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Manures and chitosan oligosaccharides application enhanced growth, productivity and economic return of cauliflower

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Abstract
A field experiment was conducted at the Research Farm of Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali during the period from November 2022 to February 2023 to investigate the growth, yield and economic return of cauliflower as influenced by different sources of manures and chitosan oligosaccharides (COS). The two factors experiment was carried out with two sets of treatment consisting of four different manures (M_0=Control; M_1= Cowdung @ 10 t/ha; M_2=Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha and three different concentrations of COS (T_0=Control; T_1= COS @ 50 mg/L and T_2=COS @ 100 mg/L). The experiment was carried out in Randomized Complete Block Design with three replications. Manures and different concentration of COS and their treatment combinations showed significant difference in respect of all growth and yield contributing characters of cauliflower. Among the manures, cowdung @ 10 t/ha exhibited best performance and among the COS concentration, COS @ 100 mg/L showed superior performance in case of all growth and yield contributing characters of cauliflower. The treatment combination of cowdung @ 10 t/ha with COS @ 100 mg/L also displayed remarkable performance compared to other treatment combination. The tallest plant (65.26 cm), the longest leaves (64.46 cm) and the tallest stem (14.80 cm) was recorded from the treatment combination of cowdung @ 10 t/ha with COS @ 100 mg/L during harvesting of cauliflower. Similar treatment combination also gave significantly the highest (21.50 cm) diameter of curd, the maximum fresh weight of curd (2.39 kg) per plant, the maximum yield per plot (21.54 kg) and yield (74.81 t/ha). The highest net return (294103.00 Tk./ha) and benefit cost ratio (2.90) were obtained from cowdung 10 t/ha with COS 100 mg/L treatment combination. The finding of this study suggests that cowdung @ 10 t/h with COS @ 100 mg/L foliar application exhibited superior performance and very useful for growth and yield of cauliflower and also profitable for cultivation.

Keywords: Manures, chitosan oligosaccharides, application, growth, productivity, cauliflower

1. Introduction

Cauliflower (*Brassica oleracea*) is an economically important and one of the most popular winter vegetable crops grown in Bangladesh (Akter *et al.*, 2011) [1]. Among the vegetables, cauliflower is widely appreciated and significant vegetable globally, as well as in Bangladesh due to its delicious taste, high nutrient content, beneficial antioxidant and anti-inflammatory properties. It contains notable number of vitamins including riboflavin, thiamine, nicotinic acid and significant amount of proteins and minerals like calcium and magnesium. One hundred gram of cauliflower edible part (Curd) contains 89% moisture, 2.3 g protein and 50 mg vitamin C. Cauliflower curds are abundant in phenolic compounds, minerals, vitamin A and glucosinolates, which may help reduce the risk of cancer (Shams and Farag 2019) [28]. The curd is formed by the shortened flower parts which are fleshy and closely crowded. It may be cooked alone or mixed with other vegetables (Kashyap *et al.* 2017) [18]. In Bangladesh, cauliflower is cultivated over an area of 56,446.94 acres, yielding a total production of 343,758.71 metric tons. (BBS, 2024) [5]. It can be grown in nearly all types of soil with good soil fertility (Islam, 2008) [15]. Compared to other cauliflower growing countries of the world, the average yield of cauliflower in Bangladesh is very low mainly due to low yielding variety, poor crop management practices and lack of improved technologies. Proper growth and higher yield of cauliflower mainly depend on nutrient availability in soil, which is completely related to the judicious application of manures and fertilizers.

But in Bangladesh continuously use of chemical fertilizer rather than manures badly affects the texture, structure, aeration, water holding capacity and microbial activity of soil (Rahman *et al.*, 2013) [24]. To enhance the productivity of vegetable crops and to earn high economic return, chemical fertilizers, pesticides and other chemical inputs are increasingly used which adversely affected the sustainability of agricultural system and make problems on environment and ecology. Moreover, long term use of only chemical fertilizers also has detrimental effect on soil physical and biological properties, biodiversity, quality of the produce and human health.

Organic manures are obtained from decomposed organic materials, either from green plants or animals (Simarmata *et al.* 2016) [29]. Organic manures enhance the size, biodiversity, and activity of the microbial population in the soil, affecting its structure, nutrient turnover, and various other physical, chemical, and biological properties. (Devi *et al.* 2018) [9]. Its enhance the longevity during post-harvest operations in terms of deterioration and loss of weight due to presence of micronutrients which nourishes the cellular and sub cellular parts of curd (Basnet *et al.* 2017) [4]. In Bangladesh, a good soil contains more than 3% organic matter but soil of the most region have less than 2%, at even some region soils have less than 1% organic matter. For continuous cropping, organic manures applied to the crop fields through cowdung, poultry manure, mustard oil cake, vermicompost etc., are insufficient than the requirement.

Vermicompost are products obtained from the accelerated biological degradation of organic wastes by earthworms and microorganisms. It undergoes significant humification through the fragmentation of parent organic materials by earthworms and the colonization of microorganisms. The use of compost and vermicompost has also been observed to improve plant growth and quality. The vermicompost promote growth from 50-100% over conventional compost and 30-40% over chemical fertilizers (Sinha *et al.*, 2010) [30].

Among the organic manures mustard oil cake play crucial role on growth, development and productivity of plants. It is a rich sour of different nutrient including 4.93% N, 0.53% P_2O_5, 0.65% K_2O. Nowadays, mustard oil cake is referred to as "plant horlicks" because it releases nutrients slowly, allowing plants to access nutrients over an extended period. It has been found to be the most prospective because they do not only reduce nematode development but also triggering plant growth by supplying sufficient amount of S, Zn and B (Thomsen *et al.*, 2005) [33].

Chitosan oligosaccharide (COS), a nontoxic plant biostimulant degraded from chitosan (Mattaveewong *et al.*, 2016) [21], has been shown to be an effective elicitor of plant immunity, environmentally friendly and easily soluble in water (Muanprasat *et al.*, 2017) [22]. COS has been largely used in many plants as immunity elicitor including wheat (Wang *et al.*, 2015) [34], oilseed rape (Yin *et al.*, 2013) [37], tobacco (Jia *et al.*, 2022) [17] and tomato (Zhang *et al.*, 2009) [38]. COS not only triggering the plant immunity to defense plant diseases, but also enhanced several secondary metabolites content in plant. Interestingly, COS treatment improves vitamin and polyphenols contents in cherry fruits (Kerch *et al.*, 2011) [19]. Eco-friendly characteristics of these biomaterials with remarkable antimicrobial and eliciting properties has been getting more interest to the researchers in recent years. Considering the above factors, the present experiment was undertaken to find out the best solutions that could be suggestive for increasing production and gaining higher profitability of cauliflower. Therefore, the present research work was undertaken to fulfill the following objectives;

- To select the most effective manures for better growth, productivity and profitability of cauliflower
- To determine the best concentration of chitosan oligosaccharides for better growth, productivity and profitability of cauliflower; and
- To investigate the effective combination of manures and chitosan oligosaccharides for better growth, productivity and economic return of cauliflower.

2. Materials and Methods

2.1 Description of the experimental site

2.1 Period and site selection

The research work was conducted at the Research Farm of Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali during the period from November 2022 to February 2023 to investigate the growth, yield and profitability of cauliflower as influenced by different sources manures and chitosan oligosaccharides. Geographically, the research farm is located at $22^0 37'$ N latitude and $89^0 10'$ E longitudes. The area is covered Gangetic Tidal Floodplains and falls under Agroecological Zone "AEZ- 13". The area lies at 0.9 to 2.1 meter above mean sea level. This region occupies a vast area of tidal floodplain land in the south-west part of Patuakhali district.

2.2 Treatments of the experiment

The two factors experiment was carried out with two sets of treatment consisting of four different manures (M_0=Control; M_1= Cowdung @ 10 t/ha; M_2=Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha and three different concentrations of chitosan oligosaccharides (COS) (T_0=Control; T_1= COS @ 50 mg/L and T_2=COS @ 100 mg/L).

2.3 Design and layout of the experiment

The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. Total experimental area was divided into three equal blocks which denoted the replications. The total number of plots was 36 and size of each unit plot was 1.8 m x 1.6 m. There were 12-unit plots in each block. The distance between two adjacent blocks and plots were 100 and 50 cm, respectively.

2.4 Application of manures, fertilizers and COS

The total amount of cowdung, vermicompost, mustard oil cake, was applied as basal dose at the time of final land preparation as per treatment. COS was applied two times after transplanting of seedings in the main field. Firs application was done after 15 days of transplanting and 2nd application was done after 45 days of transplanting.

2.5 Transplanting of seedlings: The seedlings of white Marble (F1 hybrid) variety of cauliflower were used as experimental materials. On 8 December 2022, 27 days old, healthy and disease-free seedlings of uniform size were transplanted into the experimental plots, maintaining a spacing of 60 cm × 40 cm to accommodate 12 plants in each unit plot. Intercultural operations including gap filling, weeding, earthing-up, irrigation and insect pest management was done whenever necessary.

2.6 Methods of data collection: Five plants were randomly selected from the middle rows of each unit plot to avoid border effects, and data were recorded for each plot. Measurements were taken for various parameters to evaluate plant growth, yield attributes, and overall yield as influenced by the different treatments in the experiment. Data were recorded from sample plants during the period of experiment.

2.6.1 Plant height: The plant height was measured at 30, 45, 60 days after transplanting and during harvesting by using a meter scale. The measurement was taken from the ground level to the tip of the largest leaf of an individual plant. Mean value of the five selected plants was calculated for each unit plot and expressed in centimeter (cm).

2.6.2 Number of leaves per plant: The total number of leaves per plant was counted at 30, 45, 60 days after transplanting and during harvesting from five selected plants and mean value was recorded.

2.6.3 Length of the largest leaf: The length of largest leaves was estimated at 30, 45, 60 days after transplanting and during harvesting by using a meter scale. The measurement was taken from base to tip of the leaf. Thus, mean was recorded and expressed in centimeter (cm).

2.6.4 Days taken to curd initiation

Days required for curd initiation from transplanting was recorded from the first curd initiation.

2.6.5 Diameter of curd: The curds from the sample plants were vertically sliced in the middle using a sharp knife. The diameter of each curd was measured in centimeters (cm) with a measuring tape, taking the horizontal distance from one side to the other at the widest part of the cut curd, and the average value was recorded.

2.6.6 Fresh weight curd: The weight of curd was recorded from randomly selected five plants. The weight of curd was recorded at harvest and then converted to kilogram (kg).

2.6.7 Yield per hectare

Yield per hectare was calculated out by converting from the per plot yield data to per hectare and was measured in ton (t).

2.7 Economic analysis

Economic analysis was done to measure the profitability of the treatment combination of different manures and COS concentration. All input costs including the cost for land lease and interest on invested capital were considered for computing the cost of production. Interests on invested capital were calculated @ 9% for 6 months. Price of 1 kg cauliflower at harvest was considered to be Tk 6.00 in farmer field. Cost and analysis were done in details according to the procedure of Alam *et al.* (1989) [3]. The benefit cost ratio (BCR) was calculated by using following formula:

$$\text{Benefit cost ratio} = \frac{\text{Gross return (Tk./ha)}}{\text{Total cost of production (Tk./ha)}}$$

2.8 Statistical analysis

The collected data on various parameters under the study were statistically analyzed by using Statistix 10 software. The means for all the treatments were calculated and analysis of variance for each parameter was performed by F-test. The significance of difference between the pair of means was compared by Tukey's test at the 1 and 5% significant level of probability (Gomez and Gomez, 1984) [11].

3. Results and Discussion

3.1 Plant height

Height of plant is one of the most important growth contributing characters of plants. It is influenced by several factors including genetic makeup, nutrient availability, environmental or climatic conditions, and soil characteristics etc. Among those, nutrient availability in soil is one of the most important factors for attaining desirable plant height.

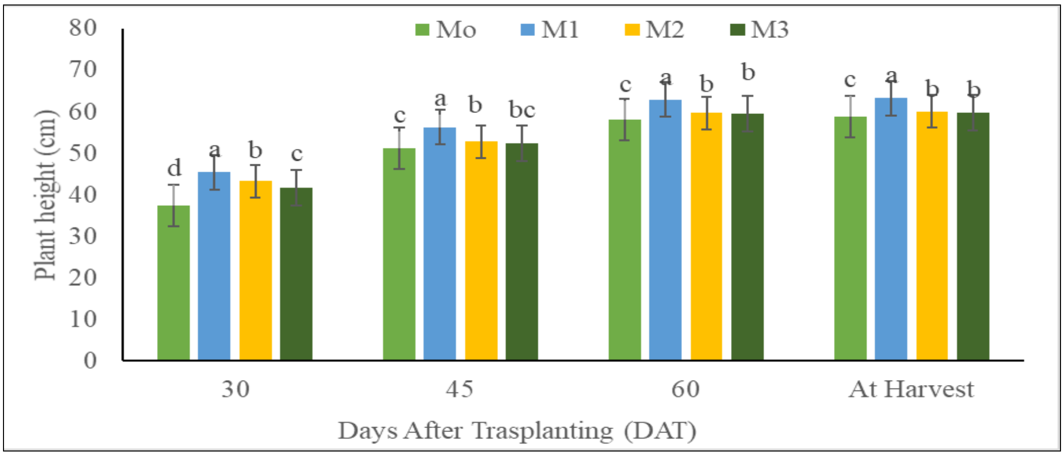

Fig 1: Effect of manures on the plant height of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

Plant height was significantly influenced by different manures at different time points after transplanting (DAT) (Fig.1). Among the different manures, the tallest plant (45.45, 56.24, 62.91 and 63.31 cm) was recorded from cowdung @ 10 t/ha followed by vermicompost @ 1.5 t/ha (43.30, 52.81, 59.73 and 60.08 cm) whereas the shortest plant (37.50, 51.22, 58.17 and 58.86 cm) was noted from control treatment at 30, 45, 60 DAT and during harvesting, respectively (Fig. 1). Similar trends of results were obtained by several researchers, they reported that cowdung manures increased the plant height compared to control (Yeasmin *et al.*, 2021; Akter *et al.*, 2016; Bose *et al.*, 2014 and Rahman *et al.*, 2013) [2, 8, 24, 36]. Cowdung acts as an organic manure, adding nutrients like nitrogen, phosphorus, and potassium to the soil. It also improves soil aeration and water-holding capacity, making it easier for plants to absorb nutrients and water, ultimately promoting taller and healthier growth.

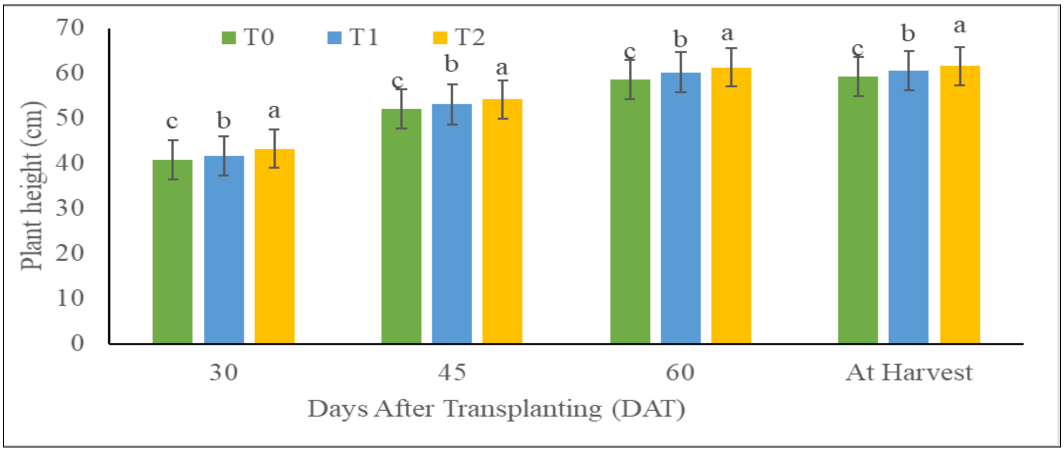

Fig 2: Effect of chitosan oligosaccharides on the plant height of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

Different concentration of chitosan oligosaccharides (COS) treatment had markedly influenced the height of plants at different time points after transplanting (Fig. 2). At 30, 45, 60 DAT and at the time of harvesting, the highest plant height (43.30, 54.24, 61.35 and 61.65 cm) was recorded from 100 mg/L COS followed by 50 mg/L COS (41.75, 53.13, 60.26 and 60.6 1cm) whereas the lowest plant height (40.85, 52.16, 58.68 and 59.33 cm) was noted from without COS treatment, respectively (Fig. 2). Recently, oligosaccharides have gained significant attention because of their various health benefits and potential applications in agriculture (Bose *et al.*, 2021) [7]. Similar findings were reported by Shahnila *et al.* (2025) [27] and Islam *et al.* (2023) [16], they found that alginate oligosaccharides foliar spray increased the plant height of garlic and onion, respectively. Sultana *et al.* (2017) [32] also reported that plant height of tomato and brinjal increased with increasing concentration of oligo-chitosan up to 100 ppm. In addition, Salachna and Łopusiewicz (2022) [26] reported that chitosan oligosaccharide lactate application at 50 and 100 mg/L increased plant height (by 14.6% and 13.2%) in baby leaf red perilla.

Table 1: Combined effect of manures and chitosan oligosaccharides on the plant height of cauliflower at different days after transplanting.

Treatments	Plant height (cm) at different DAT			
	30	45	60	At harvest
M_0T_0	36.33	50.33	56.66f	58.00f
M_0T_1	37.30	51.13	58.46de	59.00ef
M_0T_2	38.86	52.20	59.40cde	59.60def
M_1T_0	44.20	54.93	60.73bc	61.20cd
M_1T_1	45.10	56.26	63.20a	63.46b
M_1T_2	47.06	57.53	64.80a	65.26a
M_2T_0	42.46	51.26	58.06ef	58.53ef
M_2T_1	43.00	52.80	59.86bcde	60.20cde
M_2T_2	44.43	54.36	61.26b	61.53c
M_3T_0	40.40	52.13	59.26cde	59.60def
M_3T_1	41.60	52.33	59.53bcde	59.80cde
M_3T_2	42.86	52.86	59.93bcd	60.20cde
Level of significance	NS	NS	*	**
CV (%)	1.90	1.69	1.04	0.97

Values having same letter(s) within the column do not differ significantly at 5% level of probability. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha; T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS; *= Significant at 5% level of probability; **= Significant at 1% level of probability; CV= Co-efficient of Variation; NS= Not significant.

Combined effect of different manures and COS showed nonsignificant difference in relation to plant height at 30 and 45 DAT but highly significant at 60 DAT and during harvesting of cauliflower (Table 1). The highest plant height (47.06, 57.53, 64.80 and 65.26 cm) was noted from M_1T_2 (Cowdung 10 t/ha and COS 100 mg/L) treatment combination followed by M_1T_1 (45.10, 56.26, 63.20 and 63.46 cm) and M_2T_2 (44.43, 54.36, 61.26 and 61.53 cm), respectively at 30, 45, 60 DAT and during harvesting of cauliflower. In contrast, the shortest plant (36.33, 50.33, 56.66 and 58.00 cm) was measured from control treatment (without any manures and COS). Plant height is a crucial factor influencing the growth and yield of crops. It affects light capture, biomass production, and lodging resistance, ultimately impacting overall crop yield. Taller plants can access more sunlight, allowing them to photosynthesize more effectively and produce more biomass.

3.2 Number of leaves per plant

Leaf number of cauliflower per plant was varied significantly by application of different organic manures at different time points after transplanting (DAT) (Fig. 3). Among the organic manures, cowdung 10 t/ha performed best in respect of number of leaves per plant and it was (12.75, 16.06, 20.60 and 21.57) followed by Mustard oil cake 2 t/ha (11.37, 15.33, 20.02 and 20.77) at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. On the contrary, the lowest number of leaves per plant (14.95, 19.13 and 20.15) was counted from control treatment at 45, 60 DAT and during harvesting, respectively. The application of manures leads to an increase in the number of leaves primarily because manures provide essential nutrients, particularly nitrogen, that are crucial for leaf growth and development. Manures enhance soil fertility by adding organic matter and improving nutrient availability, ultimately stimulating plant growth, including leaf production. The present research results are in agreement with Hussain *et al.* (2020) [14], they noticed that organic regime increased the number of leaves per plant of cauliflower.

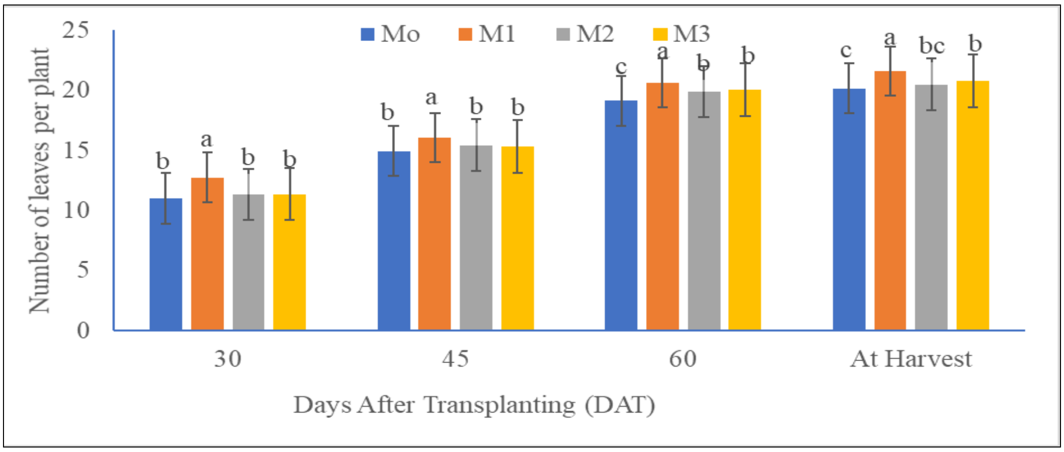

Fig 3: Effect of manures on the number of leaves of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

Significant variation was observed in respect of number of laves per plant due to application of different concentration of COS at different DAT (Fig. 4). The highest number of leaves (12.11, 15.75, 20.93 and 21.90) produced when COS 100 mg/L was used as foliar spray flowed by COS 50 mg/L (11.83, 15.75, 20.41 and 21.21) at 30, 45, 60 DAT and during harvesting of cauliflower, respectively (Fig. 4). In contrast, the lowest number of leaves (10.90, 14.80, 18.36 and 19.13) at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. Chitosan oligosaccharide applications often lead to increased leaf numbers due to the stimulation of plant growth and development. Chitosan, particularly in its oligosaccharide form, acts as a biostimulant, positively impacting various aspects of plant physiology, ultimately contributing to enhanced leaf production. Similar findings were reported by Islam *et al.* (2023) [16] and Shahnila *et al.* (2025) [27], they noted that alginate oligosaccharides foliar spray increased the number of leaves per plant of onion and garlic, respectively.

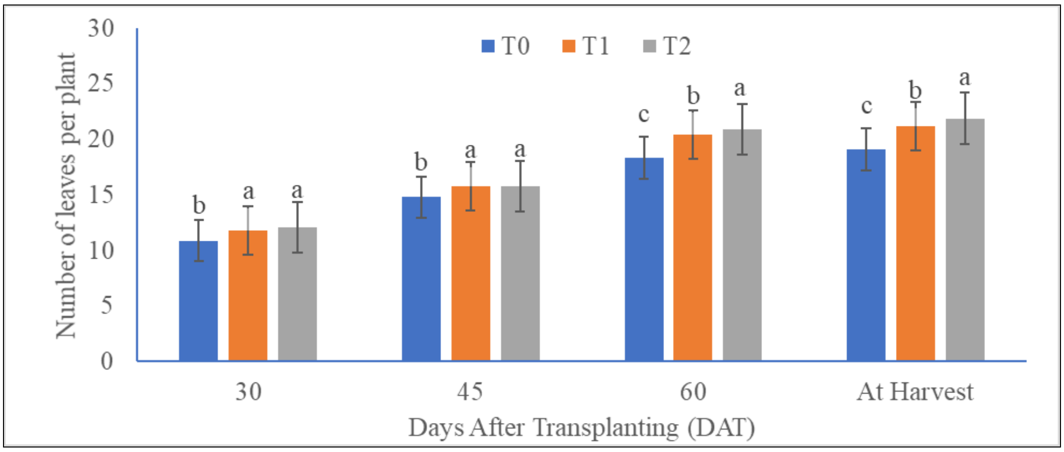

Fig 4: Effect of chitosan oligosaccharides on the number of leaves of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

Number of leaves per plant of cauliflower was significantly affected by the combined effect of manures and different concentration of COS at 30 and 60 DAT but nonsignificant effect was observed at 45 DAT and during harvesting (Appendix IV and Table 2). Maximum number of leaves per plant of cauliflower (13.06, 16.46, 22.06 and 23.13) was recorded from the treatment combination of M_1T_2, which was statistically identical with the treatment combination of M_1T_1 (12.93, 16.20, 20.93 and 21.93) at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. On the other hand, the minimum number of leaves per plant (9.60, 14.20, 18.00 and 18.66) was counted from the plants where no manures and COS was applied. The combined application of COS and manures likely leads to synergistic effects. COS can enhance the uptake and utilization of nutrients from the manure, leading to greater plant growth and leaf production. Manures provide essential nutrients like nitrogen, phosphorus, and potassium, which are crucial for leaf development and overall plant growth.

Table 2. Combined effect of manures and chitosan oligosaccharides on the number of leaves of cauliflower at different days after transplanting.

Treatments	Number of leaves at different DAT			
	30	45	60	At harvest
M_0T_0	9.60e	14.20	18.00f	18.66
M_0T_1	12.06abc	15.00	19.46cde	20.60
M_0T_2	12.46ab	15.66	19.93bcd	21.20
M_1T_0	12.26abc	15.53	18.80def	19.66
M_1T_1	12.93a	16.20	20.93ab	21.93
M_1T_2	13.06a	16.46	22.06a	23.13
M_2T_0	10.80d	14.73	18.46ef	19.06
M_2T_1	10.86d	15.86	20.40bc	21.20
M_2T_2	11.33cd	15.73	20.73bc	21.20
M_3T_0	10.93d	14.73	18.20ef	19.13
M_3T_1	11.46bcd	15.86	20.86ab	21.13
M_3T_2	11.60bcd	15.40	21.00ab	22.06
Level of significance	**	NS	*	NS
CV (%)	2.98	2.96	2.15	2.04

Values having same letter(s) within the column do not differ significantly at 5% level of probability. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha; T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS; *= Significant at 5% level of probability; **= Significant at 1% level of probability; CV= Co-efficient of Variation; NS= Not significant.

4.3 Length of the largest leaves

Effect of different manures had significant difference on the length of the largest leaves at different time points after transplanting (Fig. 5). Among the manures, cowdung @ 10 t/ha produced the longest leaves (35.36, 53.04, 60.47 and 60.93 cm) whereas smallest leaves (30.04, 43.93, 55.44 and 55.97 cm) were measured from without manures treatment at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. Similar trends of findings were reported by Yadav *et al.* (2022) [35] and they reported that organic manures produced largest leaves compared to control treatment. Manures significantly impact the leaf size of cauliflower by improving soil health and providing essential nutrients. They enhance nutrient uptake, leading to larger and more robust leaves. Manures like vermicompost and poultry manure have been shown to increase plant height, leaf area, and overall yield of cauliflower.

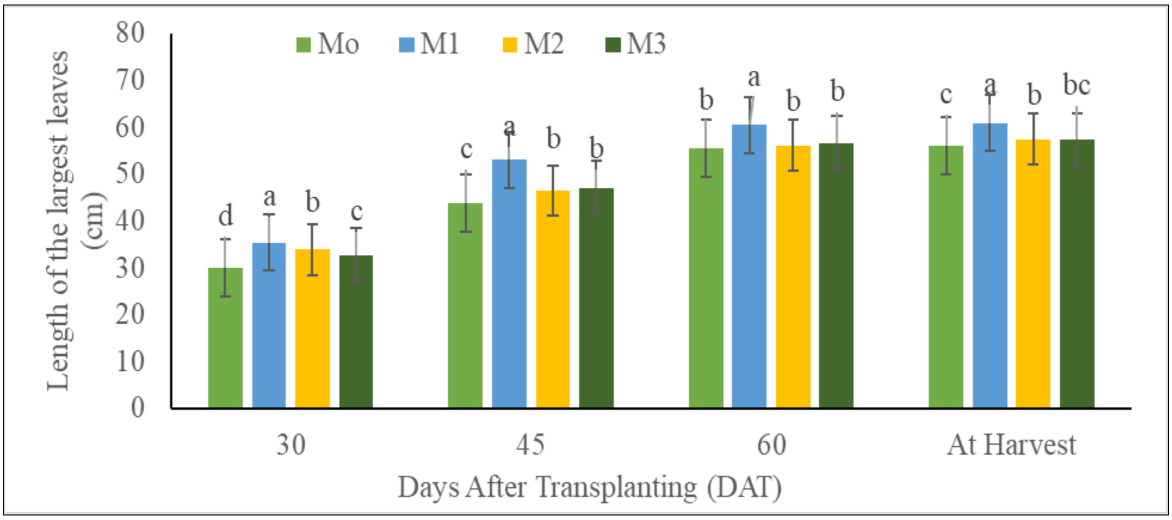

Fig 5: Effect of manures on the length of the largest leaves of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

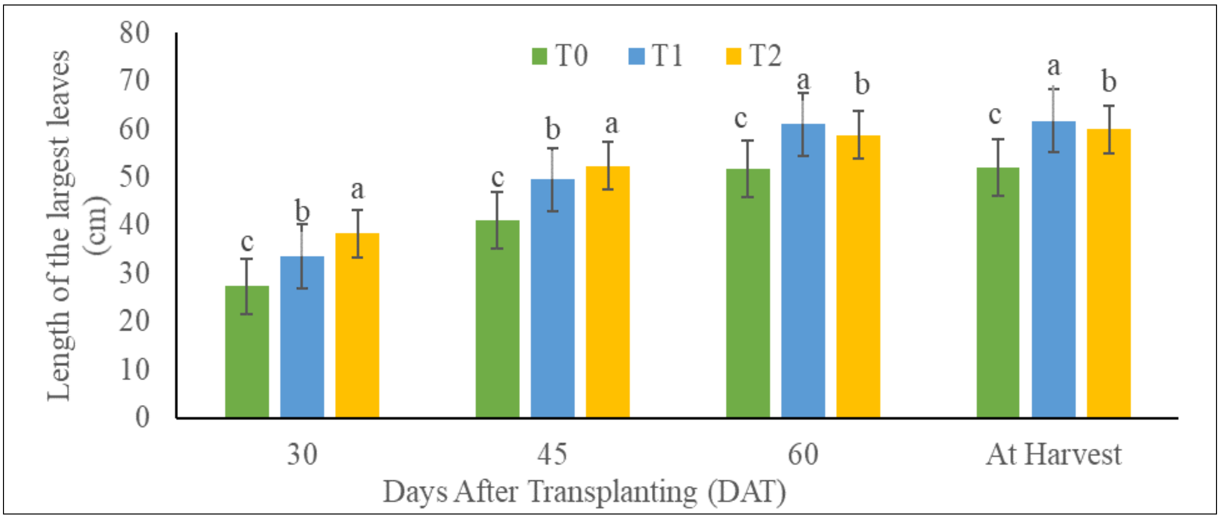

Fig 6: Effect of chitosan oligosaccharides on the length of the largest leaves of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

Different concentration of COS showed significant variation on length of the largest leaves at different days after transplanting (Fig. 6). The longest leaf (38.25, 52.35, 58.79 and 59.91 cm) was obtained from the COS 100 mg/L followed by COS 50 mg/L (33.52, 49.48, 60.96 and 61.75 cm) while the shortest leaf (27.28, 41.08, 51.77 and 52.06 cm) was recorded from the control treatment at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. COS, a type of natural biopolymer, can significantly impact cauliflower leaf size by promoting growth and enhancing overall plant health, including leaf number and size. Ma *et al.* (2012) [20] reported that oligochitosan treatment increased the shoot length in salinity stress condition compared to control treatment which supported our results. Similar findings were also reported by Howlader *et al.* (2025) [13], they reported that chitosan @ 500 ppm showed larger leaves of tomato in salinity stress condition.

Table 3: Combined effect of manures and chitosan oligosaccharides on the length of the largest leaves of cauliflower at different days after transplanting.

Treatments	Length of the largest leaves (cm) at different DAT			
	30	45	60	At harvest
M_0T_0	21.93g	35.66g	49.93g	50.86de
M_0T_1	33.53d	44.66ef	59.26bc	59.66bc
M_0T_2	34.66d	51.46bc	57.13cd	57.33c
M_1T_0	28.60f	44.60ef	53.90def	53.93d
M_1T_1	34.63d	53.60b	63.66a	64.40a
M_1T_2	42.86a	60.93a	63.86a	64.46a
M_2T_0	28.33f	42.46f	52.46efg	52.53de
M_2T_1	35.00cd	49.26cd	61.13ab	62.13ab
M_2T_2	38.53b	47.80de	54.76de	57.66c
M_3T_0	30.26ef	41.60f	50.80fg	50.93de
M_3T_1	30.93e	50.40bcd	59.80bc	60.73b
M_3T_2	36.93bc	49.20cd	59.40bc	60.26bc
Level of significance	**	**	**	**
CV (%)	1.98	2.52	2.12	1.74

Values having same letter(s) within the column do not differ significantly at 5% level of probability. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha; T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS; **= Significant at 1% level of probability; CV= Co-efficient of Variation.

There was significant difference in respect of length of the largest leaves was observed in respect of combined effect of manures and different concentration of COS at different time points after transplanting (Table 3). The highest (42.86, 60.93, 63.86 and 64.46 cm) leaf length was observed when the plant grown under Cowdung @ 10 t/ha and COS 100 mg/L followed COS 50 mg/L with same manures that is Cowdung 10 t/ha at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. In contrast, the shortest leaves (21.93, 35.66, 49.93 and 50.93 cm) was noted when it was grown under control condition at 30, 45, 60 DAT and during harvesting of cauliflower, respectively. The results obtained from M_1T_2 combination indicated that use of Cowdung contribute right amount plant nutrients compare to other sources of nutrients which helped to provide the maximum length of the largest leaves.

4.4 Days taken to curd initiation

The analysis of variance showed that there was significant effect among different manures on days taken to the curd initiation of cauliflower (Fig. 7). Early curd formation was observed from the plot that not received any manures. Minimum days required for curd formation (71.23 days) were noted from the application of cowdung @ 10 t/ha, while maximum days to curd formation of cauliflower

(72.42 days) were observed from control treatment. It was noted that the curd initiation was delayed where no manures were applied. Similar findings were reported by Farahzety and Siti Aishah (2013) [10], they revealed that organic manures application enhance early curd formation and maturity of cauliflower.

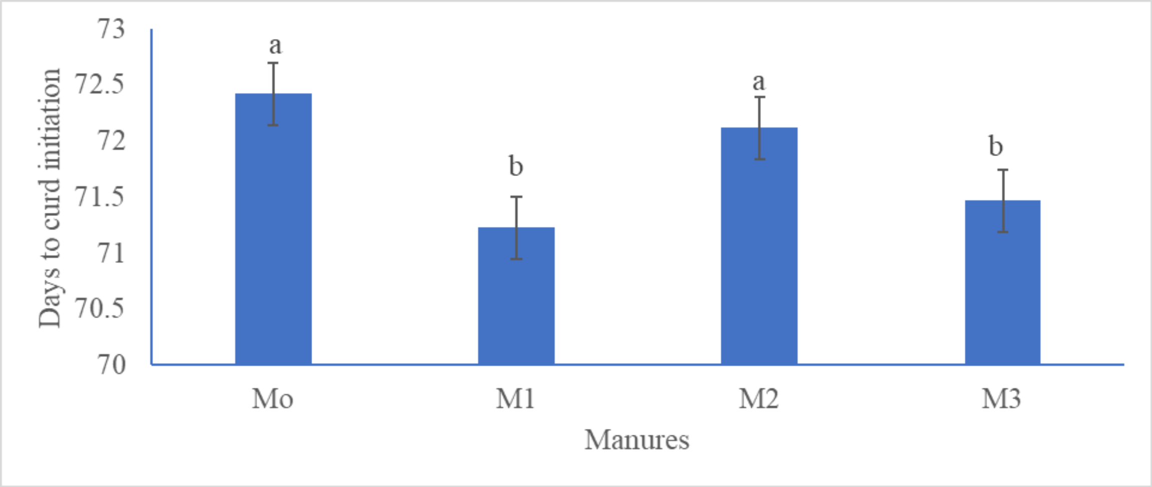

Fig 7: Effect of manures on the days to curd initiation of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

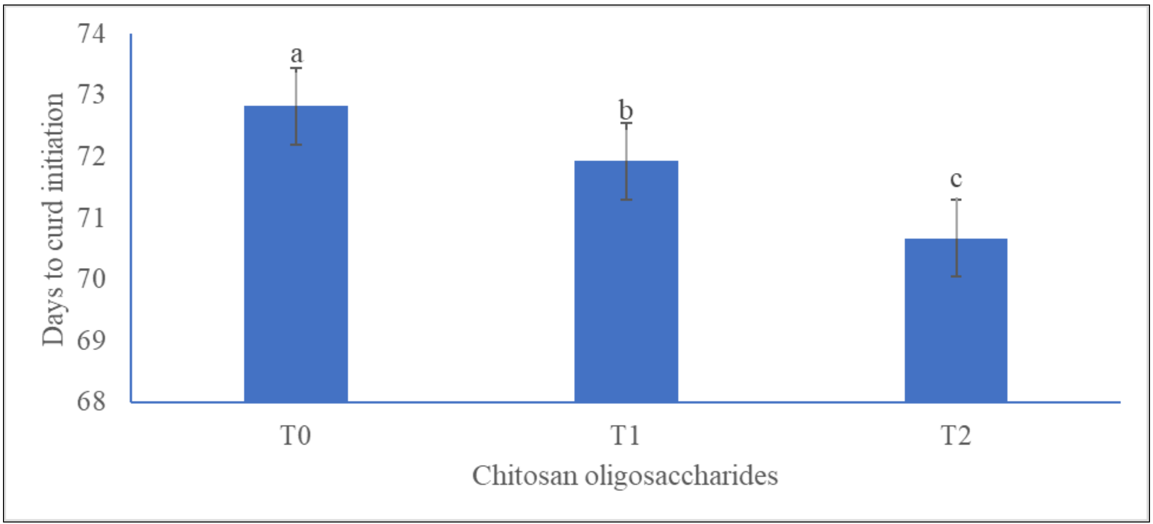

Fig 8: Effect of chitosan oligosaccharides on the days to curd initiation of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

Different concentration of COS showed significant difference in respect of days taken to curd initiation of cauliflower (Fig. 8). The minimum days (70.67 days) taken to curd initiation was recorded when COS @ 100 mg/L applied which was closely followed by COS 50 mg/L (71.93 days) while the maximum days (72.82 days) required for curd initiation when no COS was applied.

Statistically significant variation was observed in case of combined effect of manures and different concentration of COS on days taken to curd initiation of cauliflower (Table 4). The treatment combination cowdung @ 10 t/ha with COS @ 100 mg/L required the minimum days (70.12 days) for curd initiation which was statistically similar with treatment combination of mustard oil cake @ 2 t/ha with same concentration of COS (70.55 days) whereas the maximum days taken to curd initiation (73.78 days) in case of control treatment.

4.5 Diameter of curd

Significant variation was found on diameter of curd by applying different manures (Fig. 9). Among different manures, cowdung @ 10 t/ha produced significantly the maximum diameter of curd (19.52 cm) followed by mustard oil cake @ 2 t/ha (18.21 cm). In contrast, the lowest curd diameter (12.80 cm) was obtained from the control treatment. Other sources of plant nutrient showed intermediary results compared to the highest and lowest value of curd diameter. Bopche and Agrawal, (2024) [6] reported similar findings, they revealed that manures enhanced curd diameter of cauliflower compared to control treatment. Manures increase cauliflower curd diameter by providing essential nutrients, improving soil structure, and enhancing water and nutrient uptake, ultimately leading to larger and heavier curds.

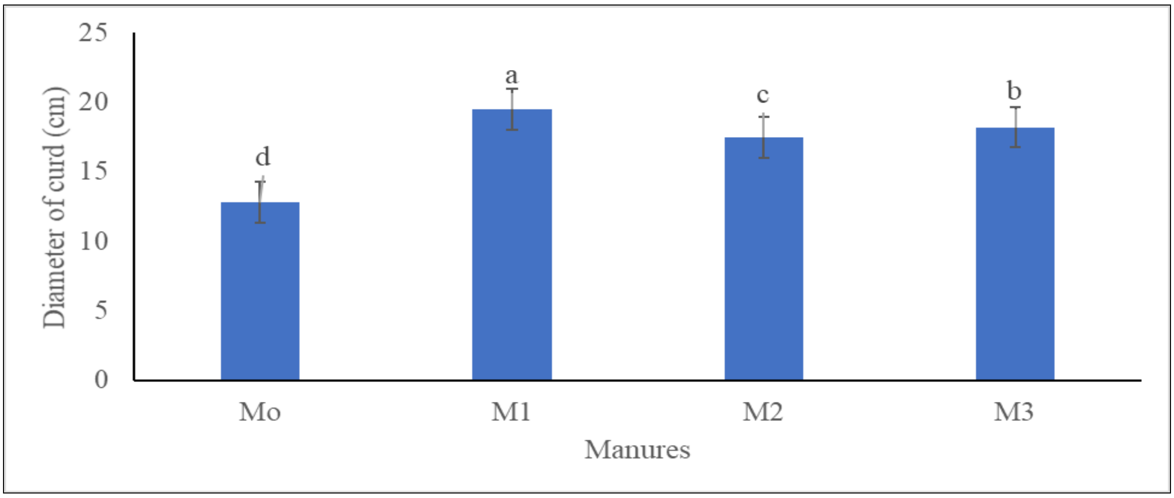

Fig 9: Effect of manures on the curd diameter of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

Different concentration of COS exhibited significant differences in case of curd diameter of cauliflower (Fig. 10). Foliar application of COS @ 100 mg/L showed maximum curd diameter (19.10 cm) followed by COS @ 50 mg/L (16.67 cm) while the minimum curd diameter (15.25 cm) was noted from control treatment. COS likely enhance cauliflower curd diameter by promoting plant growth and development. They can stimulate photosynthesis, increase plant biomass, and potentially influence cell division and expansion, all of which contribute to larger, heavier curds. Similar findings were reported by Shahnila et a. (2025) [27], they reported that alginate oligosaccharides foliar spray increased the clove diameter of garlic.

Combined effect of manures and different concentration of COS was statistically significant in respect of curd diameter of cauliflower at different time points after transplanting (Table 4). The highest curd diameter (21.50 cm) was observed when plant grown under cowdung @ 10 t/ha with COS @ 100 mg/L followed by mustard oil cake @ 2 t/ha with same concentration of COS (20.20 cm). In contrast, the lowest curd diameter (10.20 cm) was noted in control treatment.

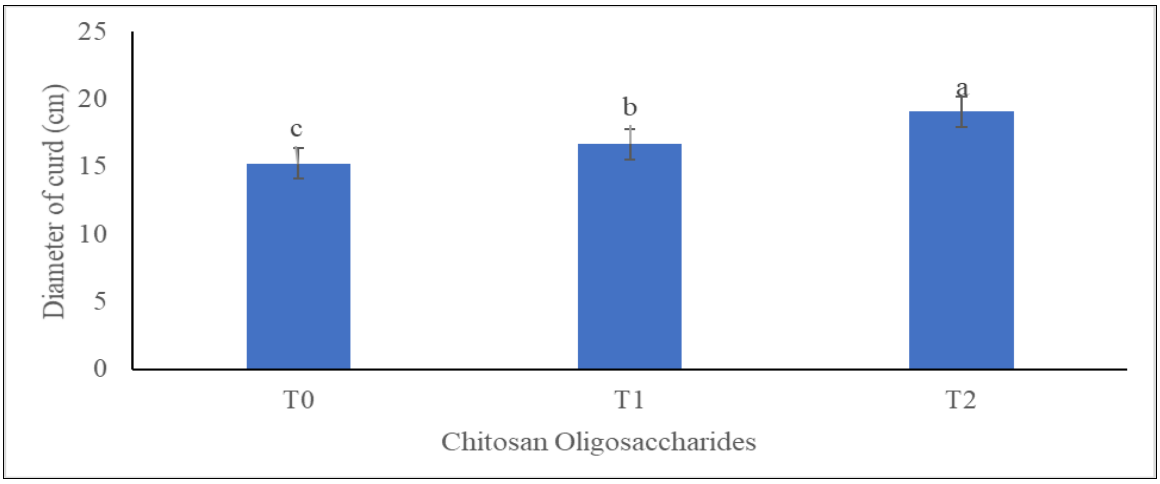

Fig 10: Effect of chitosan oligosaccharides on the curd diameter of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

4.6 Fresh weight of curd: Different manures treatment effect was varied significantly in case of curd fresh weight of cauliflower (Fig.11). Maximum weight of curd per plant (2.06 kg) was noted from the cowdung @ 10 t/ha followed by vermicompost @ 1.5 t/ha (1.87 kg) which was statistically identical with mustard oil cake @ 2 t/ha (1.86 kg) where the control treatment gave minimum weight of curd (1.73 kg) (Fig. 17). Bopche and Agrawal, (2024) [6] obtained similar results and they noted that manures produced higher curd weight that control. Manures increase the curd weight of cauliflower primarily by enhancing plant growth and nutrient availability, which leads to larger leaves and a greater overall plant size. This, in turn, supports the development of a larger and heavier curd.

Different concentration of COS showed statistically significant variation in respect of fresh weigh of curd of cauliflower (Fig. 12). The highest curd weight per plant (2.11 kg) was counted from COS @ 100 mg/L followed by COS @ 50 mg/L (1.95 kg) while the lowest curd weight per plant (1.54 kg) was noted from control treatment. Similar findings were recently reported that the application of oligosaccharides enhanced curd development, biomass accumulation and seed yield of cauliflower (Rajib *et al.*, 2023) [25]. Howlader *et al.* (2025) [13] also found similar trend of results, they noted that alginate oligosaccharides preharvest treatment significantly enhanced fresh weight of tomato fruits compared to control treatment.

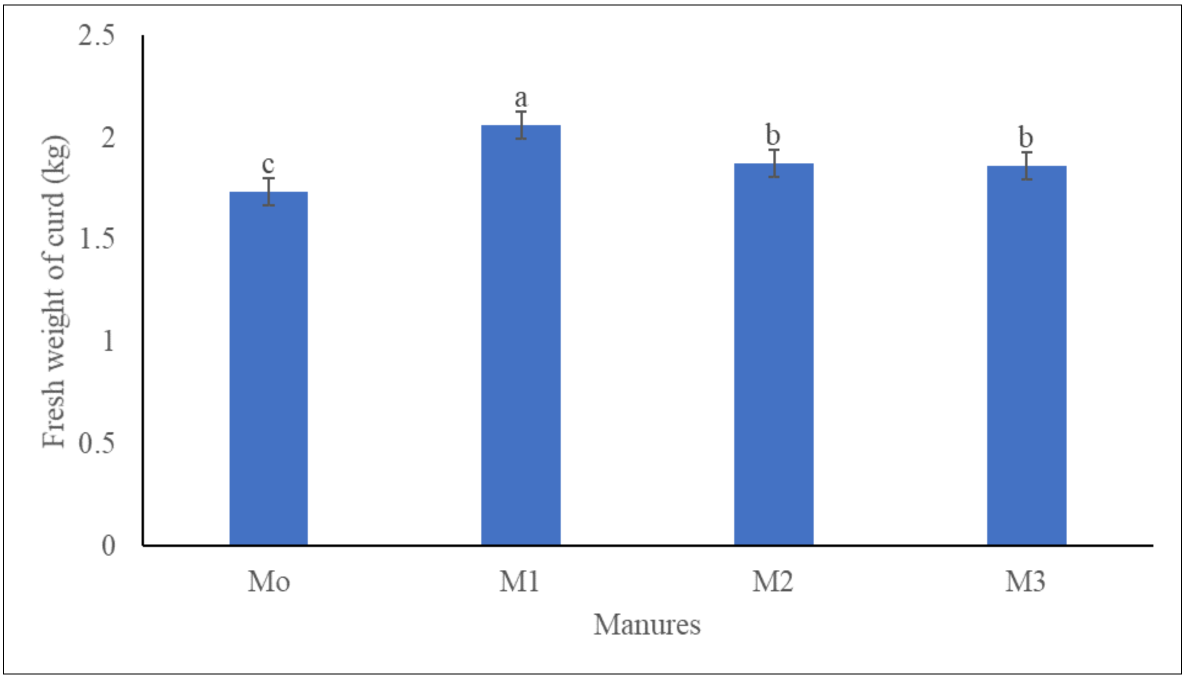

Fig 11: Effect of manures on the curd fresh weight of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

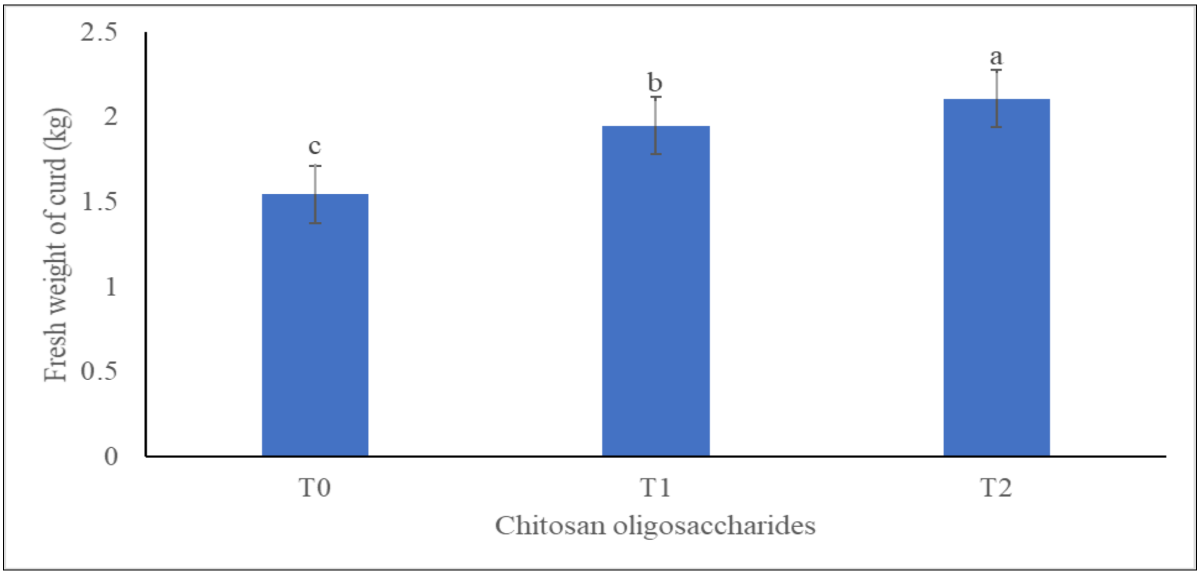

Fig 12: Effect of chitosan oligosaccharides on the curd fresh weight of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

Curd weight of cauliflower per plant was significantly affected by the combined effect of the manures and different concentration of COS (Table 4). Among the treatment combinations, cowdung @ 10 t/ha with COS @ 100 mg/L performed the highest weight of curd per plant (2.39 kg) followed by COS @ 50 mg/L with same source of plant nutrient (2.14 kg) while the lowest curd weight per plant (1.39 kg) was observed from control treatment. The treatment combinations M_3T_2 and M_2T_2 showed intermediary results compared to the highest and the lowest values.

4.7 Yield per hectare: Yield (t/ha) was significantly influenced by the application of different manures (Fig. 13). The highest yield (64.39 t/ha) was recorded from cowdung @ 10 t/ha followed by vermicompost @ 1.5 t/ha (58.62 t/ha) whereas the lowest yield (52.72 t/ha) was recorded from control treatment. Narnolia *et al.* (2024) [23] reported similar findings and they observed that organic manures produced higher yield compared to inorganic fertilizers and control treatment. Similar trend of results was also revealed by Rahman *et al.* (2013), Suem *et al.* (2013) [31], Bose *et al.* (2014), Akter *et al.* (2016) [2, 8, 24], in case of potato, onion, cabbage and garlic, respectively.

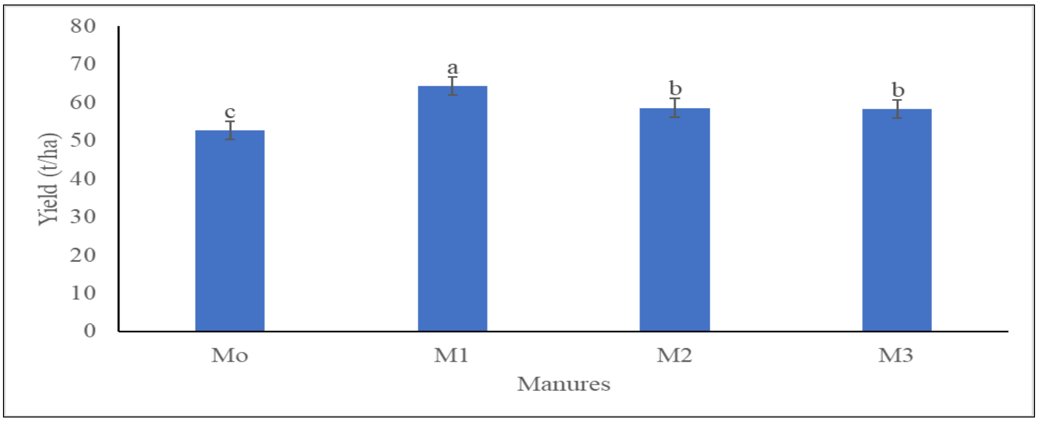

Fig 13: Effect of manures on the yield of cauliflower. Vertical bars represent standard error. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha.

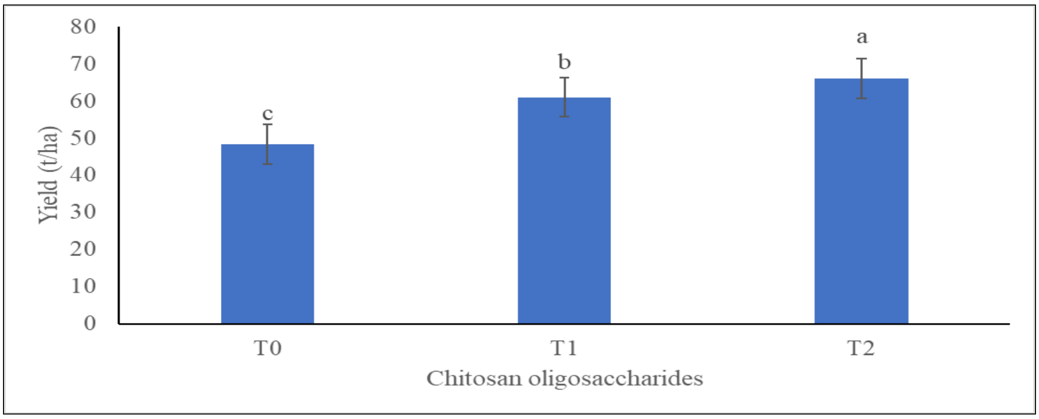

Fig 14: Effect of chitosan oligosaccharides on the yield of cauliflower. Vertical bars represent standard error. Here, T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS.

Different concentration of COS showed significant variation in respect of yield of cauliflower (Fig. 14). The highest yield (66.08 t/ha) was recorded from COS @ 100 mg/L treatment followed by COS @ 50 mg/L (61.01 t/ha) whereas the lowest yield (48.38 t/ha) was noted from control treatment. The present studied results are in agreement with the findings of Sultana *et al.*, (2017) [32], those who reported that oligochitosan increased the yield of tomato and brinjal compared to control treatment. Islam *et al.* (2023) [16], Shahnila *et al.* (2025) [27] and Howlader *et al.* (2025) [13] reported similar findings in case of onion, garlic and tomato, respectively when alginate oligosaccharides were applied.
Significant variation was observed in case of yield (t/ha) of cauliflower in respect of combined effect of manures and different concentration of COS (Table 4). It was noted that the highest yield (74.81 t/ha) was recorded from the treatment combination of cowdung @ 10 t/ha and COS @ 100 mg/L followed by COS @ 50 mg/L (66.90 t/ha) with same organic manures. In contrast the lowest yield was noted from (43.62 t/ha) control treatment.

Table 4. Combined effect of manures and chitosan oligosaccharides on the days to curd initiation, curd diameter, fresh weight of curd and yield per hectare of cauliflower at harvest

Treatments	Days to curd initiation	Curd diameter (cm)	Fresh weight of curd (kg)	Yield (t/ha)
M_0T_0	73.78a	10.20h	1.39f	43.62f
M_0T_1	72.81b	12.16g	1.70d	53.66d
M_0T_2	70.67def	16.03f	1.95c	60.88c
M_1T_0	72.20b	18.03cd	1.64de	51.45de
M_1T_1	71.36cde	19.03bc	2.14b	66.90b
M_1T_2	70.12f	21.50a	2.39a	74.81a
M_2T_0	72.84b	16.40ef	1.59df	49.88de
M_2T_1	72.16bc	17.43de	2.02bc	63.39bc
M_2T_2	71.34de	18.66cd	2.00bc	62.60bc
M_3T_0	72.46b	16.36ef	1.55ef	48.55e
M_3T_1	71.38cd	18.06cd	1.92c	60.10c
M_3T_2	70.55ef	20.20b	2.11b	66.04b
Level of significance	**	**	**	**
CV (%)	1.38	2.49	2.75	2.78

Values having same letter(s) within the column do not differ significantly at 5% level of probability. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha; T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS; **= Significant at 1% level of probability; CV= Co-efficient of Variation.

4.8 Economic return analysis

4.8.1 Total cost of production: Total production cost was statistically significant in case of manures application during cauliflower cultivation (Table 5). It was found that the highest production cost (214156.5 Tk./ha) was recorded from mustard oil cake @ 2 t/ha whereas the lowest production cost (126556.5 Tk./ha) was noted from control treatment. The results from M_1 (148456.5 Tk./ha) and M_2 (159406.5 Tk./ha) showed medium result but significantly varied from both M_0 and M_3.

Total production cost in case of different concentration of chitosan oligosaccharides was varied significantly during cauliflower cultivation (Table 5). It was noted that T_1 (control) treatment showed the lowest production cost (126556.5 Tk./ha) while T_2 (COS @ 100 mg/L) showed the maximum production cost (132896.6 Tk./ha) followed by COS 50 mg/L (129726.5 Tk./ha).

Significant variation was observed on total cost of production (Tk./ha) with the combined effect of manures and COS application during cauliflower cultivation (Table 5). It was observed that the highest cost of production (220496.6 Tk./ha) was recorded from M_3T_2 followed by M_3T_1 (217326.5 Tk./ha) and M_3T_0 (214156.5 Tk./ha). In contrast, the minimum production cost (126556.5 Tk./ha) was calculated from M_0T_0.

4.8.2 Gross return

Gross return (Tk./ha) was statistically significant in case of manures application during cauliflower cultivation (Table 5). The highest gross return (386347.00 Tk./ha) was recorded from cowdung @ 10 t/ha followed by vermicompost @ 1.5 t/ha (351753.00 Tk/ha) and mustard oil cake @ 2 t/ha (349393.00 Tk/ha) whereas the lowest gross return (316527.00 Tk./ha) was calculated from control treatment.

Gross return (Tk./ha) varied significantly due to the application of different concentration of COS (Table 5). The highest gross return (396520.00 Tk./ha) was counted from COS @ 100 mg/L treatment followed by COS 50 mg/L (366085.00 Tk/ha) whereas the lowest gross return (290410 Tk./ha) was calculated from control treatment.

Gross return (Tk./ha) was statistically significant in respect of combined effect of manures and COS application during cauliflower cultivation (Table 5). It was noted that the highest gross return (448900.00 Tk./ha) was recorded from M_1T_2 treatment followed by M_1T_1 (401420.00 Tk./ha), M_3T_2 (396240.00 Tk./ha), M_2T_1 (380340.00 Tk./ha) and M_2T_2 (375620.00 Tk./ha). In contrast, the lowest gross return (262280.00 Tk./ha) was noted from M_0T_0.

4.8.3 Net return

Significant variation was observed in case of net return (Tk./ha) in accordance with manures application during cauliflower cultivation (Table 5). It was noted that the highest net return (234720.00 Tk./ha) was recorded from cowdung @ 10 t/ha treatment followed by vermicompost @ 1.5 t/ha (189177.00 Tk./ha) whereas the lowest net return (132067.00 Tk./ha) was calculated from mustard oil cake @ 2 t/ha.

Net return (Tk./ha) was significantly varied among the different concentration of COS during cauliflower cultivation (Table 5). It was noted that the highest net return (228036.00 Tk./ha) was counted from COS @ 100 mg/L treatment followed by COS 50 mg/L (200771.00 Tk./ha) while the lowest net return (128266.00 Tk./ha) was noted from control treatment.

Net return was significantly affected by the combined effect of manures and COS application during cauliflower cultivation (Table 5). The highest net return (294103.00 Tk./ha) was counted from M_1T_2 treatment followed by M_1T_1 (249793.00 Tk./ha), M_2T_1 (217763.00 Tk./ha) and M_2T_2 (209873.00 Tk./ha). In contrast, the lowest net return (77184.00 Tk./ha) was calculated from M_3T_0.

4.8.4 Benefit cost ratio (BCR)

Statistically significant variation was found on benefit cost ratio (BCR) in accordance with manures application during cauliflower cultivation (Table 5). It was found that the highest BCR (2.60) was recorded from cowdung @ 10 t/ha whereas the lowest BCR (1.63) was recorded from mustard oil cake @ 2 t/ha (M_3) which was significantly different from M_2 (2.20).

Significant variation was observed on benefit: cost ratio (BCR) according to different concentration of COS (Table 5). It was observed that the highest BCR (2.98) was calculated from COS @ 100 mg/L treatment followed by COS @ 50 mg/L (2.82) while the lowest BCR (2.29) was counted from control treatment.

Benefit: cost ratio (BCR) was significantly varied among the combined effect of manures and COS application during cauliflower cultivation (Table 5). It was noted that the highest BCR (2.90) was recorded from M_1T_2 treatment followed by M_0T_2 (2.75) and M_1T_1 (2.65). In contrast, the lowest BCR (1.36) was recorded from M_3T_0.

Table 5. Effect of manures and chitosan oligosaccharides on total production cost, gross return, net return and BCR of cauliflower at harvest

Treatment	Total cost of production (Tk/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	BCR
Manures				
M_0	126556.5d	316527c	186800b	2.50b
M_1	148456.5c	386347a	234720a	2.60a
M_2	159406.5b	351753b	189177b	2.20c
M_3	214156.5a	349393b	132067c	1.63d
Level of significance	**	**	**	**
Chitosan oligosaccharides				
T_0	126556.5c	290410c	128266c	2.29c
T_1	129726.5b	366085b	200771b	2.82b

T_2	132896.6a	396520a	228036a	2.98a
Level of significance	**	**	**	**
Manures × Chitosan oligosaccharides				
M_0T_0	126556.5g	262280f	135724g	2.07fg
M_0T_1	129726.5fg	321980d	192253de	2.48cd
M_0T_2	132896.6f	365320c	232423bc	2.75ab
M_1T_0	148456.5ef	308720de	160264fg	2.08f
M_1T_1	151626.5e	401420b	249793b	2.65bc
M_1T_2	154796.6de	448900a	294103a	2.90a
M_2T_0	159406.5d	299300de	139894g	1.88gh
M_2T_1	162576.5cd	380340bc	217763cd	2.34de
M_2T_2	165746.6c	375620bc	209873cd	2.27ef
M_3T_0	214156.5b	291340e	77184h	1.36j
M_3T_1	217326.5ab	360600c	143273g	1.66i
M_3T_2	220496.6a	396240b	175743ef	1.80hi
Level of significance	**	**	**	**
CV (%)	8.3	2.78	5.26	3.06

Values having same letter(s) within the column do not differ significantly at 5% level of probability. Here, M_o= No manures; M_1= Cowdung @ 10 t/ha; M_2= Vermicompost @ 1.5 t/ha; M_3= Mustard oil cake @ 2 t/ha; T_o= Control (without COS); T_1= 50 mg/L COS; T_2= 100 mg/L COS; **= Significant at 1% level of probability; CV= Co-efficient of Variation.

Conclusion

The findings of the present research demonstrated that the application of manures and chitosan oligosaccharides displayed influential impact on growth, productivity and economic return of cauliflower. It was shown that among different manures used in the present study, cowdung 10 t/ha exhibited best performance in respect of growth, productivity and economic return of cauliflower. Among the different concentration of COS, 100 mg/L displayed superior performance than other concentration as well as control. Among the treatment combinations, cowdung 10 t/ha and COS 100 mg/L combinedly demonstrated superior performance in respect of all most all studied parameters and also in case of economic return. Finally, it can be concluded that cowdung 10 t/ha and COS 100 mg/L is promising for proper growth and increasing productivity and higher profitability of cauliflower.

Conflict of interest

Author declared no conflict of interests.

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