International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Effect of Exogenous Application of Humic Acid, GA_3 and Vermiwash on Growth, Yield and Quality of Cabbage (Brassica Oleracea Var. Capitata L.) Under Valley Condition of Srinagar Garhwal

Khemraj Meena[1], Khulakpam Naseeruddin Shah[2], Vivek Singh[3], Deepak Kumar Rana[4]

[1]Post Graduate, Hemvati Nandan Bahuguna Garhwal University
[2]Assistant Professor, Hemvati Nandan Bahuguna Garhwal University
[3]Guest Lecturer, Hemvati Nandan Bahuguna Garhwal University
[4]Head of Department, Hemvati Nandan Bahuguna Garhwal University

Abstract:
The effect of exogenous application of humic acid, GA_3 and vermiwash on the growth, yield and quality of cabbage was studied in a field experiment. The experiment was conducted in a randomized block design at the Horticultural Research Centre, Chauras Campus, H.N.B. Garhwal University, Srinagar, Uttarakhand, with three replications and ten treatments. All of the growth, yield and quality contributing characteristics of cabbage were found to be significant. The growth parameters at 30, 45 DAT and at harvest were found to be maximum under T_9 (GA_3 @ 150 ppm). Yield parameters were found to be highest in T_9 (GA_3 @ 150 ppm) total plant weight (2188.67 g), average weight of head (1454.33 g), yield per hectare (321.43 q) whereas dry weight of head (10.00 g) in T_6 (Vermiwash @ 100%), head diameter (18.98 cm) and core diameter (4.53 cm) in T_8 (GA_3 @ 100 ppm) and core length (8.62 cm) in T_1 (Humic acid @ 100 ppm). Quality parameters were found to be highest under T_6 (Vermiwash @ 100%) for head compactness (35.39%), whereas total soluble solids (5.20 ^{0}Brix) in T_3 (Humic acid @ 200 ppm) and ascorbic acid (56.07 mg) in T_1 (Humic acid @ 100 ppm). Economic parameters were found to be highest under T_6 (Vermiwash @ 100%) for cost of cultivation (1,92,510 ₹/ha), gross return (10,66,030 ₹/ha) and net return (8,73,520 ₹/ha). Hence, it may be suggested that concentration of 150 ppm GA_3 could use for enhancing the production of cabbage under subtropical condition of Srinagar Garhwal.

Keywords: Cabbage, Foliar Spray, GA_3, Growth, Humic Acid, Quality, Vermiwash, Yield

1. Introduction:

- Cabbage (*Brassica oleracea* var. *capitata* L.) has chromosome number 2n = 18 and is a member of the Brassicaceae family, which grows all over the world in tropical and subtropical climates. Cabbage was first domesticated in Europe over 6000 years ago. The Portuguese were the first to introduce cabbage

in India **(Singh and Verma, 2021)**. According to the USDA, 100 g of green edible cabbage contains 92% water, 27 kilocalories of food energy, 4.6 g of carbohydrate, 1.8 g protein, 124 mg of vitamin C, 120 mg of carotene, 39 mg of calcium, 31 mg of magnesium and 0.8 mg of iron **(Choudhary *et at.*, 2014)**.

- Cabbage contains *indole-3-carbinol*, a compound that promotes DNA repair in cells and appears to inhibit cancer cell growth. The presence of the glucoside *"sinigrin"* gives cabbage its flavor **(Moniruzzaman *et al.*, 2019)**. In 2021-22, India will produce 9.6 million tons of cabbage across 400 thousand hectares. Cabbage is grown throughout India, but the major cabbage growing states are West Bengal, Odisha and Gujarat **(NHB 2021-22)**.
- Humic acid plays an essential role in vegetable production. It increases cation exchange capacity and soil fertility through the transformation of mineral elements into plant available forms. Humic substances increase nutrient uptake into the plant root and through the cell membrane **(El-Hassan and El-Shinawy, 2015)**.
- Vermiwash is a coelomic fluid extraction that contains enzymes, plant growth hormones such as cytokinins, gibberellins and vitamins, as well as micro and macronutrients. Nitrogen in the form of mucus and nitrogenous excretory substances stimulate growth hormones and enzymes in vermiwash **(Verma *et al.*, 2018)**.
- Gibberellic acid is produced by the plant pathogen *"Gibberella fujikuroi"* as a metabolic by product. It is a pentacyclic diterpene acid that promotes cell growth and enlargement. GA_3 stimulates cell division and elongation, seed germination, bolting in response to long days, prevents genetic dwarfism, increases fruit size, dormancy, induces maleness and extends shelf life. It also stimulates the production of mRNA molecules, which code for hydrolytic enzymes. It is a very powerful hormone that occurs naturally in plants and regulates their development **(Gupta and Chakrabarty, 2013).**

2. Materials and Methods:

- The experiment was carried out at the Horticultural Research Centre, Chauras Campus, H.N.B. Garhwal University, Srinagar (Garhwal), Uttarakhand, India, during the winter season of 2022-2023. The experimental site is located in the Alaknanda valley (78^0 47' 30" E longitude and 30^0 13' 9" N latitude, at an elevation of 540 m above mean sea level), which has a semi-arid, subtropical climate with dry summers and harsh winters with occasional dense fog in the morning hours from the beginning of December to the middle of February.
- The experiment used Randomized Block Design, with three replications and ten treatments. T_0 (Control), T_1 (Humic acid @ 100 ppm), T_2 (Humic acid @ 150 ppm), T_3 (Humic acid @ 200 ppm), T_4 (Vermiwash @ 50%), T_5 (Vermiwash @ 75%), T_6 (Vermiwash @ 100%), T_7 (GA_3 @ 50 ppm), T_8 (GA_3 @ 100 ppm), T_9 (GA_3 @ 150 ppm) where the treatments spraying was performed at 20 and 40 days after transplanting. The entire experimental field was divided into three equal-sized blocks, each with ten plots. Each plot was 2.4 x 1.8 m in size. Cabbage seedlings were planted at a spacing of 60 x 45 cm. All of the intercultural operations and plant protection measures that were recommended for successful crop growth were carried out.
- The growth parameters were taken from randomly selected five plants from each plot. Meter scale was used to measure the plant height, plant spread of cabbage plants and number of unwrapped leaves were counted at 30,45 DAT and at harvest. These observations were made between 10:00 am to 12:00 noon on a clear sunny day.

- Cabbage head were harvested by pulling out the whole plant. The root portion along with some unwrapped leaves attached to the head was cut with the help of sharp knife. The first harvesting was started from 50 DAT. The total plant weight (g), average weight of head (g), head diameter (cm), polar diameter (cm), equatorial diameter (cm), core length (cm), core diameter (cm), yield per plot (kg), yield per hectare and it was expressed in quintal.
- The cabbage head quality traits analysis was carried out according to the procedure given by **Ranganna (2014)**. The head compactness (%), total soluble solids (^{0}Brix), ascorbic acid (mg/100g), dry weight of head (g/100g), moisture content of head (%). The quality parameters were taken from randomly selected five plants from each plot.
- The economic parameters calculated for one hectare production of cabbage performed separately from each treatment *i.e.,* cost of cultivation (₹/ha), gross return (₹/ha), net return (₹/ha), cost-benefit ratio.
- The statistically analysis for experimental data was performed separately for each stage of observation by using the standard procedure described by **Snedecor and Cochran (1967)**. The analysis of variance was performed using a simple randomized block design (RBD) with values calculated at the 5% level.

3. Results:

3.1 Growth Attributes:

- Table 1 shows that all growth characters were affected by the treatments and there was a statistically significant difference between control and foliar application. The current study found that foliar applications of humic acid, GA_3 and vermiwash significantly increased the growth parameters of cabbage. The maximum (29.63, 35.73 and 38.40 cm respectively) plant height at 30, 45 DAT and at harvest was recorded in T_9 (GA_3 @ 150 ppm), whereas the minimum (19.72, 25.64 and 28.64 cm respectively) was recorded in treatment T_0 (Control).
- The maximum (2065.38, 3370.20 and 3870.20 cm^2 respectively) plant spread at 30, 45 DAT and at harvest was recorded in T_9 (GA_3 @ 150 ppm), while the minimum (729.63, 1854.53 and 2003.20 cm^2 respectively) was recorded in T_0 (Control).
- The maximum (12.47, 13.80 and 13.70 respectively) number of unwrapped leaves at 30, 45 DAT and at harvest was recorded in T_9 (GA_3 @ 150 ppm). On the other hand, the minimum (8.33, 8.57 and 10.57 respectively) number of unwrapped leaves was recorded in T_0 (Control).

3.2 Yield Attributes:

- The results shown in Tables 2 and 3 showed that the treatments had an effect on all yield characteristics and that there was a statistically significant difference between control and foliar application. The current study found that foliar applications of humic acid, GA_3 and vermiwash significantly increased cabbage yield parameters. The maximum (2188.67 g) total plant weight at harvesting was recorded in T_9 (GA_3 @ 150 ppm). However, the minimum (1514.67 g) total plant weight was recorded in treatment T_0 (Control).
- The maximum (1454.33 g) average weight of head at harvesting was recorded in T_9 (GA_3 @ 150 ppm), whereas the minimum (881 g) was recorded in T_0 (Control).
- The maximum (18.98 cm) head diameter was recorded in T_9 (GA_3 @ 150 ppm), while the minimum (17.00 cm) was recorded in T_5 (Vermiwash @ 75%).
- The maximum (18.16 cm) polar diameter of head was recorded in T_9 (GA_3 @ 150 ppm). However, the minimum (14.97 cm) polar diameter was recorded in T_0 (Control).

- The maximum (16.89 cm) equatorial diameter of head was recorded in T_9 (GA_3 @ 150 ppm). On the other hand, the minimum (12.41 cm) equatorial diameter was recorded in T_0 (Control).
- The maximum (8.62 cm) core length of head was recorded in T_1 (Humic acid @ 100 ppm) and T_8 (GA_3 @ 100 ppm), whereas the minimum (6.45 cm) was recorded in T_0 (Control).
- The maximum (4.53 cm) core diameter of head was recorded in T_8 (GA_3 @ 100 ppm), while, the minimum (3.17 cm) was recorded in T_4 (Vermiwash @ 50%).
- The maximum (17.36 kg) yield per plot was recorded in T_9 (GA_3 @ 150 ppm). However, the minimum (11.58 kg) yield per plot was recorded under T_0 (Control).
- The maximum (321.43 q) yield per hectare was recorded in T_9 (GA_3 @ 150 ppm). On the other hand, the minimum (214.50 q) yield per hectare was recorded under T_0 (Control).

3.3 Quality Attributes:

- Table 3 shows that all quality characters were affected by the treatments and there was a statistically significant difference between control and foliar application. The current study found that foliar applications of humic acid, GA_3 and vermiwash significantly improved cabbage quality parameters. The highest (35.39%) head compactness was recorded in T_6 (Vermiwash @ 100%) whereas, the lowest (23.04%) was recorded in T_8 (GA_3 @ 100 ppm).
- The maximum (5.20 ^{0}Brix) total soluble solids were recorded in T_3 (Humic acid @ 200 ppm), while the minimum (4.2 ^{0}Brix) was recorded in T_0 (Control).
- The maximum (56.07 mg) ascorbic acid was recorded in T_1 (Humic acid @ 100 ppm). On the other hand, the minimum (45.66 mg) ascorbic acid was recorded in T_3 (Humic acid @ 200 ppm).
- The maximum (10 g) dry weight of head was recorded in T_6 (Vermiwash @ 100%). However, the minimum (7.67 g) dry weight of head was recorded in T_0 (Control).
- The minimum (90.00%) moisture content of head was recorded in T_6 (Humic acid @ 200 ppm), whereas the maximum (93.67%) was recorded in T_3 (Vermiwash @ 100%).

3.4 Economic Attributes:

- Table 4 shows that all economic characteristics were affected by the treatments and there was a statistically significant difference between control and foliar application. The current experiment shows that foliar application of humic acid and GA_3 significantly increased the economic parameters of cabbage. The highest (1,92,510 ₹/ha) cost of cultivation was recorded in T_6 (Vermiwash @ 100%), whereas the lowest (68,962 ₹/ha) was recorded in T_0 (Control).
- The maximum (10,66,030 ₹/ha) gross return was recorded in T_6 (Vermiwash @ 100%). On the other hand, the minimum (6,00,520 ₹/ha) gross return was recorded in T_7 (GA_3 @ 50 ppm).
- The highest (8,73,520 ₹/ha) net return was recorded in T_6 (Vermiwash @ 100%), while the lowest (5,30,118.2 ₹/ha) was recorded in T_7 (GA_3 @ 50 ppm).
- The maximum (1:11.7) Cost-Benefit ratio was recorded in T_3 (Humic acid @ 200 ppm). However, the minimum (1:4.3) Cost-Benefit ratio was recorded in T_5 (Vermiwash @ 75%).

Table 1: Effect of Humic acid, GA_3 and Vermiwash on plant height (cm), plant spread (cm^2), number of unwrapped leaves at 30, 45 DAT and at harvest of cabbage

Treatment	Plant height (cm)			Plant spread (cm^2)			Number of unwrapped leaves		
	30 DAT	45 DAT	At harvest	30 DAT	45 DAT	At harvest	30 DAT	45 DAT	At harvest
T_0	19.72	25.64	28.64	729.43	1,854.53	2,003.20	8.33	8.57	10.57
T_1	20.99	28.47	30.47	1,248.97	2,227.43	2,394.10	11.47	10.53	11.03
T_2	23.73	28.73	31.73	1,264.03	2,137.93	2,471.27	11.63	11.83	11.83
T_3	27.11	29.27	32.27	1,560.48	2,563.27	2,763.27	12.00	10.80	10.87
T_4	25.13	30.00	32.83	1,495.53	2,777.60	2,877.60	12.40	10.47	10.93
T_5	23.87	30.37	33.03	1,326.77	2,506.73	2,973.40	11.27	12.40	12.30
T_6	26.00	31.20	34.53	1,455.53	2,892.47	3,159.13	11.90	12.07	11.97
T_7	25.97	32.13	34.13	1,293.90	2,364.47	2,597.80	11.70	12.20	12.20
T_8	25.27	33.20	35.87	1,444.33	3,067.07	3,533.73	12.33	12.97	13.07
T_9	29.63	35.73	38.40	2,065.38	3,370.20	3,870.20	12.47	13.80	13.70
SEm ±	1.26	0.71	0.25	154.64	209.36	64.80	0.30	0.24	0.20
CD @ 5%	3.77	2.14	0.77	463.01	626.86	194.02	0.89	0.70	0.61
CV	8.82	4.07	1.34	19.29	14.08	3.91	4.46	3.52	2.99

Table 2: Effect of Humic acid, GA_3 and Vermiwash on total plant weight (g), average weight of head (g), head diameter (cm), polar diameter (cm), equatorial diameter (cm), core length (cm) and core diameter (cm) of cabbage

Treatment	Total plant weight (g)	Average weight of head (g)	Head diameter (cm)	Polar diameter (cm)	Equatorial diameter (cm)	Core length (cm)	Core diameter (cm)
T_0	1,514.67	881.00	17.07	14.97	12.41	6.45	3.30
T_1	1,674.33	1,035.00	17.25	15.10	14.17	8.62	3.47
T_2	1,603.33	991.00	17.24	15.55	15.06	8.13	3.51
T_3	1,884.33	1,311.67	18.87	15.67	15.13	8.45	3.41
T_4	1,811.67	1,180.67	18.03	16.76	15.41	8.32	3.17
T_5	1,697.67	1,087.00	17.00	16.33	14.83	7.61	3.44
T_6	1,744.00	1,030.33	17.95	15.07	14.28	7.25	3.43
T_7	1,816.00	1,124.00	17.42	17.61	15.19	6.90	3.48
T_8	2,070.33	1,339.67	18.98	18.12	16.72	8.62	4.53
T_9	2,188.67	1,454.33	18.94	18.16	16.89	8.47	3.71
SEm ±	42.26	30.40	0.37	0.36	0.29	0.21	0.09
CD @ 5%	126.53	91.01	1.11	1.08	0.89	0.63	0.28
CV	4.06	4.60	3.59	3.82	3.42	4.65	4.58

Table 3: Effect of Humic acid, GA_3 and Vermiwash on yield per plot (kg), yield per hectare (q), head compactness (%), total soluble solids (^{0}Brix), ascorbic acid content (mg/100g), dry weight of head (g/100g) and moisture content of head (%) of cabbage

Treatment	Yield/plot (kg)	Yield/ha (q)	Head compactness (%)	Total soluble solids (^{0}Brix)	Ascorbic acid (mg/100g)	Dry weight of head (g/100g)	Moisture content of head (%)
T_0	11.58	214.50	33.33	4.27	52.28	7.67	92.33
T_1	12.03	222.79	32.99	4.47	56.07	8.67	91.33
T_2	11.81	218.79	29.15	4.70	53.60	9.67	90.33
T_3	13.72	254.23	31.37	5.20	45.66	6.33	93.67
T_4	12.81	237.27	25.39	4.93	55.20	8.83	91.17
T_5	13.26	245.48	28.42	4.87	55.58	9.00	91.00
T_6	16.45	304.58	35.39	4.87	55.87	10.00	90.00
T_7	16.21	300.25	25.99	4.93	54.13	9.67	90.33
T_8	16.65	308.37	23.04	4.83	55.60	8.00	92.00
T_9	17.35	321.43	27.44	4.93	54.77	08.67	91.33
SEm ±	0.31	5.70	1.86	0.14	1.96	0.33	0.33
CD @ 5%	0.92	17.05	5.57	0.41	5.86	0.99	0.99
CV	3.75	3.75	11.01	4.94	6.29	6.68	0.63

Table 4: Effect of Humic acid, GA_3 and Vermiwash on cost of cultivation (₹/ha), gross return (₹/ha), net return (₹/ha) and cost-benefit ratio of cabbage

Treatment	Estimated yield (q/ha)	Selling rate of cabbage head (₹/kg)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Cost-Benefit ratio
T_0	214.50	35	68,962.0	7,50,750	6,81,788.0	1:9.8
T_1	222.79	35	69,620.7	7,79,800	7,10,179.3	1:10.2
T_2	218.79	35	69,676.0	7,65,800	6,96,123.9	1:9.9
T_3	254.23	35	69,731.4	8,89,840	8,20,108.6	1:11.7
T_4	237.27	35	1,31,010.0	8,30,480	6,99,470.0	1:5.3
T_5	245.48	35	1,61,760.0	8,59,180	6,97,420.0	1:4.3
T_6	304.58	35	1,92,510.0	10,66,030	8,73,520.0	1:4.5
T_7	300.25	20	70,401.7	6,00,520	5,30,118.2	1:7.5
T_8	308.37	20	71,293.5	6,16,760	5,45,466.5	1:7.6
T_9	321.43	20	72,185.2	6,42,860	5,70,674.7	1:7.9

4. Discussion:

4.1 Growth Attributes:

- The current study found that foliar applications of humic acid, GA_3 and vermiwash significantly increased the growth parameters of cabbage. The maximum plant height at 30, 45 DAT and at harvest

was recorded in T_9 (GA_3 @ 150 ppm), whereas the minimum was recorded in treatment T_0 (Control). Plant height increases may be due to foliar application of GA_3 in the presence of bright sunlight, as it affects photosynthesis and source formation, changing source and sink metabolism and resulting in increased stem length, which stimulates vegetative growth and is involved in the initiation of cell multiplication in the cambium, which is responsible for better plant height of the cabbage. Similar observation has also been reported by **Yadav *et al.* (2000)** and **Meena *et al.* (2019)** in cabbage.

- The maximum plant spread at 30, 45 DAT and at harvest was recorded in T_9 (GA_3 @ 150 ppm), while the minimum was recorded in T_0 (Control). Plant spread may have increased as a result of GA_3 application because it induced nutrient transport from the root to the aerial parts of the plant, cell division, cell elongation, and cell enlargement. It also influences protein and chlorophyll synthesis, which leads to an increase in photosynthetic activities in leaf tissues, cell expansion, and cell wall formation, all of which promote plant spread. The results are in conformity with the findings of **Roy and Nasiruddin (2011)**, **Lendve *et al.* (2010)** and **Painkra *et al.* (2023)** in cabbage.
- The maximum number of unwrapped leaves at 30, 45 DAT and at harvest was recorded in T_9 (GA_3 @ 150 ppm). On the other hand, the minimum number of unwrapped leaves was recorded in T_0 (Control). The increased number of unwrapped leaves could be attributed to foliar GA_3 spraying, which stimulates plant physiological processes and causes new leaves to form at a faster rate, resulting in increased vegetative growth and more nucleoprotein and carbohydrate synthesis, which is responsible for increased leaf initiation. Similar finding was also reported by **Meena *et al.* (2018)** in cauliflower and **Singh *et al.* (2018)** in cabbage.

4.2 Yield Attributes:

- The current study found that foliar applications of humic acid, GA_3 and vermiwash significantly increased cabbage yield parameters. The maximum total plant weight at harvesting was recorded in T_9 (GA_3 @ 150 ppm). However, the minimum total plant weight was recorded in treatment T_0 (Control). Total plant weight increases could be attributed to increased photosynthesis, higher food accumulation, better plant growth with improved chlorophyll formation and increasing growth characters (plant height, plant spread, number of unwrapped leaves) via cell division, cell elongation and cell expansion, which could have resulted in increased plant weight. This finding was also confirmed by **Chauhan and Tandel (2010)** in cabbage.
- The maximum average weight of head at harvesting was recorded in T_9 (GA_3 @ 150 ppm), whereas the minimum was recorded in T_0 (Control). The increased average weight of the head could be due to a faster rate of photosynthesis, resulting in increased carbohydrate accumulation. This excess of storage food promotes cell elongation, cell division and cell expansion, resulting in a higher average head weight. The number of wrapped leaves is also related to the weight of the cabbage head. Similar results are in accordingly obtained by **Chauhan and Tandel (2010)** and **Kotecha *et al.* (2011)** in cabbage.
- The maximum head diameter was recorded in T_9 (GA_3 @ 150 ppm), while the minimum was recorded in T_5 (Vermiwash @ 75%). The spray of GA_3 may increase head diameter by enhancing and activating enzymatic activities for various physiological processes and metabolic activities such as vegetative growth, photosynthetic area, and leaf pigments. Similar finding was also observed by **Chaurasiy *et al.* (2014)** in cabbage.
- The maximum polar diameter of head was recorded in T_9 (GA_3 @ 150 ppm). However, the minimum polar diameter was recorded in T_0 (Control). Polar diameter is influence by head diameter. If head

diameter increase, polar diameter will definitely increase. By spraying of GA_3, the plant will enhance and activate the enzymatic activities for various physiological process and metabolic activities like vegetative growth, photosynthetic area and leaf pigments that ultimately maximize head diameter The results are in harmony with **Painkra *et al.* (2023)** in cabbage.

- The maximum equatorial diameter of head was recorded in T_9 (GA_3 @ 150 ppm). On the other hand, the minimum equatorial diameter was recorded in T_0 (Control). Equatorial diameter increases due to the head diameter is positively corresponded to the equatorial diameter of the cabbage. This finding has been supported by **Sonam *et al.* (2020)** in cauliflower.
- The maximum core length of head was recorded in T_1 (Humic acid @ 100 ppm) and T_8 (GA_3 @ 100 ppm), whereas the minimum was recorded in T_0 (Control). Core length increases because it is most relevant that if the polar diameter increases simultaneously the core length also increases.
- The maximum core diameter of head was recorded in T_8 (GA_3 @ 100 ppm), while, the minimum was recorded in T_4 (Vermiwash @ 50%). Core diameter increases because the core diameter is directly proportional to the equatorial diameter. If equatorial diameter increase, core diameter also increases.
- The maximum yield per plot was recorded in T_9 (GA_3 @ 150 ppm). However, the minimum yield per plot was recorded under T_0 (Control). Yield is accumulated effort of result of several factors like total plant weight, average weight of head, head diameter, leaf area and core diameter these influence directly and indirectly yield per plot **(Meena *et al.*, 2019)**. The results are in conformity with the findings of **Chanwala *et al.* (2019)** in broccoli and **Patel *et al.* (2011)** in cauliflower.
- The maximum yield per hectare was recorded in T_9 (GA_3 @ 150 ppm). On the other hand, the minimum yield per hectare was recorded under T_0 (Control). This outcome was consistent with the conclusion drawn by **Reza *et al.* (2015)** in broccoli and **Bhosale *et al.* (2010)** in cabbage.

4.3 Quality Attributes:

- The current study found that foliar applications of humic acid, GA_3 and vermiwash significantly improved cabbage quality parameters. The highest head compactness was recorded in T_6 (Vermiwash @ 100%) whereas, the lowest was recorded in T_8 (GA_3 @ 100 ppm). Head compactness increases because of nutrient supply and microbial activity in the root zone that enhance photosynthetic efficiency. Efficient photosynthesis leads to the production of more carbohydrates, which are essential for dense cabbage heads. Proper hormonal balance is crucial for various plant processes, including cell elongation and differentiation. By promoting balanced hormone levels, vermiwash contribute to the regulation of growth processes, resulting in more compact cabbage head. Similar finding was also reported by **Yassen *et al.* (2020)** in lettuce.
- The maximum total soluble solids were recorded in T_3 (Humic acid @ 200 ppm), while the minimum was recorded in T_0 (Control). Total soluble solids increase might be due to the more production of metabolic activities within the plants. It enhances enzymatic reactions involved in sugar production and accumulation. Humic acid enhances chlorophyll production and photosynthesis, which are fundamental processes for sugar synthesis. Improved photosynthetic efficiency can lead to increased production of sugars in the leaves, potentially contributing to higher TSS. Similar results are in according with those obtain by **Kazemi (2014)** in cucumber and **El-Hassan and El-Shinawy (2015)** in red cabbage.
- The maximum ascorbic acid was recorded in T_1 (Humic acid @ 100 ppm). On the other hand, the minimum ascorbic acid was recorded in T_3 (Humic acid @ 200 ppm). Ascorbic acid increases due to the influences of the metabolic pathways and enzymatic activities in plants. Ascorbic acid is

synthesized through complex metabolic pathways and alterations in these pathways could potentially impact its production. Humic acid may indirectly influence these pathways and contribute to increased ascorbic acid content. The result is consonance with the finding of **Verma *et al.* (2017)** in cabbage.

- Dry weight of head was maximum recorded in T_6 (Vermiwash @ 100%). However, the minimum dry weight of head was recorded in T_0 (Control). Dry weight of head increases might be due to enzyme activation and electron transport in photosynthesis resultant in plants make more photosynthate leading more dry matter content. Moreover, when crop reaches their maturity, it accumulates a huge amount of fiber and sugar that might have ultimately increase dry weight of head. This finding is similar with **Yassen *et al.* (2020)** in lettuce.
- The minimum moisture content of head was recorded in T_6 (Humic acid @ 200 ppm), whereas the maximum was recorded in T_3 (Vermiwash @ 100%). The moisture content of the head increases because moisture content is inversely correlated to the dry weight of the head. Moisture content increases as dry weight of head declines. The result is consonance with the finding of **El-Hassan and El-Shinawy (2015)** in red cabbage.

4.4 Economic Attributes:

- The current experiment shows that foliar application of humic acid and GA_3 significantly increased the economic parameters of cabbage. The highest cost of cultivation was recorded in T_6 (Vermiwash @ 100%), whereas the lowest was recorded in T_0 (Control). This might be due to higher cost of vermiwash resultant in higher cost of cultivation as compared to control. This finding has been supported by **Yasmin *et al.* (2021)** in brinjal.
- The maximum gross return was recorded in T_6 (Vermiwash @ 100%). On the other hand, the minimum gross return was recorded in T_7 (GA_3 @ 50 ppm) due to higher yield obtained and higher rate of cabbage selling by vermiwash treatment which ultimately increased in gross return as compare to GA_3. This finding is also agreement with **Yasmin *et al.* (2021)** in brinjal.
- The highest net return was recorded in T_6 (Vermiwash @ 100%), while the lowest was recorded in T_7 (GA_3 @ 50 ppm) this might be due to the fact that T_6 treatment obtained higher yield of cabbage which ultimately increased the net return. This finding has been supported by **Jadhav *et al.* (2014)** in radish.
- The maximum Cost-Benefit ratio was recorded in T_3 (Humic acid @ 200 ppm). However, the minimum Cost-Benefit ratio was recorded in T_5 (Vermiwash @ 75%) due to the fact that the cost of cultivation was higher in T_5 as compared to T_3. Beside this, the net return was found to be maximum in T_3 with respect to T_5. Hence concluded that T_3 has maximum Cost-Benefit ratio. This finding is also agreement with **Fathima and Denesh (2013)** in chilli.

5. Conclusion:

On the basis of results obtained from the present investigation, it may be concluded that application of GA_3 @ 150 ppm (T_9) treatment gave the maximum growth and yield. In terms of quality, application of Humic acid @ 200 ppm (T_3) and Vermiwash @ 100% (T_6) treatment are superior over other treatments. Hence, it may be suggested that concentration of 150 ppm GA_3 could use for enhancing the production of cabbage under valley condition of Srinagar Garhwal.

6. Conflict of interest:

The authors declare that they have no conflict of interest.

7. References:

1. Bhosale AM, Sawant VP, Naik DM, Barkule SR and Shinde SB., "Effect of foliar application of growth regulators on growth, yield and quality of cabbage Cv. Golden Acre", The Asian Journal of Horticulture, 2010, 5(2): 495-497.
2. Chanwala P, Soni AK, Sharma D and Choudhary G., "Effect of foliar spray of plant growth regulators on growth and quality of sprouting broccoli (Brassica oleracea var. italica L.)" International Journal of Current Microbiology and Applied Science, 2019, 8(8): 1846-1852.
3. Chauhan UM and Tandel YN., "Effect of plant growth regulators on growth, yield and quality of cabbage (Brassica oleracea var. capitata L.) Cv. Golden Acre", The Asian Journal of Horticulture, 2010, 4(2): 512-514.
4. Chaurasiy J, Meena ML, Singh HD, Adarsh A and Mishra PK., "Effect of GA_3 and NAA on growth and yield of cabbage (Brassica oleracea var. capitata L.) Cv. Pride of India", An International Journal of life sciences, 2014, 9(3): 1139-1144.
5. Choudhary AK, Negi MS, Savita, Jaipaul and Kumar A., "Scientific Cultivation of Cabbage (Brassica oleracea var. capitata L.)" Advances in Vegetable Agronomy, Indian Agricultural Research Institute New Delhi, 2014, pp: 79-86.
6. El-Hassan SA and El-Shinawy MZ., "Influence of compost, humic acid and effective microorganisms on organic production of Red Cabbage", Egypt Journal of Horticulture, 2015, 42(1): 533-545.
7. Fathima PS and Denesh GR., "Influence of humic acid spray on growth and yield of chilli (Capsicum annum L.)", International Journal of Agricultural Sciences, 2013, 9(2): 542-546.
8. Gupta R and Chakrabarty SK., "Gibberellic acid in plant still a mystery unresolved", Plant Signaling and Behavior, 2013, 8(9): 25504-25509.
9. Jadhav PB, Kireeti A, Patil NB, Dekhane SS and Patel DJ., "Effect of different levels of vermiwash spray on growth and yield of radish Cv. local variety", The Asian Journal of Horticulture, 2014, 9(2): 449-452.
10. Kazemi M., "Effect of foliar application of humic acid and calcium chloride on tomato growth" Bulletin of Environment, Pharmacology and Life Sciences, 2014, 3(3): 41-46.
11. Kotecha AV, Dhruve JJ and Vihol NJ., "Effect of foliar application of micronutrients and growth regulators on growth and yield of cabbage (Brassica oleracea var. capitata L.) Cv. Golden Acer", The Asian Journal of Horticulture, 2011, 6(2): 381-384.
12. Lendve, VH, Chawan SD, Barkule SR and Bhosale AM., "Effect of foliar application of growth regulators on growth of cabbage Cv. Pride of India", The Asian Journal of Horticulture, 2010, 5(2): 475-478.
13. Meena MK, Aravindakshan K, Dhayal M, Singh J and Meena SL., "Effect of Biofertilizers and Growth Regulators on Growth Attributes of Cauliflower (Brassica oleracea var. botrytis L.) Cv. Pusa Paushja", International Journal of Current Microbiology Applied Science, 2018, 7(1): 885-890.
14. Meena SL, Aravindakshan K, Arya CK, Meena KK and Meena MK., "Effect of bioregulators and boron on growth attributes of cabbage (Brassica oleracea var. capitata L.) Cv. Golden Acre", International Journal of Chemical Studies, 2019, 7(3): 1540-1543.
15. Moniruzzaman M, Khatoon R, Moniruzzaman M and Rahman MM. 2019. Effect of GA_3 and NAA on growth and yield of cabbage. Bangladesh Journal of Agriculture Research, 44(2): 367-376.
16. National Horticulture Board, "Horticultural Statistics at a Glance: Production Overview", Ministry of Agriculture and Farmers Welfare, Horticulture Statistics Division, 2022, pp: 1-2.

17. Painkra B, Shrivastava LK, Mishra VN, Sharma D and Devangan UK., "Effect of foliar application of micronutrients and growth regulators on growth and yield parameters of cabbage in a Vertisol of Chhattisgarh", The Pharma Innovation Journal, 2023, 12(7): 638-644.
18. Patel VM, Patel NK and Chaudhari SR., "Influence of GA_3 and NAA on yield parameters of cauliflower Cv. Snowball-16", International Journal of Forestry and Crop Improvement, 2011, 2(2): 213-214.
19. Ranganna S., "Handbook of Analysis and Quality Control for Fruit and Vegetable Products (2^{nd} edt.)", Tata McGraw-Hill Publishing Company Limited, New Delhi, 2014, pp: 352-355.
20. Reza M, Islam M, Hoque A, Sikder RK, Mehraj H and Uddin AFMJ., "Influence of different GA_3 concentrations on growth and yield of broccoli", American-Eurasian Journal of scientific Research, 2015, 10(5): 332-335.
21. Roy R and Nasiruddin KM., "Effect of different level of GA_3 on growth and yield of Cabbage", Journal of Environment Science and Natural Resources, 2011, 4(2): 79-82.
22. Singh HN, Vishwakarma G and Singh J., "Effect of gibberellic acid and nitrogen on yield and marketability of cabbage (Brassica oleracea var. capitata L.) Cv. Pride of India", Journal of Pharmacognosy and Phytochemistry, 2018, 7(3): 900-903.
23. Singh SK and Verma A., "Effect of plant growth regulators on yield of Cabbage (Brassica oleracea var. capitata L.) in hilly regions of Chhattisgarh", The Pharma Innovation Journal, 2021, 10(10): 1903-1905.
24. Snedecor GW and Cochran WG., Statistical Methods: Lowa State University. Press USA, 1967, p: 465.
25. Sonam, Suneeta, Singh S and Saxena AK., "Efficacy of plant growth regulator (GA_3) on growth and yield attributes of cauliflower (Brassica oleracea var. botrytis L.) at Dehradun valley", International Journal of Chemical Studies, 2020, 8(5): 101-104.
26. Verma R, Maurya BR, Meena VS, Dotaniya ML, Deewan P and Jajoria M., "Enhancing production potential of cabbage and improves soil fertility status of Indo-Gangetic plain through application of bio-organics and mineral fertilizer", International Journal of Current Microbiology and Applied Sciences, 2017, 6(3): 301-309.
27. Verma S, Babu A, Patel A, Singh SK, Pradhan SS, Verma SK, Singh JP and Singh RK., "Significance of vermiwash on crop production: A review", Journal of Pharmacognosy and Phytochemistry, 2018, 7(2): 297-301.
28. Yadav RL, Dhaka RS and Fageria MS., "Effect of GA_3, NAA and Succinic acid on growth and yield of cabbage Cv. Golden Acre", Haryana Journal of Horticulture Science, 2000, 29(3/4): 269-270.
29. Yasmin M, Rahman MS, Rahman MA, Shikha FS and Alam MK., "Effect of foliar application of vermiwash on growth and quality of brinjal", Journal of Wastes and Biomass Management, 2021, 3(1): 31-34.
30. Yassen AA, Essa EM, Marzouk NM and Zaghloul SM., "Impact of vermicompost and foliar spray of vermiwash on growth, yield and nutritional status of lettuce plants", Plant Archives, 2020, 20(1) p: 449-455.