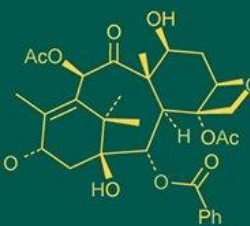
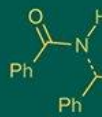


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Effect of different varieties and planting density on growth and yield of Swiss chard (*Beta vulgaris* L. var. *cicla*)

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Abstract

A field experiment was conducted during the winter season of 2025-26 at the Instructional-cum-Research Farm, Horticulture Section, Rajarshree Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur, to evaluate the effect of different varieties and planting density on the growth and yield of Swiss chard (*Beta vulgaris* L. var. *cicla*). The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising five varieties (Barese White, Golden Sunrise, Red Rhubarb, Yellow Dorat and Swiss Chard Green) and three planting densities (45 × 30 cm, 30 × 30 cm and 30 × 20 cm). Observations were recorded on plant height, number of leaves per plant, leaf length, leaf width, leaf area, days to harvest, petiole length, average leaf weight, fresh yield per plant, yield per plot and yield per hectare. The results revealed significant variation among varieties and planting densities for most growth and yield parameters. Among the varieties, Yellow Dorat exhibited superior performance with respect to plant growth and yield attributes and produced the highest yield per plot, while Barese White recorded the highest yield per hectare and remained statistically at par with Yellow Dorat for several parameters. Although wider spacing promoted better vegetative growth, the planting density of 30 × 20 cm resulted in significantly higher yield per plot and yield per hectare owing to the greater plant population. The interaction effect of varieties and planting density was non-significant for most of the traits studied. Therefore, cultivation of Yellow Dorat at a planting density of 30 × 20 cm is recommended for obtaining higher growth and yield of Swiss chard under the agro-climatic conditions of western Maharashtra.

Keywords: Swiss chard, *Beta vulgaris* L. var. *cicla*, varieties, planting density, growth, yield

Introduction

Swiss chard (*Beta vulgaris* L. var. *cicla*) is an important leafy vegetable belonging to the family Chenopodiaceae. It is cultivated for its tender leaves and fleshy petioles and is widely adapted to diverse agro-climatic conditions. The crop is characterized by rapid growth, high biomass production, and the ability to produce multiple harvests from a single planting, making it suitable for commercial cultivation. Its adaptability to a wide range of environmental conditions and relatively short crop duration have contributed to its increasing popularity among vegetable growers (Echer *et al.*, 2012) [4].

The productivity of Swiss chard is greatly influenced by varietal differences and crop management practices. Different varieties possess distinct genetic characteristics that affect plant growth, leaf development, and yield potential. Considerable variation among Swiss chard genotypes has been reported for growth traits such as plant height, number of leaves, leaf length, leaf width, and leaf area, which ultimately influence marketable yield (Pokluda and Kuben, 2002) [16]. Therefore, selection of suitable varieties is essential for achieving higher productivity under specific agro-climatic conditions.

Planting density is another important agronomic factor affecting crop performance. Appropriate spacing ensures efficient utilization of sunlight, water, nutrients, and available growing space, thereby promoting optimum plant growth and maximizing yield. Wider spacing generally enhances individual plant growth due to reduced competition, whereas closer spacing increases plant population and may improve total yield per unit area.

However, excessively high or low planting densities can adversely affect crop growth and productivity (López-Bellido *et al.*, 2005; Seid *et al.*, 2013) [10, 18]. Hence, optimizing planting density according to varietal characteristics is necessary for sustainable Swiss chard production. Although several studies have evaluated the influence of varieties and planting density on Swiss chard, information under the agro-climatic conditions of western Maharashtra is limited. Since varietal performance and optimum spacing vary with location and environmental conditions, region-specific studies are essential for developing suitable production recommendations.

Therefore, the present investigation was undertaken to evaluate the effect of different varieties and planting densities on the growth and yield of Swiss chard under open-field conditions in Kolhapur, Maharashtra. The findings of the study are expected to provide useful information for identifying suitable varieties and optimum planting density for maximizing crop productivity in the region.

2. Objectives

1. To study the effect of planting density on growth of different Swiss chard varieties.
2. To study the effect of planting density on yield of different Swiss chard varieties.
3. To identify the most suitable variety and optimum planting density for maximizing growth and yield of Swiss chard

3. Materials and Methods

3.1 Experimental Site

The experiment was conducted during the winter season of 2025-26 (November 2025 to January 2026) at the Instructional-cum-Research Farm of the Horticulture Section, Rajarshee Chhatrapati Shahu Maharaj Government College of Agriculture, Kolhapur, Tal. Karveer, Dist. Kolhapur, Maharashtra.

3.2 Experimental Design and Treatments

Particulars	Description
Crop	Swiss chard (<i>Beta vulgaris</i> L. var. <i>cicla</i>)
Season	November 2025 - January 2026
Design	Factorial Randomized Block Design (FRBD)
Replications	3
Factors	2 (Varieties and Spacing)
Treatment Combinations	15
Net Plot Size	1.8 m × 1.8 m
Observational Plants	5 plants per plot
Fertilizer Dose	FYM + 80:40:40 N:P ₂ O ₅ :K ₂ O kg/ha

Factor A: Varieties (5)

- V₁: Barese White
- V₂: Golden Sunrise
- V₃: Red Rhubarb
- V₄: Yellow Dorat
- V₅: Swiss chard Green

Factor B: Planting density/spacing (3)

- S₁: 45 cm × 30 cm (24 plants/plot)
- S₂: 30 cm × 30 cm (36 plants/plot)
- S₃: 30 cm × 20 cm (54 plants/plot)

3.3 Crop Establishment and Management

Seeds were sown on 10 November 2025 in pro trays, and healthy seedlings were transplanted on 11 December 2025 into the experimental field according to the respective treatment combinations. Recommended agronomic practices, including irrigation, nutrient management, intercultural operations, and plant protection measures, were followed uniformly throughout the crop growth period.

3.4 Observations recorded

3.4.1 Growth parameters

3.4.1.1 Plant height (cm): Plant height was measured from the collar region to the tip of the rosette on five tagged plants at 15 DAT, 30 DAT, and harvest, and the mean was recorded.

3.4.1.2 Number of leaves: The number of leaves was counted on five tagged plants at 15 DAT, 30 DAT, and harvest, and the mean was calculated.

3.4.1.3 Leaf length (cm): Leaf length was measured on five tagged plants at 15 DAT, 30 DAT, and harvest using a measuring scale, and the average was recorded.

3.4.1.4 Leaf width (cm): Leaf width was measured at the widest portion of leaves from five tagged plants at 15 DAT, 30 DAT, and harvest, and the mean was calculated.

3.4.1.5 Days to harvest: Days to harvest were recorded from transplanting to marketable maturity for each treatment, and the average was computed.

3.4.1.6 Leaf area (cm²): Leaf area was estimated by tracing five fully expanded leaves from each treatment on graph paper and expressing the average area in cm².

3.4.1.7 Petiole length (cm): Petiole length was measured from the leaf blade base to its attachment on the stem in five tagged plants at 15 DAT, 30 DAT, and harvest, and the mean was recorded.

3.4.2 Yield parameters

3.4.2.1 Average leaf weight (g): The weight of five mature leaves was recorded using an electronic balance, and the average leaf weight was calculated.

3.4.2.2 Fresh yield per plant (g): Fresh weight of five randomly selected plants from each treatment was recorded, and the average was expressed as fresh yield per plant.

3.4.2.3 Yield per plot (kg): All plants from each plot were harvested above the collar region, and the total fresh yield was recorded in kilograms.

3.4.2.4 Yield per hectare (t ha⁻¹): Yield per hectare was calculated from plot yield using the following formula:

$$\text{Yield (t ha}^{-1}\text{)} = \frac{\text{Yield per plot (kg)} \times 10,000}{\text{Plot area (m}^2\text{)} \times 1000}$$

3.5 Statistical Analysis

The experimental data were subjected to statistical analysis by adopting the appropriate for a Factorial Randomized Block Design (FRBD) by Panse and Sukhatme (1985) [15].

The significance of treatment differences was tested at the 5% level of significance. The standard error of mean [SE(m) ±] and critical difference (CD) were worked out wherever treatment effects were found to be significant.

4. Results and Discussion

4.1 Growth parameters

4.1.1 Plant height

Plant height was significantly influenced by variety throughout the crop growth period, whereas the effect of spacing was non-significant at 15 and 30 DAT but became significant at harvest (Table 1). At 15 DAT, the maximum plant height was recorded in Yellow Dorat (10.99 cm), which was statistically at par with Golden Sunrise (10.27 cm). At 30 DAT, Golden Sunrise recorded the tallest plants (23.94 cm), followed by Yellow Dorat (23.04 cm) and Red Rhubarb (22.88 cm). At harvest, Yellow Dorat produced significantly taller plants (34.31 cm), followed by Golden Sunrise (31.88 cm) and Red Rhubarb (31.47 cm). Wider spacing (45 × 30 cm) resulted in greater plant height at harvest (30.58 cm), while the interaction between variety and spacing was non-significant at harvest.

The superior plant height observed in Yellow Dorat may be attributed to its inherent genetic potential, vigorous vegetative growth, and efficient utilization of available resources. Similar findings have been reported by Pokluda and Kuben (2002) ^[16] in Swiss chard; Bozokalfa *et al.* (2016) ^[2] in Swiss chard; Nath *et al.* (2020) ^[14] in Spinach; Khedkar *et al.* (2023) ^[8] in Palak; Apahidean *et al.* (2024) ^[1] in Swiss chard; Sharma and Singh (2024) ^[19] in Beetroot; Dhital *et al.* (2025) ^[3] in Beetroot. The increase in plant height under wider spacing at harvest could be due to reduced competition for light, nutrients, moisture, and growing space, allowing better plant development. Similar findings have been reported by Echer *et al.* (2012) ^[4] in Swiss chard; Islam *et al.* (2014) ^[7] in Indian spinach; Hailay and Haymanot (2019) ^[6] in Swiss chard; Wolde *et al.* (2019) ^[23] in Swiss chard; Gayathri *et al.* (2021) ^[5] in Beetroot; Apahidean *et al.* (2024) ^[1] in Swiss chard.

Table 1: Plant height (cm) of Swiss chard as influenced by varieties and spacing

Treatment	15 DAT	30 DAT	At Harvest
Varieties			
V ₁ : Barese White	8.84	18.66	24.30
V ₂ : Golden Sunrise	10.27	23.94	31.88
V ₃ : Red Rhubarb	8.74	22.88	31.47
V ₄ : Yellow Dorat	10.99	23.04	34.31
V ₅ : Swiss chard Green	9.89	18.38	24.25
SEm±	0.27	0.58	0.83
CD@5%	0.79	1.67	2.40
Spacings			
S ₁ : 45×30 cm	10.08	21.33	30.58
S ₂ : 30×30 cm	9.75	22.06	28.93
S ₃ : 30×20 cm	9.41	20.76	28.21
SEm±	0.21	0.45	0.64
CD@5%	NS	NS	1.86
Interaction	NS	Significant	NS

4.1.2 Number of leaves per plant

Number of leaves per plant was significantly influenced by variety throughout the crop growth period, whereas the effect of spacing and the interaction between variety and spacing remained non-significant at all growth stages (Table 2). At 15 DAT, the maximum number of leaves per plant

was recorded in Swiss chard Green (5.22), which was statistically at par with Barese White (5.18). At 30 DAT, Barese White recorded the highest number of leaves per plant (9.56), followed by Yellow Dorat (8.98) and Golden Sunrise (8.18). At harvest, Barese White produced the maximum number of leaves per plant (12.78), which was statistically at par with Yellow Dorat (12.38), followed by Red Rhubarb (11.20). The interaction between variety and spacing remained non-significant throughout the crop growth period.

The higher number of leaves observed in Barese White may be attributed to its inherent genetic characteristics, vigorous vegetative growth, and greater leaf production potential under the prevailing environmental conditions. Similar findings have been reported by Pokluda and Kuben (2002) ^[16] in Swiss chard; Nath *et al.* (2020) ^[14] in Spinach; Khedkar *et al.* (2023) ^[8] in Palak; Sahil *et al.* (2023) ^[17] in Lettuce; Tejaswi *et al.* (2024) ^[21] in Palak; Sharma and Singh (2024) in Beetroot; and Dhital *et al.* (2025) ^[3] in Beetroot.

Table 2: Number of leaves per plant as influenced by varieties and spacing

Treatment	15 DAT	30 DAT	Harvest
Varieties			
V ₁ : Barese White	5.18	9.56	12.78
V ₂ : Golden Sunrise	4.78	8.18	11.04
V ₃ : Red Rhubarb	4.76	7.44	11.20
V ₄ : Yellow Dorat	4.67	8.98	12.38
V ₅ : Swiss chard Green	5.22	8.00	10.64
SEm±	0.13	0.32	0.40
CD@5%	0.38	0.93	1.15
Spacings			
S ₁ : 45×30 cm	4.97	8.32	11.57
S ₂ : 30×30 cm	4.88	8.32	11.71
S ₃ : 30×20 cm	4.91	8.65	11.55
SEm±	0.10	0.25	0.31
CD@5%	NS	NS	NS
Interaction	NS	NS	NS

4.1.3 Leaf length

Leaf length was significantly influenced by variety throughout the crop growth period, whereas the effect of spacing was non-significant at 15 DAT but became significant at 30 DAT and harvest (Table 3). At 15 DAT, the maximum leaf length was recorded in Golden Sunrise (7.52 cm), which was statistically at par with Yellow Dorat (7.16 cm). At 30 DAT, Yellow Dorat recorded the maximum leaf length (15.96 cm), which was statistically at par with Golden Sunrise (15.84 cm) and Red Rhubarb (14.64 cm). At harvest, Yellow Dorat produced significantly longer leaves (22.48 cm), followed by Red Rhubarb (19.88 cm) and Golden Sunrise (19.10 cm). The maximum leaf length under spacing treatments was recorded at 30 × 20 cm, measuring 15.59 cm at 30 DAT and 20.16 cm at harvest, which was statistically at par with 30 × 30 cm. The interaction between variety and spacing remained non-significant throughout the crop growth period.

The superior leaf length observed in Yellow Dorat may be attributed to its inherent genetic potential, vigorous vegetative growth, and efficient utilization of available resources. Similar findings have been reported by Nath *et al.* (2020) ^[14] in Spinach; Sahil *et al.* (2023) ^[17] in Lettuce; Thao *et al.* (2024) ^[22] in Mizuna; and Dhital *et al.* (2025) ^[3] in Beetroot. The increased leaf length under closer spacing (30

× 20 cm) may be attributed to greater inter-plant competition for light, which promoted leaf elongation as an adaptive response to maximize light interception. Similar findings have been reported by Woldu *et al.* (2019) ^[23] in Swiss chard; Yadav *et al.* (2023) ^[24] in Cabbage; and Thao *et al.* (2024) ^[22] in Mizuna.

Table 3: Leaf length (cm) as influenced by varieties and spacing

Treatment	15 DAT	30 DAT	Harvest
Varieties			
V ₁ : Barese White	5.54	13.51	16.44
V ₂ : Golden Sunrise	7.52	15.84	19.10
V ₃ : Red Rhubarb	6.35	14.64	19.88
V ₄ : Yellow Dorat	7.16	15.96	22.48
V ₅ : Swiss chard Green	6.82	13.97	17.72
SEm±	0.24	0.50	0.67
CD@5%	0.68	1.45	1.94
Spacings			
S ₁ : 45×30 cm	6.61	14.01	18.14
S ₂ : 30×30 cm	6.62	14.76	19.07
S ₃ : 30×20 cm	6.81	15.59	20.16
SEm±	0.18	0.39	0.52
CD@5%	NS	1.12	1.50
Interaction	NS	NS	NS

4.1.4 Leaf Width: Leaf width was significantly influenced by variety throughout the crop growth period, whereas the

effect of spacing was non-significant at 15 and 30 DAT but became significant at harvest (Table 4). At 15 DAT, the maximum leaf width was recorded in Barese White (3.81 cm), followed by Golden Sunrise (3.42 cm). At 30 DAT, Barese White recorded the maximum leaf width (11.38 cm), followed by Yellow Dorat (9.90 cm) and Swiss chard Green (9.60 cm). At harvest, Barese White produced significantly wider leaves (14.06 cm), which was statistically at par with Yellow Dorat (13.36 cm) and Swiss chard Green (12.99 cm). Wider spacing (45 × 30 cm) resulted in significantly greater leaf width (13.23 cm) at harvest, which was statistically at par with 30 × 30 cm, while the interaction between variety and spacing remained non-significant throughout the crop growth period.

The superior leaf width observed in Barese White may be attributed to its inherent genetic potential, favourable leaf morphology, and efficient utilization of available resources. Similar findings have been reported by Nath *et al.* (2020) ^[14] in Spinach; Sahil *et al.* (2023) ^[17] in Lettuce; Thao *et al.* (2024) ^[19] in Mizuna; and Dhital *et al.* (2025) ^[3] in Beetroot. The increased leaf width under wider spacing at harvest could be due to reduced competition for light, nutrients, moisture, and growing space, which favoured greater leaf expansion. Similar findings have been reported by Woldu *et al.* (2019) ^[23] in Swiss chard; and Thao *et al.* (2024) ^[19] in Mizuna.

Table 4: Leaf width (cm) as influenced by varieties and spacing

Treatment	15 DAT	30 DAT	Harvest
Varieties			
V ₁ : Barese White	3.81	11.38	14.06
V ₂ : Golden Sunrise	3.42	8.19	10.45
V ₃ : Red Rhubarb	3.01	8.40	11.70
V ₄ : Yellow Dorat	3.11	9.90	13.36
V ₅ : Swiss chard Green	3.33	9.60	12.99
SEm±	0.11	0.26	0.52
CD@5%	0.33	0.74	1.51
Spacings			
S ₁ : 45×30 cm	3.44	9.67	13.23
S ₂ : 30×30 cm	3.24	9.49	12.65
S ₃ : 30×20 cm	3.33	9.32	11.66
SEm±	0.09	0.20	0.40
CD@5%	NS	NS	1.17
Interaction	NS	NS	NS

4.1.5 Leaf area: Leaf area was significantly influenced by both variety and spacing, whereas the interaction between variety and spacing remained non-significant (Table 5). Among the varieties, Swiss chard Green recorded the maximum leaf area (174.84 cm²), which was statistically at par with Red Rhubarb (169.64 cm²), Yellow Dorat (165.78 cm²), and Barese White (164.89 cm²). The minimum leaf area was observed in Golden Sunrise (148.38 cm²). Among the spacing treatments, 30 × 30 cm recorded the maximum leaf area (172.72 cm²), which was statistically at par with 30 × 20 cm (167.52 cm²), while the minimum leaf area was recorded under 45 × 30 cm spacing (153.88 cm²). The interaction between variety and spacing was non-significant.

The higher leaf area observed in Swiss chard Green may be attributed to its inherent genetic potential, vigorous vegetative growth, and greater leaf expansion capacity. Similar findings have been reported by Moratagi *et al.* (2021) ^[13] in Cauliflower; Khedkar *et al.* (2023) ^[8] in Palak; and Sharma and Singh (2024) ^[19] in Beetroot. The significant influence of spacing on leaf area may be attributed to differences in the availability of light, moisture, nutrients, and growing space. Optimum spacing (30 × 30 cm) provided favourable conditions for leaf expansion, resulting in greater leaf area than the wider spacing. Similar findings have been reported by Silatar *et al.* (2018) ^[20] in Knol-khol and Moratagi *et al.* (2021) ^[13] in Cauliflower.

Table 5: Leaf area (cm²) at harvest as influenced by varieties and spacing

Treatment	S ₁ (45×30 cm)	S ₂ (30×30 cm)	S ₃ (30×20 cm)	Mean
V ₁ : Barese White	157.80	168.73	168.13	164.89
V ₂ : Golden Sunrise	138.67	160.20	146.27	148.38
V ₃ : Red Rhubarb	145.60	187.40	175.93	169.64
V ₄ : Yellow Dorat	151.93	172.33	173.07	165.78
V ₅ : Swiss chard Green	175.40	174.93	174.20	174.84
Mean	153.88	172.72	167.52	164.71
Source	SEm±		CD@5%	
Variety	4.85		14.05	
Spacing	3.76		10.88	
Interaction	8.40		NS	

4.1.6 Petiole length

Petiole length was significantly influenced by both variety and spacing throughout the crop growth period, whereas the interaction between variety and spacing was significant only at 15 DAT and remained non-significant at 30 DAT and harvest (Table 6). At 15 DAT, Red Rhubarb recorded the maximum petiole length (4.31 cm), followed by Barese White (4.15 cm) and Golden Sunrise (3.90 cm). At 30 DAT, Yellow Dorat recorded the longest petiole (9.71 cm), followed by Red Rhubarb (8.08 cm) and Golden Sunrise (7.50 cm). At harvest, Yellow Dorat produced significantly longer petioles (15.38 cm), followed by Red Rhubarb (12.32 cm) and Golden Sunrise (12.26 cm). Among the spacing treatments, 30 × 20 cm recorded the maximum petiole length at all growth stages, with 4.05 cm, 7.77 cm and 11.99 cm at 15 DAT, 30 DAT and harvest, respectively.

The superior petiole length observed in Yellow Dorat may be attributed to its inherent genetic potential, vigorous vegetative growth, and favourable plant architecture. Similar findings have been reported by Bozokalfa *et al.* (2016) [2] in Swiss chard; Moratagi *et al.* (2021) [13] in Cauliflower; and Apahidean *et al.* (2024) [1] in Swiss chard. The increased petiole length under closer spacing (30 × 20 cm) may be attributed to the adaptive response of plants to increased competition for light, resulting in enhanced petiole elongation for improved light interception. Similar findings have been reported by Moratagi *et al.* (2021) [13] in Cauliflower and Apahidean *et al.* (2024) [1] in Swiss chard.

Table 6: Petiole length (cm) as influenced by varieties and spacing

Treatment	15 DAT	30 DAT	Harvest
Varieties			
V ₁ : Barese White	4.15	6.68	9.26
V ₂ : Golden Sunrise	3.90	7.50	12.26
V ₃ : Red Rhubarb	4.31	8.08	12.32
V ₄ : Yellow Dorat	3.20	9.71	15.38
V ₅ : Swiss chard Green	3.39	5.12	7.44
SEm±	0.15	0.21	0.31
CD@5%	0.43	0.59	0.91
Spacings			
S ₁ : 45×30 cm	3.62	7.18	10.57
S ₂ : 30×30 cm	3.69	7.31	11.44
S ₃ : 30×20 cm	4.05	7.77	11.99
SEm±	0.12	0.16	0.24
CD@5%	0.34	0.46	0.70
Interaction	Significant	NS	NS

4.1.7 Days to harvest

Days to harvest was significantly influenced by both variety and spacing, whereas the interaction between variety and spacing remained non-significant (Table 7). Among the varieties, Golden Sunrise recorded the minimum days to

harvest (39.67 days), followed by Swiss chard Green (40.00 days) and Barese White (40.67 days), while Red Rhubarb required the maximum days (42.00 days) to attain harvestable maturity. Among the spacing treatments, 30 × 20 cm recorded the earliest harvest (38.80 days), followed by 30 × 30 cm (40.80 days), whereas the maximum crop duration was observed under 45 × 30 cm spacing (42.40 days). The interaction between variety and spacing was non-significant.

The variation in days to harvest among the varieties may be attributed to their distinct genetic potential and maturity behaviour. Varieties with rapid vegetative growth attained harvestable maturity earlier, whereas slower-growing varieties required a longer period to reach marketable stage. Similar findings have been reported by Moniruzzaman (2011) [12] in Hybrid cabbage and Silatar *et al.* (2018) [20] in Knol-khol. The significant effect of spacing on days to harvest may be attributed to differences in crop microclimate and resource availability under varying planting densities, which influenced the rate of vegetative growth and maturity. Similar findings have been reported by Moniruzzaman (2011) [12] in Hybrid cabbage and Silatar *et al.* (2018) [20] in Knol-khol.

Table 7: Days to harvest as influenced by varieties and spacing

Treatment	S ₁ (45×30 cm)	S ₂ (30×30 cm)	S ₃ (30×20 cm)	Mean
V ₁ : Barese White	42	41	39	40.67
V ₂ : Golden Sunrise	41	40	38	39.67
V ₃ : Red Rhubarb	44	42	40	42.00
V ₄ : Yellow Dorat	43	41	39	41.00
V ₅ : Swiss chard Green	42	40	38	40.00
Mean	42.40	40.80	38.80	40.67
Source	SEm±		CD@5%	
Variety	0.34		0.98	
Spacing	0.26		0.76	
Interaction	0.59		NS	

4.2 Yield parameters

4.2.1 Average leaf weight (g)

Average leaf weight was significantly influenced by variety, spacing, and their interaction (Table 8). Among the varieties, Yellow Dorat recorded the highest average leaf weight (13.51 g), which was statistically at par with Barese White (13.19 g), followed by Golden Sunrise (12.15 g), whereas Swiss chard Green recorded the lowest average leaf weight (11.50 g). Among the spacing treatments, 30 × 30 cm recorded the maximum average leaf weight (13.06 g), which was statistically at par with 45 × 30 cm (12.30 g), while the minimum average leaf weight was observed under

30 × 20 cm spacing (11.95 g). The maximum average leaf weight (14.84 g) was recorded in Yellow Dorat planted at 30 × 30 cm (V₄S₂), whereas the minimum (10.89 g) was observed in Swiss chard Green planted at 45 × 30 cm (V₅S₁). The higher average leaf weight observed in Yellow Dorat may be attributed to its superior genetic potential, vigorous vegetative growth, and greater accumulation of biomass in leaves. Similar findings have been reported by Bozokalfa *et al.* (2016) [2] in Swiss chard. Bozokalfa, K.M., Eşiyok, D. and Kaygısız-Aşçıoğlu, T. (2016) [2]. Diversity pattern among agromorphological traits of Swiss chard (*Beta vulgaris* L. subsp. *vulgaris*) genetic resources of

Turkey. *Turkish Journal of Agriculture and Forestry*, 40: 684-695.

The significant effect of spacing on average leaf weight may be due to differences in plant density, which influenced leaf growth and biomass accumulation. Optimum spacing (30 × 30 cm) provided favourable conditions for leaf development, resulting in higher average leaf weight. Similar findings have been reported by Islam *et al.* (2014) [7] in Indian spinach. The significant interaction between variety and spacing indicates that the response of average leaf weight to planting density varied among the Swiss chard varieties.

Table 8: Average leaf weight (g) as influenced by varieties and spacing

	S ₁ (45 cm × 30 cm)	S ₂ (30 cm × 30 cm)	S ₃ (30 cm × 20 cm)	Mean
V ₁ : Barese White	13.89	11.99	13.69	13.19
V ₂ : Golden Sunrise	11.36	13.92	11.16	12.15
V ₃ : Red Rhubarb	11.65	12.51	11.31	11.82
V ₄ : Yellow Dorat	13.69	14.84	12.00	13.51
V ₅ : Swiss chard Green	10.89	12.04	11.57	11.50
Mean	12.30	13.06	11.95	12.43
	V	S	V × S	
SEm±	0.37	0.29	0.64	
CD@5%	1.08	0.83	1.86	

4.2.2 Fresh yield per plant (g)

Fresh yield per plant was significantly influenced by variety, whereas the effect of spacing and the interaction between variety and spacing remained non-significant (Table 9). Among the varieties, Barese White recorded the highest fresh yield per plant (152.46 g), which was statistically at par with Yellow Dorat (151.22 g), followed by Golden Sunrise (120.40 g) and Red Rhubarb (119.16 g), whereas Swiss chard Green recorded the lowest fresh yield per plant (110.41 g). Although spacing had a non-significant effect, the maximum fresh yield per plant (137.75 g) was recorded

under 30 × 30 cm spacing, followed by 45 × 30 cm (129.57 g) and 30 × 20 cm (124.87 g). The interaction between variety and spacing remained non-significant.

The higher fresh yield per plant observed in Barese White may be attributed to its superior genetic potential, vigorous vegetative growth, and greater accumulation of photosynthates, resulting in enhanced production of marketable biomass. Similar findings have been reported by Pokluda and Kuben (2002) [16] in Swiss chard; Khedkar *et al.* (2023) [8] in Palak; and Thao *et al.* (2024) [19] in Mizuna.

Table 9: Fresh yield per plant (g) as influenced by varieties and spacing

	S ₁ (45 cm × 30 cm)	S ₂ (30 cm × 30 cm)	S ₃ (30 cm × 20 cm)	Mean
V ₁ : Barese White	160.57	137.10	159.70	152.46
V ₂ : Golden Sunrise	111.23	137.47	112.50	120.40
V ₃ : Red Rhubarb	115.40	133.63	108.43	119.16
V ₄ : Yellow Dorat	160.13	163.23	130.30	151.22
V ₅ : Swiss chard Green	100.50	117.33	113.40	110.41
Mean	129.57	137.75	124.87	130.73
	V	S	V × S	
SEm±	5.27	4.08	9.13	
CD@5%	15.27	NS	NS	

4.2.3 Yield/plot (kg): Yield per plot was significantly influenced by variety and spacing, whereas the interaction between variety and spacing remained non-significant (Table 10). Among the varieties, Yellow Dorat recorded the highest yield per plot (3.70 kg), which was statistically at par with Barese White (3.69 kg) and Swiss chard Green (3.53 kg), whereas Golden Sunrise recorded the lowest yield per plot (3.12 kg). Among the spacing treatments, 30 × 20 cm recorded the highest yield per plot (4.29 kg), followed by 30 × 30 cm (3.52 kg), while the lowest yield per plot (2.55 kg) was recorded under 45 × 30 cm spacing. The interaction between variety and spacing remained non-significant. The higher yield per plot observed in Yellow

Dorat may be attributed to its superior genetic potential, vigorous vegetative growth, and greater production of marketable biomass. Similar findings have been reported by Silatar *et al.* (2018) [20] in Knol-khol; Nath *et al.* (2020) [14] in Spinach; Mishra *et al.* (2022) [11] in Cabbage; and Yadav *et al.* (2023) [24] in Cabbage. The significantly higher yield per plot under closer spacing (30 × 20 cm) may be attributed to the higher plant population per unit area, which increased the cumulative yield despite comparatively lower space available for individual plants. Similar findings have been reported by Silatar *et al.* (2018) [20] in Knol-khol; Gayathri *et al.* (2021) [5] in Beetroot; Mishra *et al.* (2022) [11] in Cabbage; and Yadav *et al.* (2023) [24] in Cabbage.

Table 10: Yield/plot (kg) as influenced by varieties and spacing

	S ₁ (45 cm × 30 cm)	S ₂ (30 cm × 30 cm)	S ₃ (30 cm × 20 cm)	Mean
V ₁ : Barese White	2.70	3.93	4.43	3.69
V ₂ : Golden Sunrise	2.57	2.93	3.87	3.12
V ₃ : Red Rhubarb	2.33	3.53	3.80	3.22
V ₄ : Yellow Dorat	2.83	3.53	4.73	3.70
V ₅ : Swiss chard Green	2.33	3.67	4.60	3.53
Mean	2.55	3.52	4.29	3.45
	V	S	V × S	
SEm±	0.12	0.09	0.21	
CD@5%	0.35	0.27	NS	
CV	10.35			

4.2.4 Yield/ha (t)

Yield per hectare was significantly influenced by variety and spacing, whereas the interaction between variety and spacing remained non-significant (Table 11). Among the varieties, Yellow Dorat recorded the highest yield per hectare (11.42 t ha⁻¹), which was statistically at par with Barese White (11.39 t ha⁻¹) and Swiss chard Green (10.90 t ha⁻¹), whereas Golden Sunrise recorded the lowest yield per hectare (9.64 t ha⁻¹). Among the spacing treatments, 30 × 20 cm recorded the highest yield per hectare (13.23 t ha⁻¹), followed by 30 × 30 cm (10.86 t ha⁻¹), while the lowest yield per hectare (7.88 t ha⁻¹) was recorded under 45 × 30 cm spacing. The interaction between variety and spacing remained non-significant.

The higher yield per hectare observed in Yellow Dorat may be attributed to its superior genetic potential, vigorous

vegetative growth, and greater production of marketable biomass. Similar findings have been reported by Pokluda and Kuben (2002) [16] in Swiss chard; Nath *et al.* (2020) [14] in Spinach; Sahil *et al.* (2023) [17] in Lettuce; Apahidean *et al.* (2024) [1] in Swiss chard; Tejaswi *et al.* (2024) [21] in Palak. The significantly higher yield per hectare under closer spacing (30 × 20 cm) may be attributed to the higher plant population per unit area, which resulted in greater cumulative yield despite comparatively lower yield per individual plant. Similar findings have been reported Echer *et al.* (2012) [4] in Swiss chard; Islam *et al.* (2014) [7] in Indian spinach; Kadam *et al.* (2018) [9] in Beetroot; Woldu *et al.* (2019) [23] in Swiss chard; Gayathri *et al.* (2021) [5] in Beetroot; Tejaswi *et al.* (2024) [21] in Palak; Apahidean *et al.* (2024) [1] in Swiss chard.

Table 11: Yield/ha (t) as influenced by varieties and spacing

	S ₁ (45 cm × 30 cm)	S ₂ (30 cm × 30 cm)	S ₃ (30 cm × 20 cm)	Mean
V ₁ : Barese White	8.34	12.14	13.68	11.39
V ₂ : Golden Sunrise	7.92	9.05	11.94	9.64
V ₃ : Red Rhubarb	7.20	10.91	11.73	9.95
V ₄ : Yellow Dorat	8.74	10.90	14.61	11.42
V ₅ : Swiss chard Green	7.20	11.32	14.20	10.90
Mean	7.88	10.86	13.23	10.66
	V	S	V × S	
SEm±	0.37	0.28	0.64	
CD@5%	1.06	0.82	NS	
CV	10.35			

5. Conclusion

Among the five Swiss chard varieties evaluated, Yellow Dorat (V₄) exhibited superior performance for most growth and yield parameters. It recorded the highest plant height, leaf length, petiole length, average leaf weight, yield per plot, and yield per hectare. Barese White (V₁) was statistically at par with Yellow Dorat for several yield traits and produced the highest number of leaves per plant, widest leaves, and maximum fresh yield per plant.

Among the spacing treatments, 30 cm × 20 cm (S₃) was found to be the most suitable for commercial cultivation as it produced the highest yield per plot and yield per hectare, along with longer leaves, longer petioles, and earlier harvest. Although the wider spacing of 45 cm × 30 cm (S₁) resulted in taller plants with broader leaves, and 30 cm × 30 cm (S₂) recorded higher average leaf weight, fresh yield per plant, and leaf area, the overall performance for growth and yield was superior under 30 cm × 20 cm (S₃). Therefore, cultivation of Yellow Dorat (V₄) at a spacing of 30 cm × 20 cm is recommended for achieving higher growth and yield of Swiss chard under the experimental conditions.

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