Effect of Spacing and Plant Growth Regulators on Organoleptic Quality of Strawberry (*Fragaria x ananassa* Duch) cv. Winter Dawn

Abstract

Sensory quality encompasses the various characteristics of a product that add value for both buyers and consumers. Consumers prefer fruits that are visually appealing, firm and have good flavour and nutritional value. On the other hand, producers and handlers prioritize the appearance and texture of the fruit as well as its ability to maintain quality of the fruits. The experiment was conducted at the College of Agriculture, Ummedganj Kota, Rajasthan over two growing seasons (2021-22 and 2022-23) to assess the effects of plant spacing and plant growth regulators on the organoleptic quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn. The hedonic sensory evaluation rating for organoleptic tests indicated that maximum score for colour (7.41), flavour (7.58), taste (7.77) and general appearance (7.84) was recorded under S_2 (30 cm ×30 cm). In terms of plant growth regulators (PGRs), maximum effect on organoleptic quality for colour (8.85), flavour (8.72), taste (8.65) and general appearance (8.49) was recorded under treatment treated with SA at 100 ppm. Moreover, in interaction effect treatment combination of S_2+SA_{100} ppm (30 cm ×30 cm + Salicylic acid at 100 ppm) received a higher and more favourable score of colour (8.87), flavour (8.74), taste (8.86) and general appearance (8.65), respectively. It can be concluded that a plant spacing of 30 cm × 30 cm combined with a 100 ppm Salicylic acid treatment produces optimal results in terms of sensory quality parameters.

Key words: Organoleptic quality, Plant spacing, Plant growth regulators, Winter Dawn.

1. Introduction

Strawberry (*Fragaria x ananassa* Duch.) is a natural hybrid species which belongs to the Rosaceae family that is cultivated all over the world for its aggregate accessory fruits. The modern cultivated variety is a hybrid of *Fragaria virginiana* and *Fragaria chiloensis* (Hancock *et al.,* 2000). In India, strawberry is generally cultivated in the hills and the climatic variability that exists in these areas and the broad adaptability of the plant allow its harvesting for more than half part of the year. Strawberry is a non-climacteric, delicious fruit known for its flavour, taste, fresh use and satisfactory vitamin C content.

The most abundant bioactive phyto-chemicals reported to be found in strawberry fruits are ellagic acid and certain flavonoids: anthocyanin, catechin, quercetin and kaempferol (Hannum 2004). Strawberry fruits contain phenolic compounds that have antioxidant, anticancer, anti-artherosclerotic and anti-neurodegenerative properties. Specific antioxidants present in strawberries include quercetin, kaempferol, chlorogenic acid, p-coumaric acid and ellagic acid (Olsson *et al*., 2004).

Plant spacing is crucial for ensuring excellent growth, output and quality. One of the most crucial factors is spacing. It assists in achieving high output per square meter. Marketable strawberry yields are higher with closer spacing than with wider spacing but quality in respect to size & other parameters are good in wider spacing. Plant growth hormones are thought to be essential for many activities in the life cycle of a plant under unfavorable environmental conditions where growth ingredients alter during the growing season with corresponding fluctuations in growth and development.

Salicylic acid plays a crucial role in the growth and development of the plant for crucial physiological functions such as increasing the plant's response to stress conditions (biotic and abiotic) increasing the plant's resistance to system-acquired resistance (SAR) or both.

A plant that uses triacontanol has faster cell division resulting in bigger roots and branches. Triacontanol has been demonstrated to improve hormone functionality and root enzymatic activity when administered to plants at their peak growth period.

NAA hormone has many beneficial effects on plants including the ability to initiate flowering speed up, chlorophyll production, prevent fruit falling, improve crop maturity and boost agricultural yields

The most important components of strawberry quality are appearance, firmness, flavor, maturity and absence of damage to the fruit. As the strawberry flavor and fragrance are among the most popular hedonic characteristics for consumers. Strawberry fruits are widely used in a variety of manufacturing, including foods, beverages, confectionaries, perfumes and cosmetics.

The strawberry crop encounters various internal and external challenges that adversely affect plant growth, development, and ultimately reduce crop productivity and postharvest quality. The objective of this research is to enhance overall organoleptic quality by emphasizing and investigating the effects of plant spacing and hormonal treatments to support sustainable fruit quality.

2. Material and Methods

The study was conducted at the College of Agriculture, Ummedganj Kota, Rajasthan over two growing seasons (2021-22 and 2022-23) to assess the influence of plant spacing and growth regulators on the organoleptic quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn. The experiment followed a factorial randomized block design with eighteen treatment combinations that included two plant spacing (15 cm × 30 cm and 30 cm × 30 cm) and three plant growth regulators: salicylic acid (at 50 ppm, 100 ppm and 150 ppm), Triacontanol (at 5 ppm, 10 ppm and 15 ppm) and NAA (at 25 ppm, 50 ppm and 75 ppm). For this purpose strawberry fruits were harvested done when the fruits attained more than 75% color. At harvest, the fresh strawberry fruits were assessed by a panel of judges for quality parameters, including color, taste, aroma, texture and general appearance. An organoleptic scoring system ranging from 1 to 9 point Hedonic scale was used. The mean of scores given by the judges were used for statistical analysis as shown in table 1 below:

Table-1.Hedonic scale rating for various organoleptic attributes described by Ranganna, 2009

Hedonic scale	Colour	Flavor	Taste	General appearance
Like extremely	9	9	9	9
Like very much	8	8	8	8
Like moderately	7	7	7	7
Like slightly	6	6	6	6
Neither like or dislike	5	5	5	5
Dislike slightly	4	4	4	4
Dislike moderately	3	3	3	3
Dislike very much	2	2	2	2
Dislike extremely	1	1	1	1

2.1 Statistical Analysis

The data recorded during field experimentation and data obtained from laboratory determination were subjected to the statistical analysis of variance using factorial randomized block design as described by Panse and Sukhatme (1985). The overall significance of difference among the treatments was tested, using critical differences (C.D.) at 5% level of significance. The results were statistically analyzed with the help of a windows-based computer package OPSTAT which calculated the standard error of the difference in mean (SEd) and Critical difference (CD) between the treatments at 5% level of significance. Graphs were prepared by using Microsoft Excel (MS office ver. 2007).

3. Results and Discussion

3.1 Organoleptic score

3.1.1 Colour and Flavour

3.1.2 Effect of Spacing

The maximum colour and flavour mean score measuring of (7.21), (7.60) (7.41) and (7.17), (7.99) and (7.58) respectively were recorded in S_2 (30 cm ×30 cm) during the years of 2021-22, 2022-23 and in the overall combined data, indicating notable superiority over other spacing levels. In contrast, the minimum colour and flavour mean score, (7.02), (7.26), (7.14) and (6.92), (7.81) and (7.37) respectively were recorded at the spacing level, S_1 (15 cm ×30 cm) during the years of 2021-22, 2022-23 and in the overall combined data. The result of this study indicate that selecting a 30 cm×30 centimeter spacing is a preferable option for attaining great colour and flavor compared to choosing a 15×30 cm spacing. The results are in accordance with Shiranal *et al.* (2019).

3.1.3 Effect of plant growth regulators (PGRs)

The maximum colour and flavour mean score measuring of (8.73), (8.92), (8.85) and (8.65), (8.87) and (8.72) respectively was found to be the maximum in treatments treated with SA @ 100ppm. Following closely, NAA @ 75 ppm demonstrated colour and flavor mean score of (8.36), (8.63), (8.50) and (8.23), (8.54) and (8.39) for both successive harvesting years and in the overall combined data. Conversely, the minimum colour and flavour mean score measuring of (6.24), (6.40), (6.32) and (6.05), (7.14) and (6.60) were recorded in plants treated with TA@5ppm for both successive harvesting years and in the overall combined data, respectively. The findings indicated that using salicylic acid (SA) at a concentration of 100 ppm showed great effectiveness compared to other plant growth regulators. These findings closely align with previous studies by Akhtar *et al.* (2015).

3.1.4 Interaction effect of spacing and plant growth regulators (S × PGRs)

The interplay between different spacing levels and plant growth regulators significantly affected the colour and flavour of the strawberry. The maximum colour and flavour mean score measuring of (8.81), (8.93), (8.87) and (8.69), (8.80), (8.74) respectively were recorded in treatment combination of S_2+SA100 ppm (30 cm ×30 cm + SA@100 ppm) for both years of 2021-2022, 2022-2023 and in pooled data. The maximum mean scores for colour (8.49), (8.66), (8.58) and flavour (8.35), (8.67) and (8.51) recorded in treatment combination of S_2+NAA75

ppm (30 cm ×30 cm spacing + NAA at 75 ppm) for both individual years of 2021-2022 & 2022-2023 and in pooled data respectively. Conversely, the minimum colour and flavor mean score (6.22), (6.31), (6.26) and (6.03), (6.95) and (6.49) were noted in S_2+TA@5 ppm (15 cm×30 cm spacing + TA@5 ppm) for the years 2021-22, 2022-23 and in the combined data, respectively. The present study is also in consonance with the reports of Kazemi *et al.* (2013).

3.2 Taste and General Appearance

3.2.1 Effect of spacing

Regarding analyzing the data, the highest mean scores for taste and general appearance, measuring of (7.74), (7.81), (7.77) and (7.55), (8.13), (7.84) were observed in S_2 (30 cm ×30 cm) during the years 2021-22, 2022-23 and in the overall combined data respectively, indicating notable superiority over other spacing levels. In contrast, the minimum mean scores for taste and general appearance recorded (7.32), (7.45), (7.39) and (6.87), (7.64), (7.26), were noted at the spacing level, S_1 (15 cm ×30 cm) during the years of 2021-22, 2022-23 and in the overall combined data, respectively. These findings are consistent with the results reported by Datta *et al.* (2023) and Bhatia *et al.*(2017).

3.2.2 Effect of plant growth regulators (PGRs)

In the assessment of various levels of plant growth regulators, the mean score for taste and general appearance, measuring of (8.47), (8.84), (8.65) and (8.24), (8.75) and (8.49) was observed to be the highest in treatments treated with SA @ 100 ppm. Close behind, NAA @ 75 ppm demonstrated mean scores for taste and general appearance of (8.08), (8.16), (8.12) and (7.75), (8.48) and (8.12) for both individual years of 2021-2022 & 2022-2023 and in overall combined data, respectively. Conversely, the minimum mean scores for taste and general appearance measuring of (6.33), (6.42), (6.38) and (6.36), (6.72) and (6.54) found in treatment treated with TA@5ppm for both individual years of 2021-2022 & 2022-2023 and in overall combined data, respectively. The results showed that application of salicylic acid (SA) at a concentration of 100 ppm was more successful than using other plant growth regulators. These findings closely align with previous studies by El-sayed *et al*. (2015) and Sandhyarani *et al.* (2024).

3.2.3 Interaction effect of spacing and plant growth regulators (S × PGRs)

The interaction between different spacing levels and plant growth regulators significantly influenced the taste and general appearance of strawberries. The highest mean scores for taste and general appearance, measuring of (8.83), (8.89), (8.86) and (8.51), (8.78), (8.65) were observed in treatment combination of S_2+SA100 ppm (30 cm ×30 cm spacing + SA at 100 ppm). Followed by S_2+NAA75 ppm (30 cm ×30 cm spacing + NAA at 75 ppm) demonstrated taste and general appearance mean scores of (8.35), (8.43), (8.39) and (8.05), (8.76) and (8.40) for both individual years of 2021-2022 & 2022-2023 and in the pooled data, respectively. On the other hand, the minimum mean scores for taste and general appearance measuring of (6.30), (6.36), (6.33) and (6.12), (6.30) and (6.21) were noted in treatment combination of S_1+TA@5ppm (15 cm ×30 cm spacing + TA at 5 ppm) for the years 2021-22, 2022-23 and in the combined data, respectively. This resulted in the best outcomes for the growth and development of the plants. The current study aligns with Meena *et al.* (2023) and kumar *et al.* (2019).

Table 2- Effect of Spacing and PGRs on Color and Flavor of Strawberry cv. Winter Dawn

Treatments	Color (Out of 9 Point)			Flavor (Out of 9 Point)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Spacing(S)					
S_1 15 × 30cm	7.02	7.26	7.14	6.92	7.81	7.37
S2 30 × 30 cm	7.21	7.60	7.41	7.17	7.99	7.58
SE(m)±	0.02	0.06	0.03	0.06	0.01	0.03
CD(P=0.05)	0.06	0.17	0.09	0.17	0.03	0.09
	Plant Growth Regulators (PGRs)					
SA 50 ppm	7.45	7.58	7.52	7.30	8.12	7.71
SA 100 ppm	8.73	8.92	8.85	8.65	8.87	8.72
SA 150 ppm	7.66	8.20	7.93	7.93	8.37	8.15
NAA 25 ppm	6.44	6.76	6.60	6.23	7.75	6.99
NAA 50 ppm	6.51	7.11	6.81	6.81	7.94	7.38
NAA 75 ppm	8.36	8.63	8.50	8.23	8.54	8.39
TA 5 ppm	6.24	6.40	6.32	6.05	7.14	6.60
TA 10 ppm	6.27	6.60	6.43	6.10	7.20	6.65
TA 15 ppm	6.39	6.69	6.54	6.12	7.28	6.70
SE(m)±	0.01	0.03	0.02	0.02	0.01	0.02
CD(p=0.05)	0.03	0.08	0.04	0.08	0.01	0.04
Treatment Combinations	Interaction effect of Spacing and PGRs					
S_1+SA 50 ppm	7.18	7.41	7.29	7.13	8.05	7.59
S_2+SA 50 ppm	7.72	7.75	7.74	7.46	8.18	7.82
S_1+ SA 100 ppm	8.65	8.91	8.78	8.62	8.77	8.69
S_2+SA 100 ppm	8.81	8.93	8.87	8.69	8.80	8.74
S_1+SA 150 ppm	7.56	7.98	7.77	7.52	8.30	7.91
S_2+SA 150 ppm	7.75	8.41	8.08	8.34	8.43	8.38
S_1+NAA 25 ppm	6.39	6.46	6.42	6.21	7.72	6.97
S_2+NAA 25 ppm	6.49	7.06	6.78	6.24	7.78	7.01
S_1+ NAA 50 ppm	6.42	6.93	6.67	6.50	7.93	7.22
S_2+NAA 50 ppm	6.61	7.28	6.95	7.13	7.95	7.54
S1+NAA 75 ppm	8.22	8.60	8.41	8.10	8.41	8.26
S2+ NAA 75 ppm	8.49	8.66	8.58	8.35	8.67	8.51
S1+TA 5 ppm	6.22	6.31	6.26	6.03	6.95	6.49
S2+TA 5 ppm	6.25	6.49	6.37	6.08	7.33	6.71
S1+TA 10 ppm	6.24	6.35	6.30	6.08	7.05	6.57
S2+TA 10 ppm	6.29	6.85	6.57	6.11	7.36	6.73
S1+TA 15 ppm	6.35	6.41	6.38	6.10	7.15	6.63
S2+TA 15 ppm	6.44	6.96	6.69	6.14	7.41	6.78
SE(m)±	0.03	0.08	0.04	0.08	0.01	0.04
CD(p=0.05)	0.08	0.24	0.12	0.25	0.04	0.13

Table 3-Effect of Spacing and PGRs on Taste and General appearance of Strawberry cv. Winter Dawn

Treatments	Taste (Out of 9 Point)			General appearance (Out of 9 Point)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
	Spacing(S)					
S_1 15 × 30cm	7.32	7.45	7.39	6.87	7.64	7.26
S2 30 × 30 cm	7.74	7.81	7.77	7.55	8.13	7.84
SE(m)±	0.07	0.07	0.06	0.06	0.01	0.03
CD(P=0.05)	0.21	0.21	0.18	0.19	0.03	0.09
	Plant Growth Regulators (PGRs)					
SA 50 ppm	7.91	7.96	7.93	7.59	8.37	7.98
SA 100 ppm	8.47	8.84	8.65	8.24	8.75	8.49
SA 150 ppm	7.99	8.04	8.02	7.65	8.43	8.04
NAA 25 ppm	7.50	7.57	7.54	6.82	7.88	7.35
NAA 50 ppm	7.74	7.81	7.78	7.24	8.11	7.68
NAA 75 ppm	8.08	8.16	8.12	7.75	8.48	8.12
TA 5 ppm	6.33	6.42	6.38	6.36	6.72	6.54
TA 10 ppm	6.68	6.72	6.70	6.47	7.00	6.74
TA 15 ppm	7.06	7.12	7.09	6.77	7.22	6.99
SE(m)±	0.04	0.03	0.03	0.03	0.01	0.02
CD(p=0.05)	0.10	0.11	0.08	0.08	0.02	0.04
Treatment Combinations	Interaction effect of Spacing and PGRs					
S_1+SA 50 ppm	7.68	7.75	7.71	7.26	8.07	7.67
S_2+SA 50 ppm	8.13	8.18	8.15	7.92	8.67	8.30
S_1+ SA 100 ppm	8.11	8.78	8.44	7.96	8.72	8.34
S_2+SA 100 ppm	8.83	8.89	8.86	8.51	8.78	8.65
S_1+SA 150 ppm	7.81	7.87	7.84	7.31	8.13	7.72
S_2+SA 150 ppm	8.18	8.20	8.19	7.98	8.73	8.36
S_1+NAA 25 ppm	7.07	7.15	7.11	6.38	7.78	7.08
S_2+NAA 25 ppm	7.93	8.00	7.96	7.25	7.98	7.61
S_1+ NAA 50 ppm	7.48	7.55	7.52	7.03	8.03	7.53
S_2+NAA 50 ppm	8.00	8.07	8.04	7.46	8.19	7.82
S1+NAA 75 ppm	7.82	7.89	7.85	7.45	8.20	7.83
S2+ NAA 75 ppm	8.35	8.43	8.39	8.05	8.76	8.40
S1+TA 5 ppm	6.30	6.36	6.33	6.12	6.30	6.21
S2+TA 5 ppm	6.35	6.48	6.42	6.59	7.13	6.86
S1+TA 10 ppm	6.59	6.61	6.60	6.14	6.65	6.39
S2+TA 10 ppm	6.77	6.83	6.80	6.80	7.36	7.08
S1+TA 15 ppm	7.04	7.07	7.06	6.17	6.88	6.52
S2+TA 15 ppm	7.08	7.16	7.12	7.37	7.56	7.46
SE(m)±	0.11	0.10	0.09	0.09	0.02	0.05
CD(p=0.05)	0.30	0.31	0.25	0.27	0.05	0.13

Conclusion

The study concluded that a plant spacing of 30 cm × 30 cm, combined with the application of salicylic acid at a concentration of 100 ppm, produced the best results for organoleptic qualities such as color, flavor, taste, and overall appearance. These findings present a promising approach for strawberry cultivation, as the improved fruit characteristics are likely to enhance marketability.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

References

A.O.A.C. (1980) Official methods of analysis. Association of Official Analytical Chemist. Washington, D.C. USA.

Akhtar, I., & Rab, A. (2015). Effect of fruit ripening stages on strawberry (*fragaria X ananassa*. Duch) fruit quality for fresh consumption. *Journal of Agricultural Research* (03681157), **53**(3): 413-424.

Bhatia, S.K., Sharma, R., Kumar, R (2017). Effect of different planting time and spacing on growth, yield and quality of strawberry (*Fragaria* × *ananassa*) cv. Ofra. *International Journal of Pure and Applied Bioscience*, **5**(5): 207-211.

Datta, H. S., Barua, P. C., Kotoky, U., Das, R., Saikia, H., & Devanath, H. (2023). Crop Geometry and Mulch on Strawberry Postharvest Quality. In Edible Berries-New Insights. *Intech Open.*

El-Sayed, R., &Habasy, Y. (2015). Effect of spraying salicylic acid on fruiting of Valencia orange trees. *Alexandria Journal of Agricultural Sciences*, **60**(3): 119-126.

Hancock, J., &Erez, A. (2000). Strawberries. Temperate Fruit Crops in Warm Climate. *Springer Science and Business Media*.

Hannum, S. M. (2004). Potential impact of strawberries on human health: a review of the science. *Critical Reviews in Food Science and Nutrition*, **44**(1): 1-17.

Kazemi, M (2013). Foliar application of salicylic acid and calcium on yield, yield component and chemical properties of strawberry. *Bulletin of Environment, Pharmacology and Life Sciences*,**2**(11): 19-23.

Kumar, S., & Kaur, G. (2019). Effect of pre and post harvest applications of salicylic acid on quality attributes and storage behaviour of strawberry cv. Chandler. *Journal of Pharmacognosy and Phytochemistry*, **8**(4): 516-522.

Meena, R. L., Ram, R. B., Bunker, R. R., Meena, D. C., Meena, A. K., Meena, S. K., & Kumar, M. (2023). The efficacy of different mulching with spacing on quality of strawberry (*Fragariaananassa*Duch.) cv.chandler.*The Pharma Innovation Journal*, **12**(3): 2238-2242.

Olsson, M. E., Ekvall, J., Gustavsson, K. E., Nilsson, J., Pillai, D., Sjöholm, I., & Nyman, M. G. (2004). Antioxidants, low molecular weight carbohydrates, and total antioxidant

capacity in strawberries (*Fragaria× ananassa*): effects of cultivar, ripening, and storage. *Journal of Agricultural and Food Chemistry*, ***52***(9): 2490-2498.

Panse, V.G. and Shukhatme, P.V. (1967). Statistical Methods for Agricultural Workers, 2nd eds. Indian Council of Agriculture Research, New Delhi.

Sandhyarani, M., Lakshmi, R. R., Madhavi, M., & Kanaka, B. Studies on organoleptic evaluation in mango (Mangiferaindica L.) germplasm.

Shiranal, R., Patil, S. N., & CJ, N. K. (2019). Effect of pruning intensities and time of pruning on organoleptic evaluation of guava cv. Sardar under different planting densities. *Journal of Pharmacognosy and Phytochemistry*, **8**(1): 2248-2250.