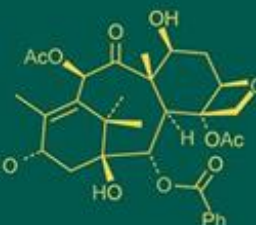
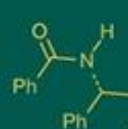
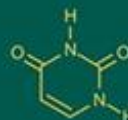
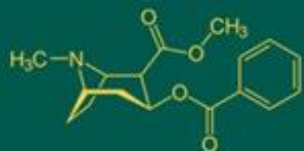


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Effect of foliar application of nutrients on Swiss chard for its growth and yield

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Abstract

The present investigation entitled “Effect of foliar application of nutrients on Swiss chard for its growth and yield” was conducted at the experimental farm of Regional Wheat Rust Research Station, Mahabaleshwar and laboratory analysis was carried out in the Department of Soil Science during 2024-2025. The experiment was laid out in a Randomized Block Design (RBD) with seven treatments and three replications. The treatments comprised T₁: Control (Water spray), T₂: Phule Micrograde II, T₃: Calcium nitrate, T₄: Magnesium sulphate, T₅: Zinc sulphate, T₆: 19:19:19 and T₇: 12:61:00. The Swiss chard crop was transplanted on 9th April, 2025 and observations on growth and yield parameters were recorded and statistically analyzed. The results revealed that foliar application of nutrients significantly influenced growth and yield attributes of Swiss chard. Treatment T₆ (19:19:19) recorded superior performance with maximum plant height (38.97 cm), stem diameter (15.63 mm), petiole width (1.17 cm), number of leaves (10.13), leaf area (186.53 cm²), fresh yield per plant (212.27 g), dry yield per plant (20.10 g), yield per plot (3.40 kg) and yield per hectare (23.59 t/ha). Treatments T₂ (Phule Micrograde II) and T₃ (Calcium nitrate) remained statistically at par with T₆ for several parameters, while the control treatment recorded the lowest values.

Keywords: Foliar application, growth, nutrients, swiss chard, yield

Introduction

Swiss chard (*Beta vulgaris* var. *cicla*), a leafy vegetable of the family Chenopodiaceae, is widely cultivated across the world due to its year round availability and low cost (Dlamini *et al.* 2020; Ustundag *et al.* 2016) ^[1, 2]. It is a perennial leafy vegetable crop, though it is commonly cultivated as an annual in Mediterranean climates (Ivanović *et al.* 2019) ^[3]. It is considered an important crop owing to its year round availability, high productivity and low cultivation cost, along with its richness in minerals, vitamins and phenolic compounds. Both the leaves and stems serve as edible parts of the plant and are widely consumed, either fresh in salads or as cooked vegetables in various traditional dishes (Trifunovic *et al.* 2015) ^[4]. It is considered a desirable food crop because of its remarkable adaptability. Moreover, it exhibits tolerance to low light intensity as well as both cold and hot weather conditions (Kolota *et al.* 2010) ^[5]. It also thrive in environments with elevated salinity and in soils with limited water availability (Kolota *et al.* 2010; Ninfali and Angelino 2013) ^[5, 6].

The growth and yield of any crop are closely linked to its nutritional status. While most nutrients are absorbed by plants through their roots from the soil, they can also be effectively taken up through the leaves when supplied as foliar sprays in the right composition (Dhakne V. R. *et al.* 2023) ^[7]. Foliar feeding is a technique of supplying plants with nutrients by applying liquid fertilizers directly to their leaves. Nutrient absorption occurs primarily through the stomata and also through the epidermis. This method is particularly effective for supplying secondary nutrients (calcium, magnesium and sulfur) and micronutrients (zinc, manganese, iron, copper, boron and molybdenum) (Patil *et al.* 2018) ^[8]. Foliar fertilization enables the efficient use of chemical fertilizers and is considered one of the most eco-friendly and target-oriented methods for delivering nutrients in precise amounts (Shahid *et al.* 2017) ^[9]. Despite the recognized importance of foliar nutrition in horticultural crops, limited information is available regarding its effect on Swiss chard under Indian ^[7] Regional Wheat Rust Research Station, Mahabaleshwar-412 806, Dist. Satara, Maharashtra, India agro-climatic conditions. Most of the existing studies have focused on micronutrient application, whereas the combined effect of macro and micronutrients through foliar feeding on Swiss chard remains largely unexplored (Senanayake *et al.* 2023) ^[10].

This highlights the need for systematic investigation to optimize foliar nutrient application strategies for enhancing growth and yield of Swiss chard.

Materials and Methods

The research was conducted between the 25th of March and the 24th of May 2025 (Summer) at Regional Wheat Rust Research Station, Mahabaleshwar (17° 93' North latitude and 73° 61' East longitudes) which comes under high rainfall area and farm is situated an elevation of 1270 m above mean sea level. The soil of the experimental soil was red in colour which are susceptible to leaching and degree of erosion due to heavy rainfall in the region and having pH of 6.8, EC of 0.27 dS/m with low Nitrogen and Potassium content contrastingly, high amount of phosphorous and micronutrients (Cu, Fe, Mn and Zn). To avoid experimental error, this study used 7 treatments with 3 replications for each treatment in the experiment as presented in Table 1. The experimental field was ploughed thoroughly with the help of tractor followed tractor-drawn cultivator was carried out prior to transplanting followed by leveling of the land to get the soil to a good tilth. After leveling, the field was divided into small plots according to treatments and replications with randomized block design following standard package of practices and swiss chard was transplanted on 9th April at 4 leaf stage with row to row and plant to plant spacing of 30cm×30 cm. Growth parameters of the crop were recorded at intervals of 15 days and yield attributes were recorded at the time of harvest. Foliar application of different nutrients as mentioned in treatments detail has been applied on swiss chard at 20 DAT and at 40 DAT (Days after Transplanting). Statistical analysis was carried out for all parameters given by Panse and Sukamte 1985^[11].

Table 1: Treatment details

Treatment	Details
T ₁	Control (Water spray)
T ₂	Phule Micrograde II
T ₃	Calcium nitrate
T ₄	Magnesium sulphate
T ₅	Zinc sulphate
T ₆	19: 19: 19
T ₇	12: 61: 00

(Foliar spray @ 20 and 40 DAT)

Result and Discussion

Growth parameters

Plant height (cm)

The data pertaining to plant height at 15, 30 and 45 days after transplanting as effected by foliar application of nutrients is presented in the Table 2 and illustrated in Fig. (a). Plant height did not differ significantly among the treatments at 15 DAT, with values ranging from 12.15 to 14.56 cm. However, significant differences were observed at 30 and 45 DAT. At both stages, T₆ (19 : 19 : 19) recorded the highest plant height (32.23 and 38.97 cm, respectively) and was statistically at par with T₂ (Phule Micrograde II) and T₃ (Calcium nitrate). The

lowest plant height was recorded in T₁ [Control (Water spray)] (26.50 and 30.13 cm). The increase in the plant height due to foliar application of the nutrients is mainly attributed to the elevated nutrient status in plant. Being a leafy vegetable the effect is seen more prominently. The readily available nutrients *via* leafy plant parts had significant effect on this character. But the role of nitrogen, calcium and mixture of micronutrients observed to be more in increasing vegetative growth of swiss chard. The above mentioned findings are substantiated by a team of researchers where different nutrient sprays show significantly higher maximum plant height for crops such as application of chicken manure show significant difference among treatments by Dlamini *et al.* (2020)^[11] in swiss chard; Thajeel *et al.* (2026)^[12] reported that foliar spray with a nano-fertilizer at a dose of 4 ml/L significantly affected in swiss chard.

Stem diameter (mm)

The effect of different treatments on Stem diameter at different growth stages is given in Table 2. The data pertaining to stem diameter at 15 DAT revealed non-significant differences among the various treatments. As the observation was recorded before initiation of treatments it had no significant variation, whereas significant differences were observed among the treatments with respect to stem diameter at both 30 and 45 DAT with treatment T₆ (19:19:19) recorded the maximum stem diameter of (12.37 mm and 15.63 mm), which was statistically at par with T₂ (Phule Micrograde II), T₃ (Calcium nitrate) and T₇ (12:61:00), registered (11.60 and 14.63 mm), (11.70 and 14.67 mm), (11.27 mm and 14.77 mm) respectively. The minimum stem diameter was observed in T₁ [Control (Water spray)] at both 30 and 45 DAT. The rise in stem diameter through foliar nutrient application can be attributed to improved nutrient availability, which resulted in better cell division and stem development. T₆ treatment (19:19:19) was observed to have the maximum stem diameter because all essential nutrients were available in balanced amounts. Abbas *et al.* (2012)^[13] in dill also found combination of foliar fertilizer with plant growth regulators show significant variation in stem diameter compared to control.

Petiole width (cm)

The effect of different treatments on petiole width at 15, 30 and 45 DAT is presented in Table 2. Petiole width showed non-significant differences among the treatments at 15 DAT. However, it is evident from the results that the treatments differed significantly when the crop attained 30 to 45 days after transplanting. Where T₆ (19:19:19) recorded the highest petiole width (0.72 and 1.17 cm, respectively) and was statistically at par with T₃ (Calcium nitrate) and T₇ (12:61:00). The lowest values were recorded in T₁ [Control (Water spray)]. Increased thickness of the petioles could be attributed to improved transportation and storage of assimilates by the plant. Treatment T₆ (19 : 19 : 19) showed maximum petiole width, suggesting better growth of leaf-supporting structures through balanced application of nutrients.

Table 2: Effect of foliar application of nutrients on Plant height, Stem diameter and Petiole width of Swiss chard

Tr.No	Treatments	Plant height (cm)			Stem diameter (mm)			Petiole width (cm)		
		15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
T ₁	Control (Water spray)	12.90	26.50	30.13	6.37	9.57	11.73	0.22	0.57	0.94
T ₂	Phule Micrograde II	14.42	29.73	36.37	9.00	11.60	14.63	0.25	0.63	1.04
T ₃	Calcium nitrate	12.81	29.73	36.10	9.30	11.70	14.67	0.20	0.69	1.11
T ₄	Magnesium sulphate	12.15	27.23	31.47	7.93	10.30	12.60	0.20	0.57	0.95
T ₅	Zinc sulphate	14.56	27.43	33.63	8.57	10.83	13.60	0.21	0.63	0.97
T ₆	19: 19: 19	13.57	32.23	38.97	8.97	12.37	15.63	0.23	0.72	1.17
T ₇	12: 61: 00	13.85	27.93	33.70	8.73	11.27	14.77	0.23	0.70	1.10
	Mean	13.47	28.69	34.34	8.41	11.09	13.95	0.22	0.64	1.04
	SE(m) ±	0.80	1.00	1.36	0.69	0.45	0.48	0.02	0.03	0.04
	CD @ 5%	NS	3.07	4.18	NS	1.40	1.49	NS	0.09	0.13

Number of leaves

Observations recorded for number of leaves per plant revealed significant differences among the treatments. The detailed observation has been presented in the Table 3. Ranging from 7.53 to 10.13 of T₁ and T₆ treatment where, T₆ (19:19:19) produced the highest number of leaves per plant (10.13) and it remained statistically at par with T₂ (Phule Micrograde II) and T₃ (Calcium nitrate), which recorded 9.53 and 9.37 leaves per plant, respectively. The lowest number of leaves per plant was observed in T₁ [Control (Water spray)] with 7.53 leaves. It is possible that the higher absorption of nutrients led to a greater production of carbohydrates, proteins and fats which are utilized in building up of new cells. Studies conducted earlier have also shown similar results where different foliar fertilization approach enhanced the amount of leaves compared to the control, where no nutrients were applied i.e. [El-Saady et al. \(2016\)](#) ^[14] explained that the highest leaves per plant were resulted from fertilization plants with mineral NPK fertilizers ratio of 2:1:1 at 125 kg/fed in spinach; [Hajnal-Jafari et al. \(2020\)](#) ^[15] in swiss chard reported that the highest number was achieved after the treatment with a 10% suspension applied foliarly in comparison to the control.

Leaf area (cm²)

The effect of various treatments on Leaf area at harvest is given in Table 3 and shown in Fig. (b). The treatments exhibited significant variation with respect to leaf area. Among the different treatments, T₆ (19:19:19) registered the highest leaf area (186.53 cm²) and was statistically comparable with T₂ (Phule Micrograde II) and T₃ (Calcium nitrate), which recorded 176.80 cm² and 176.10cm², respectively. While, the least leaf area was noted in T₁ [Control (Water spray)] with 140.20cm². Nutrients absorbed through the stomata or leaf cuticle enter the plants metabolic pathways immediately. This is critical for mobile macronutrients directly driving leafy biomass. Higher leaf area in T₆ (19 : 19 : 19) could be due to the optimal supply of NPK nutrients via foliar application, which facilitated cell division and growth and therefore led to an increase in leaf production. The availability of adequate amounts of nutrients could have led to greater leaf size and dense canopy, thus leading to increased photosynthetic leaf area. Similar results of treatment differences in growth parameters obtained in this study are in agreement with those obtained by [Joshi et al. \(2015\)](#) ^[16] showed that micronutrient concentration with 1 ppm considerably increased leaf area per plant in spinach with comparison to control; [Miliauskiene et al. \(2022\)](#) showed statistically significant highest leaf area was determined when plants were sprayed with solution containing 35- 45 nm ZnO NPs in swiss chard.

Table 3: Effect of foliar application of nutrients on Leaf area and Number of leaves of Swiss chard

Tr. No.	Treatments	Number of leaves	Leaf area (cm ²)
T ₁	Control (Water spray)	7.53	140.20
T ₂	Phule Micrograde II	9.53	176.80
T ₃	Calcium nitrate	9.37	176.10
T ₄	Magnesium sulphate	7.70	147.20
T ₅	Zinc sulphate	7.97	159.40
T ₆	19: 19: 19	10.13	186.53
T ₇	12: 61: 00	8.20	161.60
	Mean	8.63	163.98
	SE(m) ±	0.37	6.63
	CD at 5%	1.13	20.44

Leaf length (cm)

The observations on leaf length at 15, 30 and 45 DAT as effected by different treatments are presented in Table 4. When the crop attained 15 DAT, the treatments did not exhibit significant differences with respect to leaf length. However, The findings revealed that there was significant differences observed among the treatments with respect to leaf length at 30 and 45 DAT. Treatment T₆ (19 : 19 : 19) recorded the highest leaf length (16.07 cm) and (20.67 cm) remained statistically at par with T₂ (Phule Micrograde II) and T₃ (Calcium nitrate). The lowest leaf length was observed in T₁ [Control (Water spray)] at both stages. The higher leaf length under foliar nutrient application may be associated with improved metabolic activity and leaf expansion. Balanced nutrition in T₆ (19:19:19) favoured the development of longer leaves compared to the control. Similar results were also observed by [Kisan et al. \(2015\)](#) ^[17] mentioned that the leaf length was maximum in ZnO-NPs treated leaf samples at the concentration of 500 ppm in spinach; [Maji et al. \(2022\)](#) ^[18] reported that chitosan @ 100 ppm produced the longest leaves (8.27 cm, 13.23 cm, respectively) at 30 DAS and 60 DAS in palak.

Leaf width (cm)

The results pertaining to leaf width at 15, 30 and 45 DAT as influenced by various treatments are presented in Table 4. The data recorded for leaf width at 15 DAT did not show any significant differences among the treatments, indicating that the different foliar nutrient applications had no noticeable effect on leaf width during the initial growth stage of the crop. The recorded parameter was significantly influenced by the different foliar nutrient treatments at both 30 and 45 DAT where, treatment T₆ (19 : 19 : 19) consistently produced the highest values (8.43 and 11.07 cm, respectively) and In contrast the treatment T₁ [Control (Water spray)] consistently registered the minimum values, whereas T₂ (Phule Micrograde II) and T₃

(Calcium nitrate) remaining statistically at par with highest value. Higher leaf width under foliar nutrition might be due to increased production and translocation of photosynthates to actively growing leaves, resulting in broader leaf lamina. Above result was in conformity with those of [Kisan et al. \(2015\)](#) ^[17]

observed slight improvement in leaf width was observed in ZnO-NPs treated leaf samples in spinach; [Maji et al. \(2022\)](#) ^[18] showed that chitosan @ 100 ppm produced the wider leaves (4.76 cm, 7.29 cm, respectively) at 35 and 60 Days after sowing in palak.

Table 4: Effect of foliar application of nutrients on Leaf length and Leaf width of Swiss chard

Tr. No	Treatments	Leaf length (cm)			Leaf width (cm)		
		15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
T ₁	Control (Water spray)	8.07	11.97	14.83	3.83	6.47	8.33
T ₂	Phule Micrograde II	8.81	15.30	19.27	4.17	7.70	9.67
T ₃	Calcium nitrate	6.98	15.00	19.07	3.50	7.83	9.63
T ₄	Magnesium sulphate	6.57	12.80	16.00	2.79	6.70	8.53
T ₅	Zinc sulphate	8.50	13.37	16.77	3.91	6.90	8.97
T ₆	19: 19: 19	6.51	16.07	20.67	3.49	8.43	11.07
T ₇	12: 61: 00	7.50	13.43	16.20	3.87	7.37	9.37
Mean		7.56	13.99	17.54	3.65	7.34	9.37
SE(m) ±		0.85	0.59	0.78	0.45	0.31	0.48
CD @ 5%		NS	1.83	2.40	NS	0.96	1.47

Yield Parameters

Average leaf weight (g)

The treatment-wise variation in average leaf weight at harvest is shown in Table 5 and illustrated through Fig. (c). A significant effect of different nutrient treatments on average leaf weight was observed at harvest stage. The treatment receiving T₆ (19:19:19) showed the best performance with an average leaf weight of 14.60 g and was statistically at par with T₂ (Phule Micrograde II), T₃ (Calcium nitrate) and T₇ (12:61:00), which recorded 13.93 g, 13.87 g and 12.67 g, respectively. Whereas, the lowest value was registered in T₁ [Control (Water spray)] with 10.23 g.

Fresh yield per plant (g)

A marked variation in fresh weight per plant was noticed under different foliar nutrient treatments and its details are mentioned in Table 5. The highest fresh weight per plant was obtained in T₆ (19:19:19) with 212.27 g, which clearly indicated its superiority over the other treatments. Treatments T₂ (Phule Micrograde II) and T₃ (Calcium nitrate) followed next with fresh weight per plant values of 197.73 g and 196.40 g, respectively and these treatments were statistically at par with T₆. However, T₄ (Magnesium sulphate) and T₁ [Control (Water spray)] recorded comparatively lower values of 170.13 g and 162.47 g with T₁ registering the minimum fresh weight per plant.

Dry yield per plant (g)

Information related to dry yield per plant under the influence of different treatments has been presented in Table 5. An assessment of dry yield per plant under various treatments revealed a significant treatment effect. Treatment T₆ (19:19:19) recorded the maximum dry yield per plant (20.10 g), followed by T₂ (Phule Micrograde II) and T₃ (Calcium nitrate), registering 19.88 g and 19.02 g, respectively and these treatments were statistically at par with each other. In contrast, lowest dry yield values were observed in T₁ [Control (Water spray)] (17.16 g).

Yield/plot (kg)

Details regarding the effect of different nutrient treatments on yield per plot are presented in Table 5. Significant treatment differences were noticed for yield per plot during the course of investigation. Treatment T₆ (19:19:19) recorded the maximum yield per plot (3.40 kg), followed by T₂ (Phule Micrograde II) with 3.16 kg and T₃ (Calcium nitrate) with 3.14 kg. Treatments T₂ and T₃ were statistically at par with T₆. The minimum yield per plot was associated with T₁ [Control (Water spray)] with 2.60 kg.

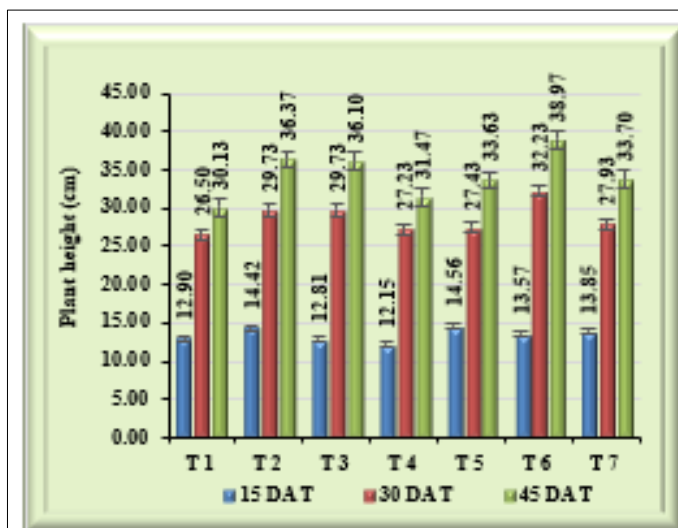
Yield/ha (t)

Information pertaining to the influence of different nutrient treatments on yield per hectare has been furnished in Table 5, whereas its graphical illustration is presented in Fig. (d). Similar to the above parameter, dry weight per plant also exhibited significant variation due to different nutrient treatments during the course of investigation, ranging from 18.05 t to 23.59 t. Treatment T₆ (19 : 19 : 19) recorded the highest dry weight per plant (23.59 t), followed by T₂ (Phule Micrograde II) and T₃ (Calcium nitrate), registering 21.97 t and 21.82 t, respectively. In contrast, lowest dry weight per plant values were observed in T₁ [Control (Water spray)] (18.05 t).

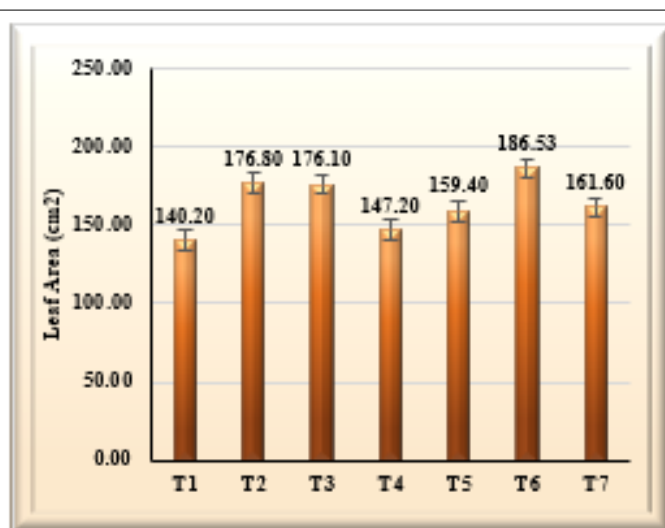
The increase in yield and yield attributing traits can be due to the fact that the supply of balanced amount of nitrogen, phosphorus, potassium and also micro-nutrients obtained by using foliar feeding, hence leading to proper nutrient absorption and metabolic processes in plants. The sufficient availability of these nutrients could have led to fast cell division, leaf expansion and *growth*, thereby giving rise to greater height, leaf area and biomass formation. Ultimately, this has improved the crop's *yield*. The obtained results go in line with the findings of [Zewail et al. \(2020\)](#) ^[19] in swiss chard; [Kour et al. \(2022\)](#) ^[20] in spinach beet; [Maji et al. \(2022\)](#) ^[18] in palak; [Miliauskiene et al. \(2022\)](#) in swiss chard; [Turun et al. \(2022\)](#) in spinach; [Eslamiparvar et al. \(2025\)](#) ^[21] in spinach.

Table 8: Effect of foliar application of nutrients on Yield attributing characters of Swiss chard

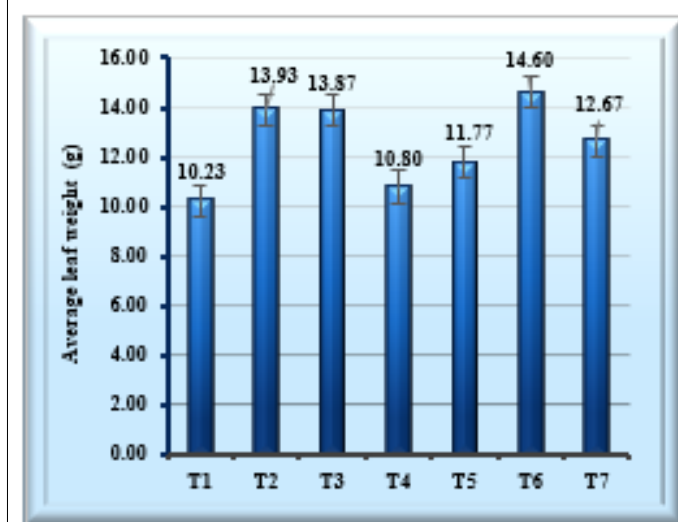
Tr. No	Treatments	Average leaf weight (g)	Fresh yield per plant (g)	Dry yield per plant (g)	Yield per plot (kg)	Yield per hectare (t)
T ₁	Control (Water spray)	10.23	162.47	17.16	2.60	18.05
T ₂	Phule Micrograde II	13.93	197.73	19.88	3.16	21.97
T ₃	Calcium nitrate	13.87	196.40	19.02	3.14	21.82
T ₄	Magnesium sulphate	10.80	170.13	17.29	2.72	18.90
T ₅	Zinc sulphate	11.77	173.33	18.03	2.77	19.26
T ₆	19: 19: 19	14.60	212.27	20.10	3.40	23.59
T ₇	12: 61: 00	12.67	190.07	18.64	3.04	21.12
	Mean	12.55	186.06	18.59	2.98	20.67
	SE(m) ±	0.65	7.59	0.62	0.12	0.84
	CD @ 5%	1.99	23.40	1.91	0.37	2.60



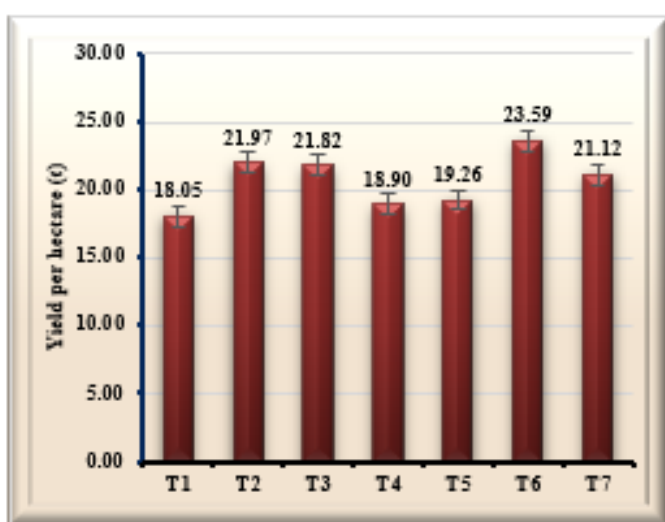
(a)



(b)



(c)



(d)

(T₁: Control (Water spray), T₂: Phule Micrograde II, T₃: Calcium nitrate, T₄: Magnesium sulphate, T₅: Zinc sulphate, T₆: 19:19:19 and T₇: 12:61:00)

Fig (a). Effect of foliar application of different nutrients on Plant height (cm) of Swiss chard, **Fig (b).** Effect of foliar application of different nutrients on Leaf area (cm²) of Swiss chard, **Fig (c).** Effect of foliar application of different nutrients on Average leaf weight (g) of Swiss chard, **Fig (d).** Effect of foliar application of different nutrients on Yield per hectare (t) of Swiss chard.

Conclusion

Foliar nutrient application significantly enhanced the growth, yield and yield-attributing parameters of Swiss chard, with treatment T₆ (19 : 19 : 19) consistently recorded the highest values at 30 and 45 DAT for growth and yield attributing characters.

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