^{-1} (T_5) had the maximum leaf count (9.10) over control with 6.53 leaf number. While, treatments boron @30gL^{-1} (T_4) and potassium @1.5gL^{-1} (T_6) shared the almost same number of leaves i.e., 8.00 and 8.16, respectively. At 50 DAT most of the treatments showed non-significant effects except T_5 with the maximum (12.66) number of leaves, whereas, at final harvest T_4 had the highest (19.13) leaf count which was significantly compared to (14.70) leaf count of T_1 (control). The probable reason behind is that boron and potassium help in cell division which tends to increase the number of leaves, easy uptake of nutrients and transfer of carbohydrates in plant cell membrane which results in overall growth and development of the plant. These results were supported with the findings of Bhat *et al.* (2010), Al-Bayati (2019) and Mahmood *et al.* (2019).

Leaf length (cm)

Results presented in Table 2 and Fig. 1 revealed that at 30 DAT treatments with humic acid @5mLL^{-1} (T_2), boron @30gL^{-1} (T_4), humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) and humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3), potassium @1.5gL^{-1} (T_6) were found non-significant but statistically superior to T_1 (control). At 50 DAT T_5 had the longest (18.98cm) leaf length compared to control (14.90cm), while at the time of harvest both treatments T_5 and T_6 had the maximum leaf length values (30.49cm and 29.88cm, respectively) which were superior to control (25.36cm). However, T_5 and T_6 did not differ statistically. It is due to the effect of humic acid and potash fertilizers which increased the

Fig. 1 : (A) Plant height, (B) number of leaves, (C) leaf length, (D) leaf width, and (E) chlorophyll index of cauliflower under 30 DAT, 50 DAT and at harvest.

Table 2 : Effect of foliar application of humic acid, boron, and potassium on different vegetative traits of cauliflower.

Treatments	Plant height (cm)			Number of leaves			Leaf length (cm)			Leaf width (cm)			Chlorophyll index (SPAD value)			Stem diameter at final harvest (cm)
	30 DAT	50 DAT	At final harvest	30 DAT	50 DAT	At final harvest	30 DAT	50 DAT	At final harvest	30 DAT	50 DAT	At final harvest	30 DAT	50 DAT	At final harvest	
T_1	15.40^{b}	20.91^{d}	25.17^{d}	6.53^{d}	9.50^{c}	14.70^{d}	11.44^{b}	14.90^{e}	25.36^{d}	6.68^{d}	9.02^{d}	14.51^{e}	51.70^{c}	69.52^{a}	79.15^{b}	2.19^{e}
T_2	17.92^{ab}	23.42^{cd}	29.13^{c}	6.96^{cd}	10.80^{b}	16.93^{c}	12.79^{ab}	16.35^{d}	26.45^{cd}	7.88^{c}	10.31^{c}	15.76^{d}	54.35^{bc}	72.44^{a}	83.57^{bc}	2.27^{de}
T_3	17.71^{ab}	22.32^{cd}	28.66^{c}	7.26^{c}	11.20^{b}	17.90^{b}	13.14^{a}	17.33^{c}	27.32^{c}	7.75^{c}	11.40^{b}	16.19^{d}	56.08^{b}	74.62^{a}	91.93^{a}	2.33^{cd}
T_4	18.33^{ab}	24.36^{bc}	32.09^{b}	8.00^{b}	11.76^{ab}	19.13^{a}	12.03^{ab}	18.64^{ab}	28.54^{b}	9.24^{b}	12.31^{b}	17.05^{c}	62.21^{a}	71.06^{a}	87.26^{bc}	2.47^{b}
T_5	18.88^{a}	27.45^{a}	35.70^{a}	9.10^{a}	12.66^{a}	18.70^{ab}	12.43^{ab}	18.98^{a}	30.49^{a}	10.61^{a}	14.55^{a}	19.41^{a}	64.23^{a}	82.20^{a}	91.14^{a}	2.59^{a}
T_6	18.70^{a}	26.63^{ab}	35.75^{a}	8.16^{b}	9.40^{c}	18.33^{ab}	13.28^{a}	17.79^{bc}	29.88^{a}	9.06^{b}	11.35^{b}	17.92^{b}	56.87^{b}	71.93^{a}	87.21^{bc}	2.38^{c}

The means with the same letters in a column are non-significant while different letters are significant at $P<0.05$ using Duncan's multiple range test.
DAT = days after transplanting.

growth characteristics. This result was in agreement with Al-Jaf *et al.* (2018), Burhan and Al-Taey (2018), Obaid *et al.*(2020) and Rachid *et al.* (2020).

Leaf width (cm)

Results in Table 2 and Fig. 1 denoted that at 30 DAT application of humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) showed the widest (10.61cm) leaf compared to control (6.68cm), in contrast, treatment humic acid @5mLL^{-1} (T_2) resulted similar effects and was not statistically significant with humic acid @5mL L^{-1} + boron @30gL^{-1} (T_3) and boron @30g L^{-1} (T_4) and potassium @1.5gL^{-1} (T_6). At 50 DAT treatment T_5 had the maximum (14.55cm) leaf width and T_3, T_4 and T_6 were statistically superior to T_1 (control). However, T_3 was not found significant with T_4 and T_6. At final harvest, the widest (19.41cm) leaf was observed in T_5, followed by T_6 (17.92cm), whereas, T_2 and T_3 had similar effects with lowest in T_1 (control), which was significant compared to other treatments. The increase in leaf width with the combined application of humic acid + potassium might be due to improved nutrient uptake, cellular expansion, enhanced photosynthetic activity. These results were close in conformity with Mahmood *et al.* (2019) and Obaid *et al.* (2020).

Chlorophyll index (SPAD value)

Results stated in Table 2 and Figure 1 revealed that at 30 DAT humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) and boron @30gL^{-1} (T_4) had the highest chlorophyll index (64.23 and 62.21 SPAD unit, respectively) compared to control but did not differ statistically. At 50 DAT chlorophyll index did not show any significant difference among treatments including T_1 (control). At harvest, plants sprayed with humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3) and humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) revealed positive and maximum (91.93 and 91.14 SPAD unit, respectively) effects in chlorophyll index compared to T_1 (control). While humic acid @5mLL^{-1} (T_2) was not found statistically different from boron @30gL^{-1} (T_4) and potassium @1.5gL^{-1} (T_6) but significant compared to T_1 (control). This attributed due to the effect of humic acid, potassium and boron which resulted in enhanced cell division, cell elongation and photosynthetic activity. This process enhances the absorption of nitrogen, facilitating the production of amino acids. These effects ultimately lead to an increase in the accumulation of chlorophyll content. Similar findings were reported by Mahmood *et al.* (2019).

Stem diameter (cm)

Results showed in Table 2 denoted that humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) noticed with the maximum (2.59cm) stem diameter, followed by boron @30gL^{-1} (T_4)(2.47cm) which was significantly superior compared to T_1 (control) (2.19cm). These findings were corroborated with the findings of Al-Jaf *et al.* (2018) and Rachid *et al.* (2020).

Yield and attributing traits

Days to 50% curd initiation

Results stated in Table 3 revealed that application of humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) showed earliness in 68.83 days compared to T_1 (control) (78.33 days). Humic acid @5mL L^{-1} + boron @30gL^{-1} (T_3) revealed comparative and non-significant results with boron @30g L^{-1} (T_4) and potassium @1.5gL^{-1} (T_6) i.e., 74.58 days, 73.09 days and 74.95 days respectively, but were remarkable and superior to T_1 (control). Plants with T_1 (control) took 78.33 days to reach 50% curd initiation which was the slowest among the treatments. Potassium regulates the hormonal balance in plants, particularly flowering and fruiting and energy transfer which is essential for plant growth and development, whereas, humic acid improves the availability of nutrients which might have resulted in early curd initiation. These results were supported with the findings of Obaid *et al.* (2020).

Days to curd maturity

Results showed in Table 3 stated that application of humic acid @5mL L^{-1} + potassium @1.5gL^{-1} (T_5) showed earliest maturity (68.83 days), followed by boron @30gL^{-1} (T_4) (84.50 days) and potassium 1.5gL^{-1} (T_6) (84.82 days) which did not differ statistically but superior to humic acid @5mLL^{-1} (T_2). Treatment (T_2) had the slowest maturity (94.81 days), inferior to T_1 (control). Humic acid and potassium promote improved water and nutrient uptake which facilitates faster growth and earlier maturity in cauliflower. These results were in agreement with Obaid *et al.* (2020).

Curd weight (g)

Results presented in Table 3 showed that plants treated with humic acid @ 5mL L^{-1} + potassium @ 1.5 gL^{-1} (T_5) observed with maximum (752.89g) curd weight and the average curd weight (645.41g) was noticed in T_3. Both treatments T_5 and T_3 were found significant and superior compared to T_1 (control). The lowest (540.39g) curd weight was observed in control. The highest attained curd weight was observed with humic acid + potassium application as, it promotes cell expansion and contributes to the increase in curd size and weight. Similar findings were reported by Islam *et al.* (2010); Porto *et al.* (2012) and Obaid *et al.* (2020).

Curd diameter (cm)

Results shown in Table 3 revealed that combined application of humic acid @5mLL^{-1} and potassium @1.5gL^{-1} (T_5) had the maximum (15.39cm) curd diameter when compared to control. Plants treated with humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3) had similar effects as boron @30gL^{-1} (T_4) and potassium @1.5gL^{-1} (T_6) with curd diameter i.e., 15.04cm, 14.99cm and 15.03cm, respectively, which had no significant differences. However, the lowest (13.92cm) and significant curd diameter was observed in T_1 (control). This was probably due to potassium levels promoted cell enlargement which ultimately increased curd diameter and humic acid helped in readily absorption of the nutrients. These findings were supported by De Moura *et al.* (2023).

Curd size (cm^2)

Results of Table 3 depicted that application of humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) recorded with the largest (146.65cm^2) curd size, followed by potassium @1.5gL^{-1} (T_6) (133.66 cm^2), which was significant when compared to T_1 (control). Humic acid @5mLL^{-1} + boron @30g L^{-1} (T_3) was comparable and did not differ significantly from boron @30gL^{-1} (T_4) with a curd size of 129.12cm^2 and 130.43cm^2, respectively. The smallest (112.72cm^2) size of curd was observed in control. This is due to the enhanced cellular and photosynthetic activity by humic acid and potassium resulted into increased curd size. These results were in agreement Katkat *et al.* (2009) and Obaid *et al.* (2020).

Curd compactness (gcm^{-3})

Results for curd compactness Table 3 revealed that most of the treatments including T_1 (control) were not found significant except boron @30gL^{-1} (T_4) which had the highest (44.20gcm^{-3}) and significant curd compactness. Boron plays an important role in regulating the movement of water and nutrients and, the formation and strengthening of the cell wall, which helps in the forming structural integrity contributing to curd compactness. Similar results were reported by Obaid *et al.* (2020) and Al-Bayati (2019).

Curd yield per plot (kg)

Results shown in Table 3 demonstrated that treatment containing humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) was observed with highest (18.06kg) curd yield per plot, whereas, an average (15.48kg) curd yield per plot was obtained in treatment humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3), these both treatments were superior and significant over T_1 (control). While, the lowest (12.96kg) curd yield per plot was noticed in control. The combined application of humic acid + potassium showed an increase in nitrogen uptake leading to an

Table 3 : Effect of foliar application of humic acid, boron and potassium on yield characteristics of cauliflower.

Treatments	Days to 50% curd initiation	Days to maturity	Curd weight (g)	Curd diameter (cm)	Curd size (cm^2)	Curd compactness (g/cm^3)	Curd yield/plot (kg)	Curd yield/ha (q)
T_1	78.33^c	91.60^{cd}	540.39^e	13.92^d	112.72^e	40.90^b	12.96^e	144.03^e
T_2	75.84^{bc}	94.81^d	609.13^d	14.62^c	125.78^d	39.58^b	14.61^d	162.40^d
T_3	74.58^b	88.36^c	645.41^c	15.04^b	129.12^c	39.25^b	15.48^c	172.07^c
T_4	73.09^b	84.50^b	$730. 56^{ab}$	14.99^b	130.43^c	44.20^a	17.52^{ab}	194.73^{ab}
T_5	68.83^a	77.33^a	752.89^a	15.39^a	146.65^a	39.25^b	18.06^a	200.00^a
T_6	74.95^b	84.82^b	701.48^b	15.03^b	133.66^b	41.10^b	16.83^b	186.99^b

The means with the same letters in a column are non-significant while different letters are significant at $P<0.05$ using Duncan's multiple range test.

increase in vegetative growth and photosynthetic activity that resulted into increased curd yield/plot. The present findings were supported by the results of Mahmood *et al.* (2019).

Curd yield per hectare (q)

Results related to curd yield per hectare Table 3 stated that plants treated with humic acid @5mL L^{-1} and potassium @1.5gL^{-1} (T_5) had the highest curd yield per hectare (200.00q), while an average yield (172.07q) was obtained in humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3). Both T_5 and T_3 were found superior and significant to T_1 (control). T_1 (control) had the lowest curd yield (144.03q) when compared to other treatments. This might be due to the potassium application a balanced nutrient uptake optimized that promoted vigorous vegetative growth and humic acid protects the plant from various stress conditions that ultimately lead to increased curd yield per hectare. These results were in agreement with Dizayee (2019) and De Moura *et al.* (2023).

Qualitative traits

Total soluble solids (^{0} Brix)

Results stated in Table 4 depicted that humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) had the highest (6.36^{0}Brix) total soluble solids (TSS) which was significant compared to control. The lowest (5.93^{0}Brix) TSS was observed in T_1 (control). While, average TSS (6.14^{0}Brix) was observed in humic acid @5mL L^{-1} (T_2) among treatments. Humic acid played a crucial role in enhancing the efficiency of potassium uptake and its utilization which promoted its positive effects on sugar synthesis, transport and resulted in higher TSS. These results were supported by Shaheen *et al.* (2007) and Obaid *et al.* (2020).

Vitamin C content (mg/100g fresh weight of curd)

Results of vitamin C content (Table 4) stated that humic acid @5mL L^{-1} + boron @30g L^{-1} (T_3) was comparable to boron @30gL^{-1} (T_4), humic acid @5 mLL^{-1} + potassium @1.5gL^{-1} (T_5) and potassium @1.5gL^{-1} (T_6) with a vitamin C content of 39.59, 40.74, 40.51 and 38.40mg/100g fresh weight of curd, respectively which was significant to T_1 (control). The lowest (29.18mg/100g fresh weight of curd) vitamin C content was observed in T_1 (control). This probably due to the use of humic acid, boron and potassium that contributed to physiological processes and supported carbohydrate metabolism, helps in the efficient conversion of sugars into ascorbic acid within plant tissues. These results were in accordance with Bhat *et al.* (2010) and Al-Bayati (2019).

Dry matter content of leaves (%)

Results of dry matter content of leaves (Table 4) revealed that humic acid @5mLL^{-1} (T_2) had the highest dry matter content in leaves (38.62 %) when compared to T_1 (control). Plants treated with humic acid @5mL L^{-1} + boron @30gL^{-1} (T_3) had similar results with humic acid @5mLL^{-1} and potassium @1.5gL^{-1} (T_5) and potassium @1.5gL^{-1} (T_6) i.e., 36.54%, 37.07% and 36.91% respectively, which were not statistically significant. The lowest (35.31%) and significant dry matter content of leaves was recorded in control. It might be due to humic acid that facilitated increased absorption of nutrients, improve carbon assimilation efficiency and promoted the accumulation of essential materials. Similar findings were reported by Mahmood *et al.* (2019) and Rezazadeh *et al.* (2012).

Shelf life (days)

Results for shelf life (Table 4) was recorded highest in boron @30gL^{-1} (T_4) and comparable to humic acid @5mLL^{-1} + potassium 1.5gL^{-1} (T_5) and potassium @1.5gL^{-1} (T_6) i.e., 8.06 days, 7.93 days and 8.10 days, respectively, which was not significant to T_1 (control).

Table 4 : Effect of foliar application of humic acid, boron and potassium on different qualitative traits of cauliflower.

Treatments	TSS (^{0} Brix)	Vitamin C content (mg/100 g F W curd)	Dry matter content of leaves (%)	Shelf life (days)
T_1	5.93^d	29.18^c	35.31^c	7.66^{ab}
T_2	6.14^{bc}	34.82^b	38.62^a	6.93^c
T_3	6.21^b	39.59^a	36.54^b	7.26^{bc}
T_4	6.24^{ab}	40.74^a	37.51^{ab}	8.06^a
T_5	6.36^a	40.51^a	37.07^b	7.93^a

The means with the same letters in a column are non-significant while different letters are significant at P<0.05 using Duncan's multiple range test. F W = fresh weight.

The lowest (6.93 days) and significant shelf life was observed in humic acid @5mLL^{-1} (T_2), which was inferior to T_1 (control). The application of boron did not affect directly on shelf life, it influenced physiological processes, cell wall integrity and crop resistance towards stress conditions which resulted in extending the post-harvest quality and shelf life of curd which was agreed by Dizayee (2019).

Conclusion

As per the obtained results from the study treatment with humic acid @5mLL^{-1} + potassium @1.5gL^{-1} provided promising results for various growth, yield and qualitative traits of cauliflower. However, some traits like number of leaves, curd compactness (gcm^{-3}) and shelf life (days) were found the best with boron @30gL^{-1} (T_4). While, the treatment with humic acid @5mLL^{-1} + boron @30gL^{-1} (T_3) was found good for the traits including chlorophyll index (SPAD unit). Therefore, it can be concluded that for most of the traits the combined foliar use of humic acid @5mLL^{-1} + potassium @1.5gL^{-1} (T_5) was found effective to optimize overall performance of cauliflower and it can be employed for the improved production of the crop.

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Authors contribution

Vishal Tripathi designed the experiment. Aparnna Rani Swain conducted the research and collected the data. Deven Verma analyzed the data. Aparnna Rani Swain, Etalesh Goutam, Diksha Choudhary and Yaman Kumarprepared and edited the manuscript.

Conflict of interest

All the authors declare no competing interest.

Data availability statement

All the data sets are presented in the tables.

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