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BIOSTIMULATORS EFFECT ON GROWTH AND FRUITING PROCESSES OF TWO SWEET CHERRY CULTIVARS GRAFTED ON GISELA 3 ROOTSTOCK

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Abstract

The present study followed in the period 2020-2022 the effect that the supplementation of basic, mineral fertilization with three biostimulators had on the growth and fruiting processes of two cherry cultivars grown at ICDP Pitesti, Arges, in the southern area of Romania, in a temperate continental climate, with multiannual average temperature of 10.1 °C (extreme temperatures of -24.4 °C and 38.8 °C, respectively), total precipitation of 662.6 mm and sunshine of 2273.1 hours. The study was carried out in a demonstration batch of cherry (cultivars 'Regina' and 'Kordia', grafted on 'GiSelA 3' rootstock) established in 2017, with planting distances of 4x1 m, in which the necessary water and nutrients were provided through an automatic fertigation system. Fertilization of the trees was supplemented with three biostimulators, two foliar (applied in the phenological stages BBCH 53-green tip, BBCH 69-petal fall and BBCH 72-sepals beginning to fall), BSA, containing amino acids - most of which are arginine, proline, threonine, lysine - N, C, B, Mn, Zn and BSB respectively, containing amino acids, proteins, betaine, vitamins, N, C, K and a root bio-stimulator (BSC), containing salts of humic and fulvic acids, amino acids, micro and macro-elements, living bacteria) applied in a single phase, in the BBCH 53 phenological stage. The index of leaf chlorophyll content, indicators of growth and fruiting processes and those of fruit quality were recorded, which were later compared both with each other, as well as with the blank version. Data were statistically analysed (descriptive analysis, ANOVA analysis of variance, and Duncan Multiple range test, p ≤0.05). The results indicated that CCI registered significant increases compared to the Control as early as May in all variants treated with biostimulators (from 18.28 to 19.54-19.98 in May, from 23.12 to 26.59- 29.18 in June and from 25.18 to 27.36-30.05 in July). Later, significant differences were also revealed between treatments with biostimulators, BSC stood out, with the highest CCI values both at the June and July determinations (29.18 and 30.34, respectively). The same soil applied BSC stimulated the annual increase of TCSA (6.78 cm^2 compared to 4.76 cm^2 in the Control), although smaller but still statistically assured effects were recorded for the two foliar biostimulators (5.50 BSB and 5.67 BSA respectively). However, high fruit yield for high annual increases of TCSA (7.2-11.7 cm^2) was obtained in the foliar treatment with BSA (15-24.5 kg/tree). For all three biostimulators, significant increases compared to the Control were observed regarding fruit weight (by a maximum of 19% in 'Regina' and 8% in 'Kordia') and total soluble content (on average by a maximum of 4%). Also, in these variants, and especially for BSB, fruit firmness increased significantly from 52.3 to 56.9 HPE-II-FFF Bareiss units. BSB was also the biostimulant for which the lowest TTA was determined (0.46% compared to the Control with 0.57%). Last but not least, BSA and BSB increased both TSC (from 13.6 to 14.5 and 14.8%) and vitamin C content (from 15.8 to 16.1 and 16, 6 mg/100 g respectively). Therefore, supplementing basic, mineral fertilization with biostimulators containing humic acids, humic acids, fulvic acids, amino acids, micro and macro elements, and live bacteria (BSC) applied to the soil stimulated the accumulation of photosynthetic pigments and vegetative growth, while the foliar one, BSA, stimulated both vegetative growth and fruit yield. All three biostimulant increased fruit weight, firmness, and TSS, while low acidity and high sugar and vitamin C levels were recorded only in foliar treated sweet cherry.

Cuvinte cheie: 'Regina', 'Kordia', ICC, spor anual SSTT, producție, calitate fructe.
Key words: 'Regina', 'Kordia', CCI, annual increase of TCSA, yield, fruit quality.

1. Introduction

Sweet cherry trees have particular spring phenology, which, on the background of climate warming trends, sets the early installation of stress status. Although sweet cherries absorb only little soil N before bud break (up to 3 to 4 weeks after bud break), the previous season's stored N is critical for supplying initial spring phenophases (Ouzounis and Lang, 2011). Because flowering occurs before leaves' full expansion, the first stages of flowering and fruiting, but also initial vegetative growth cannot be supported by soil N absorption (Ouzounis and Lang, 2011). To accomplish the commercial purpose, increasing the efficiency of the sweet cherry orchards was possible by lowering planting distances and the early fruit-bearing by using the vegetative rootstocks of low vigor, such as GiSelA. Although cherry trees grafted on such interspecific rootstocks of low vigor (*P. cerasus* · *P. canescens*) GiSelA (Gi) rootstocks tend to produce large crops, they also produce small-size fruits if total leaf area is too small to support the crop loads (Ouzounis and Lang, 2011).

The remobilization of N reserves during spring is not possible without the hydration of the tissues and therefore, without the activation of the root system, which constitutes the first stress to be coped, if the soil temperature remains low. Even in common weather conditions, in early spring, root uptake of N is often limited by cold soils and low canopy transpiration rates (Ouzounis and Lang, 2011) and the restricted availability of N for growth may contribute to unfavourable leaf area-to-fruit ratios. The stress can become even more acute when the soil is cold and there is an increase in the air temperature, which intensifies transpiration, and the plant needs to compensate for this water lost through root absorption.

On the climate dynamics background, late spring frosts are becoming increasingly frequent. In addition, the general trend of increasing air temperature not only during summer but also in spring (Paltineanu and Chitu, 2020) stimulates earlier vegetation start that overlaps (over a longer time) with late spring frost period and can have serious consequences in commercial cherry orchards. In unprotected orchards, extreme manifestations of climatic factors, such as hail and heavy and long-lasting rains, can affect the yield quality, but can also represent a stress factor through tissue damage (causing the plant to redirect assimilates-otherwise intended for growth and fruiting-toward reparation processes), by nutrients leakage and creating favorable conditions for disease or pest attack.

Last but not least, following the trend of climate warming, heat episodes are becoming more and more intense, even earlier, frequent, and longer and exert an abiotic pressure on sweet-cherry trees.

For these reasons, in addition to provide the trees with necessary reserves to start and go through the vegetative season, special attention should be paid by to reduce the negative influence of environmental conditions and this could be accomplished by supplementing orchard nutrition plans with special products with ability to change physiological processes in plants, linked to growth, production, fruit set, and stress mitigation (Alfonso et al., 2022), generically called plant biostimulators and which, according to EU fertilizer legislation (2019), are defined as "... any microorganism or substance based on natural resources, in the form in which it is supplied to the user, applied to plants, seeds or soil and any other substrate with the intention to stimulate natural processes of plants to benefit their nutrient use efficiency and/or their tolerance to stress, regardless of its nutrients content, or any combination of such substances and/or microorganisms intended for this use" (Afonso et al., 2022).

Starting from previous studies related to the trend of climate change in the Pitesti-Arges area, this paper aimed to study the effect that the addition of basic, mineral fertilization of trees with two foliar and one root biostimulators had on growth-fruiting processes and sweet cherry quality for Regina and Kordia cultivars grafted on low vigor rootstock GiSelA 3.

2. Material and methods

Study Site

A trial was conducted in a demonstrative sweet cherry orchard at the Research Institute for Fruit Growing, Pitesti, Arges (44.89°S, 24.86°S, 287 m above sea level) during the 2020-2022 period. Based on multiannual data (1969-2021), the research area has a temperate climate with a mean annual temperature of 10.0 °C (-24.4°C min abs and 38.8°C max abs), an annual rainfall summing 678.1 mm, and duration of sunshine of 2260.8 hours. Compared to multiannual data, 2020-2022 period was warmer, drier and sunnier, with an annual average temperature of 11.35°C, 613.5 mm rainfall and 2386 sunshine hours. The months with the highest water deficit were July (78.7-10.25 mm compared to the multiannual 47.4 mm), June (with 99.6 mm in 2022 compared to 16.73 mm), April (with 62 mm in 2020, compared to the normal of 10.9 mm), August (with 83.7 mm in 2020, compared to the normal of 47.7 mm) and September (83.7 mm in comparison to 12.4 mm multiannual average of the month).

The study started on spindle-shaped trees of 4-year-old 'Regina' and 'Kordia' grafted on 'GiSelA 3' rootstock, planted at 4.0 m x 1.5 m on an alluvial soil, with a sandy-loam texture 80 cm in depth lying on a gravel layer (Chitu et al., 2010). Orchard management practices according to the principles of integrated fruit production were maintained during the trial. The plot was fertigated by a drip irrigation system, according to an expected fruit yield of 20 t/ha. The grass on the alleys between tree rows were mowed four times during the growing season, and left on the ground for decomposition.

Trial Design and Treatments

The study was carried out as a randomized complete block design with three replicates per treatment. The two cultivars were placed on two adjacent rows and, for each of them, the blocks were located on a single row and consisted of six trees with at least one buffer tree on either side. Within each of the three blocks, trees were randomly allocated to four different treatments: Control, BSA, containing amino acids - mainly arginine, proline, threonine, lysine - N, C, B, Mn, Zn, BSB, containing amino acids, proteins, betaine, vitamins, N, C, K and the soil-applied biostimulator (BSC, containing salts of humic and fulvic acids, amino acids, micro and macro elements, live bacteria). All treatments were applied manually. Both foliar biostimulators were applied in the phenological stages BBCH 53-green tip, BBCH 69-petal fall, and BBCH 72-sepals beginning to fall, while the BSC was applied in a single phase, in the phenological stage BBCH 53.

Sweet cherry foliar chlorophyll content index, annual increase of trunk cross-sectional area, and yield

Leaves chlorophyll content index (CCI) was determined with a CCM-200 portable chlorophyll content meter to observe treatments' influence on chlorophyll content index of intact leaf samples. Three determinations were done on fully expanded leaves (n = 270, i.e. 90 x 3 replicates), at three moments from the last applications, noted as TLA 1 (after 10 days), TLA 2 (30 days), and TLA3 (after 60 days). For each treated tree, trunk cross-sectional area (TCSA, cm^2) was calculated at the start and the end of the vegetation season (based on trunk diameter measurements with an electronic calliper), and the annual increase of TCSA was obtained. Fruit from each treated tree were hand-picked at commercial maturity and weighed to calculate sweet cherry yield.

Fruit Samples

Samples of fruits were randomly picked per each treatment for quality assessment: measurement of fruit weight (Kern Weighing Scale, KERN & SOHN GmbH, Balingen, Germany), pulp firmness (Bareiss Food Hardness Tester – HPE III FFF fruit penetrometer, Bareiss North America Inc.), of individual fruit (n = 90 per treatment, i.e., 30 fruit × 3 replicates). From the 30 fruits, subsamples of 10 fruits were then pooled (30 per treatment) and assessed for total soluble solids (TSS, Palette Series refractometer, Atago Co., Ltd., Tokyo, Japan), and pH (Dostmann electronic pH-meter, Dostmann electronic Wertheim-Reicholzheim, Germany). Samples of 100 g fruit per treatment were also picked for quality assessments regarding vitamin C, total titratable acidity, and total sugar level. Vitamin C content and total titratable acidity were determined by titration by iodine (vitamin C) and with standardized NaOH solution (TTA), while total sugar content was estimated by the Fehling-Soxhlet method, 1968 (Mazilu et al., 2021, 2023).

Statistical Analysis

Data were presented as means and standard deviation (SD) for each treatment and were compared using analysis of variance (ANOVA) and tested with Duncan's post hoc multiple comparisons (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY, USA: IBM Corp), at a significance level of 0.05. Only statistically assured effects were discussed. To measures linear correlation between two sets of data sets Pearson correlation coefficients were calculated in IBM SPSS 26.0. Microsoft Excel was used to represent parameters correlations depending on biostimulator treatment.

3. Results and discussions

Statistical descriptors of the data, summarized in Table 1, indicated that during the three years of the study, the chlorophyll content index had an average of 25.4 and oscillated between the limits of 9.32 and 52.06, the annual increase of trunk cross-sectional area fluctuated around the average of 5.68 cm^2 (0.79-11.77 cm^2), and the average fruit yield, 10.91 t/ha, rose from a minimum level of 0.48 to a maximum of 30.5 t/ha. Mean fruit weight (10.05 g) ranged from 5.72 to 14.59 g, mean pulp firmness (55.10 HPE-FFF-Bareiss units) ranged from 20.4 to 86.6 units, and the fruit pH had an average of 3.8 (with the limits of 2.9 and 5.22 respectively). Mean levels of total dry weight, total soluble solids, vitamin C and total titratable acidity were 18.31 (16.24-20.79%), 17.83 degrees Brix (3.4-28.60), 14 .26 % (9.7-16.39%), 16.07 mg/100 g (12.15-20.25 mg/100 g) and 0.54% (16.24 -20.79%) respectively. It could also be observed that, of the total dry weight, 77.87% were sugars, 2.56% organic acids, and 0.09% vitamin C.

The representation of the intensity of the correlations established between the quality indicators of the fruits (Tables 2 and 3) indicated that the fruits with high weight presented low pH (R=-0.155***) and firmness (R=-0.055 *). Also, by the accumulation of soluble solids, fruit firmness and pH decreased (R=-0.274***, R=-0.145***).

Regarding the biochemical indicators, the most intense correlation was the highly significant positive one between DW and TSC (R=0.421***). There was also an increase in the vitamin C content of highly acidic fruits (R=0.507***), observation supported by the results of previous studies which attests to the fact that vitamin C stability was increased at low pH (Farah et al., 2020). The correlations also indicate a reduction in the level of this vitamin in fruits with a high content of sugars (R=-0.253*), probably explained by the oxidation of vitamin C as the ripening of the fruit progresses (Gerasko et al., 2022).

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Sweet cherry foliar chlorophyll content index, annual increase of trunk cross-sectional area, and yield

The analysis of the variance of leaf chlorophyll content (Table 4) indicated significant differences between the cultivars, time from the last application (TLA), and treatments, but especially a significant effect of the interaction between TLA and the treatment with biostimulators.

In leaves treated with biostimulators, the total chlorophyll content index increased significantly between TLA1 and TLA2 (by 34.6%-49.2%) and non-significantly from TLA2 to TLA3 (by 2.7%-3.0%). Unlike the variants treated with biostimulators, in the Control, each of the two increases recorded for ICC (by 26.5% from TLA 1 to TLA 2 and 8.9% from TLA 2 to TLA 3) were significant, but CCI was each time lower (Fig. 1). Although in TLA1 no significant differences were observed between the three variants treated with biostimulators (CCI between 19.54 and 19.98), later, both in TLA2 and TLA3, the highest CCI were recorded in BSC (29.18 and 30.05 respectively), while CCI determined in BSA (26.88 and 27.62) and BSB (26.59 and 27.36) were significantly lower compared to BSC, but higher than Control.

The annual increase in TCSA fluctuated significantly only depending on the biostimulator treatment (Table 5), and this aspect was reflected in the significantly higher TCSA registered in BSC (6.78 cm^2), compared to the Control (4.76 cm^2) and both foliar treatments, BSA (5.67 cm^2) and BSB (5.50 cm^2) respectively (Fig. 2).

Variations in fruit yield depending on the treatment were not statistically ensured, being highlighted in this case a significant effect of the cultivar (Table 5). The most productive of the two cultivars was 'Regina', with an average yield of 14.96 t/ha, compared to 8.58 t/ha for 'Kordia' (Fig. 3).

Fruit quality

Among the fruit quality indicators, in this study were determined fruit weight, firmness, dry weight, total soluble solids, sugars, pH, total titratable acidity, and vitamin C content. As presented in Figure 4, in general, fruit weight was higher for 'Kordia' cv. (on average 10.32 g compared to 9.76 g for 'Regina'), while the effect of the treatment varied depending on the cultivar (Table 5). In all variants treated with biostimulators, a significant increase in fruit weight was recorded compared to the Control, although the highest increase in fruit weight after treatments was observed for 'Regina' cv. (with 17.2% - 19.2% compared to the Control). Among the four treatments, only in BSA the difference between the two cultivars was non-significant (Fig. 4).

Contrary to fruit weight, pulp firmness recorded significantly higher values for 'Regina' (on average 59.0 HPE-II-FFF Bareiss units vs. 51.4 HPE-II-FFF Bareiss units 'Kordia'). Under the treatment effect a significant increase in the pulp firmness was registered for all three biostimulants, although the highest firmness was recorded in BSB (56.9 HPE-II-FFF Bareiss units vs. 52.3 HPE-II-FFF Bareiss units in Control) (Fig. 5).

The most intense variations of TSS were those related to the cultivar (Table 5) and this indicator reached the highest level in 'Kordia' cv. (on average 18.5 °Brix), while a smaller effect was registered related to the treatment. Thus, in all three biostimulant treated variants, a significant increase in TSS, from 17.4 °Brix in Control to 17.9 -18.1 °Brix, was observed (Fig. 6).

TSC was significantly influenced by the cultivar (Table 2) and resulted in higher sugar content in 'Regina', respectively 15.0%, compared to 13.5% in 'Kordia'. TSC also recorded more or less significant increases in the treated variants (Fig. 7). Therefore, on the average of the cultivars, significant increases in TSC were observed in BSA (from 13.6% in Control to 14.5%) and especially in BSB (in which TSC reached the highest level, 14.8%).

TTA showed significantly different concentrations depending on the cultivar, but also depending on the treatment (Table 5). The lowest fruit acidity was recorded in 'Regina' (0.49%, compared to 0.60% in 'Kordia'), and significant effects of the biostimulants were observed only in the case of BSB treatment, in which TTA decreased to 0.46% compared to Control (0.57%) (Fig. 8).

Vitamin C was, similar to TSC and TTA, another quality indicator significantly influenced by the cultivar and the treatments (Table 5). A more intense effect of the cultivar was observed, which justifies the very large difference between the vitamin C levels of the cultivars (on average 13.5 mg/100 g in 'Regina' and 18.7 mg/100 g in 'Kordia') (Fig. 9). Although on the average of the cultivars in all variants treated with biostimulators the vitamin C content increased significantly compared to the Control, the highest increase, from 15.8 mg/100 g to 16.6 mg/100 g, was recorded in BSB.

According to literature data the vegetative growth was negatively correlated with yielding capacity because an abundant yield significantly weakened tree growth, while non-fruiting cherry trees had a stronger increase in the number of shoots and a larger leaf area (Kurlus et al., 2020). Although there is no doubt that climatic conditions have a significant impact on the growth and fruiting of sweet cherry trees, some other studies also reported significant effects of the rootstock, training system, pruning, tinning (mechanical or chemical), irrigation, fertilization and biostimulants on both vegetative growing and yield (Radunic et al., 2011; Balducci et al., 2019; Drobek, et al., 2019; Kurlus et al., 2020; Blanco et al., 2019; Csihon et al., 2020; Rutkowski and Łysiak, 2022).

The graph in figure 10 shows how fruit yield varied in the two sweet cherry cultivars, depending on the annual increase in TCSA for each of the four treatments with biostimulators. It can be seen that the correlations between the annual growth of TCSA and fruit yield were in all four analysed cases significant and described by degree 2 polynomial equations. A fruit yield tendency to increase from 6.8 to 14.8 kg/tree was highlighted in untreated Control for annual increase in TCSA between 0.9 and 6.5 cm^2, followed by a decrease of the yield when annual increase of TCSA rose from 6.5 to 11.5 cm^2. It can be therefore stated that untreated trees directed their assimilates either to fruiting or vegetative growth. In BSB treatment, for both, small growth of TCSA (between 0.8 and 2.6 cm^2), and large growths (7.8-10.5 cm^2), the fruit yield was only slightly higher compared to the Control and even recorded a small reduction, compared to the Control, in the range of annual TCSA increases between 2.6 and 8 cm^2.

In the area of small annual increases of TCSA (1.5-3.7 cm^2), high fruit yield was obtained in BSA treatment (13-13.5 kg/tree), and especially in BSC (15-18.5 kg/tree).

However, a reduction in the BSC effect was observed compared to BSA (and even compared to BSB) in the case of trees with above-average annual growth of TCSA, and therefore the highest fruit yield resulted in BSA (15-24.5 kg/tree compared to 13.0-14.5 in BSC treatment).

The graphical representation of the fruit firmness variation depending on the weight of the fruit for 'Regina' (Fig. 11-left) and 'Kordia' (Fig. 11-right) indicated for 'Regina' cv. a positive linear correlation but non-significant in the Control treatment, another non-significant correlation described by a polynomial equation of grade 2 in the BSB and polynomial significant correlations, in BSA and BSC. Unlike 'Regina', in 'Kordia' cv. the correlations between the two parameters were significant in all treatments, negative linear for Control and polynomial grade 2 for biostimulators.

As presented, in **'Regina'**, the firmness of small (6.5-9.0 g) and large (12.4-14.3 g) fruits was higher in BSA (60.8-70.1 and 61.7 -67.4 HPE-II FFF Bareiss units respectively), while in the medium fruit weights domain (9.0-12.4 g) the highest firmness was determined in BSB (60.0-61.3 HPE-II FFF Bareiss units). In **'Kordia'**, for under-average weight fruits (6.7-12.5 g), the firmness increased in BSC (53-70 HPE-II FFF Bareiss units) and especially in BSB (53-77.8 HPE-II FFF Bareiss units vs. 47.0-54.0 HPE-II FFF Bareiss units in Control). For above-average weight sweet cherries (12.5 -14.6 g), all three treatments with biostimulators increased fruit firmness compared to the Control, and, among these three, the effect of BSA was slightly highlighted.

In figure 12 the variation of the total soluble solids depending on the weight of the fruits in 'Regina' (left) and 'Kordia' (right) cvs. is represented. In all analysed cases, the relationships between the two indicators were described by polynomial equations of grade 2 and were significant for all biostimulator treatments and non-significant for the Control. In 'Regina', TSS of fruits with a weight between 5.7 and 8.1 g was lower in biostimulator-treated variants compared to the Control, but higher than the Control for sweet cherries with above-average weight (9.4 -12.9 g), especially in BSC. In 'Kordia' cv., although for fruits with a weight between 6.2 and 12.0 g, the firmness was slightly higher compared to Control, especially in BSB and BSC, for large fruits, with a weight of 12-14 g, the differences between all four analysed variants were small.

The analysis of the correlation of the total sugar content depending on the sweet cherries dry weight (Fig. 13) indicated for all four treatments the existence of significant correlations (polynomial grade 2), except for the BSC. The effects of foliar treatments with BSA and BSB were strongly highlighted. A smaller variation interval can be observed for sweet cherry DW in all three biostimulants treatments compared to Control. Therefore, for DW levels between 17.2 and 21.4%, TSC was higher compared to the Control (14.1-15.3% in BSB treatment and 13.3-14.8% in BSA treatment with, vs 12.7-13.7% in Control).

4. Conclusions

In this study, the soil application of the biostimulator (BSC, containing salts of humic and fulvic acids, amino acids, micro and macro-elements, and living bacteria) increased leaves chlorophyll content index and stimulated the vegetative growth of cherry trees, while the two foliar biostimulators (BSA, containing amino acids - mainly arginine, proline, threonine, lysine - N, C, B, Mn, Zn and BSB, containing amino acids, proteins, betaine, vitamins, N, C, K) also had significant but smaller effects. However, it should be noted that the foliar application of BSA ensured a balanced partitioning of assimilates between growth and fruiting. All three biostimulants increased fruit weight, total soluble solids, and firmness. The two foliar-applied biostimulators increased total sugar content and vitamin C, and BSB reduced fruit acidity. These effects testify to the fact that, in the pedoclimatic conditions of the Arges area, treatments with biostimulators, in addition to an adequate nutrition plan, stimulated growth and fruiting processes, and increased the quality of sweet-cherry fruits. Nonetheless, taking into account the dynamics of climatic factors, long-term studies are needed to assess the biostimulators effect of reducing the abiotic stress consequences.

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References

1. Afonso S., Oliveira I., Meyer A.S., and Gonçalves B., 2022. Biostimulants to improved tree physiology and fruit quality: A review with special focus on sweet cherry. Agronomy, 12(3): 659.
2. Balducci F., Capriotti L., Mazzoni L., Medori I., Albanesi A., Borraccini G., Giampieric F., Mezzetti B., and Capocasa F., 2019. The rootstock effects on vigor, production and fruit quality in sweet cherry (*Prunus avium* L.). Journal of Berry Research, 9(2): 249-265.
3. Blanco V., Torres-Sánchez R., Blaya-Ros P.J., Pérez-Pastor A., and Domingo R., 2019. Vegetative and reproductive response of ‘Prime Giant’sweet cherry trees to regulated deficit irrigation. Scientia Horticulturae, 249: 478-489.
4. Chitu V., Chitu E., Marin F.C., Ionita A.D., Cirjaliu-Murgea M., and Filipescu L., 2010. Foliar ecological products effect on apple growth, yield and quality. In 6th International ISHS Symposium on Mineral Nutrition of Fruit Crops. Acta Horticulturae.
5. Csihon Á., Gonda I., Orosz-Tóth M., and Holb I.J., 2020. Effect of N, P, K and Mg fertilizers on some vegetative and generative parameters of a sweet cherry cultivar. International Journal of Horticultural Science, 26: 27-30.
6. Drobek M., Frąc M., and Cybulska J., 2019. Plant biostimulants: Importance of the quality and yield of horticultural crops and the improvement of plant tolerance to abiotic stress—A review. Agronomy, 9(6): 335.
7. Farah H.S., Alhmoud J.F., Al-Othman A., Alqaisi K.M., Atoom A.M., Shadid K., Shakya A., and AlQaisi T., 2020. Effect of pH, temperature and metal salts in different storage conditions on the stability of vitamin C content of yellow bell pepper extracted in aqueous media. Syst. Rev. Pharm, 11: 661-667.
8. Gerasko T., Pyda S., Paschenko Y., Ivanova I., Pokoptseva L., and Tymoshchuk T., 2022. Content of biologically active substances in sweet cherry fruits at different stages of fruit development in the conditions of the living mulch.
9. Kurlus R., Rutkowski K., and Łysiak G.P., 2020. Improving of cherry fruit quality and bearing regularity by chemical thinning with fertilizer. Agronomy, 10(9): 1281.
10. Mazilu I.E., Paraschiv M., Dinu M.D., and Cosmulescu S.N., 2021. Biochemical changes in two *Aronia melanocarpa* cultivars’ berries during the harvest season. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 49(3): 12393-12393.
11. Mazilu I.C.E. and Cosmulescu S., 2023. Effect of cultivar, year, and their interaction on nutritional and energy value components in *Aronia melanocarpa* berries. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 51(4): 13478-13478.
12. Ouzounis T., and Lang G.A., 2011. Foliar applications of urea affect nitrogen reserves and cold acclimation of sweet cherries (*Prunus avium* L.) on dwarfing rootstocks. HortScience, 46(7): 1015-1021.
13. Paltineanu C. and Chitu E., 2020. Climate change impact on phenological stages of sweet and sour cherry trees in a continental climate environment. Scientia Horticulturae, 261: 109011.
14. Radunic M., Jazbec A., Pecina M., Čosić T., and Pavičic N., 2011. Growth and yield of the sweet cherry (*Prunus avium* L.) as affected by training system. African journal of biotechnology, 10(24): 4901-4906.
15. Rutkowski K., and Łysiak G.P., 2022. Thinning methods to regulate sweet cherry crops—A review. Applied Sciences, 12(3): 1280.

Tables and Figures

Table 1. Statistic descriptors for chlorophyll content index, annual increase of TCSA, fruit yield, and fruit quality parameters

	CCI	Annual increase of TCSA (cm^2)	Fruit yield (t/ha)	Fruit weight (g)	Pulp firmness (HPE-II-FFF Bareiss units)	Dry weight (%)	TSS (°Brix)	Total sugar content (%)	pH	Total titratable acidity (%)	Vitamin C (mg/100 g)
Mean	25.40	5.68	12.54	10.05	55.10	18.31	17.83	14.26	3.80	0.54	16.07
Median	24.60	5.47	12.25	10.02	56.30	18.13	17.90	14.41	3.80	0.55	15.56
Mode	22.80	5.74	8.00	10.48	53.00	17,59^{a}	19.60	12,79^{a}	3.90	0.62	13,22^{a}
Std. Deviation	6.70	2.34	5.66	1.42	10.96	0.99	2.77	1.21	0.30	0.11	2.71
Range	42.74	10.98	30.02	8.87	66.20	4.55	25.20	6.69	2.32	0.54	8.10
Minimum	9.32	0.79	0.48	5.72	20.40	16.24	3.40	9.70	2.90	0.31	12.15
Maximum	52.06	11.77	30.50	14.59	86.60	20.79	28.60	16.39	5.22	0.85	20.25

Table 2. Correlation strength between fruit weight, total soluble solids (TSS), pulp firmness, and fruit pH (Pearson Correlation coefficients and significance are presented)

	TSS	pH	Pulp firmness
Fruit weight	0,047	-0,155***	-0,055*
Pulp firmness	-0,274***	-0,145***	
pH	-0,035		

Table 3. Correlation strength between fruit dry weight content (DW), total titratable acidity (TTA), total sugar content (TSC), and vitamin C (Pearson Correlation coefficients and significance are presented)

	Vitamin C	TSC	TTA
DW	0,038	0,421***	0,160
TTA	0,507***	-0,167	
TSC	-0,253*		

Table 4. Significance of cultivar, time from the last application, treatment main effect and interactions on leaves chlorophyll content index

Factor		sig.
Cultivar	main effect	***
TLA*	main effect	***
Treatment	main effect	***
Cultivar * TLA	interaction	n.s
Cultivar * Treatment	interaction	n.s
TLA* Treatment	interaction	***
Cultivar * TLA* Treatment	interaction	n.s

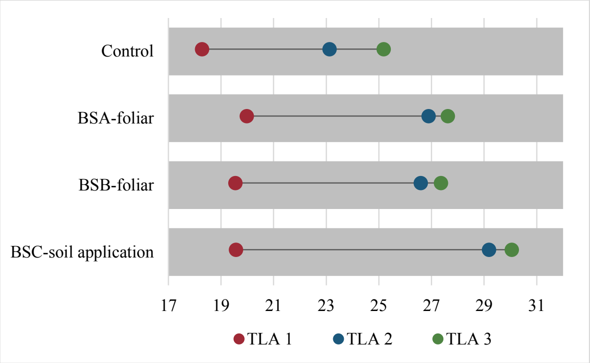
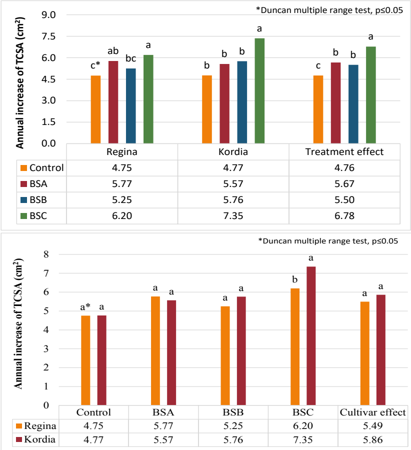


Fig. 1. Sweet cherry leaves chlorophyll content index variation depending on biostimulator treatments and time from last application

Table 5. Significance of cultivar and treatment main effect and interaction on sweet cherry annual increase of trunk cross-sectional area, fruit yield, and fruit quality indicators

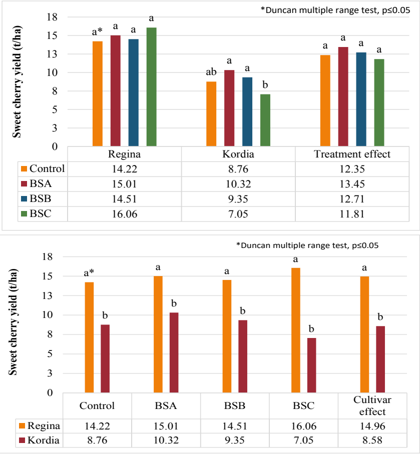
Factor		Annual increase of TCSA	Fruit yield	Fruit weight	Pulp firmness	DW	TSS	TSC	pH	TTA	Vitamin C
Cultivar	**main effect**	n.s.	***	***	***	n.s	***	***	***	***	***
Treatment	**main effect**	***	n.s	***	***	n.s	**	**	n.s	***	**
Cultivar * Treatment	**interraction**	n.s.	n.s	***	n.s	n.s	n.s	n.s	*	n.s	n.s
Treatment	**simple effect**										
Regina		**	n.s	***	***	n.s	*	n.s	***	**	n.s
Kordia		***	n.s	***	***	n.s	n.s	*	n.s	*	*
Cultivar	**simple effect**										
Control		n.s	***	***	***	n.s	*	**	***	***	***
BSA-foliar		n.s	***	n.s	***	n.s	***	***	**	n.s	***
BSB-foliar		n.s	***	***	***	n.s	***	**	***	*	***
BSC-soil application		**	***	***	***	n.s	***	*	*	*	***



	Regina	Kordia	Treatment effect
Control	4.75	4.77	4.76
BSA	5.77	5.57	5.67
BSB	5.25	5.76	5.50
BSC	6.20	7.35	6.78

	Control	BSA	BSB	BSC	Cultivar effect
Regina	4.75	5.77	5.25	6.20	5.49
Kordia	4.77	5.57	5.76	7.35	5.86

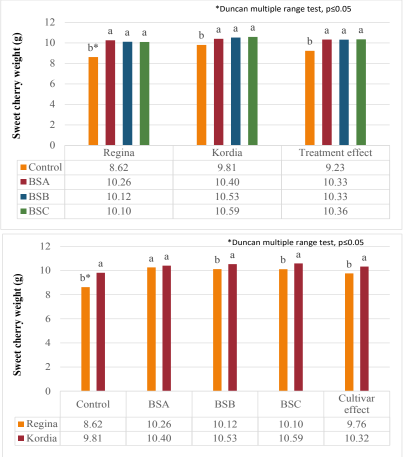
Fig. 2. Treatment and cultivar main effect and interaction on sweet-cherry annual increase of trunk cross-sectional area



	Regina	Kordia	Treatment effect
Control	14.22	8.76	12.35
BSA	15.01	10.32	13.45
BSB	14.51	9.35	12.71
BSC	16.06	7.05	11.81

	Control	BSA	BSB	BSC	Cultivar effect
Regina	14.22	15.01	14.51	16.06	14.96
Kordia	8.76	10.32	9.35	7.05	8.58

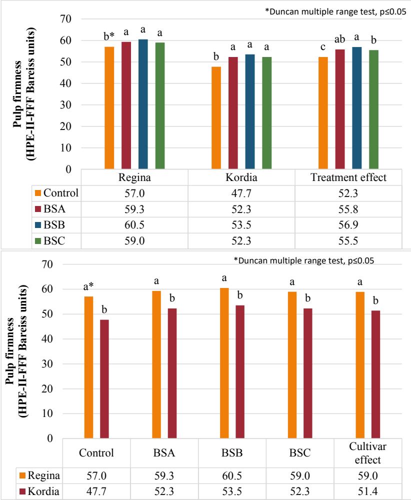
Fig. 3. Treatment and cultivar main effect and interaction on sweet-cherry yield



	Regina	Kordia	Treatment effect
Control	8.62	9.81	9.23
BSA	10.26	10.40	10.33
BSB	10.12	10.53	10.33
BSC	10.10	10.59	10.36

	Control	BSA	BSB	BSC	Cultivar effect
Regina	8.62	10.26	10.12	10.10	9.76
Kordia	9.81	10.40	10.53	10.59	10.32

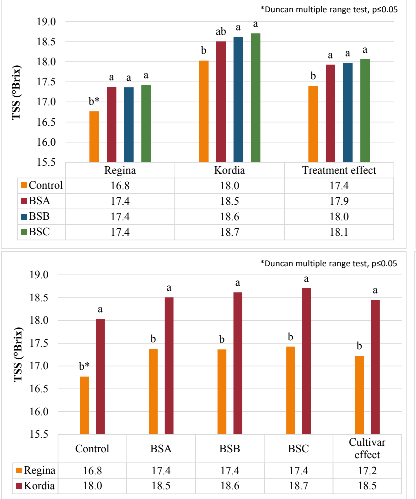
Fig. 4. Treatment and cultivar main effect and interaction on fruit weight



	Regina	Kordia	Treatment effect
Control	57.0	47.7	52.3
BSA	59.3	52.3	55.8
BSB	60.5	53.5	56.9
BSC	59.0	52.3	55.5

	Control	BSA	BSB	BSC	Cultivar effect
Regina	57.0	59.3	60.5	59.0	59.0
Kordia	47.7	52.3	53.5	52.3	51.4

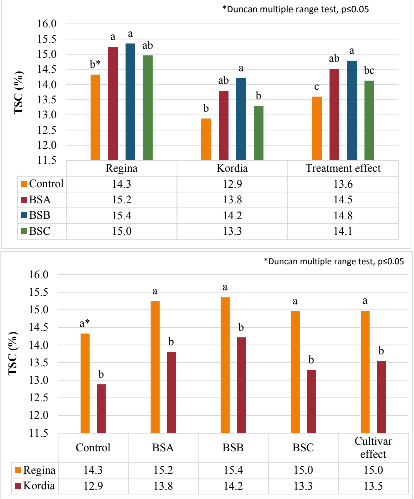
Fig. 5. Treatment and cultivar main effect and interaction on pulp firmness



	Regina	Kordia	Treatment effect
Control	16.8	18.0	17.4
BSA	17.4	18.5	17.9
BSB	17.4	18.6	18.0
BSC	17.4	18.7	18.1

	Control	BSA	BSB	BSC	Cultivar effect
Regina	16.8	17.4	17.4	17.4	17.2
Kordia	18.0	18.5	18.6	18.7	18.5

Fig. 6. Treatment and cultivar main effect and interaction on fruit total soluble solids (TSS)



	Regina	Kordia	Treatment effect
Control	14.3	12.9	13.6
BSA	15.2	13.8	14.5
BSB	15.4	14.2	14.8
BSC	15.0	13.3	14.1

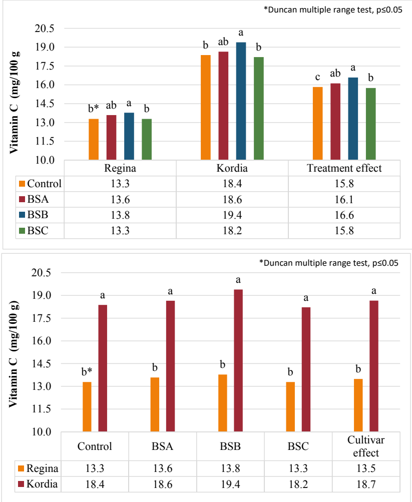
	Control	BSA	BSB	BSC	Cultivar effect
Regina	14.3	15.2	15.4	15.0	15.0
Kordia	12.9	13.8	14.2	13.3	13.5

Fig. 7. Treatment and cultivar main effect and interaction on fruit total sugar content (TSC)

	Regina	Kordia	Treatment effect
Control	0.48	0.66	0.57
BSA	0.54	0.59	0.56
BSB	0.40	0.52	0.46
BSC	0.53	0.63	0.58

	Control	BSA	BSB	BSC	Cultivar effect
Regina	0.48	0.54	0.40	0.53	0.49
Kordia	0.66	0.59	0.52	0.63	0.60

Fig. 8. Treatment and cultivar main effect and interaction on fruit total titratable acidity (TTA)



	Regina	Kordia	Treatment effect
Control	13.3	18.4	15.8
BSA	13.6	18.6	16.1
BSB	13.8	19.4	16.6
BSC	13.3	18.2	15.8

	Control	BSA	BSB	BSC	Cultivar effect
Regina	13.3	13.6	13.8	13.3	13.5
Kordia	18.4	18.6	19.4	18.2	18.7

Fig. 9. Treatment and cultivar main effect and interaction on fruit vitamin C content

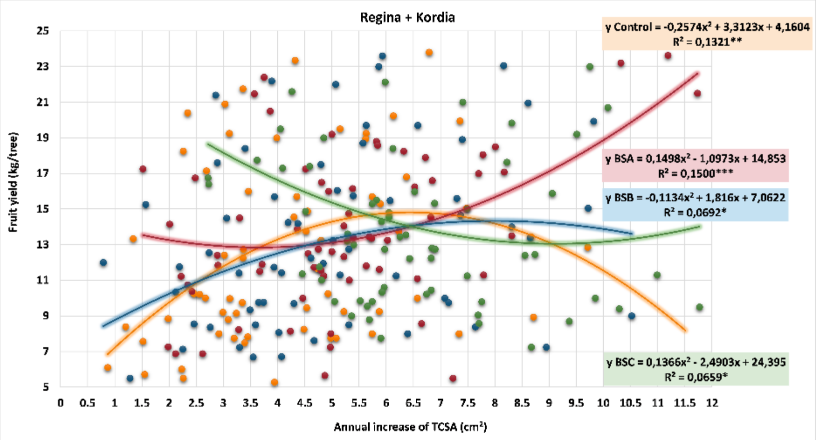


Fig. 10. Annual increase of TCSA effect on sweet cherry fruit yield depending on biostimulator treatment

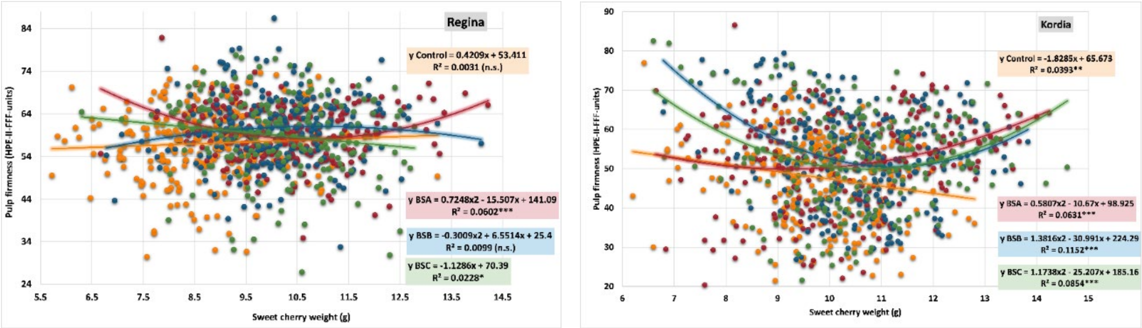


Fig. 11. Sweet cherry weight effect on pulp firmness depending on biostimulator treatment on 'Regina' (left) and 'Kordia' cvs. (right)

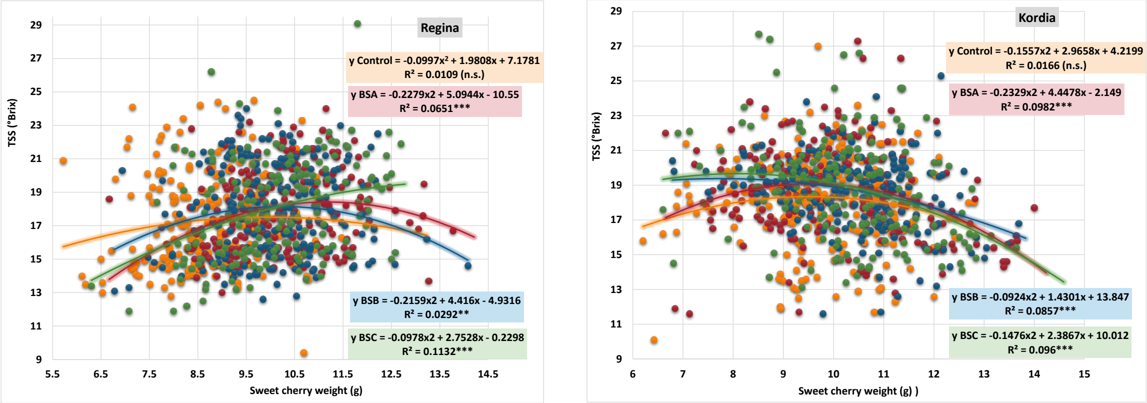


Fig. 12. Sweet cherry weight effect on pulp firmness depending on biostimulator treatment on 'Regina' (left) and 'Kordia' cvs. (right)

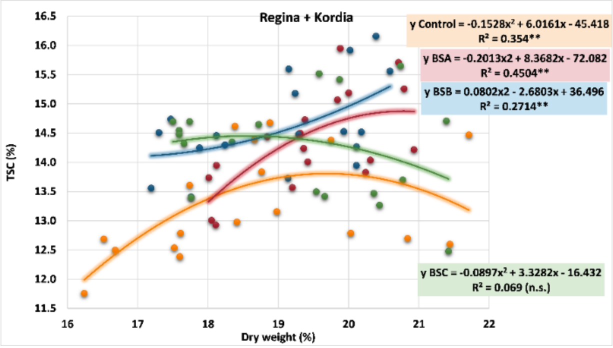


Fig. 13. Sweet cherry dry weight effect total sugar content depending on biostimulator treatment