The Effect of Foliar Application of Organic Matter and Salicylic Acid on The Growth and Yield in Strawberry (Fragaria Ananassa)

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Abstract

The research was carried out in one of the greenhouses of the Horticulture and Landscape Division nursery in the Plant Production Department - Directorate of Agriculture – Najaf Governorate for the agricultural season 2018-2019. Experiment aimed to study the effect of foliar application of organic matter and salicylic acid on the growth and yield of the Strawberry. The study included nine treatments, which are three concentrations of organic matter of (HumiferT-ULTRA) was used (0, 3, and 6) ml.L⁻¹, and Salicylic Acid treatment with three concentrations (0, 100, and 200) mg.L⁻¹. Furthermore, it was implemented as a factorial experiment according to the Randomized Complete Block Design (RCBD) with three replicates. The results showed that the treatment of 3 ml.L⁻¹ of organic matter was significantly achieved the heist values in plant height, percentage of carbohydrates, and anthocyanin pigment in the fruit, while the other traits were superior significantly at the level of 6 ml.L⁻¹. On the other hand, the foliar application of with salicylic acid resulted in significant superiority in all the studied traits, especially at the concentration of 200 mg.L⁻¹ except the leaf content of chlorophyll and the plant yield, which recorded a significant superiority at the concentration of 100 mg.L⁻¹. Finally, the interaction of the study factors had a significant effect on all the studied traits.

Keywords: Salicylic, Strawberry, Fragaria, Organic.

1.Introduction

Strawberry, *Fragarra ananassa* Duch. belongs to the Rosaceae family, it is a perennial plant adapted to a wide range of climates [1]. It is a small fruit of high economic importance, and its genus Fragaria is the most consumed among the small fruit varieties [2]. However, most of the production is concentrated in the northern hemisphere, especially the regions with a temperate climate characterized by moderate temperatures in winter and summer [3]. Therefore, most of the available varieties are not adapted to high temperatures [4]. It is noticed from research and studies that there is a trend to increase the cultivation of strawberries by farmers due to the high demand for it by consumers, which achieves high profits. Despite this, some areas of cultivation are not suitable due to environmental conditions, including low soil fertility and poor physical, chemical, and biological properties of the soil. In traditional agriculture, farmers tend to use chemical fertilizers to increase production, but adding organic fertilizers is an important factor to increase the soil content of organic matter. [5]. Organic fertilization is the most important way to develop and raising the agricultural production value and reduce the environmental pollution resulting from the excessive use of mineral fertilizers [6,7]. Organic fertilizers contain a wide range of organic compounds dissolved in water, such as sugars, proteins, amino acids, organic acids, and phytohormone-like compounds [8,9], and all these compounds contribute directly or indirectly to plant growth and development, organic matter supplies macro and micronutrients to plants and improves soil chemical and physical properties. Incorporation of organic matter increase nutrient availability and provide food for soil microorganisms. Organic matter acts as a soil conditioner and considers nutrients reservoir [10]. Many researches also indicated the effectiveness of foliar fertilization in increasing the yield and improving its quality [11]. Besides, the abundance of vegetative growth. In other studies, it was noted that it is possible to quickly address the deficiency of the main elements in plants by foliar application of their solutions on the vegetative parts, which have a faster effect compared to what is added to the soil. On the other hand, it has been found in several studies that growth regulators have a role in the growth, increase and improvement of yield, as most processes are affected or subject to the influence of plant growth regulators. [12,13], stated that Salicylic Acid is a growth regulator that belonged to the phenols, known for its ability to regulate various aspects of plant growth and development. Further, it works in different ways in
modulating biotic and abiotic stress responses and works to maintain concentration Auxin and cytokinin, increasing its readiness. Likewise, the readiness of the basic materials needed by the plant during synthesis processes, such as amino acids and some energy compounds such as NAD and NADPH, which nitrogen include in their composition. Thus, the research aims to study the effect of foliar application of organic matter and salicylic acid and their interactions on the growth and production of the Strawberry.

2. Materials and Methods

The experiment was carried out in one of the non-air-conditioned greenhouses of the Horticulture and Landscape dept. Directorate of Agriculture - Najaf Governorate for the period from 1/10/2018 to 1/7/2019. The field divided to plots of 0.80m width, 0.30m height and 26m length, a distance of 0.50 and the Albion variety was used. Seedlings were planted on 1/10/2018, the distance between the rows 0.20 m and the distance between plants 0.30 m. A drip irrigation system was followed, with a drainage rate ranged between 3-4 L.hr⁻¹ whenever needed, in addition to fertilization operations that were carried out uniformly for all treatments according to the fertilizer program. The first factor was organic matter (HumiferT-ULTRA) with three concentrations (0, 3, 6) mL L⁻¹ symbolized as (H0, H3, and H6) respectively. The second factor was salicylic Acid with also three concentrations (0, 100, 200) mg L⁻¹ symbolized as (S0, S1, and S2) respectively. The first foliar application of on 10/3/2018, the second foliar application of after two weeks of the first foliar application, and the third after two weeks of the second spray. The experiment was carried out as a 3 x 3 factorial experiment, according to a Randomized Complete Block Design (RCBD) with three replicates and by 15 plants per experimental unit. Moreover, the treatment rates were compared according to the Duncan Multiples Range Test at a probability level (5%), by Genstat discovery program for the statistical analysis.

2.1 Studied parameters

Plant height (cm), Number of leaves (leaf.plant⁻¹), Leaf area (cm²), Shoot dry weight (g.plant⁻¹), Leaf content of chlorophyll (ng.100 g⁻¹ fresh weight) was estimated according to the (Makinney 1941) method modified by [15]. Fruit weight (g), Yield per plant (g.plant⁻¹), Fruit content of total acidity (g.100 g⁻¹ fresh weight) was calculated on the basis that citric acid was predominant in the strawberry fruit. Total acidity was estimated as reported in [16]. Fruit content of ascorbic acid (vitamin C) (mg.100 g⁻¹ fresh weight), Vitamin C was estimated according [16]. Percentage of carbohydrates in fruits percentage was measured as stated in [17]. Fruit content of anthocyanin pigment (g.100g⁻¹ fresh weight), was measured as reported in [16].

3. Results

3.1 Plant height (cm)

Table 1 showed that foliar application of organic matter (HumiferT-ULTRA) achieved the best values of plant height, especially the treatment H3 that achieved the highest rate of plant height of 22.54 cm. Subsequently, without significant difference from the treatment H6, which recorded 22.49 cm, while foliar salicylic acid led to a significant increase in plant height, especially at treatment S2, which achieved the highest values in plant height of 23.10 cm, the lowest plant height observed at treatment S0, which recorded 20.65 cm. The interaction between the organic matter with salicylic acid also affected plant height, the treatment H6.S2 achieved the highest rate of 23.63 cm.

| Humifer T-ULTRA levels | Salicylic acid levels | Mean |
|------------------------|-----------------------|------|
|            | S0    | S1    | S2    | Mean |
| H0        | 18.41 e | 20.23 d | 22.53 ab | 20.39 b |
| H3        | 22.12 ab | 22.37 ab | 23.15 a | 22.54 a |
| H6        | 21.43 cd | 22.42 ab | 23.63 a | 22.49 a |
| Mean      | 20.65 b | 21.61 b | 23.10 a |
3.2 Number of leaves (leaf.plant⁻¹)

Table 2 showed that the organic matter led to a significant increase in the number of leaves, as treatment H6 achieved the best values reached 21.79 leaves.plant⁻¹, which significantly superior over treatment H3. Moreover, the foliar application of salicylic acid recorded significant effect as for treatment S1 record 21.32 leaf.plant⁻¹, which did not differ significantly from treatment S2, while the interaction between foliar application of organic matter and salicylic acid had an obvious effect, the highest number of leaves resulted in the treatment H6.S2, which reached 23.28 leaf.plant⁻¹.

Table 2. The effect of foliar application of Humic acid and Salicylic acid on the number of leaves (leaf.plant⁻¹).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                        | S0        | S1 | S2 |      |
| H0                     | 17.22 e   | 19.31 c | 18.61 d | 18.38 c |
| H3                     | 18.42 d   | 21.31 b | 21.41 b | 20.38 b |
| H6                     | 18.76 d   | 23.34 a | 23.28 a | 21.79 a |
| Mean                   | 18.13 b   | 21.32 a | 21.10 a |      |

3.3 Leaf area (cm²)

Table 3 showed that foliar application of organic matter recorded significant effect on leaf area, treatment H6 was significantly increased the average leaf area, reached 53.26 cm², while the treatment H0 achieved the lowest leaf area reached 46.22 cm². On the other hand, the treatment with salicylic acid (S3) recorded the highest area of 53.99 cm², which was significantly superior to the treatment, while the treatment S0 and gave the lowest leaf area for plants, similarly the interaction treatment H6.S2 between the two factors was significantly superior in this trait, reaching 57.37 cm² compared to all the interaction factors.

Table 3. The effect of foliar application of Humic acid and Salicylic acid and their interaction on the leaf area (cm²).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                        | S0        | S1 | S2 |      |
| H0                     | 43.65 e   | 46.60 c | 48.43 b | 46.22 c |
| H3                     | 47.32 be  | 44.80 d | 56.19 ab | 49.43 b |
| H6                     | 46.20 c   | 56.23 ab | 57.37 a | 53.26 a |
| Mean                   | 45.72 c   | 49.21 b | 53.99 a |      |

3.4 Shoot dry weight (g.plant⁻¹)

The results of table 4 indicate that there are significant effect on the shoot dry weight of the plant with foliar application of humic acid. Thus, treatment H6 was significantly superior in increasing the shoot dry weight, reached 14.17 g.plant⁻¹, followed with a significant difference of treatment H3, which record 13.65 g.plant⁻¹. Furthermore, there are significant differences in this trait as a result of treatment with salicylic acid, the treatment S2 achieved the highest shoot dry weight, compared with the control treatment.

Table 4. The effect of foliar application of Humic acid and Salicylic acid on the shoot dry weight (g.plant⁻¹).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                        | S0        | S1 | S2 |      |
| H0                     | 10.21 e   | 10.64 e | 14.17 b | 11.67 c |
| H3                     | 12.16 d   | 13.44 c | 15.35 a | 13.65 b |
| H6                     | 14.12 b   | 13.09 c | 15.23 a | 14.17 a |
| Mean                   | 12.16 b   | 12.39 b | 14.91 a |      |

3.5 Leaf content of chlorophyll (mg.100 g⁻¹ fresh weight)

Table 5 showed that the organic matter had a significant effect on the chlorophyll content in leaves, as the treatment H6 achieved the highest chlorophyll content of 55.54 mg.100 g⁻¹ fresh weight, which did not differ significantly from the
treatment H3 that recorded 54.32 mg.100 g$^{-1}$ fresh weight, Alternatively, the highest chlorophyll content was in treatment S1 reached 54.69 mg.100 g$^{-1}$ fresh weight which was not significantly different from H6 treatment (53.27 mg.100 g$^{-1}$ fresh weight, correspondingly, the treatment H6.S1 was significantly achieved the highest values of chlorophyll content reached 56.21 mg.100 g$^{-1}$ fresh weight.

**Table 5.** The effect of foliar application of Humic acid and Salicylic acid on the leaf content of chlorophyll (mg.100 g$^{-1}$ fresh weight).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                         | S0                    | S1   | S2   | Mean |
| H0                      | 45.08 d               | 53.55 b | 50.11 c | 49.58 b |
| H3                      | 54.22 ab              | 54.32 ab | 54.42 ab | 54.32 ab |
| H6                      | 55.14 a               | 56.21 a | 55.29 a | 55.54 a |
| Mean                    | 51.48 b               | 54.69 a | 53.27 ab | |

3.6 Fruit weight (g)

The results of Table 6 indicated that the organic matter led to an increase fruit weight, and treatment H3 achieved the highest fruit weight of 16.02 g, compared to the control treatment that recorded the lowest fruit weight of 13.96 g, which decreased significantly compared to treatment H6. The results also indicated the presence of significant differences in treatment with salicylic acid, the treatment S2 achieved the highest fruit weight of 17.36 g. The interaction showed a significant increase in this trait, as the treatment H3.S2 recorded the highest average of fruit weight was 18.45 g, while the treatment H0.S0 recorded the lowest average of fruit weight, which was 13.12 g.

**Table 6.** The effect of foliar application of Humic acid and Salicylic acid and their interaction on the fruit weight (g).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                         | S0                    | S1   | S2   | Mean |
| H0                      | 13.12 c               | 13.43 c | 15.33 b | 13.96 c |
| H3                      | 14.20 bc              | 15.42 b | 18.45 a | 16.02 a |
| H6                      | 14.36 bc              | 14.16 bc | 18.32 a | 15.61 b |
| Mean                    | 13.89 c               | 14.33 b | 17.36 a | |

3.7 Plant yield (g.plant$^{-1}$)

Table 7 showed that foliar application of with organic matter has a significant effect in increasing the plant yield. Therefore, the plant yield at treatment H6 reached 432.59 g.plant$^{-1}$, which did not differ significantly from the treatment H3, which recorded 396.84 g.plant$^{-1}$, the treatment S1 plants were achieved the best value reached 476.28 g.plant$^{-1}$, compared to the comparison treatment, which gave the lowest plant yield amounted to 311.24 g.plant$^{-1}$.

**Table 7.** The effect of foliar application of Humic acid and Salicylic acid and their interaction on the plant yield (g.plant$^{-1}$).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                         | S0                    | S1   | S2   | Mean |
| H0                      | 311.24 d              | 350.19 c | 315.72 d | 325.71 b |
| H3                      | 370.12 b              | 441.31 ab | 379.10 | 396.84 ab |
| H6                      | 376.41 b              | 44.10 ab | 476.28 | 432.59 a |
| Mean                    | 352.59 b              | 412.20 a | 390.36 ab | |

3.8 Fruit content of total acidity (g. 100 g$^{-1}$ fresh weight)

Table 8 that there was no significant effect of organic matter in total acidity, However, the high concentration of organic matter of treatment H6 recorded the lowest fruit content of total acidity of 4.19 g. 100 g$^{-1}$ fresh weight, compared to the control treatment that recorded 4.25 g. 100 g$^{-1}$ fresh weight. Thus, the treatment H3 record the highest fruit content of total acidity was 4.39 g. 100 g$^{-1}$ fresh weight treatment. The treatment with salicylic acid led to a significant increase in the fruit content of total acidity, as the treatment recorded 4.59 g. 100 g$^{-1}$ fresh weight, which did not differ significantly from treatment S1, which recorded 4.20 g. 100 g$^{-1}$ fresh weight.
Table 8. The effect of foliar application of Humic acid and Salicylic acid and their interaction on the fruit content of total acidity (g. 100 g⁻¹ fresh weight).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean     |
|--------------------------|-----------------------|----------|
|                          | S0        | S1        | S2        |       |
| H0                       | 3.33 b    | 4.21 ab   | 5.21 a    | 4.25 a |
| H3                       | 4.47 ab   | 4.31 ab   | 4.41 ab   | 4.39 a |
| H6                       | 4.32 ab   | 4.10 ab   | 4.16 ab   | 4.19 a |
| Mean                     | 4.04 b    | 4.20 ab   | 4.59 a    |        |

3.9 Fruit content of ascorbic acid (vitamin C) (mg. 100 g⁻¹ fresh weight)

Table 9 showed that the treatment of plants with organic matter led to a significant effect, the treatment H6 recorded 27.67 mg. 100 g⁻¹ fresh weight. Also, it did not differ significantly from treatment H3, which recorded 27.15 mg. 100 g⁻¹ fresh weight, the treatment of salicylic acid led to a significant increase, treatment S2 achieved the highest content of vitamin C of 29.98 mg. 100 g⁻¹ fresh weight, which did not differ significantly from treatment S1 that recorded 28.45 mg. 100 g⁻¹ fresh weight.

Table 9. The effect of foliar application of Humic acid and Salicylic acid on the Fruit content of ascorbic acid (mg. 100 g⁻¹ fresh weight).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean     |
|--------------------------|-----------------------|----------|
|                          | S0        | S1        | S2        |       |
| H0                       | 19.23 d   | 24.05 c   | 28.17 b   | 23.81 b |
| H3                       | 21.00 cd  | 30.11 ab  | 30.34 ab  | 27.15 a |
| H6                       | 20.35 d   | 31.21 a   | 31.45 a   | 27.67 a |
| Mean                     | 20.19 b   | 28.45 a   | 29.98 a   |        |

3.10 Percentage of Carbohydrates in Fruits

Table 10 showed that treatment with humic acid H3 had a significant effect in the percentage of carbohydrates reached 22.85%, which did not differ significantly from the treatment H6 of 22.26%. the salicylic acid treatment of S2 achieved the highest percentage of carbohydrates reached 24.76%, compared to other treatments, the interaction treatments between the extract of organic matter and salicylic acid showed significant differences, as the highest percentage of carbohydrates in fruits reached 26.31% at treatment H3.S2.

Table 10. The effect of foliar application of Humic acid and Salicylic acid on the percentage of carbohydrates in fruits (%).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean     |
|--------------------------|-----------------------|----------|
|                          | S0        | S1        | S2        |       |
| H0                       | 18.71 d   | 19.15 c   | 21.86 b   | 19.90 b |
| H3                       | 20.25 bc  | 21.99 b   | 26.31 a   | 22.85 a |
| H6                       | 20.48 bc  | 20.19 bc  | 26.13 a   | 22.26 a |
| Mean                     | 19.81 b   | 20.44 b   | 24.76 a   |        |

3.11 Fruit content of anthocyanin pigment (g. 100 g⁻¹ fresh weight)

The results in Table 11 showed that the treatment H3 of organic matter led to a significant increase in anthocyanin pigment in the fruits was 19.24 g. 100 g⁻¹ fresh weight, which did not differ significantly from the treatment H6 that amounted to 18.75 g. 100 g⁻¹ fresh weight, the treatment of salicylic acid led to a significant increase in fruit content of anthocyanin, as treatment S2 achieved the highest values reached 20.86 g. 100 g⁻¹ fresh weight. The highest content of anthocyanin reached 22.16 g. 100 g⁻¹ fresh weight at interaction treatment H3.S2, which did not differ significantly from treatment H6.S2, that recorded 22.01 g. 100 g⁻¹ fresh weight.
The effect of foliar application of Humic acid and Salicylic acid on anthocyanin content in fruit (g. 100 g⁻¹ fresh weight).

| Humifer T-UL TRA levels | Salicylic acid levels | Mean |
|-------------------------|-----------------------|------|
|                         | S0                    | S1   | S2   |      |
| H0                      | 15.76 d               | 16.13 cd | 18.41 b | 16.76 b |
| H3                      | 17.06 c               | 18.52 b  | 22.16 a  | 19.24 a  |
| H6                      | 17.25 bc              | 17.01 c  | 22.01 a  | 18.75 ab |
| Mean                    | 16.69 b               | 17.22 b  | 20.86 a  |      |

4. Discussion

A significant effects which observed in all traits as shown in the above may be due to the foliar application of organic matter (humic acid) and its role in improving the characteristics of vegetative growth which may be the reason for increasing the vital activities of plants and revitalizing them through stimulating enzymatic systems and increasing the formation of DNA, RNA. Thus, stimulating the production of Phytohormones such as Auxins and Cytokinines, or, the organic matter may contain the same Phytohormones -like compounds, which increased the plant height as shown in Table 1 and increased the plant's leaf area as shown in Table 3. Also, the presence of macro and micronutrients along with these Phytohormones has led to improving the vegetative growth of plants that increased the number of leaves as shown in Table 2. Besides, an increase in the leaves content of chlorophyll as in Table 5, by increasing the metabolic activities of plants due to the presence of nutrients that are stimulating the synthesis of amino acids and chlorophyll, thus increasing the chlorophyll content of leaves. This encouraged an increase in the efficiency of photosynthesis and carbon fixation process, which leads to an increase of nutrients in the plant, carbohydrates, proteins, and energy compounds ATP [19], which reflected positively on the increase in the shoot dry weight as shown in Table 4. The plants which treated with organic matter achieved a significant increase in the average of fruit weight and plant yield as shown in Table 7. This is due to the role of organic matter in increasing the vegetative growth like leaf area as in Table 3, content of chlorophyll Table 5, which increased the products of carbon fixation and the accumulation of products of this process, then increased the dry weight of the plant Table 4, which consequently reflected fruit weight and the yield. The significant increase in vitamin C, carbohydrates, anthocyanin may be attributed to the significant increase vegetative growth like chlorophyll content Table 5, which increase the efficiency of the carbon fixation, and accumulate carbohydrates, soluble sugars, organic acids, soluble salts. The treatment of plants with salicylic acid led to significant differences in the vegetative and fruit growth characteristics. The results also showed that foliar application of the strawberry plant with the growth regulator of salicylic acid had a positive effect on both the studied fruit and vegetative growth characteristics. However, the treatment of plants with salicylic acid led to an increase in plant height Table 1, number of leaves Table 2, leaf area Table 3, and shoot dry weight Table 4. The reason may be attributed to the indirect effect of salicylic acid by raising the levels of natural plant hormones, especially gibberellins, Auxin, and Cytokinines, as the Auxin level within the plant tissue increases through induction by gibberellins [20]. Salicylic acid reduce the ethylene levels and raise the level of auxin. Therefore, Auxin has a role in cell growth and the synthesis of RNA and proteins, in addition to Auxin's role in stimulating the cell wall loosening by breaking cell wall bonds and rearranging them in new sites under the effect of swelling pressure led to increasing the expansion and plant height, leaf area, number of leaves, shoot dry weight. Salicylic acid induced high level of Cytokinines, Cytokinines increases the content of chlorophyll in leaves by stopping the degradation of chlorophyll and delaying the aging of plant leaves [21]. Cytokinines led to the activated the products of the photosynthesis process, which led to improving the vegetative growth and reflected on the shoot dry weight Table 4. Also, the increase in photosynthesis activity by the action of cytokinin, which had a co-effect with Auxin, led to an increase in the plant yield as in Table 7.

Salicylic acid caused a significant increase in the fruit content of vitamin C as in Table 9 and carbohydrates Table 10 and anthocyanin Table 11, that due to the role of salicylic acid in raising the level of Phytohormones, which was reflected in the increase in efficiency of carbonate fixation in the leaves.

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