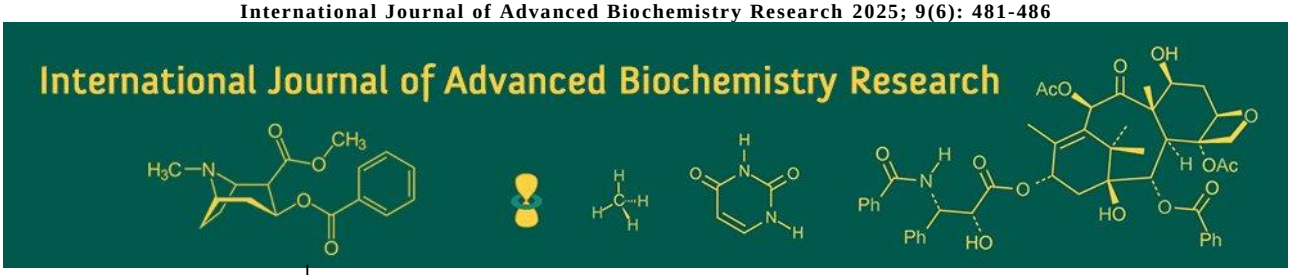

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Response of mulching and GA_3 on the performance of cabbage (*Brassica oleracea* var Capitata)

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Abstract
The present investigation entitled "Response of mulching and GA_3 on the performance of cabbage (*Brassica oleracea* var capitata)" was conducted at Agriculture Research Farm, Department of Horticulture, Raja Balwant Singh College, Bichpuri, Agra during *Rabi* season of 2024-25 to assess the influence of different mulching materials and GA_3 concentrations on various growth and yield parameters of cabbage. The experiment comprised of two factors, factor A: mulching - 3 types (M_0=Control (No mulching), M_1=Black Polythene mulch and M_2=Straw mulch) and factor B: GA_3 - 3 levels (G_0=Control (0 ppm GA_3), G_1=25 ppm GA_3 and G_2=50 ppm GA_3). Nine treatment combinations were used (M_0G_0, M_1G_0, M_2G_0, M_0G_1, M_1G_1, M_2G_1, M_0G_2, M_1G_2 and M_2G_2). The test crop; green cabbage was used for the experiment. The variety, Pusa Mukta was considered for the present study. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications. The layout of the experiment was prepared for distributing the combination of mulching and GA_3. Both Mulching and GA_3 consisted of 3 different treatments. Treatment combinations were allotted at random. The study demonstrated that the combined application of black polythene mulch and gibberellic acid (GA_3) at 50 ppm significantly enhanced the growth and yield parameters of cabbage. Among the treatments, black polythene mulch (M_1) consistently recorded the highest values for plant height (39.12 cm), leaf length (28.22 cm) and leaf width (16.50 cm) at 90 days after transplanting (DAT), while the control (M_0) recorded the lowest. Similarly, GA_3 at 50 ppm (G_2) significantly improved plant growth traits, with a maximum plant height of 39.85 cm, leaf length of 27.78 cm and leaf width of 17.04 cm, whereas the untreated control (G_0) recorded the lowest values. The interaction of mulching and GA_3 was also significant, with the M_1G_2 treatment producing the maximum plant spread (along and across the row), stem diameter, and earliest head initiation (37.24 days), in contrast to M_0G_0, which showed the least performance. Yield-related traits such as fresh weight of the whole plant, trimmed head weight and head diameter were also significantly enhanced by the M_1 and G_2 treatments, with their combination (M_1G_2) recording the highest values (1.30 kg, 0.72 kg, and 43.18 cm, respectively).

Keywords: Mulching, GA_3, FRBD (Factorial Randomized Block Design), interaction effect, growth and yield

Introduction
Cabbage is botanically known as *Brassica oleracea* var capitata and belongs to the *Cruciferae* family. Cabbage is a biennial, herbaceous and dicotyledonous plant. It was originated in the sea coast of England, Denmark and north-western part of France. It is characterized by a short stem bearing a compact, globular cluster of immature leaves-commonly referred to as the cabbage head-which may be green, red or purplish depending on the variety. Cabbage is commonly used as salad, boiled vegetable, cooked in curries and processed. It is known to possess medicinal properties and used against ailments like gout, diarrhoea, stomach and celiac troubles. It is a rich source of essential nutrients such as vitamin C, B6, K, folate, biotin, calcium, magnesium, potassium and manganese. Medicinally, cabbage juice is believed to counteract the effects of toxic mushrooms and soothe hoarseness. The characteristic flavour of cabbage is due to the glycoside "sinigrin," which contains sulphur. (Moniruzzaman *et al*., 2019) [8]. In India, cabbage is the second most important vegetable among the Cole crops.
Growth regulators such as gibberellic acid (GA_3) enhances plant height and biomass accumulation. These growth promoters influence physiological and metabolic processes, thereby enhancing nutrient uptake and productivity.

To enhance cabbage productivity, agronomists have explored numerous strategies, including the optimization of nutrient management, varietal improvement and improved cultural practices. The application of plant growth regulators (PGRs) has emerged as a promising method for enhancing yield without compromising quality. PGRs offer new opportunities in overcoming environmental constraints and improving germination, growth, root and shoot development, and overall yield.

Among the various factors influencing cabbage production, soil moisture and nutrient availability are crucial for optimizing yield. One of the most effective agronomic practices to address these factors is mulching. Mulching improves soil temperature by absorbing solar radiation, conserves soil moisture, and suppresses weed growth, particularly beneficial in winter cultivation (Bahadur *et al.*, 2018) [2]. Mulching can suppress weed physiological functions such as germination and shoot/root development, thereby reducing production costs (Duppong *et al.*, 2004) [5]. Therefore, the present investigation was conducted to assess the influence of GA_3 and mulching on growth and yield of cabbage.

Materials and Methods

The present investigation entitled "Response of mulching and GA_3 on the performance of cabbage (*Brassica oleracea* var capitata)" was conducted at Agriculture Research Farm, Department of Horticulture, Raja Balwant Singh College, Bichpuri, Agra during *Rabi* season of 2024-25. The experiment comprised of two factors, factor A: mulching - 3 types (M0=Control (No mulching), M1=Black Polythene mulch and M2=Straw mulch) and factor B: GA_3 - 3 levels (G0=Control (0 ppm GA_3), G1=25 ppm GA_3 and G2=50 ppm GA_3). Nine treatment combinations were used (M0G0, M1G0, M2G0, M0G1, M1G1, M2G1, M0G2, M1G2 and M2G2). The test crop; green cabbage was used for the experiment. The variety, Pusa Mukta was considered for the present study. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications. The layout of the experiment was prepared for distributing the combination of mulching and GA_3. Both Mulching and GA_3 consisted of 3 different treatments. Treatment combinations were allotted at random. All agronomic activities were performed efficiently at the experimental field. The field observations were recorded timely according to prescribed format.

Statistical analysis

In order to test the significance of result, standard statistical method based on the analysis of variance technique as suggested by Panse and Sukhatme (1967) [9] was employed. The treatments differences were compared with the critical difference (CD) at 5% level of probability to ascertain their significance; all the results have been summarized in the suitable Tables presented under "Experimental Findings" given the means of treatments.

Results and Discussion

(A) Growth Parameters

Diameter of stem (cm): Diameter of stem (cm) was significantly influenced by different mulching materials, GA_3 levels, and their interaction at all stages of crop growth (90 DAT). From all the mulching treatments, black polythene mulch (M1) recorded the significantly highest diameter of stem (cm), followed by straw mulch (M2), whereas control (M0) recorded the lowest diameter of stem (cm). Application of GA_3 at 50 ppm (G2) recording the maximum diameter of stem (cm) followed by G1 (25 ppm) and G0 (control) the minimum diameter of stem (cm). The interaction effect revealed that M1G2 exhibited the significantly maximum diameter of stem (cm) which was followed by M2G2 and M1G1 whereas, M0G0 recorded the lowest diameter of stem. The enhanced stem diameter may be attributed to the improved nutrient and water availability from mulching and the growth-promoting effects of GA_3.

Plant Height (cm): Plant height was significantly influenced by different mulching materials, GA_3 levels, and their interaction at all stages of crop growth (90 DAT). Among the mulching treatments, black polythene mulch (M1) recorded the significantly highest plant height, followed by straw mulch (M2), whereas control (M0) recorded the lowest plant height. Application of GA_3 significantly enhanced plant height, with G2 (50 ppm) recording the maximum plant height followed by G1 (25 ppm) and G0 (control) the minimum plant height. The interaction effect revealed that M1G2 produced the significantly maximum plant height followed by M2G2 and M1G1 whereas, M0G0 recorded the lowest plant height. This enhancement can be attributed to the synergistic effect of mulching and GA_3. Mulching conserves soil moisture and maintain optimal soil temperature, creating a favourable microenvironment for plant growth. Concurrently, GA_3, a plant growth regulator, promotes cell elongation and division, leading to increased plant height. Chaurasiya *et al.* (2014) [3] and Farjana and Islam (2019) [6] found the similar results from their experiments.

Plant spread (cm) along the row: Plant spread (cm) along the row was significantly influenced by different mulching materials, GA_3 levels, and their interaction at all stages of crop growth (90 DAT). Black polythene mulch (M1) recorded the significantly highest plant spread (cm), followed by straw mulch (M2), whereas control (M0) recorded the lowest plant spread (cm). Application of GA_3 significantly enhanced plant spread (cm), with G2 (50 ppm) recording the maximum plant spread (cm) followed by G1 (25 ppm) and G0 (control) the minimum plant spread (cm). The interaction effect revealed that M1G2 produced the significantly maximum plant spread (cm) which was followed by M2G2 and M1G1 whereas, M0G0 recorded the lowest plant spread.

The increased plant spread is likely due to the combined effects of improved soil conditions from mulching and the growth-promoting properties of GA_3. Similarly, Adamović *et al.* (2023) [1] reported that black polyethylene mulch significantly increased the plant spread of cabbage. And Dev *et al.* (2020) [4] found that foliar application of GA_3 at 120 ppm significantly increased plant spread in cabbage.

Table 1: Growth parameters of cabbage as influenced by mulching and GA_3

Treatments	Diameter of stem (cm)	Plant Height (cm)	Plant spread along the row (cm)	Plant spread across the row (cm)	Length of longest leaf (cm)	Width of largest leaf (cm)
Mulching						
M0 (control)	4.57	33.30	43.00	36.73	25.11	14.82
M1	5.08	39.12	48.33	39.44	28.22	16.50
M2	4.68	36.20	45.56	38.76	26.67	15.92
SEm±	0.05	0.39	0.46	0.41	0.27	0.17
CD(P=0.05)	0.14	1.18	1.37	1.22	0.82	0.51
GA3						
G0 (control)	4.63	34.00	44.44	36.95	25.78	14.89
G1	4.50	34.78	44.89	37.52	26.44	15.31
G2	5.20	39.85	47.56	40.45	27.78	17.04
SEm±	0.05	0.46	0.53	0.47	0.32	0.19
CD(P=0.05)	0.16	1.37	1.58	1.41	0.95	0.58
Combined effect of mulching and GA_3						
M0G0	4.20	32.45	42.67	36.41	24.67	14.52
M1G0	4.90	35.29	46.00	37.45	26.67	15.26
M2G0	4.80	34.25	44.67	36.98	26.00	14.89
M0G1	4.40	32.98	43.00	36.78	25.00	14.65
M1G1	5.01	36.48	46.67	37.98	27.33	15.98
M2G1	4.10	34.87	45.00	37.81	27.00	15.29
M0G2	5.12	34.48	43.33	36.99	25.67	15.28
M1G2	5.33	45.58	52.33	42.88	30.67	18.25
M2G2	5.15	39.48	47.00	41.48	27.00	17.58
SEm±	0.09	0.97	0.91	0.81	0.55	0.34
CD(P=0.05)	0.27	2.37	2.73	2.44	1.64	1.01

Plant spread (cm) across the row

Plant spread (cm) across the row was significantly influenced by different mulching materials, GA_3 levels, and their interaction at all stages of crop growth (90 DAT). Among the mulching treatments, black polythene mulch (M1) recorded the significantly highest plant spread, followed by straw mulch (M2), whereas control (M0) recorded the lowest plant spread (cm) across the row. Application of GA_3 at 50 ppm (G2) recording the maximum plant spread (cm) across the row followed by G1 (25 ppm) and G0 (control) have the minimum plant spread.

The interaction effect revealed that M1G2 produced the significantly maximum plant spread (cm) across the row which was followed by M2G2 and M1G1 whereas, M0G0 recorded the lowest plant spread. Likewise, plant spread along the row, the increased plant spread across the row is likely due to the combined effects of improved soil conditions from mulching and the growth-promoting properties of GA_3.

Similarly, Adamović *et al*. (2023) [1] also reported that black polyethylene mulch increased the plant spread of cabbage.

Length of longest leaf (cm)

Length of leaf was significantly influenced by different mulching materials, GA_3 levels, and their interaction at all stages of crop growth (90 DAT). Black polythene mulch (M1) recorded the significantly highest length of longest leaf, followed by straw mulch (M2), whereas control (M0) recorded the lowest length of longest leaf. Application of GA_3 significantly enhanced length of longest leaf, with G2 (50 ppm) recording the maximum length of leaf followed by G1 (25 ppm) and G0 (control) the minimum length of longest leaf. The interaction effect revealed that M1G2 produced the significantly maximum length of longest leaf followed by M1G1 and M2G1 whereas, M0G0 recorded the lowest length of longest leaf. The improved leaf dimensions can be linked to the favourable soil moisture and temperature conditions maintained by mulching, along with GA_3's effect on cell expansion. Similar findings were observed by Roy and Nasiruddin (2011) [11] that GA_3 application at 50 ppm significantly increased leaf length and breadth in cabbage.

Width of largest leaf (cm)

Width of largest leaf (cm) was significantly influenced by different mulching materials, GA_3 levels, and their interaction at all stages of crop growth (90 DAT). Across the mulching treatments, black polythene mulch (M1) recorded the significantly highest width of largest leaf (cm), followed by straw mulch (M2), whereas control (M0) recorded the lowest width of largest leaf (cm). Use of GA_3 as plant growth regulator significantly enhanced width of largest leaf (cm), with G2 (50 ppm) recording the maximum width of largest leaf (cm) followed by G1 (25 ppm) and G0 (control) the minimum width of largest leaf (cm). The interaction effect exhibited that M1G2 produced the significantly maximum width of largest leaf (cm) which was followed by M2G2 and M1G1 whereas, M0G0 recorded the lowest width of largest leaf. Likewise, the width of largest leaf (cm), the improved leaf width can be linked to the favorable soil moisture and temperature conditions maintained by mulching, along with GA_3's effect on cell expansion. Similar results were reported by Sarkar *et al*. (2014) [12], who observed that foliar application of GA_3 at 50 ppm significantly increased leaf length and breadth in cabbage.

(B) Yield and quality parameters

Head initiation (days)

Head initiation (days) was significantly influenced by different mulching materials, GA_3 levels, and their interaction. Across the mulching treatments, black polythene mulch (M1) recorded the significantly earliest head initiation (days), followed by straw mulch (M2), whereas control (M0) recorded the highest head initiation (days).

Application of GA_3 at 50 ppm (G2) recording the earliest head initiation (days) followed by G0 (control) and G1 (25 ppm) the late head initiation (days). The interaction effect revealed that M1G2 exhibited the significantly earliest head initiation (days) which was followed by M0G0 and M0G1 whereas, M0G0 recorded the late head initiation. This acceleration in development can be ascribed to the enhanced growth conditions provided by mulching and the hormonal effects of GA_3.

Similar results were found by Roy and Nasiruddin (2011) [11] that GA_3 application at 50 ppm significantly reduced the days to head initiation in cabbage.

Fresh weight of whole plant (kg), Fresh weight of trimmed head (kg) and Head diameter (cm)

Fresh weight of whole plant (kg), Fresh weight of trimmed head (kg) and Head diameter (cm) were significantly influenced by different mulching materials, GA_3 levels, and their interaction. Among the mulching treatments, black polythene mulch (M1) recorded the significantly highest fresh weight of whole plant (kg), fresh weight of trimmed head (kg) and head diameter (cm), followed by straw mulch (M2), whereas control (M0) recorded the lowest fresh weight of whole plant (kg), fresh weight of trimmed head (kg) and head diameter. Application of GA_3 significantly influenced fresh weight of whole plant, fresh weight of trimmed head (kg) and head diameter (cm), with G2 (50 ppm) recording the highest fresh weight of whole plant (kg), fresh weight of trimmed head (kg) and head diameter (cm) followed by G1 (25 ppm) and G0 (control) the lowest fresh weight of whole plant (kg), fresh weight of trimmed head (kg) and head diameter (cm). The interaction effect revealed that M1G2 exhibited the significantly highest fresh weight of whole plant (kg), fresh weight of trimmed head (kg) and head diameter (cm)) which was followed by M2G2 and M1G1 whereas, M0G0 recorded the highest, emphasizing the combined benefits of mulching and GA_3.

This improvement can be attributed to better soil moisture retention and weed suppression, which together create a favourable microenvironment for continuous plant growth. GA_3 at 50 ppm (G2) played a pivotal role in enhancing these parameters. Gibberellic acid promotes both cell elongation and division, resulting in increased plant height and leaf expansion, ultimately leading to larger head formation.

Similarly, Moniruzzaman *et al.* (2019) [8] reported that GA_3 application at 75 ppm, combined with mulching, significantly increased head diameter and weight in cabbage.

Core length at harvest (cm), Head yield per plot (kg) and Head yield (q/ha)

Core length at harvest (cm), head yield per plot (kg) and head yield (q/ha) were significantly influenced by different mulching materials, GA_3 levels, and their interaction. Among the mulching treatments, black polythene mulch (M1) recorded the significantly highest core length at harvest (cm), head yield per plot (kg) and head yield (q/ha), followed by straw mulch (M2), whereas control (M0) recorded the lowest yield parameters (core length at harvest (cm), head yield per plot (kg) and head yield (q/ha)). Application of GA_3 significantly influenced core length at harvest (cm), head yield per plot (kg) and head yield (q/ha), with G2 (50 ppm) recording the highest core length at harvest (cm), head yield per plot (kg) and head yield (q/ha) followed by G1 (25 ppm) and G0 (control) the lowest core length at harvest (cm), head yield per plot (kg) and head yield (q/ha). The interaction effect revealed that M1G2 exhibited the significantly highest core length at harvest (cm), head yield per plot (kg) and head yield (q/ha) which was followed by M2G2 and M1G1 whereas, M0G0 recorded the lowest value in this respect.

Table 2: Yield and quality parameters of cabbage as influenced by mulching and GA_3

Treatments	Head initiation (days)	Fresh weight of whole plant (kg)	Fresh weight of trimmed head (kg)	Head diameter (cm)	Core length at harvest (cm)	Head yield per plot (kg)	Head yield (q/ha)	Specific gravity
Mulching								
M0 (control)	39.93	1.08	0.57	34.68	4.78	13.35	414.00	0.73
M1	37.47	1.21	0.65	39.44	5.49	16.06	463.84	0.78
M2	37.86	1.14	0.61	37.79	5.30	14.95	428.33	0.76
SEm±	0.40	0.01	0.01	0.37	0.05	0.16	4.68	0.01
CD(P=0.05)	1.20	0.04	0.02	1.11	0.16	0.49	14.03	0.02
GA_3								
G0 (control)	37.74	0.99	0.53	35.05	4.99	13.32	416.00	0.74
G1	39.92	1.18	0.62	36.92	5.26	15.38	426.33	0.75
G2	37.59	1.26	0.69	39.95	5.32	15.66	463.84	0.79
SEm±	0.46	0.01	0.01	0.43	0.06	0.19	5.40	0.01
CD(P=0.05)	1.38	0.04	0.02	1.29	0.18	0.56	16.20	0.03
Combined effect of mulching and GA_3								
M0G0	43.28	0.87	0.48	33.78	4.76	12.58	398.00	0.72
M1G0	37.98	1.11	0.58	36.47	5.24	14.40	438.00	0.75
M2G0	37.39	0.98	0.53	34.89	4.96	12.98	412.00	0.74
M0G1	37.38	1.15	0.59	34.80	4.98	13.47	415.00	0.73
M1G1	37.92	1.21	0.65	38.68	5.48	16.62	436.00	0.76
M2G1	37.49	1.19	0.61	37.28	5.33	16.06	428.00	0.75
M0G2	37.79	1.23	0.65	35.47	4.60	13.99	429.00	0.74
M1G2	37.24	1.30	0.72	43.18	5.74	17.18	517.52	0.83
M2G2	38.69	1.25	0.69	41.20	5.61	15.82	445.00	0.79
SEm±	0.80	0.03	0.01	0.74	0.10	0.33	9.36	0.05
CD(P=0.05)	2.40	0.08	0.04	2.23	0.31	0.98	28.06	0.05

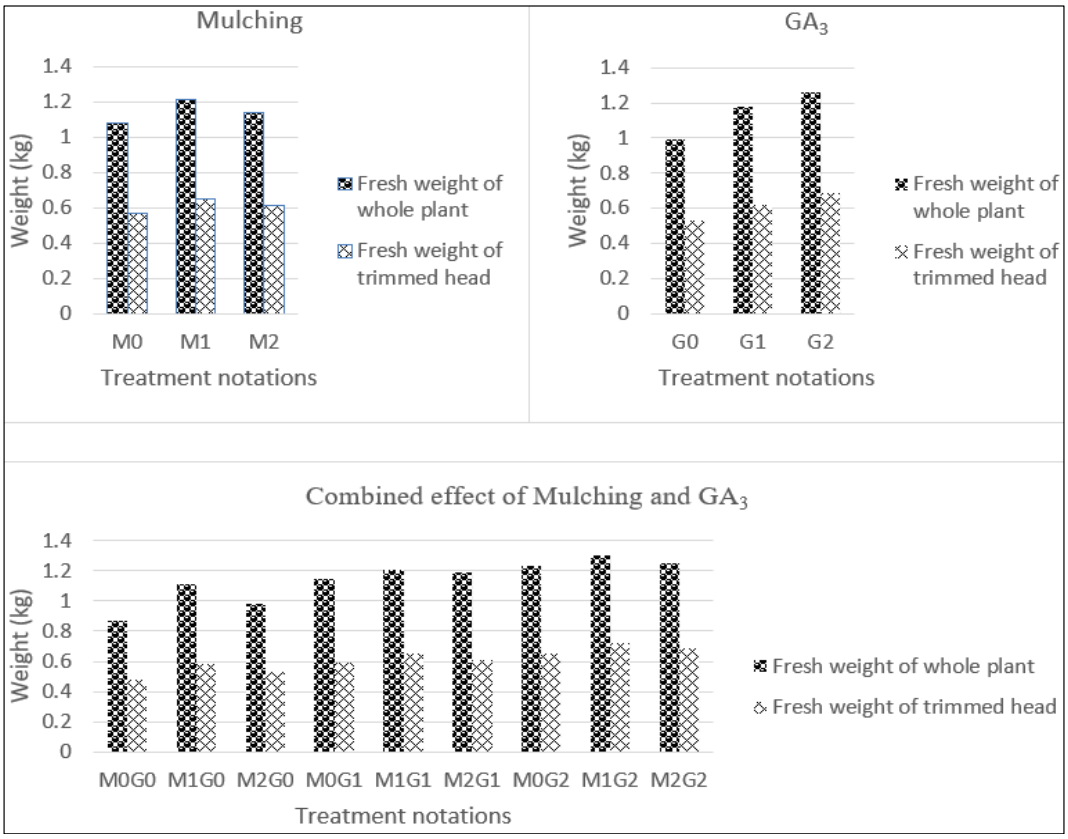

Fig 1: Effect of mulching and GA_3 on fresh weight of whole plant and fresh weight of trimmed head of cabbage

Black polythene mulch outperformed other mulching materials by maintaining consistent soil moisture and suppressing weeds, thus allowing uninterrupted nutrient uptake and plant growth. The improved soil temperature under black polythene also accelerates enzymatic and metabolic activities essential for biomass accumulation. GA_3 application, contributed to increased vegetative and reproductive growth, translating into higher head yields. The increased core length is an indicator of enhanced vertical growth, which is also linked to GA_3's ability to promote internodal elongation.

Similarly, Adamović *et al.* (2023) [1] found that the use of black polyethylene mulch significantly increased the marketable yield of cabbage.

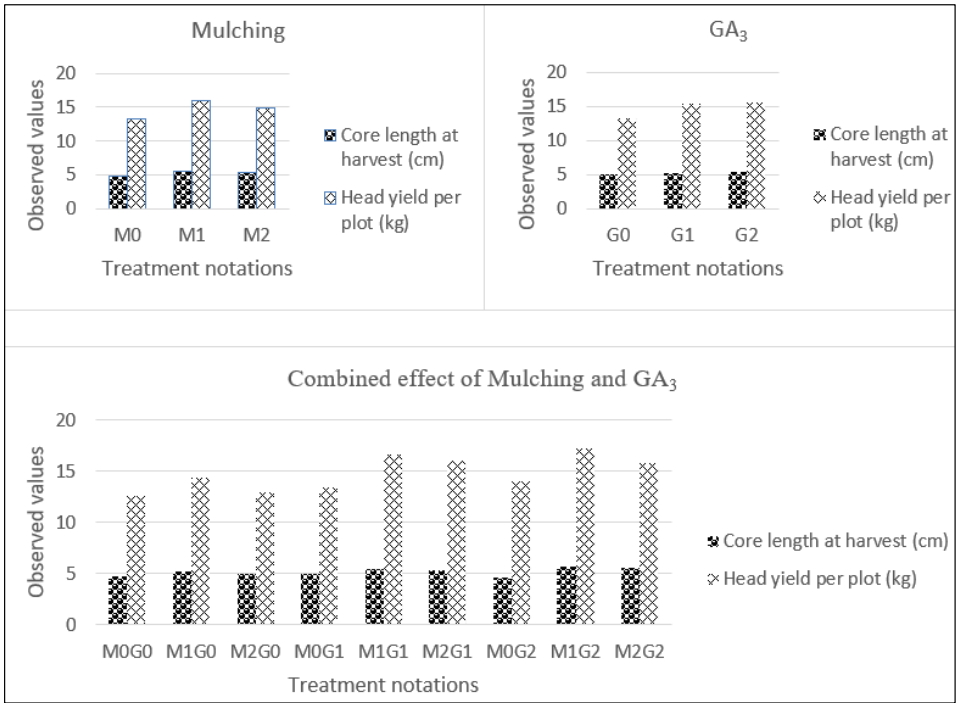

Fig 2: Effect of mulching and GA_3 on core length at harvest (cm) and head yield per plot (kg) of cabbage

Specific gravity

Specific gravity was significantly influenced by different mulching materials, GA_3 levels, and their interaction. Across the different mulching practices, black polythene mulch (M1) recorded the significantly highest specific gravity, followed by straw mulch (M2), whereas control (M0) recorded the lowest yield parameters specific gravity. Application of GA_3 significantly influenced specific gravity, with G2 recording the highest specific gravity followed by G1 (25 ppm) and G0 (control) the lowest specific gravity. The interaction effect revealed that M1G2 exhibited the significantly highest specific gravity which was followed by M2G2 and M1G1 whereas, M0G0 recorded the highest, emphasizing the combined benefits of mulching and GA_3. These results may be due to enhanced root zone temperature and better moisture conservation provided by the mulch. These conditions promote better uptake of nutrients and water, leading to the formation of denser, more compact heads.

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