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The role of foliar applications of boron and gibberallic acid (GA_3) on yield and quality in different strawberry types

Assiye Özkaya[1]*, Ayşen Melda Çolak[1], Volkan Okatan[2]

[1]Department of Horticulture, Faculty of Agriculture and Natural Sciences, Uşak University, 64200 Uşak, Turkey
[2]Department of Horticulture, Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir, Turkey

*Corresponding author e-mail: ozkayaasiye@gmail.com

Abstract

This study was carried out to investigate the effects of boric acid and giberallic acid (GA_3) applications on yield and quality in strawberry cultivars. In the experiment, 5 different doses of boric acid (Control, 100, 200, 300, 400 and 500 ppm) and GA_3 (Control, 20, 40, 60, 80 and 100 ppm) were applied. As a result of the applications, the average number of flowers was determined between 29.9-50.7. Fruit weights in the experiment varied between 17.1-22.3 g. Brix value varied between 6.3-7.9%. The pH values of the fruits were found between 2.5-2.9. Titratable acidity value was measured between 0.5-1.1 percent. It was determined that the applications made a difference in terms of yield and quality in strawberry cultivars.

Keywords: strawberry, application, boric acid, GA_3, quality

Introduction

Strawberry (*Fragaria spp*.) belonging to *Rosaceae* family is of the most popular fruits due to attractive appearance, aroma and flavor (Kepenek et al., 2002), exhibiting a wide array of variation within the species regarding different planting times, table and industrial production in different ecologies of the world. Corresponding to the obtaining the desired characteristics of the relevant plant species, breeding programs have been employed in many regions of the world in this regard. Of the targets to be desired, the relevant programs aim at increasing the yield and quality of the fruits. Herewith the programs, the recent researches have addressed on the concept of fruit quality and extended to the regulation of nutritional value but it is worthy to note that the phenomenon "quality characteristics" of fruits is a complex term and not easy to define objectively. The former reports have clearly revealed that the quality associated traits are genetically or environmentally dependent, as the clearly reported (Perkins-Veazie, 1995; Prior et al., 1998; O'Connor et al., 2002).

Today, the most important factor in the importance of strawberry cultivation has been the economic growth of strawberries in different climatic and soil conditions. In addition, the income obtained from the unit area in strawberry cultivation is quite high in relative to other products. Strawberries have a good market advantage as they ripen in periods when fresh fruit is scarce (Kıyga, 2009). The ability to grow strawberries in almost every region of our country allows the strawberry fruit to be available in the market for a longer period of time. The fact that strawberry is available for sale, especially when other fruits are not available in the market, provides a good source of income to the producers, while at the same time it is a pleasant species that appeals to the palate and meets the fruit needs of the consumers (Eti, 2006).

Important quality characteristics of strawberries are fruit size, flesh firmness, fruit shape, amount of water soluble solids (SSC), water-soluble dry matter/acid ratio, total sugars (glucose, fructose, sucrose) and acidity (Azodanlou et al., 2003).

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ORCID and Mail:
Ozkaya, A.: 0000-0002-4860-9902 (ozkayaasiye@gmail.com); Colak, A.M.: 0000-0003-0113-2104 (aysenmelda.colak@usak.edu.tr); Okatan, V.: 0000-0001-5787-7573 (okatan.volkan@gmail.com)
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Of the growth regulating substances in plants; gibberellins have been associated with the vegetative growth, fruit size, seed and bud dormancy break. It has been reported that the number of flowers in strawberry cultivars is an important parameter, albeit indirectly, in the estimation of yield (Strik and Practor, 1988). Gibberellins, on the other hand, stimulate pollen germination and pollen tube growth, and promote flowering and fruit set as a result of the external effect of gibberellins on the flower. Gibberellins affect many physiological and morphological activities (Kacar et al., 2006; Baktır, 2010; Kumar et al., 2013; Gündoğdu et al., 2019).

Boron element is prominent in strawberry nutrition as of the microelements required for plant growth and productivity. Carbohydrate, boron, which has an important role in the synthesis of phenolic compounds and nucleic acid, is one of the essential elements for plant growth. As a matter of fact, it is necessary for the healthy development of fruit set in strawberries. The plant's request should be taken into account in boron fertilization. Distorted fruit formations in strawberries are associated with many factors. It is known by researchers that malformed fruit formation is caused by insufficient pollination and fertilization and this situation is related to boron nutrition (Çakıcı and Arslan, 2012; Özkaya et al., 2017; Özkutlu et al., 2017).

Corresponding to the manifested impacts of boron and gibberallic acid; we hypothesized that the exogenous treatments of boron and gibberelic acid would increase and improve the quality traits of the strawberry fruits, in relative to non-treated plants. We also hypothesized that both cultivars of strawberry would differ in their responses against the relevant treatments, as the clearly reported that some traits of the plants are dependent on genetic structure. The aim of this study is to determine how different doses of boric acid and GA_3 applications affect yield and quality in Albion and Sabrina strawberry cultivars. For this purpose, 5 different doses of boric acid (Control, 100, 200, 300, 400 and 500 ppm) and GA_3(Control, 20, 40, 60, 80 and 100 ppm) were applied.

Material and Methods

Material

The research was carried out in a low tunnel strawberry greenhouse. Two cultivars were preferred as strawberry cultivars, Albion from neutral cultivars and Sabrina from short-day cultivars. Frigo seedlings were planted on the bobbins in a triangle shape at 30x30 cm intervals. In the strawberry garden, the first flowers and stolons of the strawberry varieties grown in order to ensure strong root development in the first year were plucked.

Method

Fruit samples were taken during the harvest period (between March and May) from this strawberry greenhouse, which was in full yield in 2020. The fruits were harvested when they were fully red in color. The samples taken were brought to the laboratory of the Vocational School located in the Sivaslı district of Uşak province, and the pomological analyzes of the fruit samples were made immediately and stored at -20 ^oC for the remaining biochemical analyzes.

Different doses of boric acid and GA_3 were used in the study. Applications were prepared in the laboratory of the Vocational School located in Sivaslı district of Uşak province. The research consists of a total of 10 repeated fertilizer applications and control groups. It consists of 5 replications of boric acid andGA_3 and control groups. Preparation of boric acid and GA_3; first, 50 ml of pure alcohol was put into small beakers. Then, Boric acid and GA_3 were weighed on a precision balance. After weighing, it was mixed in 50 ml of pure alcohol for each replication and mixed until it dissolved. Finally, for all replications, the samples were poured into bottles containing 950 ml of pure and shaken until thoroughly mixed. Boric acid and GA_3 amounts in Table 1. has also been given. Strawberry varieties selected for the experiment were determined as five replications and control groups.Twenty plants were used for each replication.

Table 1. Aplication mounts of Boric acid and GA_3

Boric acid application amounts	**GA_3application amounts**
Control	Control
100ppm= 0.1 g per 1 liter of pure water	20ppm= 0.02 g per 1 liter of pure water
200ppm= 0.2 g per 1 liter of pure water	40ppm= 0.04 g per 1 liter of pure water
300ppm= 0.3 g per 1 liter of pure water	60ppm= 0.06 g per 1 liter of pure water
400ppm= 0.4 g per 1 liter of pure water	80ppm= 0.08 g per 1 liter of pure water
500ppm= 0.5 g per 1 liter of pure water	100ppm= 0.1 g per 1 liter of pure water

First Flowering and Full Flowering

It was recorded as the first flowering date when 5% of the plants in the plot bloom and the full bloom date when 75% of them bloom (Özkaplan, 2010).

Harvest time

The first date on which the fruits in the plot were harvested was determined as the beginning of the harvest and the last harvest as the end of the harvest. The fruits were harvested when they got their full color.

Yield Per Plant

From the beginning to the end of the harvest, the fruits obtained from all plants were measured with a digital scale sensitive to 0.01 grams.

Fruit Width and Length

The average width and length of 10 randomly picked fruits were determined by measuring with a digital caliper with 0.01 mm precision.

Fruit Weight

During the harvest periods, 10 randomly picked fruits for each replication were weighed on a digital scale with an accuracy of 0.01 grams, and the average fruit weight was calculated according to the results obtained.

Total soluble solids content (TSS)

For each replication, the juices of 10 randomly taken fruits were determined by hand refractometer.

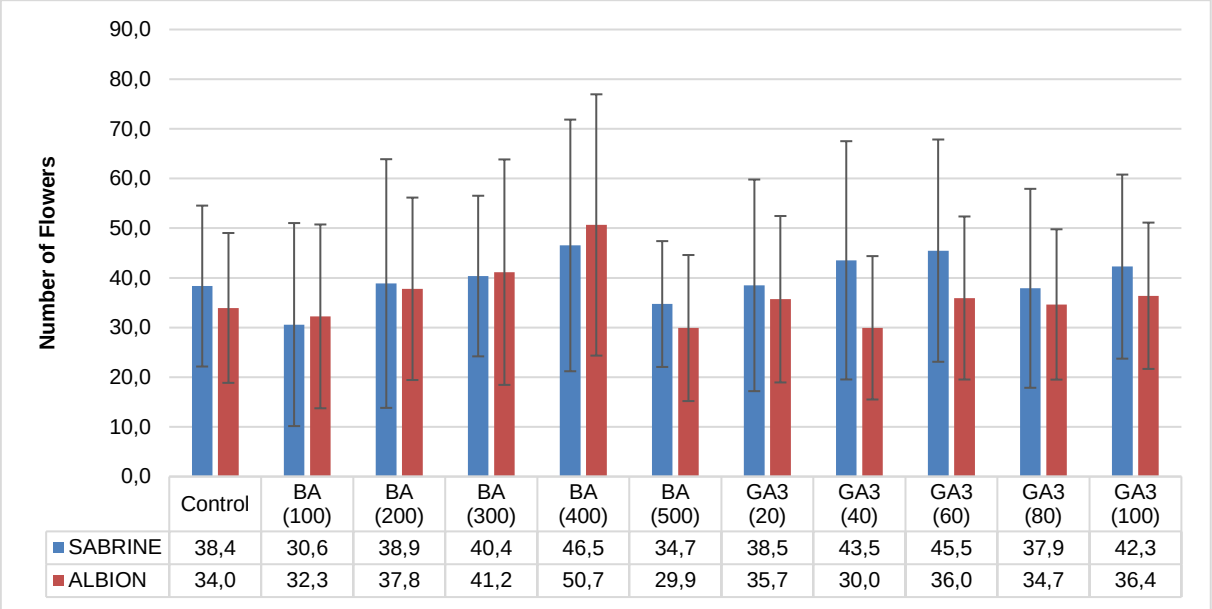
pH %
The juice of 10 randomly taken fruits was squeezed to obtain 10 ml of juice and was measured with a pH meter.

Titratable acidity values (%)
It was calculated in terms of citric acid by titration technique in 10 ml fruit juice obtained from random fruits.

Statistical analysis
Raw data of the experiments was summarized in Microsoft Excel and figures were prepared to better present the results. Then, the data was subjected to the analysis of variance and the mean separation was performed with Tukey's HSD test at $p < 0.05$. Furthermore, the "corrplot" package of R was used to perform correlation analysis.

Results and Discussion
Plant Growing
The development of strawberry plants was monitored twice a week during the growing period in the field where the research was conducted. The first trial started on 25.03.2020 and was carried out at 10-day intervals. In the meantime, the first flowering started with the first application and observations were made about it. After the last Boric and GA_3 application, full bloom was reached and flower count was done.

Number of Flowers
Various observations were made during the flowering period. The number of flowers was observed according to the amount of doses applied in the experiment. Flower counting was done at the last blooming. It was observed that the highest flower amount of Sabrina variety was in boric acid (400 ppm) application with an average of 46.5, and the lowest flower amount was observed in boric acid (100 ppm) application with an average of 30.6. It was observed that the highest average flower amount of Albion variety was in boric acid (400 ppm) application with 50.7, and the lowest average flower amount was observed in boric acid (500 ppm) application with 29.9 (Figure 1).

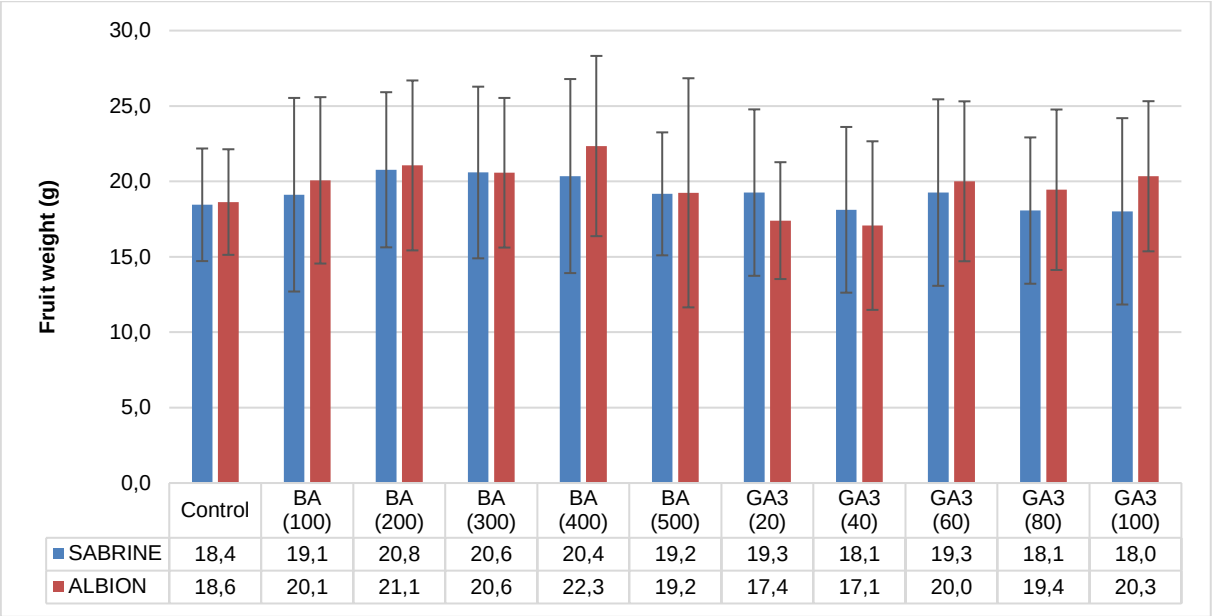


	Control	BA (100)	BA (200)	BA (300)	BA (400)	BA (500)	GA3 (20)	GA3 (40)	GA3 (60)	GA3 (80)	GA3 (100)
SABRINE	38,4	30,6	38,9	40,4	46,5	34,7	38,5	43,5	45,5	37,9	42,3
ALBION	34,0	32,3	37,8	41,2	50,7	29,9	35,7	30,0	36,0	34,7	36,4

Figure1. Number of flowers

It has been reported that the number of flowers in strawberry cultivars is an important parameter in the estimation of yield, albeit indirectly (Strik and Practor, 1988). In a study, the effects of different organic applications on yield and some quality parameters of Camarosa and Fern strawberry cultivars were investigated. In this study, the number of flowers in the applications was found to be statistically significant and nitrogen fertilizer application and green manure + farm manure + humic acid + foliar fertilizer applications formed the highest values. In a two-year study, it was determined that the number of flowers varied between varieties (34.46- 44.06) (Polat and Çelik, 2008).

Fruit Weights
It was observed that the highest average weight amount in Sabrina was in boric acid (200 ppm) application with 20.8 g, and the lowest average weight amount was GA_3(100 ppm) with 18.0 g. In the weight measurements made in Albion variety, it was seen that the highest average weight was in boric acid (400 ppm) application with 22.3 g, and the lowest average weight amount was GA_3 (40ppm) with 17.1 g (Figure 2).



	Control	BA (100)	BA (200)	BA (300)	BA (400)	BA (500)	GA3 (20)	GA3 (40)	GA3 (60)	GA3 (80)	GA3 (100)
SABRINE	18,4	19,1	20,8	20,6	20,4	19,2	19,3	18,1	19,3	18,1	18,0
ALBION	18,6	20,1	21,1	20,6	22,3	19,2	17,4	17,1	20,0	19,4	20,3

Figure2. Fruit weight of strawberry fruits

Polat and Çelik (2008) investigated the effects of different organic applications on yield and some quality parameters of Camarosa and Fern strawberry cultivars. In this study, the highest yield value was obtained from the application of green manure + farm manure + humic acid + foliar manure (Fern: 177.07 g/plant, Camarosa: 133.9 g/plant).The effects of different GA3 applications on the fruit quality of Seascape strawberry cultivar grown in Bolu ecological conditions were investigated. The effect of GA3 application prepared in two different doses (50 ppm and 100 ppm) on fruit quality parameters was determined. In the results of working; It was determined that the fruits applied 50 ppm GA3 had the lowest pH value. However, the highest fruit weight (46.01 g) was determined from the same application. It is also reported that GA3 application does not cause a significant change in aroma, taste and juice values. (Gundogdu et al., 2017).It was aimed to determine the yield and some fruit quality characteristics of two different strawberry cultivars (Festival and Camarosa) grown in the ecological conditions of Aydın/Sultanhisar district in a two-year study. In the results of working; In the second year, yield values of both cultivars decreased, while average fruit weight, fruit width and fruit length increased (Bayram, 2020).In the study conducted by Gündüz and Özdemir (2012); The effects of different two-year growing environments on the yield and fruit quality characteristics of some strawberry genotypes were investigated. In the results of working; The fruits with the highest weight are among the fruits of the Camarosa variety grown in the open, respectively, according to the years; (11.9 g and 11.3 g) reported that they were obtained.

Fruit Width and Length (mm)

In the fruit width measurements of Sabrina cultivar, it was measured that the highest value was in boric acid (200ppm) application with 34.9mm, and the lowest fruit width value was observed in GA_3 (100ppm) application with 32.4mm.It was observed that the highest value was 35.0mm in boric acid (400 ppm) fruit width measurements made in Albion variety, and the lowest value was 33.1mm in GA_3(20 ppm) and GA_3(40 ppm) applications in Albion variety (Figure 3). In the height measurements of Sabrine cultivar, it was determined that the highest value was in the application of boric acid (200 ppm) with 46.2 mm, and the lowest value of fruit length was in the control group, GA_3 (20 ppm) and GA_3 (100 ppm) applications with 43.1 mm. In the fruit length measurements made in the Albion cultivar, it was found that the highest value was in the application of GA_3 (60ppm) with 47.0mm, and the lowest fruit length value was GA_3 (40ppm) with 41.6mm (Figure 4).

As a result of the study aiming to determine the physicochemical properties of three strawberry cultivars (Rubygem, Camarosa, Amiga) grown in a commercially produced orchard in Köprübaşı district of Manisa; Fruit weight of Rubygem (28.35 g) and Amiga (28.11 g) strawberry cultivars was found to be higher than Camarosa cultivar (23.45 g). Fruit length of Amiga strawberry variety was the longest with 49.91 mm, and Camarosa variety was the shortest with 42.02 mm. Titratable acidity and pH values of strawberry fruits did not show significant differences according to the cultivars, they ranged between (0.56-0.62 g 100 mL-1), (4.15-4.32), respectively. It has been reported that the strawberry fruits grown in this region are large, the inner fullness is Rubygem and Amiga, the hardness is Amiga, the total amount of phenolic substances is the highest in Rubygem, while no significant differences are observed in terms of the chemical composition of the fruit (Türk and Şen, 2020).

The effects of seedling type and growing medium on fruit quality were investigated in soilless strawberry (Fragariaxananassa Duch.) cultivation in a glass greenhouse under the ecological conditions of the Mediterranean Region. In the experiment, as the seedling type, tube seedling and frigo seedling; Peat (T), Perlite (P), Coconut Peat (H), Volcanic Tuff (V) and their mixtures were tested as growing medium. As a result of this study; It varies according to trial years and growing environments. In terms of growing environment, average fruit length and fruit width values were determined in the highest (H+V) environment (Adak and Pekmezci, 2012).

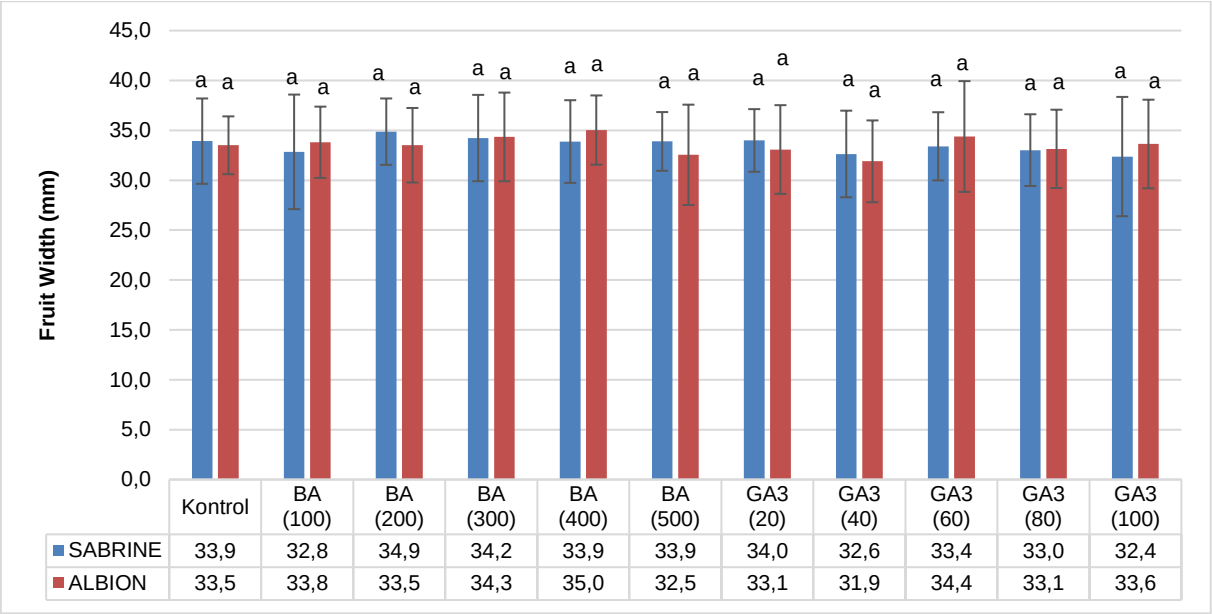


Figure 3. Fruit width of strawberry fruits (mm)

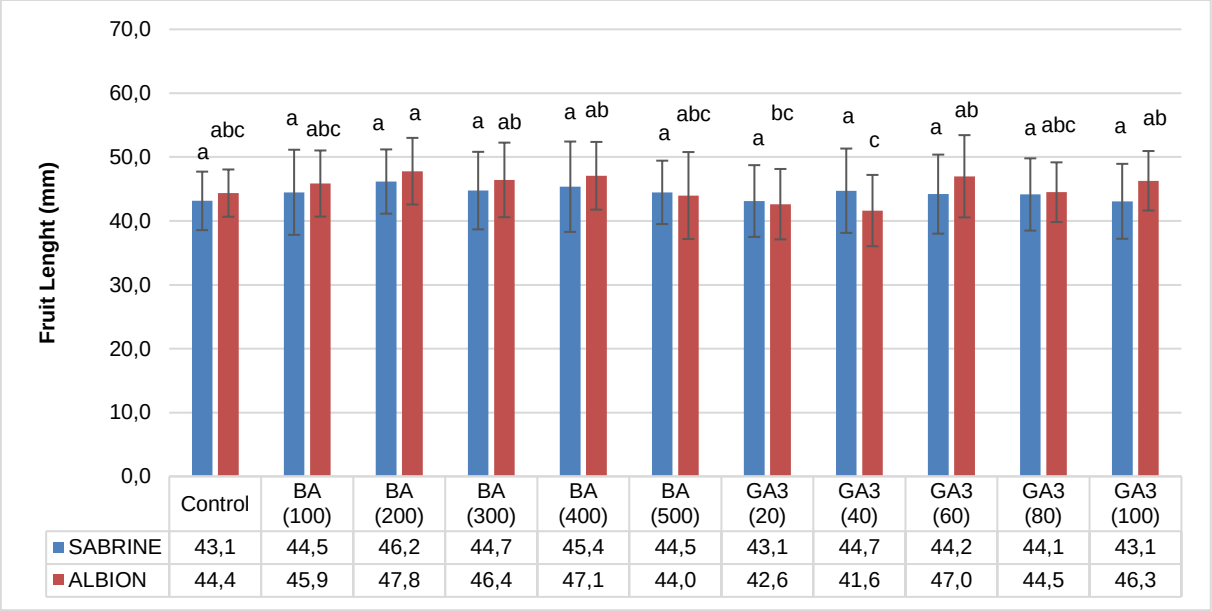
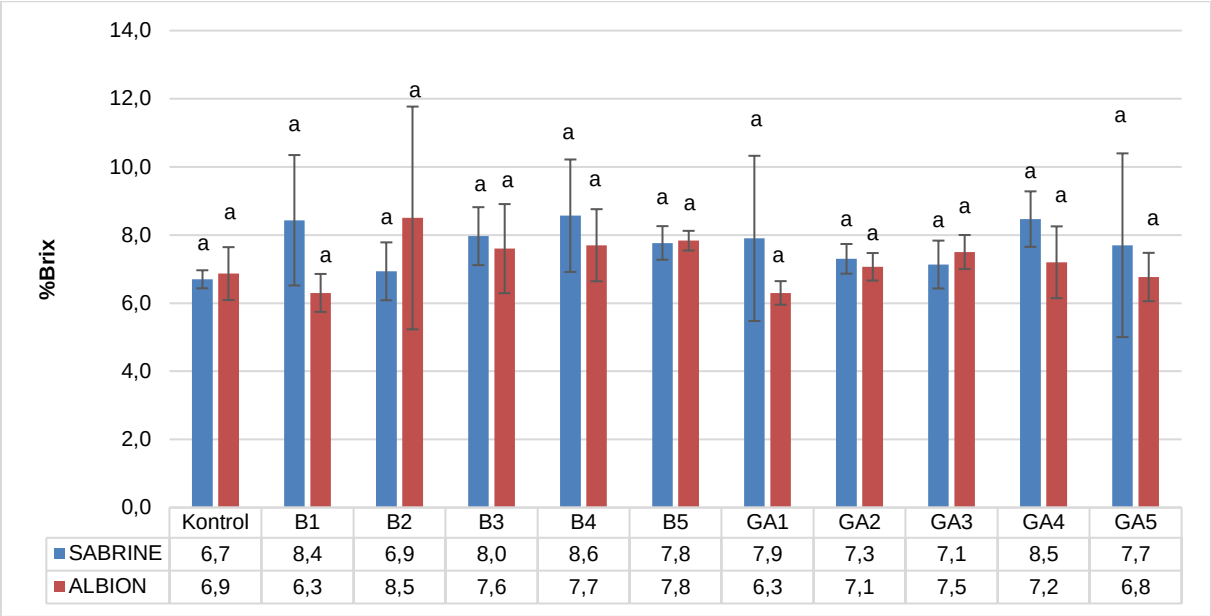


Figure 4. Fruit length of strawberry fruits (mm)

Total Soluble Solids Content (TSS) -Brix values (%)

It was determined that the highest brix amount measurements made in Sabrine cultivar were in GA_3 (20ppm) application with 7.9%, and the lowest brix amount was in the control group with 6.7%. In the measurements made in Albion variety, the highest value of brix amount was measured to be boric acid (500ppm) with 7.8%, and the lowest amount of brix was measured to be boric acid (100ppm) with 6.3% (Figure 5).



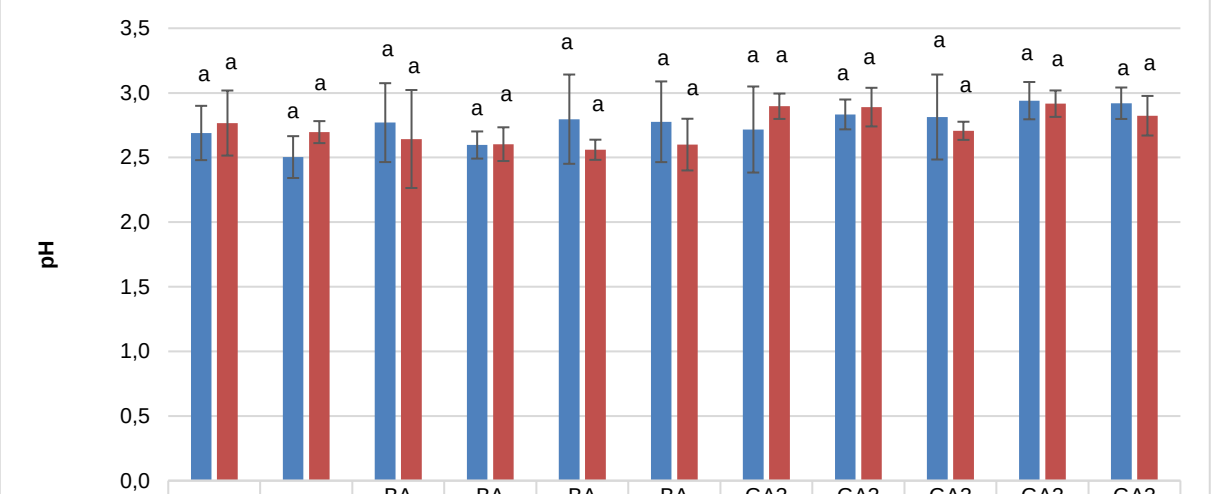
	Kontrol	B1	B2	B3	B4	B5	GA1	GA2	GA3	GA4	GA5
SABRINE	6,7	8,4	6,9	8,0	8,6	7,8	7,9	7,3	7,1	8,5	7,7
ALBION	6,9	6,3	8,5	7,6	7,7	7,8	6,3	7,1	7,5	7,2	6,8

Figure 5. Brix value of strawberry fruits (%)

It was aimed to determine the effects of growing 3 strawberry varieties (Sweet Charlie, Camarosa and Kabarla) on yield and quality, including 6 different mulch applications (black, transparent, yellow, straw, sawdust and hazelnut husk) in Persembe (Ordu) ecology. As a result of the research; The highest fruit weight was obtained from the straw mulch with the Kabarla variety (24.83 g) and with the Camarosa variety (23.51 g). Width (TSS) amount was obtained with straw mulch (6.61% brix) in Camarosa variety. The highest value in terms of titratable acidity was obtained in transparent mulch (0.50%) in Sweet Charlie variety. The highest pH value was obtained from Camarosa variety in yellow mulch (5.88). Camarosa and Sweet Charlie had better performance than Kabarla variety, and the best results in terms of yield were obtained from Camarosa variety and transparent, husk and straw mulches (Özkaplan, 2010).

pH%

It was found that the highest pH value of Sabrine was 2.9 in GA_3 (80 ppm and 100 ppm) applications, and the lowest pH value was 2.5 in boric acid (100 ppm) applications. In the pH measurements made in the Albion variety, it was found that the highest value was in GA_3 (20ppm, 40ppm and 80 ppm) applications with 2.9, and the lowest value was in boric acid (200ppm, 300ppm, 400ppm and 500ppm) applications with 2.6 (Figure 6).



	Control	BA (100	BA (200)	BA (300)	BA (400)	BA (500)	GA3 (20)	GA3 (40)	GA3 (60)	GA3 (80)	GA3 (100)
SABRINE	2,7	2,5	2,8	2,6	2,8	2,8	2,7	2,8	2,8	2,9	2,9
ALBION	2,8	2,7	2,6	2,6	2,6	2,6	2,9	2,9	2,7	2,9	2,8

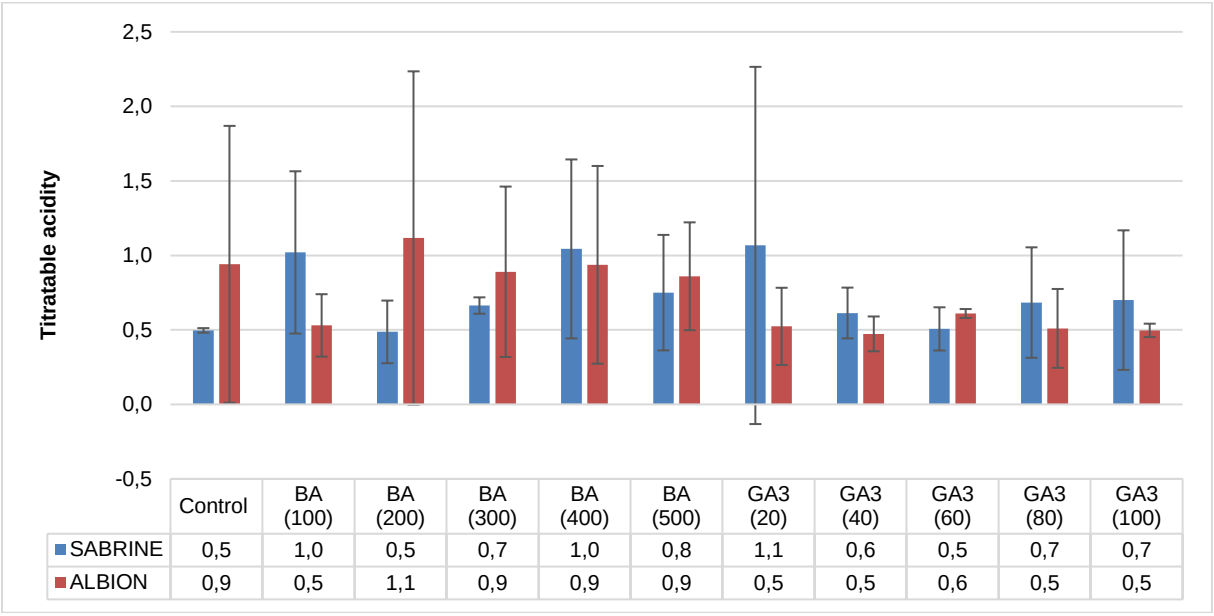
Figure 6. pH of strawberry fruits (%)

The effects of seedling type and growing medium on fruit quality were investigated in the cultivation of soilless strawberry (*Fragaria x ananassa Duch*.) in a glass greenhouse in the ecological conditions of the Mediterranean Region. In the experiment, as the seedling type, tube seedling and frigo seedling; As an alternative, mixtures of peat (T), perlite (P), coconut peat (H), volcanic tuff (V) were tested. As a result of this study; It varies according to trial years and growing

environments. There was no significant difference between seedling types in terms of titratable acidity and pH values; It has been reported that the acidity value varies between 1.12% and 1.14% and the pH values vary between 3.21 and 3.33. In terms of growing environment, average fruit length and fruit width values were determined in the highest (H+V) environment. It has been reported that frigo seedlings are advantageous in terms of seedling type, and (H) and (H+V) environments are advantageous in growing media (Adak and Pekmezci, 2012).

Titratable Acidity Values (%)

In the measurements made in Sabrine variety, the highest acidity value was obtained with 1.1% in GA_3 (20ppm) application, while the lowest acidity value was obtained from the control group and GA_3 (60ppm) applications. In the measurements made in Albion variety, it was determined that the highest acidity value was in boric acid (40ppm) application with 1.1%, and the lowest acidity value was 0.5 in boric acid (100ppm) and GA_3 (20ppm, 40ppm, 80ppm, 100 ppm) applications (Figure 7).



	Control	BA (100)	BA (200)	BA (300)	BA (400)	BA (500)	GA3 (20)	GA3 (40)	GA3 (60)	GA3 (80)	GA3 (100)
SABRINE	0,5	1,0	0,5	0,7	1,0	0,8	1,1	0,6	0,5	0,7	0,7
ALBION	0,9	0,5	1,1	0,9	0,9	0,9	0,5	0,5	0,6	0,5	0,5

Figure 7. Titratable acidity values of strawberry fruits

Çakıcı and Arslan (2012) investigated the effects of foliar potassium, boron and zinc applications on yield and quality of Camarosa strawberry cultivar. As a result of the study; It was determined that potassium, zinc and boron applied foliar in Camarosa strawberry cultivar had a positive effect on yield and quality characteristics. However, it was reported that the titratable acid content of foliar applications varied between 1.06% and 1.19% and it did not have a statistically significant effect.

The effects of different GA3 applications on the fruit quality of Seascape strawberry cultivar grown in Bolu ecological conditions were investigated. The effect of GA3 application prepared in two different doses (50 ppm and 100 ppm) on fruit quality parameters was determined. In the results of working; The highest fruit acidity (1.11%) was determined in the fruits applied 50 ppm GA3 (Gundogdu et al., 2017).

Conclusion

Different results were observed in Albion and Sabrina cultivars with different doses of GA_3 and Boric acid depending on the amount of doses applied in the experiment.In this study; the highest flower number of Sabrina and Albion cultivars was obtained from boric acid (400 ppm) application. Based on the yield parameter, the highest fruit weight in Sabrina cultivar was determined in boric acid (200 ppm) application. In the Albion cultivar, the highest fruit weight was determined in boric acid (400 ppm) application.It was determined that the highest values were obtained from boric acid (200ppm) application in the fruit width and length measurements made in Sabrina cultivar. However, in the fruit width measurements made in Albion variety, the highest value was obtained from boric acid (400 ppm) application, while the highest fruit length value was obtained from GA_3 (60 pmm) application.As a result; For Sabrina and Albion cultivars, doses of 200-400 ppm are recommended, which positively affects the yield in boric acid application, but when GA_3 applications are considered, it shows a wide variation between cultivars and applications.

Conflict of Interest

The authors are declared that they have no conflict for this research article.

Author Contribution

A.O: Field work, laboratory work, article writing; A.M.Ç.: laboratory work, article writing; V.O.;Field work and article writing

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