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Mounik A
M.Sc. (Horticulture) Scholar,
Department of Fruit Science,
College of Horticulture, UHS
Bagalkot, Karnataka, India

Sanganabasava G Gollagi
Associate Professor, Department of
Crop Physiology, HREC,
Vijayapur, Karnataka, India

Kulapati Hipparagi
Professor and Campus Head,
Department of Fruit Science,
HREC, Vijayapur, Karnataka,
India

Anand G Nanjappanavar
Assistant Professor, Department of
Fruit Science, MHREC, UHS
Bagalkot, Karnataka, India

Shivayogi Y Ryavalad
Assistant Professor and Farm
Superintendent RHREC,
Department of Seed Science &
Technology, Dharwad, Karnataka,
India

Corresponding Author:

Mounik A
M.Sc. (Horticulture) Scholar,
Department of Fruit Science,
College of Horticulture, UHS
Bagalkot, Karnataka, India

Physiological basis of evaluation of grape varieties under northern dry zone of Karnataka

Mounik A, Sanganabasava G Gollagi, Kulapati Hipparagi, Anand G Nanjappanavar and Shivayogi Y Ryavalad

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Abstract

A study entitled “Physiological basis of evaluation of grape varieties under northern dry zone of Karnataka” was conducted at Horticulture Research and Extension Centre, Vijayapur (Tidagundi). For the experiment, ten grape varieties were selected and data concerning vine physiological, growth, yield and quality parameters of the ten varieties were recorded. The experiment was laid out in Randomized Block Design (RBD) with ten varieties and three replications. The varieties were Red Globe, Fantasy Seedless, Crimson Seedless, Manjari Shyama (A-18/3), Nanasahab Purple Seedless, Sharad Seedless, Merbein Seedless, 2A-Clone, Manjari Kishmish (Kishmish Rozavis White) and Thompson Seedless. Among all the varieties studied, the variety Thompson Seedless, followed by Manjari Kishmish demonstrated its superiority among green grape varieties, boasting robust physiological characteristics, strong growth parameters and high yields. In coloured grape varieties, Crimson Seedless and Manjari Shyama emerged as the top performer, primarily due to its exceptional fruit quality attributes, including firmness and relatively higher organoleptic qualities.

Keywords: Grapes, physiology, growth, yield and quality

1. Introduction

Grapes (*Vitis vinifera* L.) belongs to the Vitaceae family with a chromosome number of $2n = 38$. It's an important fruit crop worldwide, thriving in various climates from temperate to tropical. Grape cultivation has historical roots near the Caspian Sea and was introduced to India in 1300 AD by invaders from Iran and Afghanistan. Globally, grapes hold a prominent position, contributing to about 16 per cent of total fruit production.

Grape cultivation in India has gained significance due to its high productivity compared to many other grape-producing countries. Major grape-growing states include Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu and the North Western region comprising Punjab, Haryana, Delhi, Western Uttar Pradesh, Rajasthan and Madhya Pradesh. However, it's Maharashtra and Karnataka that dominate the landscape, together contributing a substantial 94 per cent of the total grape production in the country.

Nasik district in Maharashtra leads with an area of 52.32 thousand ha and the highest production of 1123.41 thousand MT, followed by Vijayapura district in Karnataka with an area of 21.45 thousand ha and production of 253.00 thousand MT.

Karnataka, within India, emerges as a notable player in the grape cultivation landscape, with various grape varieties thriving in this state. Key grape-growing districts in Karnataka include Bangalore, Kolar, Vijayapura, Bagalkot, Belgaum, Koppal and Gulbarga, elevating the state's status to the second-largest producer in terms of both area and yield.

The growth and development of grapevines are intricately intertwined with their physiological responses to a diverse range of abiotic and biotic stresses. These responses are critical determinants of grape quality and yield (Keller, 2010) [7]. Grapes, as highly perishable non-climacteric fruits are susceptible to various abiotic factors that significantly influence their fruit quality characteristics, such as size and color. These abiotic factors encompass temperature, sunlight exposure, water availability and nutrient levels [Jones *et al.*, (2005)] [5]. A profound understanding of the physiological processes governing grape development and growth plays a

pivotal role in ensuring the production of high-quality grapes. To enhance the yield and quality of grape varieties, it is imperative to thoroughly comprehend the physiological and morphological aspects unique to each cultivar.

As there is need for adapting the newly released varieties for cultivation in Karnataka for obtaining high yield and quality. The present study was undertaken to find out the suitable grape varieties for commercial cultivation in Karnataka and also to assess the varieties for their physiological aspects, growth, yield and its quality. Keeping all these in view, the present experiment entitled “Physiological basis of evaluation of grape varieties under Northern dry Zone of Karnataka” was undertaken

2. Materials and Methods

The study was conducted at research center located in Tidagundi, Vijayapur district. This specific experimental site is situated in the northern dry zone of Karnataka. Geographically, it is situated at a latitude of 16°49' North and a longitude of 75°43' East. The soils in this area are of a medium black hue and exhibit shallow depth. The soil pH level falls within the range of 7.5 to 8.5. The mean annual temperature is 26.5°C and rainfall is 589 mm.

The grape varieties chosen for the experiment were of five years old and were planted with a spacing of 2.74 × 1.52 meters. These vines were trained using the Y-trellis training system. The selected cultivars were grafted onto the Dogridge rootstock. Pruning activities were carried out with backward pruning executed on April 3rd 2022, followed by fore pruning on October 10th 2022. The vineyard was subjected to irrigation through a drip irrigation system and the field was kept under weed-free conditions. Fertigation was employed for precise fertilizer application, optimizing nutrient delivery to the grapevines. Simultaneously, a comprehensive pest and disease management strategy was implemented, involving a variety of control measures and targeted sprays to safeguard the vines from potential threats.

The experiment was laid out using a randomized block design (RBD), comprising ten distinct treatments replicated three times, with each treatment consisting of six vines. The experiment comprised of varieties viz., V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama (A-18/3), V₅ - Nanasahab Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish (Kishmish Rozavis White), V₁₀ - Thompson Seedless. Leaf area was calculated by using the linear method (LBK method). The mathematical equation to calculate it is as follows; Leaf area (LA) = L × B × K (0.81); Where L = maximum length, B = maximum breadth and K = Correction factor. Leaf area index was calculated by taking the ratio of leaf area per plant (cm²) to

land area occupied by plant (cm²). Specific leaf area (SLA) was measured by working out the ratio between leaf area (cm²) to leaf dry weight(g) and expressed in cm² g⁻¹. Specific leaf weight (SLW) was measured as a ratio of leaf weight (mg) per unit leaf area (cm²) and expressed as g cm⁻². Chlorophyll content was recorded using chlorophyll meter SPAD-502 (Konica Minolta, Japan) at 30, 60 and 90 days after fore pruning. Using an Infrared gas analyzer (IRGA-LICOR6400; LI-6400) instrument, parameters such as photosynthetic rate (μmol m⁻² s⁻¹), transpiration rate (mmol m⁻² s⁻¹), stomatal conductance (mmol m⁻² s⁻¹) and leaf temperature (°C) were measured. Direct counting was used to calculate the total number of fruitful canes on each vine at the flower bud stage. The average fresh weight of canes pruned from randomly selected vines during the fore pruning was recorded using a digital weighing scale and the fresh weight was noted in gram. The average number of leaves per shoot was calculated by counting the number of leaves on each of the randomly selected five shoots of a vine during veraison stage. The bunches per cane and per vine were recorded by manual counting. The bunch length and width was recorded by using a measuring scale. Digital weighing balance was used to measure the weight of the bunches. The average yield for each vine was calculated by multiplying the mean bunch weight by the average number of bunches per vine and expressed in kilograms per vine. The estimated yield per hectare was calculated by multiplying the yield per vine by the total number of vines per hectare and expressed in tons per hectare. Total soluble solids were determined with the help of hand refractometer (Erma 0 to 32%), the titratable acidity of grape varieties was calculated by titration method and TSS: acid ratio was worked out. The data recorded on various observations regarding physiological, growth, yield and quality were subjected to Fisher's method of “Analysis of variance” (ANOVA). The level of significance as F - test was tested at 5 per cent and data was interpreted using critical difference values at a probability level of 0.05 per cent.

3. Results and Discussion

3.1 Physiological parameters

Significant variations were identified with regard to leaf area among the varieties, as presented in Table 1. Thompson Seedless exhibited the highest leaf area (104.97, 116.69 and 135.61 cm²) at 30th, 60th and 90th day after fore pruning respectively, while the lowest leaf area was recorded in Nanasahab Purple Seedless (85.4, 103.16 and 119.30 cm²) at 30th, 60th and 90th day after fore pruning respectively. The increase in leaf area could potentially be attributed to the genotypic vigor inherent to Thompson Seedless. These findings were consistent with those reported by Shruti (2022) [20].

Table 1: Leaf area (cm²) and leaf area index of different grape varieties after fore pruning

Treatment	Leaf area (cm ²)			Leaf area index		
	30 DAFP	60 DAFP	90 DAFP	30 DAFP	60 DAFP	90 DAFP
V ₁	94.43	111.60	125.39	1.36	2.93	3.31
V ₂	89.52	104.20	122.46	1.29	2.74	3.23
V ₃	100.96	115.70	132.90	1.45	3.04	3.51
V ₄	97.41	112.40	127.30	1.40	2.95	3.36
V ₅	85.40	103.16	119.30	1.23	2.71	3.15
V ₆	90.22	106.66	122.66	1.30	2.80	3.24
V ₇	93.09	107.39	124.17	1.34	2.82	3.28
V ₈	102.44	113.78	123.11	1.48	2.99	3.25
V ₉	99.73	113.83	132.60	1.44	2.99	3.50
V ₁₀	104.97	116.69	135.61	1.51	3.07	3.58
S.Em ±	1.20	1.29	1.31	0.02	0.03	0.04
CD at 5%	3.56	3.82	3.90	0.05	0.10	0.10

Note: DAFP: days after fore pruning V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasahab Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

Table 2: Chlorophyll content, specific leaf area (cm^2/g) and specific leaf weight (mg/cm^2) of different grape varieties after fore pruning

Treatment	Chlorophyll content (SPAD values)			Specific leaf area (SLA) (cm^2/g)	Specific leaf weight (SLW) (mg/cm^2)
	30 DAFP	60 DAFP	90 DAFP		
V ₁	22.63	34.55	38.40	152.47	6.56
V ₂	21.59	34.07	37.62	146.91	6.81
V ₃	21.30	34.21	36.17	154.32	6.48
V ₄	22.49	34.46	38.49	151.87	6.59
V ₅	20.68	32.76	35.96	147.14	6.80
V ₆	21.64	33.37	36.73	147.27	6.79
V ₇	20.43	33.12	36.45	140.21	7.13
V ₈	20.69	33.47	36.48	143.02	7.00
V ₉	21.27	34.15	38.13	155.22	6.44
V ₁₀	21.41	34.72	38.34	157.52	6.35
S.Em $\pm$	0.76	0.50	0.33	2.10	0.09
CD at 5%	NS	NS	0.98	6.23	0.28

Note: DAFP: days after fore pruning V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasahab Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

Leaf area index data in Table 1 reveals notable variations. The higher values for leaf area index were recorded in Thompson Seedless (1.51, 3.07 and 3.58) at 30th, 60th and 90th day after fore pruning respectively. Meanwhile, the minimum values were noticed in Nanasahab Purple Seedless (1.23, 2.71 and 3.15) at 30th, 60th and 90th day after fore pruning, respectively. These disparities in leaf area index are caused by the complex interconnection of genotypic attributes and environmental conditions within the grapevine varieties. Thompson Seedless, due to its inherent vigor and potentially a higher leaf count and leaf area, exhibited a significantly elevated leaf area index. These results align with observations made by Shruti (2022) [20]. Higher values for leaf area index in Thompson Seedless can be correlated with radiation interception and light conditions in the fruit zone, as noted by Winkler (1958) [26]. These factors in turn exert influence on the canopy microclimate, plant carbon balance, yield and grape composition, as established by Smart (1985) [21] and Jones *et al.* (2005) [5].

The chlorophyll content data presented in Table 2 highlights significant variations at 90 days following fore pruning. The highest chlorophyll SPAD values were noted in Red Globe (22.63), Thompson Seedless (34.72) and Manjari Shyama (38.49) at 30th, 60th and 90th day following fore pruning, respectively. In contrast, the lowest chlorophyll SPAD values were registered in Nanasahab Purple Seedless (20.68, 32.76 and 35.96) at 30th, 60th and 90th day after fore pruning, respectively. The chlorophyll content showed a consistent increase during the 30th, 60th and 90th day after fore pruning in all the grape varieties. Differences in SPAD values among grape varieties result from genetic differences that lead to variations in chlorophyll production. It can also be due to the structure of plant leaves, including thickness, size, shape and surface area, which affects the distribution of chlorophyll, subsequently influencing SPAD readings. Furthermore, environmental conditions such as light intensity, temperature, humidity and nutrient availability can have varied impacts on chlorophyll production and degradation, causing different grape varieties to respond differently and exhibit variations in SPAD readings.

The data in Table 2 shows significant distinctions in specific leaf area across the various grape varieties. The higher specific leaf area (SLA) was recorded in Thompson Seedless (157.51 cm^2/g). While, the minimum SLA was recorded in Merbian Seedless (140.21 cm^2/g). Differences in SLA among grape varieties result from genetic variations and response of different varieties to the environmental conditions. Grapevines with a higher SLA typically have larger and thinner leaves, which provide a larger surface area for photosynthesis. This results in increased

photosynthetic rates and improved production of carbohydrates (sugars) through photosynthesis, which are essential for bunch development and overall plant growth. Similar type results were observed by Chaves *et al.* (2010) [2].

Significant variations in specific leaf weight among the different grape varieties are illustrated in Table 2. The maximum specific leaf weight was recorded in Merbian Seedless (7.14 mg/cm^2). While, the minimum specific leaf weight was recorded in Thompson Seedless (4.90 mg/cm^2). This trend is primarily attributed to the varietal vigor and genetic characteristics, with Merbian Seedless thicker and denser leaves contributing to its higher SLW values. These disparities emphasize the individual growth tactics and versatility among these grapevine cultivars.

Table 3, displays significant variations in photosynthetic rates, transpiration rates and stomatal conductance among different grape varieties. Notably, Thompson Seedless exhibited the highest photosynthetic rate (15.33 $\mu\text{mol m}^{-2} \text{s}^{-1}$), transpiration rate (6.22 $\text{m mol m}^{-2} \text{s}^{-1}$) and stomatal conductance (267.18 $\text{m mol m}^{-2} \text{s}^{-1}$). Conversely, Red Glob displayed the lowest photosynthetic rate (10.87 $\mu\text{mol m}^{-2} \text{s}^{-1}$), transpiration rate (3.70 $\text{m mol m}^{-2} \text{s}^{-1}$) and Sharad Seedless had the lowest stomatal conductance (128.92 $\text{m mol m}^{-2} \text{s}^{-1}$). There was non-significant variation in leaf temperature (Table 3), with 2A- Clone registering the highest leaf temperature (33.23 $^{\circ}\text{C}$) and Red Globe the lowest (31.69 $^{\circ}\text{C}$).

The observed variations in photosynthetic rate, transpiration rate, stomatal conductance and leaf temperature among different grape varieties can be attributed to a range of factors related to genetics, physiology and environmental conditions. Genetic differences stand out as a foundational factor. Different grape varieties possess distinct genetic traits that underpin their photosynthetic and transpiration processes. These traits encompass variations in chlorophyll content, leaf structure and stomatal density, collectively impacting the efficiency of both photosynthesis and transpiration. Furthermore, the responsiveness of stomata plays a pivotal role. Stomatal conductance, which depends on the controlled opening and closing of stomata, can vary significantly. Varieties such as Thompson Seedless may have more flexible stomata, allowing for higher conductance and consequently, elevated transpiration rates. The variations can also be due to environmental conditions, leaf characteristics and water usage efficiency of different grape varieties. These variations highlight the intricate interplay of various elements influencing grapevine performance. Similar type of results was noted by Bota *et al.* (2001) [1], Lovisolo *et al.* (2008) [10], Escalona *et al.* (2010) [3], Keller (2010) [7] and Schultz & Stoll (2010) [17].

Table 3: Photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$), transpiration rate ($\text{m mol m}^{-2} \text{s}^{-1}$), stomatal conductance ($\text{m mol m}^{-2} \text{s}^{-1}$) and leaf temperature ($^{\circ}\text{C}$) of different grape varieties after fore pruning

Treatment	Photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Transpiration rate ($\text{m mol m}^{-2} \text{s}^{-1}$)	Stomatal conductance ($\text{m mol m}^{-2} \text{s}^{-1}$)	Leaf temperature ($^{\circ}\text{C}$)
V ₁	10.87	3.70	132.59	31.69
V ₂	12.94	4.66	167.46	32.03
V ₃	11.38	4.83	171.20	32.26
V ₄	13.93	4.67	169.35	32.31
V ₅	11.02	3.89	130.47	32.85
V ₆	12.71	3.76	128.92	32.96
V ₇	11.85	5.65	214.93	33.10
V ₈	12.05	4.76	182.13	33.23
V ₉	12.10	5.28	207.23	33.15
V ₁₀	15.33	6.22	267.18	32.66
S.Em $\pm$	0.18	0.08	2.14	0.42
CD at 5%	0.53	0.24	6.35	NS

Note: DAFFP: days after fore pruning V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasahab Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

3.2 Growth parameters

The pruned biomass differed significantly among the varieties is illustrated in Table 4. The highest pruned biomass was noted in Thompson Seedless (369.64 g). The lowest pruned biomass was registered in Fantasy Seedless (207.92 g). In grape cultivation, pruned biomass has been considered as an indirect indicator of vine vigor. The variation in pruned biomass among different cultivars was found to be dependent on vine vigor, with highly

vigorous varieties demonstrating an increased production of pruned biomass, attributed to greater assimilation of carbohydrates resulting from factors such as the number of canes and leaves produced. The experiment recorded a high pruned biomass, which can be associated to the higher leaf count in Thompson Seedless. Smith (1996)^[22] reported that high-yielding clones yielded larger pruning weights, while the opposite trend was observed for lower-yielding varieties.

Table 4: Fresh weight of pruned biomass (g), number of canes per vine, fruitful canes per vine and number of leaves per shoot of different grape varieties after fore pruning

Treatment	Fresh weight of pruned biomass(g)	Number of canes per vine	Fruitful canes per vine	Number of leaves per shoot
V ₁	251.11	37.89	26.60	13.43
V ₂	207.92	38.89	23.88	16.29
V ₃	280.40	46.66	32.94	16.70
V ₄	270.52	45.43	36.07	14.77
V ₅	220.41	40.59	17.65	15.75
V ₆	258.22	40.64	28.37	14.93
V ₇	308.52	42.72	31.42	17.25
V ₈	332.50	46.39	36.03	18.51
V ₉	349.93	48.94	43.73	18.56
V ₁₀	369.64	50.04	44.16	18.79
S.Em $\pm$	4.15	2.12	2.39	0.95
CD at 5%	12.33	6.31	7.11	2.81

Note: V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasahab Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

Table 4 revealed significant disparities in the number of canes per vine and fruitful canes per vine among grape varieties. Thompson Seedless exhibited the highest number of both matured and fruitful canes (50.04 and 44.16, respectively), while Red Globe had the lowest number of matured canes (37.89) and Nanasahab Purple Seedless had the lowest number of fruitful canes (17.65). The variations in number of matured and fruitful canes could be attributed to differences in vine vigor, possibly stemming from the genetic characteristics of the cultivars. Comparable observations were documented by Ratnacharyulu (2010)^[16], Soni *et al.* (2019)^[24] and Shruti (2022)^[20].

The data pertaining to number of leaves per shoot shown significant disparities among treatments (Table 4). The highest number of leaves (18.79) was registered in Thompson Seedless and the least number of leaves per shoot was noticed in Red Globe (13.43). The higher LAI and pruned biomass in Thompson Seedless are indicative of its vigorous nature. Higher LAI led to larger surface area for leaf development and subsequently greater photosynthetic capacity. This enhanced photosynthesis driven by an increased leaf area provides more

assimilates and energy resources for the vine. In response to this abundant energy supply the vine tends to develop more leaves to further capitalize on the available resources. The studies are in confirmation with the earlier works made by Joshi *et al.* (2015)^[6], Shahda (2016)^[18], Somkuwar *et al.* (2020)^[23] and Shruti (2022)^[20].

3.3 Yield parameters

The data regarding bunch weight (Table 5) reported significant variation among the varieties. The higher values for bunch weight were recorded in Red Globe (473 g), while the minimum bunch weight was registered in Nanasahab Purple Seedless (240.33 g). The higher bunch weight in Red Globe is due to higher berry length, berry diameter and higher weight of berries. It could also be due to seeded nature of Red Globe, where seeds act as a strong sink and more photosynthates are supplied for the bunch development. The genotypic nature of the cultivar could possibly explain the variation in bunch weight. Similar findings were noticed by Gaser (2006)^[4], Soni *et al.* (2019)^[24] and Patil *et al.* (2020)^[13] in Red Globe.

Table 5: Bunch weight (g), bunch length (cm) and bunch width (cm) of different grape varieties

Treatment	Bunch weight (g)	Bunch length (cm)	Bunch width (cm)
V ₁	473.00	19.75	15.92
V ₂	264.00	22.38	11.61
V ₃	320.00	16.54	11.13
V ₄	262.00	16.67	9.68
V ₅	240.33	17.75	8.82
V ₆	291.33	17.33	9.46
V ₇	268.15	20.94	9.88
V ₈	272.67	19.21	10.70
V ₉	279.33	20.79	9.59
V ₁₀	287.33	20.71	10.55
S.Em ±	4.24	0.87	0.59
CD at 5%	12.61	2.58	1.76

Note: V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasaheb Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

The data pertaining to the bunch length varied substantially among different grape varieties is depicted in Table 5. The higher values for bunch length were recorded in Fantasy Seedless (22.38 cm), while the least bunch length was observed in Crimson Seedless (16.54 cm). The noted variation in bunch length, with Fantasy Seedless having the longest bunches and Crimson Seedless having the shortest, can be attributed to the genetic makeup of these varieties. In Fantasy Seedless, it is likely that the bunch shape tends to be more vertical, with less horizontal expansion, owing to its specific genetic traits. The studies are in confirmation with the earlier works made by Gaser (2006) [4].

The data pertaining to the bunch width varied significantly among different grape varieties (Table 5). The substantial variation in bunch width, with Red Globe (15.92 cm), having the widest bunches and Nanasaheb Purple Seedless (8.82 cm) having the narrowest, can be attributed to certain factors. In Red Globe, the higher bunch width is likely associated with elevated values of berry length and diameter as observed in this experiment. This could be due to specific genetic traits or environmental conditions favouring the growth of Red Globe berries, resulting in a broader bunch width compared to other varieties. The studies are in confirmation with the earlier works made by Gaser (2006) [4] and Patil *et al.* (2020) [13] in Red Globe.

Table 6: Number of bunches per cane, bunches per vine and yield of different grape varieties

Treatment	Number of bunches per cane	Bunches per vine	Yield	
			Kg/vine	t/ha
V ₁	1.00	24.06	11.38	27.31
V ₂	1.09	27.55	7.27	17.45
V ₃	1.16	35.76	11.44	27.46
V ₄	1.18	41.28	10.82	25.96
V ₅	1.03	18.17	4.37	10.48
V ₆	1.09	30.83	8.98	21.56
V ₇	1.08	41.33	11.08	26.60
V ₈	1.14	44.67	12.18	29.23
V ₉	1.24	47.33	13.22	31.73
V ₁₀	1.32	50.50	14.51	34.82
S.Em ±	0.02	2.24	0.45	1.09
CD at 5%	0.05	6.65	1.35	3.23

Note: V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasaheb Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

A significant difference in the number of bunches per cane and vine was noted among the varieties (Table 6). Thompson Seedless displayed the highest number of bunches per cane (1.32) and per vine (50.50), while Red Globe (1) showed the least number of bunches per cane and Nanasaheb Purple Seedless (18.17) exhibited the least number of bunches per vine. The difference in number of bunches was due to variances in genotypic and phenotypic expression under current environmental conditions. The increase in the number of bunches in Thompson Seedless might be due to high fruitful canes and also might be varietal character. These findings were in accordance with supporting reference of Gaser (2006) [4], Soni *et al.* (2019) [24], Shruti (2022) [20] and Pavitra (2022) [14].

The data depicted in Table 6 showed significant difference with respect to yield among different grape varieties. The maximum yield was recorded in Thompson Seedless (14.51 kg/vine and 34.82 t/ha). Whereas, the minimum yield was reported in Nanasaheb Purple Seedless (4.37 kg/vine and 10.48 t/ha). These disparities in yield can be attributed to several key factors. Thompson Seedless, with its remarkable higher leaf area, LAI, photosynthetic rate and SLA gains a clear advantage in photosynthates production which increases its overall yield. The higher yield in Thompson Seedless might also be due to the presence of compact bunches with a greater number of berries per bunch that increased the weight of the bunch which led to increase in the yield. The variation in the yield of different varieties is due to genetic character, number of bunches, weight of the berries, number of fruitful canes and age of the vines besides their successful adoption to the varying agro-climatic conditions under which they are cultivated. These findings are in close conformity with findings reported by Gaser (2006) [4], Soni *et al.* (2019) [24] and Patil *et al.* (2020) [13].

3.4 Quality parameters

All the varieties were significantly different with respect to TSS as depicted in Table 7. The highest TSS was noted in Nanasaheb Purple Seedless (24.33 °B) and the lowest TSS was noted in Red Globe (18.40°B). The increase in TSS in Nanasaheb Purple Seedless might be because of increase in the reducing sugar. The increase in TSS may also be because of reduction in the bunch load per vine. Similar results were reported by Sharma *et al.* (2018) [19] and Soni *et al.* (2019) [24].

Table 7: TSS (°Brix), titratable acidity (%) and TSS:acid ratio of different grape varieties

Treatment	TSS (°Brix)	Titratable acidity (%)	TSS:acid ratio
V ₁	18.40	0.63	29.24
V ₂	20.30	0.52	39.04
V ₃	20.80	0.59	35.34
V ₄	21.80	0.56	39.00
V ₅	24.33	0.51	47.80
V ₆	23.00	0.51	45.10
V ₇	22.03	0.53	41.60
V ₈	20.73	0.54	38.43
V ₉	21.60	0.52	41.54
V ₁₀	22.97	0.49	46.88
S.Em ±	0.26	0.01	1.10
CD at 5%	0.76	0.03	3.28

Note: V₁ - Red Globe, V₂ - Fantasy Seedless, V₃ - Crimson Seedless, V₄ - Manjari Shyama, V₅ - Nanasaheb Purple Seedless, V₆ - Sharad Seedless, V₇ - Merbein Seedless, V₈ - 2A-Clone, V₉ - Manjari Kishmish, V₁₀ - Thompson Seedless

The titratable acidity content varied significantly among the varieties. The data obtained on titratable acidity is depicted in Table 7. The minimum titratable acidity content was recorded in Thompson Seedless (0.49%) and the maximum titratable acidity content was registered in Red Globe (0.63%). The variation in acidity levels among grape varieties can be attributed to a complex interaction of factors. In Thompson Seedless, a combination of intrinsic genetic attributes and specific environmental interactions appears to regulate acid synthesis, resulting in lower acidity levels. The canopy architecture of Thompson Seedless, characterized by an advantageous leaf-to-fruit ratio, facilitates relatively higher sugar accumulation while concurrently maintaining lower acidity levels. In contrast, the Red Globe variety demonstrates an alternative physiological mechanism influenced by its genetic attributes and environmental interactions, leading to increased organic acid production. Overall, the distinct acidity profiles observed in different grape varieties can be primarily ascribed to the intricate interplay of varietal characteristics and their specific environmental conditions. These findings are in close conformity with findings reported by Parker *et al.* (2015) ^[12], Ramteke *et al.* (2017) ^[15], Khalil *et al.* (2019) ^[8] and Shruti (2022) ^[20].

The TSS: acid ratio showed significant disparities among the different grape varieties (Table 7). The maximum TSS: acid ratio was noted in Nanasaheb Purple Seedless (47.80) and the minimum was noted in Red Globe (29.24). The elevated TSS: acid ratio observed in Nanasaheb Purple Seedless can be ascribed to its higher TSS values. Conversely, the lower values in Red Globe are a result of lower TSS levels and higher acidity values. The results obtained were in accordance with the findings reported by Subramoniam *et al.* (2006) ^[25], Khamis *et al.* (2017) ^[9], Pal *et al.* (2018) ^[11] and Shruti (2022) ^[20].

4. Conclusion

The evaluation of grape varieties conducted in the Northern dry Zone of Karnataka yielded valuable insights into the performance of different grape varieties within the region. In summary, Thompson Seedless, followed by Manjari Kishmish demonstrated its superiority among green grape varieties, boasting robust physiological characteristics, strong growth parameters and high yields. This makes it an excellent choice for growers prioritizing quantity and consistency in grape production.

Conversely, among coloured grape varieties, Crimson Seedless and Manjari Shyama emerged as the top performer, primarily due to its exceptional fruit quality attributes, including firmness and relatively higher organoleptic qualities. This positions Crimson Seedless and Manjari Shyama as the preferred option for those who emphasize on higher yield, quality and coloured table grape varieties.

The findings of this comprehensive evaluation underline the importance of balancing yield and quality in grape cultivation. While other grape varieties like Nanasaheb Purple Seedless exhibited remarkable quality, they were not chosen for the top spots due to lower yields, emphasizing the economic considerations involved in commercial grape farming. Thus, the selection of varieties reflects a judicious compromise between better yield and quality.

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