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Effect of Calcium Chelate and Carbonic Powder on Growth, Yield and Quality of Strawberry (*Fragaria* x *ananassa* Duch.) cv. Winter Dawn

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out during 2023-24 at Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh to study the effect of calcium chelate and carbonic powder on growth, yield and quality of Strawberry (Fragaria x ananassa Duch.) cv. Winter Dawn under agro-climatic conditions of Prayagraj. The experiment was laid out in RBD, replicated 3 times with 16 treatments with different combinations. The characters of growth, yield and quality characters are noted. Based on above characters it is concluded that treatment combination T_{15} (Calcium chelate (5g/L)+Carbonic powder (5g/L)+RDF(19:19:19) performed best in terms of plant height (cm) (33.74), plant spread (cm) (41.18), number of leaves per plant (44.01) ,

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petiole length (cm) (14.96) , days to first flowering (40.18) , days to first fruiting (48.57), number of flower per plant (20.62), number of fruit per plant (16.30), fruit weight (gm) (40.78),fruit per plant (g) (664.77) , fruit yield t ha^{-1} (26.59) , TSS ^{0}brix (10.45), juice content (%) (94.58) and pH(3.17) of strawberry. Importance of conducting this experiment is defined that calcium chelate and carbonic powder improves the fruit size, fruit weight and firmness. So, the quality and shelf-life of a fruit also increases. It will help to export the fruits to other countries.

Keywords: Calcium chelate; carbonic powder; strawberry; ananassa Duch; winter dawn.

1. INTRODUCTION

Strawberry (*Fragaria X ananassa* Duch.) belongs to the Rosaceae family. Strawberry is considered one of the early fruits in production, because it appears in the markets in the spring, and its fruits have a distinctive taste and aroma, and their nutritional value is high [1]. It is believed that the original habitat of the Strawberry is the temperate regions in the northern hemisphere (Europe and North America), as the strawberry was found growing wild in those areas [2]. Shalik cultivation is widespread in some Arab countries, Japan, and some Mediterranean countries, and the United States of America ranks first in production, Spain ranks second, and Morocco ranks third in terms of production sequence [3]. Calcium is one of the important elements that affect the quality of the fruits. Increasing the calcium content of the fruits is of great importance in delaying ripening and ripening in the fruits [4]. Calcium is very important in prolonging the storage life of fruits, and its concentration increases at the beginning of the growth and development of fruits, as it supports the cell wall, reduces the respiration processes that occur in fruit cells, delays the ripening process of fruits, increases their hardness and their content of vitamins, and reduces the possibility of biological injury when storing and handling. It tolerates transport and reduces fruit loss [5]. Favaro et al. [6] reported that the calcium ions (Ca) play an important role in many biochemical processes, i.e., delaying senescence and controlling physiological disorders in fruits and vegetables. Asfanani et al. [7] indicated that the calcium chelate and inhibitor of calcium channels inhibited flower bending caused by heaviness in some flower stems. Abou El-Yazied [8] indicated that the foliar application of 250 or 500 ppm chelated calcium increased leaf number and leaf area in the two tested seasons compared to the control treatment. On the other hand, Chauhadry *et al.,* [9] studied the effect of different concentration of calcium chloride (0.1, 0.2, 0.3, 0.4 and 0.5 m), showed that the highest fruit set was obtained with 0.5m calcium chloride with maximum number of compound leaves per plant and fruit weight per plant. In another study conducted by AbdEl-Gawad *et al.,* [10] showed that the addition of 750 ppm of chelate calcium mixed with ammonium nitrate increase numbers of leaves, leaf area, dry matter and the chlorophyll index compared to the control treatment. Iron is an essential element for plants but due to its low solubility, iron availability to plants is very low specially in arid regions (Eskandari, 2011). According to Beiparsya et al. [11], application of calcium chloride and carbon dioxide successfully inhibited fungal growth, maintained firmness, minimized weight loss, and extended the shelf life compared to the control group. These findings have significant implications for the apple industry, as they provide a means to improve fruit quality and increase the shelf life in fruits.

2. MATERIALS AND METHODS

A Field experiment was carried out at the Department of Horticulture, SHUATS, Prayagraj, U.P. in the months of October 2023 to February**,** 2024. The experiment was conducted on strawberry cv. Winter dawn in Randomized Block Design with three replications using 16 treatment combinations. Date of transplanting 28th October 2023, treatments are applied at 30 Days After Transplanting, 45 Days After Transplanting Treatment combinations are mentioned below:

T0: Control (RDF), T1: Calcium chelate (1g/L)+RDF (19:19:19), T2:Calcium chelate (3g/L)+RDF(19:19:19), T3: Calcium chelate (5g/L)+RDF(19:19:19), T4: Carbonic powder (1g/L)+RDF(19:19:19), T5: Carbonic powder (3g/L)+RDF(19:19:19), T6: Carbonic powder (5g/L)+RDF(19:19:19), T7: Calcium chelate (1g/L)+Carbonic powder (1g/L)+RDF(19:19:19), T8: Calcium chelate (1g/L)+Carbonic powder (3g/L)+RDF(19:19:19), T9: Calcium chelate (1g/L)+Carbonic powder (5g/L)+RDF(19:19:19), T10: Calcium chelate (3g/L)+Carbonic powder (1g/L)+RDF(19:19:19), T11: Calcium chelate

(3g/L)+Carbonic powder (3g/L)+RDF(19:19:19), T12: Calcium chelate (3g/L)+Carbonic powder (5g/L)+RDF(19:19:19), T13: Calcium chelate (5g/L)+Carbonic powder (1g/L)+RDF(19:19:19), T14: Calcium chelate (5g/L)+Carbonic powder (3g/L)+RDF(19:19:19), T15: Calcium chelate (5g/L)+Carbonic powder (5g/L)+ RDF (19:19:19).

3. RESULTS AND DISCUSSION

The maximum plant height (cm) (33.74) shown in Table 1 was recorded in T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum plant height (cm) (20.39) was recorded in T_0 Control. Here, plant height is measured using a measuring scale in centimetres. In this, trial maximum plant height is seen in the T_{16} treatment, this might be due to calcium, it plays a vital role for cell wall structure and strength in plants, including strawberries. Calcium chelate is a form of calcium that is more easily absorbed by plants. Adequate calcium levels can promote stronger stems and overall plant vigour, potentially leading to increased plant height. Carbonic powder, or calcium carbonate, can influence plant growth by adjusting soil pH. It can raise the pH of acidic soils, making essential nutrients more available to plants. However, excessive amounts can lead to alkaline conditions, which may affect nutrient uptake negatively. It may indirectly affect plant height by improving overall plant health and nutrient availability. Similar results were also found by Abdulhadi et al. [12].

The maximum plant spread (cm) (41.18) shown in Table 1 was recorded in T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum plant spread (cm) (26.95) was found recorded in T_0 Control shown in Table 1**.** In this trail treatment T16 shows the best result with respect to plant spread, this is due to Calcium is essential for plant growth and development. Chelated forms of calcium can improve nutrient uptake, strengthen cell walls, and promote overall plant health. In strawberries, adequate calcium levels can lead to stronger stems, healthier roots, and improved fruit quality. This can indirectly support better spread as healthier plants are more vigorous and can produce more runners, allowing for better coverage and spread. Carbonic powder, often derived from sources like crushed limestone or dolomite, can help to adjust soil pH. It provides calcium and magnesium to the soil, which are essential nutrients for plant growth. By maintaining proper pH levels, carbonic powder can enhance nutrient availability to plants, improve soil structure, and encourage microbial activity, all of which contribute to healthier strawberry plants. Healthier plants Aare more likely to spread vigorously through runners, leading to increased plant coverage. Similar results were also found by Naiem et al. [13].

The maximum Petiole length (cm) (14.96) was recorded in T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum Petiole length (cm) (9.44) was found in T_0 Control respectively. The minimum days to first flowering (40.18) was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19) and maximum days to first flowering (53.37) was found in treatment T0 Control. In this experiment, maximum petiole length is seen in T16 treatment is due to Calcium chelate can improve calcium availability to the plant, resulting in stronger cell walls and potentially shorter petioles. Shorter petioles often indicate sturdier plants with better support for leaves and fruit, as they are less likely to bend or break under their weight. Carbonic powder, by adjusting soil pH and providing essential nutrients like calcium and magnesium, can contribute to overall plant health and vigour. This can indirectly affect petiole length by supporting robust growth and development. Additionally, proper soil pH can optimize nutrient uptake, which may lead to balanced growth and, potentially, shorter petioles. Similar results were found by Naiem et al. [13], Kumar et al. [14].

The minimum days to first fruiting (48.57) was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19) and maximum days to first fruiting (61.31) was found in treatment T0 Control. In this trial maximum fruit set is seen in the T_{16} this might be due to adequate calcium levels are crucial for proper fruit development and can help prevent disorders such as blossom end rot. Calcium chelate provides a readily available form of calcium to the plant, which promotes strong cell wall formation in flowers and fruits. This can lead to improved pollination and fruit set, especially during the critical period of first fruit development. Carbonic powder, which likely contains carbonates or other carbon-containing compounds, can help improve soil structure and microbial activity. Healthy soil microbial populations support nutrient availability and uptake, which is essential for fruit set. Additionally, carbonic powder can aid in maintaining proper soil pH, creating optimal conditions for nutrient absorption and utilization by the plants. This can contribute to healthier plants with improved flowering and fruiting, including during the first fruit set in strawberries. Same results were observed by Eman et al. [15].

The maximum number of flower per plant (20.62) shown in Table 1 was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19) and minimum number of flowers per plant (10.77) was found in treatment T0 Control. In this trial maximum flower per plant is seen in the T_{16} this might be due to calcium is essential for cell division and growth, including in flower development. Adequate calcium levels can promote the formation of healthy flower buds, which may lead to an increased number of flowers per plant. Calcium chelate provides a readily available source of calcium, ensuring that the plant has access to this vital nutrient during critical growth stages. This can result in more robust flower production and potentially higher yields. Carbonic powder, by improving soil structure and fertility, can indirectly affect the number of flowers per plant. Healthy soil conditions supported by carbonic powder promote strong root development and nutrient uptake, which are essential for optimal flower formation. These factors combined can contribute to increased flower production and a higher number of flowers per plant. Same results was observed by Kumar *et al.,* [14].

The maximum Number of fruit per plant (16.30) shown in Table 1 was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum Number of fruits per plant (7.34) was found in treatment T0 Control. In this trial maximum fruits per plant is seen in the T_{16} this might be due to adequate calcium levels are crucial for fruit development, as calcium plays a significant role in cell division and structure. Calcium chelate provides a readily available source of calcium to the plant, ensuring that it has what it needs during critical growth stages. This can lead to stronger fruit set and development, potentially resulting in a higher number of fruits per plant. Carbonic Powder: Carbonic powder can improve soil structure, microbial activity, and nutrient availability. Healthy soil conditions supported by carbonic powder promote strong root development and nutrient uptake, which are essential for optimal fruit formation. Additionally, carbonic powder can enhance soil pH, creating favourable conditions for nutrient absorption and utilization by the plants. These factors combined can contribute to increased fruit production and a higher number of fruits per plant. Same results observed by Kumar et al. [14].

The maximum Fruit weight (gm) (40.78) shown in Table 2 was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19) whereas the minimum Fruit weight (gm) (40.78) was found in treatment T0 Control. In this trial maximum fruit weight is seen in the T_{16} this might be due to adequate calcium levels are crucial for proper fruit development and cell wall formation. Calcium chelate provides a readily available source of calcium to the plant, ensuring that it has sufficient amounts during critical growth stages. This can result in stronger, thicker cell walls in the fruits, leading to increased fruit weight. Additionally, proper calcium levels can help prevent disorders like blossom end rot, which can affect fruit development and weight negatively. Carbonic powder improves soil health and fertility, which indirectly influences fruit weight. It promotes better root development, nutrient uptake, and microbial activity in the soil. These factors contribute to healthier plants with improved nutrient availability, which can lead to larger and heavier fruits. Additionally, carbonic powder can help maintain optimal soil pH, which is essential for nutrient absorption and utilization, further enhancing fruit weight. Same results were observed by Arabloo et al. [16].

The maximum Fruit per plant (g) (664.77) was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum Fruit per plant (g) (196.47) was found in treatment T0 Control. In this trial maximum fruit per plant is seen in the T_{16} this might be due to adequate calcium levels are crucial for fruit development and can impact the number of fruits per plant. Calcium chelate provides a readily available source of calcium to the plant, promoting proper cell division and fruit development. This can lead to increased fruit set and a higher number of fruits per plant. Carbonic powder improves soil health and fertility, indirectly affecting fruit production. By enhancing soil structure, microbial activity, and nutrient availability, carbonic powder supports overall plant health and vigour. Healthy plants are more likely to produce a higher number of flowers, leading to increased fruit set and ultimately more fruits per plant. Same results were observed by Kumar et al. [14].

Table 1. List of treatment combinations for plant height, plant spread and fruit per plant

Symbols	Treatment Combination	Plant height (120DAT)	Plant spread 120 DAT	Number of flowers per plant	Number of fruits per plant
T_0	Control (RDF)	20.39	26.95	10.77	7.34
T_1	Calcium chelate (1g/L) +RDF (19:19:19)	27.47	34.13	15.10	12.29
T_2	Calcium chelate (3g/L) +RDF (19:19:19)	28.01	31.18	16.96	12.76
T_3	Calcium chelate (5g/L) +RDF (19:19:19)	28.08	31.81	17.71	12.58
T_4	Carbonic powder (1g/L) +RDF (19:19:19)	29.96	36.58	16.31	11.32
T_5	Carbonic powder (3g/L) +RDF (19:19:19)	29.13	32.15	15.37	11.65
T_6	Carbonic powder (5g/L) +RDF (19:19:19)	27.87	34.47	15.62	11.96
T_7	Calcium chelate (1g/L)+Carbonic powder (1g/L)+RDF(19:19:19)	28.02	31.66	14.69	12.04
T_8	Calcium chelate (1g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	31.72	36.96	14.87	12.10
T_9	Calcium chelate (1g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	29.91	32.68	17.15	12.68
T_{10}	Calcium chelate (3g/L)+Carbonic powder 3(1g/L)+RDF(19:19:19)	28.46	33.83	16.13	13.62
T_{11}	Calcium chelate (3g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	31.04	37.53	16.20	12.77
T_{12}	Calcium chelate (3g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	31.26	37.30	15.00	11.93
T_{13}	Calcium chelate (5g/L)+Carbonic powder (1g/L)+RDF(19:19:19)	31.74	37.92	18.63	15.75
T_{14}	Calcium chelate (5g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	31.97	39.10	19.11	16.01
T_{15}	Calcium chelate (5g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	33.74	41.18	20.62	16.30
	F-Test	S	S	S	S
	S.Ed.	**0.963**	0.743	1.487	0.574
	CD at 0.5%	**1.966**	1.517	3.037	1.172
	CV	**4.024**	2.621	5.191	5.536

Table 2. List of Treatment Combinations for TSS, pH, juice content and fruit yield

Symbols	Treatment Combination	TSS 0Brix	pH	Juice content (%)	Fruit weight (g)	Fruit yield t ha^{-1}
T_0	Control (RDF)	7.31	3.89	81.64	26.63	7.86
T_1	Calcium chelate (1g/L)+RDF (19:19:19)	8.26	3.63	88.74	34.64	17.03
T_2	Calcium chelate (3g/L)+RDF(19:19:19)	8.57	3.57	87.94	35.43	18.10
T_3	Calcium chelate (5g/L)+RDF(19:19:19)	8.88	3.74	91.74	31.80	16.04
T_4	Carbonic powder (1g/L)+RDF(19:19:19)	9.48	3.70	92.11	34.30	15.57
T_5	Carbonic powder (3g/L)+RDF(19:19:19)	8.94	3.65	90.98	36.14	16.85
T_6	Carbonic powder (5g/L)+RDF(19:19:19)	8.64	3.62	90.77	33.78	16.16
T_7	Calcium chelate (1g/L)+Carbonic powder (1g/L)+RDF(19:19:19)	8.64	3.72	91.83	34.96	16.83
T_8	Calcium chelate (1g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	9.07	3.68	92.84	35.77	17.25
T_9	Calcium chelate (1g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	9.02	3.70	93.47	37.27	18.90
T_{10}	Calcium chelate (3g/L)+Carbonic powder 3(1g/L)+RDF(19:19:19)	9.18	3.73	91.80	35.15	19.14
T_{11}	Calcium chelate (3g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	8.53	3.59	91.67	34.61	17.63
T_{12}	Calcium chelate (3g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	9.08	3.70	91.92	34.17	16.31
T_{13}	Calcium chelate (5g/L)+Carbonic powder (1g/L)+RDF(19:19:19)	10.06	3.47	91.88	37.57	23.68
T_{14}	Calcium chelate (5g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	10.17	3.29	92.83	38.27	24.49
T_{15}	Calcium chelate (5g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	10.45	3.17	94.58	**40.78**	26.59
	F-Test	S	S	S	S	
	S.Ed.	0.172	0.064	1.147	1.487	
	CD at 0.5%	0.350	0.130	2.342	3.037	
	CV	2.330	2.152	1.542	5.191	

Table 3. List of treatment combinations for cost cultivation and net return

Symbols	Treatment Combination	Total cost of cultivation	Gross return (Rs. ha-1)	Net return (Rs. ha-1)	B:C Ratio
T_0	Control (RDF)	491514.1	943032.16	451518.03	0.92
T_1	Calcium chelate (1g/L)+RDF (19:19:19)	494393.4	2043976.928	1549583.548	3.13
T_2	Calcium chelate (3g/L)+RDF(19:19:19)	500151.9	2171858.4	1671706.52	3.34
T_3	Calcium chelate (5g/L)+RDF(19:19:19)	505910.4	1924974.496	1419064.116	2.80
T_4	Carbonic powder (1g/L)+RDF(19:19:19)	492103.2	1868053.6	1375950.42	2.80
T_5	Carbonic powder (3g/L)+RDF(19:19:19)	493281.3	2022057.6	1528776.32	3.10
T_6	Carbonic powder (5g/L)+RDF(19:19:19)	494459.4	1939775.68	1445316.3	2.92
T_7	Calcium chelate (1g/L)+Carbonic powder (1g/L)+RDF(19:19:19)	494982.4	2019086.56	1524104.13	3.08
T_8	Calcium chelate (1g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	496160.5	2070002.4	1573841.87	3.17
T_9	Calcium chelate (1g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	497338.6	2268176	1770837.37	3.56
T_{10}	Calcium chelate (3g/L)+Carbonic powder 3(1g/L)+RDF(19:19:19)	500740.9	2296454.4	1795713.47	3.59
T_{11}	Calcium chelate (3g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	501919	2115698.4	1613779.37	3.22
T_{12}	Calcium chelate (3g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	503097.1	1957580	1454482.87	2.89
T_{13}	Calcium chelate (5g/L)+Carbonic powder (1g/L)+RDF(19:19:19)	506499.4	2841777.6	2335278.17	4.61
T_{14}	Calcium chelate (5g/L)+Carbonic powder (3g/L)+RDF(19:19:19)	507677.5	2939160.64	2431483.11	4.79
T_{15}	Calcium chelate (5g/L)+Carbonic powder (5g/L)+RDF(19:19:19)	508855.6	3190914.4	2682058.77	**5.27**

The maximum Fruit yield t ha^{-1} (26.59) shown in Table 2 was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum Fruit yield t ha^{-1} (7.86) was found in treatment T0 Control. In this trial maximum fruit yield is seen in the T_{16} this might be due to calcium is essential for fruit development, as it helps strengthen cell walls and prevent disorders like blossom end rot. Calcium chelate provides a readily available source of calcium, ensuring that the plants have what they need for optimal fruit development. By preventing calcium deficiencies and related issues, calcium chelate can contribute to higher fruit yield. Carbonic powder, such as calcium carbonate, influences soil pH. It can raise pH levels in acidic soils, making essential nutrients more available to plants. This can indirectly promote fruit yield by improving overall plant health and nutrient uptake. However, excessive use of carbonic powder can lead to alkaline conditions, which may negatively affect nutrient availability and, consequently, fruit yield. Same results were found by Naiem et al. [13].

The maximum TSS ^{0}Brix (10.45) shown in Table 2 was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum TSS ^{0}Brix (7.31) was found in treatment T0 Control. In this trial maximum TSS is seen in the T_{16} this might be due to calcium is essential for cell wall stability and fruit firmness in strawberries. Calcium chelate can help improve calcium uptake by the plant, leading to firmer fruit with higher TSS. Adequate calcium levels can also reduce disorders like blossom-end rot, which can negatively affect TSS. Carbonic powder typically refers to a form of calcium carbonate, which can act as a pH buffer in the soil. Proper soil pH is crucial for nutrient uptake by the plants, including calcium. By maintaining optimal pH levels, carbonic powder can indirectly influence TSS by ensuring the availability of essential nutrients. Same results were observed by Arabloo et al. [16].

The maximum juice content (%) (94.58) shown in Table 2 was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). Whereas the minimum juice content (%) (81.64) was found in treatment T0 Control. In this trial maximum juice content is seen in the T_{16} this might be due to calcium is crucial for cell wall integrity and fruit firmness. Adequate calcium levels, facilitated by calcium chelate, can lead to firmer strawberries with less susceptibility to mechanical damage and water loss. As a result, strawberries treated with calcium chelate may have higher juice content because their firmer texture helps retain more juice during handling and storage. Carbonic powder, especially if it contains calcium carbonate, can help maintain optimal soil pH, which is important for nutrient uptake by plants. Proper nutrient uptake, including calcium, can contribute to healthier plants and improved fruit quality. However, excessive calcium carbonate can lead to higher pH levels, potentially affecting fruit quality negatively. So, it's essential to apply it judiciously. Same results are found by Arabloo et al. [16], Naiem et al. [13], Ansari et al. [17].

The maximum pH (3.89) shown in Table 2 was found in treatment T0 Control and the minimum pH (3.17) was found in treatment T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19). In this trial maximum pH is seen in the T_{16} this might be due to calcium chelate primarily affects the pH of the soil rather than the fruit itself. However, by improving calcium availability to the plant, it can indirectly influence fruit pH. Calcium plays a role in cell wall formation and overall fruit quality [18]. Adequate calcium levels can lead to firmer fruit, which may have a slightly lower pH due to reduced water uptake. This can result in slightly more acidic strawberries. Carbonic powder, such as calcium carbonate, directly affects soil pH. Calcium carbonate is a common pH buffer that can help raise soil pH, making it less acidic. However, excessive application of carbonic powder can lead to overly alkaline conditions, which may negatively impact plant health and fruit quality. Similar results were found by Arabloo et al. [16].

Application of calcium chelate enhances the cell structure, firmness, quality and yield of fruits. Application of carbonic powder increases the ability of soil to absorb essential nutrients and yield of the strawberry.
The effect of these treatment combinations on total cost of cultivation, Gross return and net return are mentioned below in the Table 3, in which T_{15} shows highest Benefit cost ratio (5.27) among all the other 14 treatment combinations.

4. CONCLUSION

From the present investigation, it is concluded that treatment combination T15: Calcium chelate (5g/L) +Carbonic powder (5g/L) +RDF (19:19:19) is the best treatment for growth, yield and fruit quality viz, plant height (cm) (33.74), plant spread (cm) (41.18), number of leaves per plant (44.01) , petiole length (cm) (14.96) , days to first flowering (40.18) , days to first fruiting (48.57), number of flower per plant (20.62), number of fruit per plant (16.30), fruit weight (gm) (40.78),fruit per plant (g) (664.77) , fruit yield t ha^{-1} (26.59) , TSS ^{0}brix (10.45), juice content (%) (94.58) and pH(3.17) of strawberry.

The highest benefit cost ratio was also found in the same treatment with 5.27.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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