Original Research Article

Influence of Foliar application of Seaweed extract and humic acid on growth, yield and quality of strawberry (*Fragaria* × *ananasa* duch) cv. winter dawn

Abstract

The present investigation entitled "Influence of foliar spraying of Seaweed extract and Humic acid on growth, yield and quality of Strawberry (*Fragaria* × *ananasa* duch) cv. Winter dawn" was carried out during the year 2022 in the Department of Horticulture, Sam Higginbottom University of Agriculture Technology & Sciences Prayagraj in November 2022 to March 2023. This experiment was conducted to evaluate the best treatment combination of Seaweed Extract and Humic acid concentration for producing the best quality strawberry. The experiment was laid out in Randomized Design having 9 treatments and replicated 3 times.

The T_9 (SWE @ 8000ppm + Humic acid @ 3.0 g/L) recorded highest values in terms of growth parameters i.e. number of leaves (7.83, 15.58, 23.66, 30.08), plant height (7.88, 12.21, 15.25, 18.06), plant spread (13.38 E-W, 13.41 N-S; 15.4 E-W, 15.43 N-S; 21.55 E-W, 21.01 N-S; 24.44 E-W, 24.45 N-S) at different stages of growth i.e 30, 60, 90, and 120 days after planting as compared to T_1 (control) and all other treatments. Plant treatment T_9 also recorded earliest flowering (48.42 days) and earliest fruiting (70.42). Fruit weight (30.84g), fruit length (5.84cm) and diameter (4.05cm) are found superior followed by T_8 (SWE @ 7000ppm + Humic acid @ 3.0 g/L). Higher yield (343.52g) and higher number fruits per pant (20.66) was observed in T_9 and the lower yield and less number of fruits per plant in T_1 (control). In Fruit quality characters, higher TSS (11.13^{O}B), lower acidity (0.58%) and high amount of ascorbic acid (60.16 mg/100 g) was observed in T_9 followed by T_8. Higher concentrations of seaweed extract and humic acid have been found to have a more significant positive impact on the yield quality of strawberries, demonstrating their superiority in enhancing crop productivity.

Key words: Strawberry, Seaweed extract, Humic acid

1. INTRODUCTION

The strawberry, scientifically known as Fragaria ananassa and belonging to the Rosacae family, holds a significant position among fruit crops, encompassing approximately 20 different species. The Fragaria genus comprises 17 additional species, including diploid, tetraploid, hexaploid, and octaploid variations. The cultivated strawberry is octaploid, with a chromosome count of

2n=8x=56. Renowned for its small, firm, pink to red, and aromatic fruit, the strawberry is highly perishable and finds applications in making jams, juices, and other high-quality products, apart from being consumed fresh. Strawberry plants propagate through runners, which are sent out by the mother plant when the root system becomes woody, thus enabling the enlargement of the plant. For optimal growth and development, strawberries require a daytime temperature ranging from 22°C to 23°C and a nighttime temperature of 7°C to 13°C. Frost and winter injuries can significantly reduce berry yield. Sandy loam soils with a pH range of 5.5 to 6.5 are ideal for strawberry cultivation. With its aggregate fruit structure, strawberries have become one of the most important soft fruits globally, second only to grapes. Their wide distribution is attributed to their genotypic diversity, highly heterozygous nature, and ability to adapt to diverse environmental conditions (Larson, 1994; Childers et al., 1995). Strawberry holds a prominent position as one of the most significant fruit crops worldwide. In recent years, it has gained tremendous popularity among Indian growers in the vicinity of towns and cities due to its lucrative prices and high profitability. This surge in demand has led to a remarkable increase in both the cultivation area and production of strawberries (Sharma and Sharma, 2004; Sharma *et al*., 2006; Singh *et al*., 2006; Singh *et al*., 2007).In India, the National Bureau for Plant Genetic Resources introduced strawberries at the Regional Research Station in Shimla. Currently, strawberries are grown in Shimla, Bilaspur, Kangra, Kullu, Palampur (Himachal Pradesh), Dehradun, Nainital, Srinagar, parts of West Bengal, and extended to Pune and Mahabaleshwar (Maharashtra), Bengaluru, and Coorg (Karnataka). They are primarily cultivated as a winter crop from October to March. Maharashtra is the leading producer of strawberries in India, accounting for approximately 85 percent of the total production. In 2020, global strawberry production reached 8.9 million tonnes, with China leading at 38 percent (3.3 million tonnes), followed by the USA (1.1 million tonnes) (FAOSTAT, 2023). Ripe strawberries consist of approximately 89.5% water, 3.7%-8.5% sugar, 0.4% ash, and high levels of pectin (0.5%-1.36%), but they do not contain starch. These fruits are a rich source of vitamins and minerals (Singh et al., 2007), providing a fairly good amount of vitamin A (60 IU/100g of edible portion) and vitamin C (30-120mg/100g of edible portion). Ripe strawberries attain an attractive red color upon maturity, mainly due to the presence of an anthocyanin called pelargonidin 3-monoglucoside, along with traces of cyanidin (Singh and Sharma, 1970). The high pectin content, primarily in the form of calcium pectate, makes strawberries excellent for jelly-making (Mitra, 1991). Additionally, the fruit contains total soluble solids (7-12%), total sugars (5.0%), and acids (0.90-1.85%). In modern agriculture, there is a growing interest in using water-soluble fertilizers for multi-nutrient foliar feeding. This method effectively corrects nutrient deficiencies, as the nutrients are easily absorbed by plants. Foliar feeding minimizes environmental pollution, optimizes nutrient utilization, and enhances sugar production during times of stress. It also improves plant production, yield, and quality, particularly in situations where there is limited nutrient uptake from the soil and competition for carbohydrates among plant organs. Compared to traditional soil applications, foliar application offers rapid nutrient correction and better control over plant responses. The use of water-soluble fertilizers and humic acid has shown promising results in increasing strawberry production and quality, making it an important technique in modern agriculture. Humic compounds have been found to enhance soil structure and promote the growth of soil microbes. They also increase the cation exchange capacity of the soil, which is crucial for nutrient availability to plants. Moreover, these compounds indirectly benefit plant roots by providing essential macro and micronutrients, thereby improving soil fertility (Tan, 2003). Additionally, when plants face water stress, the application of foliar sprays containing humic molecules has been shown to enhance leaf water retention, improve photosynthetic efficiency, and support antioxidant metabolism (Jiu *et al*., 1995).Bio stimulants refer to non-fertilizer products that have beneficial effects on plant growth and do not contain chemicals or synthetic plant growth regulators (Russo and Berlyn, 1990). Macroalgae, also known as seaweeds, comprise approximately 10,000 species and contribute to 10% of global marine productivity (Craigie, 2011). In recent years, natural seaweeds have been increasingly replacing synthetic fertilizers. Various commercial seaweed extract products have been studied for their effects on fruit crops (Khan *et al*., 2009). Seaweed extracts are marketed as liquid fertilizers and bio-stimulants due to their content of numerous growth regulators, including cytokinins (Durand *et al*., 2003), auxins (Sahoo, 2000), gibberellins (Strik and Staden, 1997), In addition to being rich in growth regulators, seaweed extracts also provide a wide range of macro and micronutrients that are vital for optimal plant growth and development. Seaweeds are primitive non-flowering plants that lack true roots, stems, and leaves. They encompass a wide range of species, estimated to be between 25,000 and 30,000, exhibiting great diversity (Shyamala *et al*., 2014). Seaweeds are classified into three main groups based on pigmentation: brown algae (Phaeophyta), red algae (Rhodophyta), and green algae (Chlorophyta) (Meillisa *et al*., 2013). With a high water content of 80-90%, seaweeds possess carbohydrates that make up around 50% of their dry weight, 1-3% lipids, and 7-8% minerals. Protein content varies but can range from 10% to 47%, often containing essential amino acids in significant proportions (El-Said and El-Sikaily, 2013). Seaweeds are known for their abundance of polysaccharides, minerals, omega 3 and 6 polyunsaturated fatty acids (PUFA), vitamins, and bioactive substances such as polyphenols, which confer properties such as anti-hyperlipidemic, antihypertensive, and antibacterial effects (Chan *et al*., 2015).

2. MATERIALS AND METHODS

The experiment was conducted between November 2022 and March 2023 at the Horticulture Research Farm, Department of Horticulture at Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS). The institute is located in Prayagraj (U.P.), situated at latitude 25^0 39‟ 42” N, longitude $81^0$67‟56” E, and an altitude of 98 meters above sea level.

The experiment was carried out by applying a combination of seaweed extract and humic acid through foliar application on the winter dawn variety of Strawberry. The experiment contained was performed in Randomized block design comprising 9 treatments replicated 3 times. The treatments used are as follows in Chart 1.

Chart 1. List of treatments and their details used for the study

Treatment symbol	Treatment detail
T_1	Control
T_2	Seaweed extract @1000ppm + Humic acid @3g/lt
T_3	Seaweed extract @2000ppm + Humic acid @3g/lt
T_4	Seaweed extract @3000ppm + Humic acid @3g/lt
T_5	Seaweed extract @4000ppm + Humic acid @3g/lt
T_6	Seaweed extract @5000ppm + Humic acid @3g/lt
T_7	Seaweed extract @6000ppm + Humic acid @3g/lt
T_8	Seaweed extract @7000ppm + Humic acid @3g/lt
T_9	Seaweed extract @8000ppm + Humic acid @3g/lt

3. RESULTS AND DISCUSSION

3.1 Growth parameters

In the study, the maximum number of leaves in strawberry plants at different time intervals (30, 60, 90, and 120 days after planting) were observed. The plants treated by treatment T_9, which consisted of Seaweed extract at 8000ppm and humic acid at 3g/lt, demonstrated the highest number of leaves 7.83, 15.58, 23.66, and 30.08 respectively. As the treatments progressed from lower to higher combinations, the number of leaves per plant exhibited a gradual increase. These findings align with previous research conducted by (Alkharpothy *et al.* 2017), thus reinforcing the consistency of the results. Accordingly, the plant height was recorded at various time intervals (30, 60, 90, and 120 days after planting). The treatment T_9, which involved spraying Seaweed extract at 8000ppm and applying Humic acid at 3g/lt, resulted in the highest plant heights recorded: 7.88, 12.21, 15.25, and 18.06 respectively. Over time, as the plants grew, the treatment T_9 consistently displayed taller heights compared to the control group. These results highlight the positive impact of the Seaweed extract and Humic acid treatment on promoting plant growth, as observed in previous studies. The height of strawberry plants showed a significant improvement upon the application of SWE, possibly due to the growth regulators like cytokinin and nutrients present in it. These components may have influenced the cellular metabolism of the plants, resulting in enhanced growth and vitality. As reported by (Ramkissoon *et al*. 2017) tomato plants treated with red, brown and green species of seaweed extract resulted in increased plant height and overall increase in biomass. Similar to plant height, the plant spread of strawberry plants was also measured at various time intervals (30, 60, 90, and 120 days after planting). The treatment T9, which involved applying Seaweed extract at 8000ppm and humic acid at 3g/lt, resulted in the maximum plant spread in both the East-West and North-South directions. The observations recorded were 13.38, 15.4, 21.55, and 24.44 in the East-West direction, and 13.41, 15.43, 21.01, and 24.45 in the North-South direction, respectively, at the corresponding time intervals. These findings indicate that the higher combination of seaweed extract and humic acid T_9 positively influenced the lateral growth and overall spread of the strawberry plants. The observed increase in shoot characteristics of the strawberry plants could potentially be attributed to the presence of macronutrients found in seaweed extracts. Macronutrients, such as nitrogen, potassium, and phosphorus, play vital roles in plant nutrition, supporting growth and development (Attememe, 2009). Additionally, the auxin content present in seaweed extracts may contribute to cell division and enlargement, ultimately leading to enhanced shoot growth and an increase in the number of leaves (Gollan and Wright, 2006). Furthermore, the addition of humic acid to the treatment regimen enhances soil porosity and improves the growth of the root system. This, in turn, aids in nutrient absorption, subsequently resulting in increased shoot growth (Garcia *et al*., 2008).

3.2 Phenological parameters

The plants treated with treatment T_9 (SWE @8000ppm + Humic acid @g/lt) showed the fastest appearance of the first flower, taking only 48.42 days. On the other hand, the untreated plants took the longest time, with 62 days for the first flower to appear. The accelerated flowering observed in the plants treated with SWE may be attributed to the presence of growth regulators such as cytokinin and auxin, which are known to promote early flowering in strawberries (Hou and Huang, 2005). Seaweed extract contains natural growth regulators like cytokinin and indole acetic acid, which are thought to enhance flower initiation and induce early flowering. (Chapman and Chapman, 1980; Hegab *et al*., 2005; Battacharyya *et al*., 2015).Similarly, the treated plants with a higher concentration of seaweed extract and humic acid (T_9) exhibited early fruit appearance, taking only 70.42 days. In contrast, the untreated plants showed delayed fruit appearance, taking 84.75 days. Seaweed extract has been recognized for its ability to stimulate early flowering and fruit set in various crops, possibly due to promoting robust plant growth during the initial stages of plant development (Rana *et al*., 2022).

3.3 yield parameters

The yield of the plants was assessed based on the number of fruits per plant and the total fruit production per plant. The plants treated with a higher concentration of seaweed extract and humic acid (T_9) displayed the maximum number of fruits, with 20.06 fruits per plant. In contrast, the untreated plants had the minimum number of fruits, with only 11.41 fruits per plant. This study reveals that the application of seaweed extract and humic acid improves the yield compared to untreated and low concentration treated plants. Furthermore, the total fruit production per plant was measured, and treatment T_9 exhibited the highest yield, producing 343.52 grams of fruits per plant. On the other hand, treatment T_1, which consisted of untreated plants, recorded the lowest total fruit production per plant, with 173.14 grams. These findings highlight the positive impact of seaweed extract and humic acid treatments on enhancing the overall fruit yield. Seaweed contains essential macro elements such as nitrogen (N), phosphorus (P), potassium (K), and manganese (Mn) that fulfill the mineral requirements of plants for crucial processes like photosynthesis, respiration, cell division, and elongation. Additionally, seaweed plays a vital role in providing micro elements like iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn), which are necessary for protein synthesis, chlorophyll production, the synthesis of the hormone IAA (indole-3-acetic acid) responsible for elongation, and cell division. These elements contribute to an increased amount of processed food and its accumulation within the plant, supporting overall growth and development. (Al- Temini, 2019).

3.4 Fruit quality characters

The fruit quality characteristics, including fruit weight, fruit length, fruit diameter, TSS (Total Soluble Solutes), acidity, and ascorbic acid content, were assessed through chemical analysis of selected fruits. The fruits harvested from plants treated with T_9 showed the maximum fruit weight (30.84 g), length (5.84 cm), and diameter (4.05 cm). In this study, the foliar application of SWE significantly increased fruit length, breadth, and weight compared to the control group. SWE is known to contain cytokinins, auxins, and betaines, which may have influenced cell division during the early stages of fruit growth. The presence of SWE might have also affected the endogenous auxin concentration in developing fruits, leading to increased receptacle enlargement and consequently larger fruit size. These findings are consistent with previous studies. (Noorie and Keathley 2006) reported that SWE applications in Thompson seedless grapes resulted in a 13% increase in berry size and a 39% increase in berry weight compared to the control. Similar results were observed by (Chouliaras and Gerascapoulos 1997) in kiwifruit, (Roussos *et al.* 2009) in strawberries and (Colavita *et al.* 2011) in pears. These studies demonstrated the positive effects of SWE on enhancing fruit size and weight in various crops.

The fruits harvested from plants treated with a higher concentration of seaweed extract and humic acid (T_9) exhibited the highest content of total soluble solute, measuring 11.13 ºB. In contrast, the lowest total soluble solute content of 6.43 ºB was recorded in fruits from untreated plants. These findings align with previous studies conducted by (Abd El-Motty *et al.* 2010) in mango, (Mawgoud *et al.* 2010) in watermelon, (Khan *et al.* 2012) in grapes, (Ahmed *et al.* 2013) in Valencia orange, and (El-Miniawy *et al.* 2014) in strawberries. The increase in total soluble solids can be attributed to the higher carbohydrate content in strawberry plants treated with seaweed extract, as suggested by (El-Miniawy *et al.* 2014). Additionally, the study observed that the minimum acidity percentage of 0.58% was recorded in fruits from T_9, while the maximum acidity percentage of 0.91% was recorded in T_1 (untreated plants). The results indicate that the acidity value increased in the control group, possibly due to a lesser breakdown of metabolites in the fruits of untreated plants. These findings align with the research of (El-Moniem and Abd-Allah 2008) in grapes, (Ahmed *et al.* 2013) in Valencia orange, and (El-Moniem *et al*. 2008) in bananas, which also reported reduced acidity in plants treated with seaweed extract. Furthermore, the study found that the maximum ascorbic acid content of 60.16 mg/100g was present in T_9, while the minimum content of 52.13 mg/100g was found in T_1 (untreated plants). Application of seaweed extract significantly increased the ascorbic acid content in fruits compared to the control group. These results are consistent with the findings of (Khan *et al*. 2012), who reported higher ascorbic acid contents in grapevines treated with a mixture of amino acids and Ascophyllum nodosum extract. Similar results were also reported by (Saeid Eshghi *et al.* 2013) study on strawberries. Overall, these findings support the positive impact of seaweed extract treatment on the total soluble solute content, acidity percentage, and ascorbic acid content of fruits, as observed in various plant species across different studies.

4. CONCLUSION

From this experiment it is concluded that, the usage of higher concentrations of seaweed extract and humic acid, specifically in treatment T_9 (SWE @ 8000ppm + Humic acid @ 3.0 g/L), has shown remarkable effects on the growth parameters and yield quality of strawberries. T_9 exhibited superior results in terms of number of leaves, plant height, plant spread, flowering, fruiting, fruit weight, fruit length, fruit diameter, yield, and number of fruits per plant. Additionally, T_9 demonstrated higher total soluble solids (TSS), lower acidity, and higher ascorbic acid content in the fruits. These findings highlight the significant positive impact of seaweed extract and humic acid on strawberry production, indicating their potential to enhance crop productivity.

5. REFERENCES

Abdulraheem, S. M. (2009) Effect of nitrogen fertilizer and seaweed extracts on vegetative growth and yield of cucumber. – Diyala. *Journal of Agriculture Science.* 1: 134-145.

Abdel-Mawgoud, A.M.R., Tantaway, A., Hafez, Magda., Habib, Hoda. (2010). Seaweed Extract Improves Growth, Yield and Quality of Different Watermelon Hybrids. *Research journal of Agriculture and Sciences*. 6(2): 161-168

Ahmed, F. F., Mansour, A. E. M., Montasser, M. A. A, Merwad, M.A. and Mostafa, E. A. M. (**2013)**. Response of Valencia orange trees to foliar application of roselle, turmeric and seaweed extracts. *Journal of Applied Sciences Research.* 9:960-964.

Al-Temimi, H., Ali, A., Muhsin, Z. (2019). Effect of humic acid and seaweed extract (ALGA) on growth characteristics and nutrient content of local apricot seedlings Prunus armeniaca L.. IOP Conference Series: *Earth and Environmental Science.* 388. 012071. 10.1088/1755-1315/388/1/012071.

Alkharpotly, A. A., Mohamed, R. A., Shehata, M. N. and Awad, A. A. M. (2017). Impact of humic acid soil application and seaweed extract foliar spray on growth, yield and fruit quality of strawberry plants grown under Aswan conditions. *Journal of Soil Sciences and Agricultural Engineering.* 8:307-315

Attememe. J. Y. A. (2009). The effect of humic acid and sea weed extracts on the growth, chemical characteristics and oil characteristics of *Rosmarinus officinalis* L. the 6th scientific conference, Biology Dept., College of Education , University of Tikrit. Plants Sci. P. 1-17.

Dhriti, B., Mahbobeh, Z. B., Pramod, R., Balakrishnan, P. (2015) Seaweed extracts as biostimulants in horticulture, *Scientia Horticulturae*, Volume 196, Pages 39-48, ISSN 0304-4238.

Chapman, V. J., Chapman, D. J. (1980) Seaweeds and their uses, 3rd edn. Chapman and Hall, London, p 334**.**

Chan, P. T., Matanjun, P., Yasir, S., Tek, S. T. (2015). Oxidative stress biomarkers in organs of hyper lipidaemic and normal rats fed tropical red seaweed, *Gracilaria changii*. *Journal of Applied Phycology*. 28. 10.1007/s10811-015-0670-x.

Chouliaras, V. and Gerascapoulos, D. (1997). Effects of seaweed extract on fruit growth, weight and maturation of 'Hayward' kiwifruit. *Acta Horticulturae*. 2:485-489.

Childers, N. F., Morris, J. R. and Sibbett, G. S. (1995). Modern Fruit Science Orchard and Fruit Culture. *Horticulture Publication*, Gainesville, Florida, USA, p 22.

Colavita, G. M., Spera, N., Blackhall and Sepulveda, G. M. (2011). Effect of seaweed extract on pear fruit quality and yield. *Acta Horticulturae. (ISHS)* 909:601-607.

Craigie, J. S. (2011). Seaweed extract stimuli in plant science and agriculture. *Journal of Applied Phycology*. 23:371–393.

Durand., Brian, X., Meyer, C. (2003). The effect of marine bioactive substances (N PRO) and endogenous cytokinins on nitrate reductase activity in Arabidopsis thaliana. *Physiologia Plantarum*. 119:489- 493.

El-Miniawy, S. M., Ragab, M. E., Youssef, S. M. and Metwally, A. A. (2014). Influence of Foliar Spraying of Seaweed Extract on Growth, Yield and Quality of Strawberry Plants. *Journal of Applied Sciences Research*. 10. 88-94.

EI-Moniem, E. A. A. and Abd-Allah, A. S. E. (2008). Effect of green alga cells extract as foliar spray on vegetative growth, yield and berries quality of supervine. *American-Eurasian Journal of Agricultural and Environmental Sciences*. 4:427-433.

El-Motty, E., Shahin, M., El-Shiekh, M., Abd-El-Migeed, M. (2010). Effect of algae extract and yeast application on growth, nutritional status, yield and fruit quality of Keitte mango trees. *Agriculture and Biology Journal of North America.* 1. 421-429. 10.5251/abjna.2010.1.3.421.429.

El-Said, G.F., El-Sikaily, A. (2013) Chemical composition of some seaweed from Mediterranean Sea coast, Egypt. *Environmental Monitoring Assessment* 185, 6089–6099.

Eshaghi, S. and Garazhian, M. (2015). Improving growth, yield and fruit quality of strawberry by foliar and soil drench applications of humic acid. *Iran Agricultural Research*. 34(1): 14-20.

Garcia, M. C. V., F. S. Estrella., M. J. Lopez and J. Moreno (2008). Influence of compost amendment on soil biological properties and plants. *Dynamic Soil, Dynamic Plant*. 1. 1-9.

Gollan, J. R. and J. T. Wright (2006). Limited grazing pressure by native herbivores on the invasive seaweed caulerpa. Taxi folia in a temperate. *Australia Estuary Marine and Freshwater Research.* 57(7):685-694.

Hegab, M. Y., A. M. A. Sharawy and S. A. G. El- Saida (2005). Effect of Algae extract and mono potassium phosphate on growth and fruiting of Balady orange trees. *Minia Journal of Agricultural Research and Developoment*. 25 (1): 50- 72.

Izhar, U., Muhammad, S., Syed, T. S., Sajid, K., Zafar, I., Fazal, I. W., Ehtisham, U. H., Sayyed, H. A. S. and Rahmatullah, K. (2017). Influence of humic acid on growth and yield of strawberry cv. chandler. *Pure and Applied Biology.* Vol. 6, Issue 4, pp1171-1176.

Jiu, C. F., Dao, Q. Y. and Quing. S. W. (1995). Physiological effects of humic acid on drought resistance of wheat (in Chinese), *Yingyong Shengtai Xuebao* 6: 363–367.

Khan, A. S., Ahmad, B., Jaskani, M. J., Ahmad, R. and Malik, A. U. (2012). Foliar application of mixture of amino acids and seaweed (*Ascophylum nodosum*) extract improve growth and physico-chemical properties of grapes. *International Journal of Agriculture and Biology*. 14:383-388.

Khan, W., Rayirath, U. P., Subramanian, S., Jithesh, M. N., Rayorath, P., Hodges, D. M., Critchley, A. T., Raigie, J. S., Norrie, J., Prithiviraj, B. (2009). Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation*. 28:386-399.

Larson, K. D. (1994). Strawberry. (In) Handbook of Environmental Physiology of Fruit Crops, Vol 1, Temperate Fruits, pp 271–97.Schaffer, B. and Andersen, P. C. (Eds). CRC Press, BocaRaton, Fla.

Mitra, S. K. (1991). The strawberry In: Temperate fruits, *Horticulture and Allied Publishers*. Calcutta, India, 549-596

Meillisa, A., Siahaan, E., Jung-Nam, P., Woo, H. C., Byung-Soo, C. (2013). Effect of subcritical water hydrolysate in the brown seaweed Saccharina japonica as a potential antibacterial agent on food-borne pathogens. *Journal of Applied Phycology*. 25. 10.1007/s10811-013-9973-y.

Nabti, E., Jha, B. and Hartmann, A. (2017). Impact of seaweeds on agricultural crop production as biofertilizer. *International Journal of Environmental Science and Technology*. 14, 1119–1134.

Norrie, J. and Keathley, J. P. (2006). Benefits of *Ascophyllum nodosum* marine plant extract applications to Thompson seedless grape production. *Acta Horticulturae*. 727:243-247.

R. R. Sharma., Hare, Krishna., V. B. Patel., Anil, Dahuja., Rajbir, Singh., (2006) Fruit calcium content and lipoxygenase activity in relation to albinism disorder in strawberry, *Scientia Horticulturae*, Volume 107, Issue 2, ISSN 0304-4238.

Rajbir Singh, R.R. Sharma, S.K. Tyagi, (2007) Pre-harvest foliar application of calcium and boron influences physiological disorders, fruit yield and quality of strawberry (*Fragaria×ananassa* Duch.), *Scientia Horticulturae*, Volume 112, Issue 2, ISSN 0304-4238.

Rajbir Singh, R.R. Sharma, R.K. Goyal, (2007) Interactive effects of planting time and mulching on 'Chandler' strawberry (*Fragaria×ananassa* Duch.), *Scientia Horticulturae*, Volume 111, Issue 4, Pages 344-351, ISSN 0304-4238.

Ramkissoon, A., Ramsubhag, A., Jayaraman, J. (2017). Phytoelicitor activity of three Caribbean seaweed species on suppression of pathogenic infections in tomato plants. *Journal of Applied Phycology*. 29. 1-10. 10.1007/s10811-017-1160-0.

Rana, V. S., Sharma, V., Sharma, S., Rana, N., Kumar, V., Sharma, U., Almutairi, K. F., Avila-Quezada, G. D., Abd_Allah, E. F. and Gudeta, K. (2023). Seaweed Extract as a Biostimulant Agent to Enhance the Fruit Growth, Yield, and Quality of Kiwifruit. *Horticulturae*, *9*, 432.

Roussos, P., Nikoleta-Kleio, D., Damvakaris, T. (2009). Strawberry fruit quality attributes after application of plant growth stimulating compounds. *Scientia Horticulturae*. 119. 138-146. 10.1016/j.scienta.2008.07.021.

Russo, R. O., Berlyn, G. P. (1990). The use of organic biostimulants to low input sustainable agriculture. *Journal of Sustainable Agriculture*.1:9–42.

Sahoo, D. (2000). Farming the ocean. In: Seaweeds Cultivation and Utilization. Aravali Books International. New Delhi, India.40.

Sharma, R. R., & Sharma, V. P. (2004). Plant growth and albinism disorder in different strawberry cultivars under Delhi conditions. *Indian Journal of Horticulture*, 61(1), 92-93.

Shyamala, V., Ebciba, C., Santhiya, R., and Thangaraju, N. (2014). Phytochemical screening and in vitro antibacterial, antioxidant and anticancer activity of *Amphiroa fragilissima* (Linneaus) J V Lamoroux. *International Journal of Innovative Research in Science Engineering and Technology*, *3*, 12933-12948.

Singh, R., & Sharma, V. P. (1970). Prospects of growing strawberry in the plains. *Indian Horticulture*, *15*(3), 13-21.

Strik, W., Staden, V. J. (1997). Isolation and identification of cytokinins in a new commercial seaweed product made from *Fucus serratus* L. *Journal of Applied Phycology*. 9:327-330

Tan. K. H. (2003). Chemical composition of humic acid matter. Humic acids in soil and the environment. Principles and Controversies. Marcel and Dekker, New York. USA.

Z. X. Hou. and W. D. Huang. (2005). Immuno-histochemical localization of IAA and ABP1 in strawberry shoot apexes during floral induction. *Planta*, 222: 678-687.

Table 1. Variability in number of leaves in different treatments

Treatment symbol	No of leaves			
	(30DAP)	(60DAP)	(90DAP)	(120DAP)
T_1	2.5	5.08	11.08	19.33
T_2	3.58	9.42	16.92	25.08
T_3	4.16	10.25	16.66	24.92
T_4	4.25	10.75	17.75	25.17
T_5	4.16	10.08	17.92	25.42
T_6	3.66	11.58	20.25	24.25
T_7	4.08	8.92	19.08	24.92
T_8	4.67	10.25	21	24
T_9	7.83	15.58	23.66	30.08
F-Test	S	S	S	S
S.E.(m)(±)	0.35	0.42	0.71	0.32
CD (5%)	1.05	1.26	2.13	0.96
CV	14.12	7.14	6.76	2.23

1

Table 2. Variability in Phenological and Yield characteristics in different treatments

Treatment symbol	Phenological character		Yield characters	
	Days to first flowering (Days)	Days to first fruiting (Days)	No of fruits per plant	total fruit production/plant (g)
T_1	62	84.75	11.41	173.14
T_2	58.92	83	11.91	191.52
T_3	59.08	83	12.75	213.41
T_4	59.33	83.33	14.58	230.59
T_5	58.5	80.83	16	247.85
T_6	56.5	78.33	17.42	262.3
T_7	55.58	76.5	18	292.16
T_8	52.08	73.83	19.42	312.29
T_9	48.42	70.42	20.66	343.52
F-Test	S	S	S	S
S.E.(m)(±)	0.56	0.39	0.18	1.3
CD(5%)	1.69	1.19	0.54	1.85
CV	1.72	0.86	1.99	0.89

Table 3. Variability in Fruit Quality Characters in different treatments

Treatment symbol	Fruit Quality Characters					
	Fruit weight (g)	Fruit length (cm)	Fruit Diameter (cm)	TSS (^{O}brix)	Acidity (%)	Ascorbic acid (mg/100g)
T1	11.1	3.03	2.75	6.43	0.91	52.13
T2	14.42	3.12	3.01	7.17	0.86	53.16
T3	17.64	3.42	3.15	7.43	0.83	55.33
T4	19.94	3.8	3.26	8	0.79	55.8
T5	23.02	4.13	3.45	8.6	0.75	56.13
T6	24.68	4.28	3.57	9.26	0.7	56.83
T7	26.28	4.81	3.67	9.63	0.66	57.06
T8	28.11	5.12	3.89	10.67	0.64	58.06
T9	30.84	5.84	4.05	11.13	0.58	60.16
F-Test	S	S	S	S	S	S
S.E.(m)(±)	0.132	0.03	0.02	0.18	0.01	0.36
CD(5%)	0.39	0.1	0.07	0.56	0.02	1.08
CV	1.05	1.44	1.19	3.7	2.2	1.12

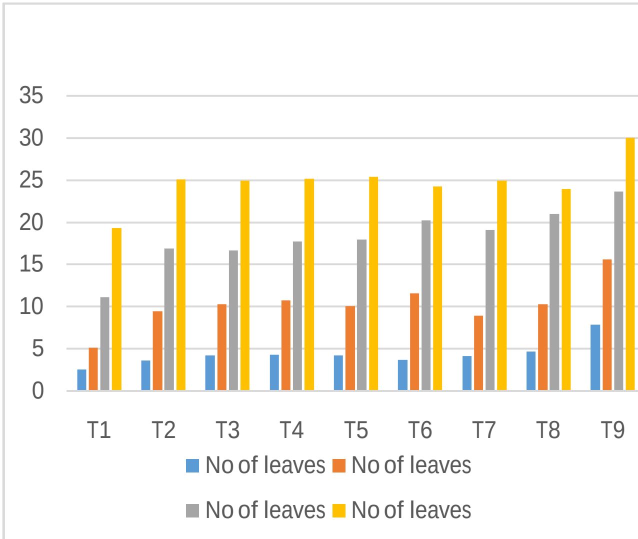

Fig. 1. Growth parameters

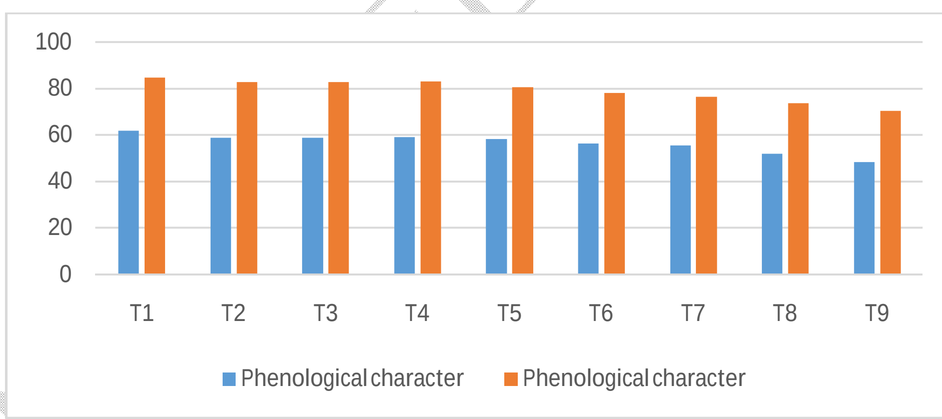

Fig. 2. Phenological parameters

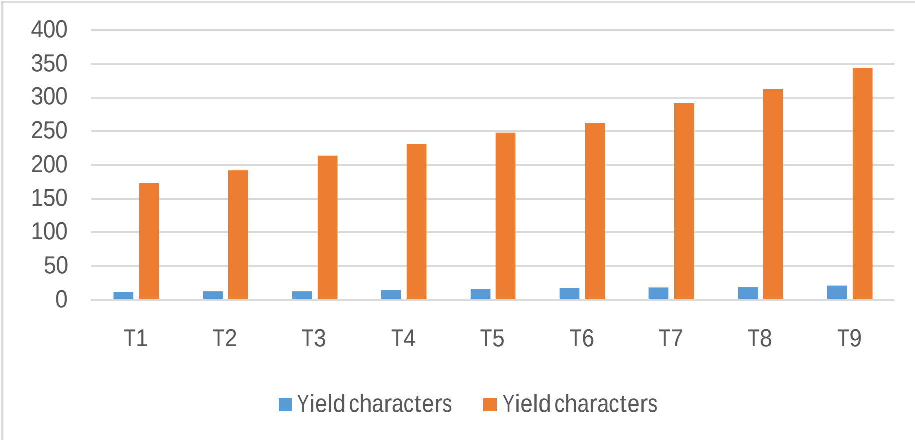

Fig. 3. Yield characters

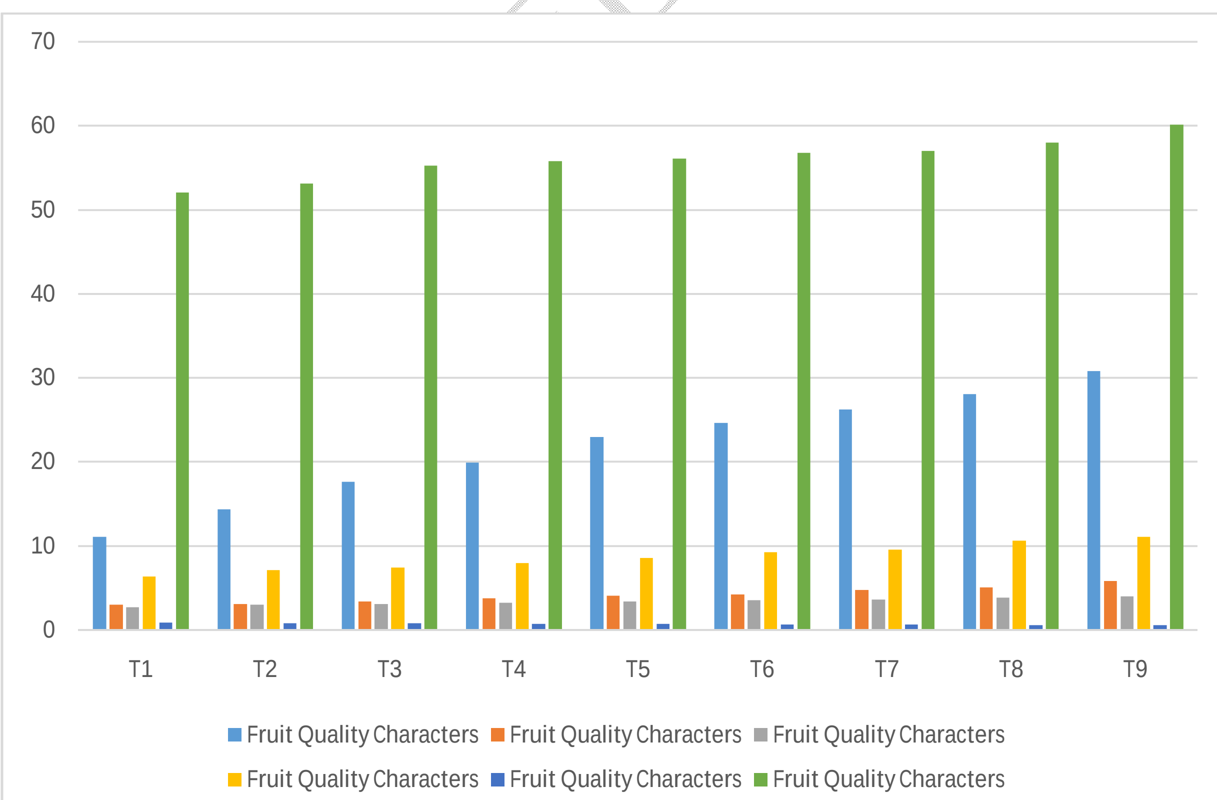

Fig. 4. Fruit quality characters