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ROLE OF 22S, 23S-HOMOBRASSINOLIDE AND GA_3 ON FRUIT QUALITY OF '0900 ZIRAAT' SWEET CHERRY AND PHYSIOLOGICAL DISORDERS

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Abstract. Acquiring high quality in sweet cherry production is of great importance. Plant growth regulators have been used to increase yield and quality in the production of sweet cherries. Brassinosteroids, a relatively new group of plant growth regulators, have been found with interesting results on plant growth and development. This research was carried out to evaluate the role of brassinosteroids and gibberellins in development of fruit quality and occurrence of physiological disorders in '0900 Ziraat' sweet cherry. Gibberellic acid (GA_3) and 22S, 23S-homobrassinolide were applied with a sprayer at full bloom and at the beginning of fruit development for a 2-year period. GA_3 was applied in concentrations of 25, 50, and 100 mg l^{-1} and 22S, 23S-homobrassinolide was applied in concentrations of 0.05, 0.1, and 0.5 mg l^{-1}. A combined application of 100 mg l^{-1} GA_3 + 0.1 mg l^{-1} 22S, 23S-homobrassinolide was also applied. Plant growth regulator applications mainly caused an increase in fruit weight and flesh to seed ration, and a decrease in fruit length. The effect was mainly due to gibberellin. Both Total soluble solids and titratable acidity were affected by the hormones and the seasons. Neither growth regulators had an influence on occurrence of the physiological disorders. They were at a lesser level in the second seasons.

Key words: Brassinosteroid, gibberellins, *Prunus avium*, quality, disorder

INTRODUCTION

There is an increasing demand by the local and international markets for high quality sweet cherry (*Prunus avium* L.) fruits. Red exocarp, green stems, characteristic texture and flavor are important aspects of sweet cherry quality [Wani et al. 2014]. Double fruit, fruit cracking and pitting are major physiological disorders which can also cause

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crop losses in sweet cherry production. Double fruits form when two pistils fuse together during development and growth [Beppu and Kataoka 2011, Engin et al. 2009]. Fruit cracking is characterized by a splitting of the outside layer of the cherry [Sekse et al. 2005, Whiting 2005]. Pitting is the situation with small sunken areas on the fruit surface. In many cases, certain varieties are more predisposed to a specific disorder than others [Usenik et al. 2005].

Gibberellic acid (GA_3) application is currently a standard application for sweet cherry growers. Cline and Trought [2007] reported improved fruit firmness in 'Bing' sweet cherry. Horvitz et al [2003] reported the application of GA_3 sprays on the cultivars 'Merton Premier' and 'Bing' increased fruit weight. The studies also reported an increase in ascorbic acid and soluble solids and a reduction in titratable acidity [Kappel and MacDonald 2002, Nguyen and Yen 2013]. Looney [1983] reported that GA_3 applied at the beginning of fruit growth reduced fruit pitting in sweet cherry. Similarly, GA_3 sprays were studied in 'Van' sweet cherry cultivar to reduce the risk of crop loss due to physiological disorders [Engin et al 2009]. Although there are numerous studies pertaining to the effects of exogenously applied gibberellins, there is no study to date that evaluates influence of brassinosteroids in sweet cherries. Brassinosteroids are a group of hormones that play a role in wide selection of developmental processes in plants, such as growth, flowering, senescence and maturation [Swamy and Rao 2008].

This research was carried to evaluate the role of two growth regulators from two families, including brassinosteroids and gibberellins, in development of fruit quality and occurrence of physiological disorders in '0900 Ziraat' sweet cherry.

MATERIALS AND METHODS

Plant materials and treatments design. The experiment was conducted at a commercial block of 14-year old '0900 Ziraat' sweet cherry (*Prunus avium*) trees, grafted on 'MaxMa 14' located at the Horticulture Experimental Farm of Çanakkale Onsekiz Mart University, 5 m above sea level. The trees were planted at 4 × 5 m spacing and trained in a modified central leader shape. A total of 24 trees were selected for the research. Selected trees were cultivated under the same cultural practices such as pruning, fertilization, irrigation and disease control. Five uniform branches about the same length and diameter in each tree were selected for the measurements.

Treatments. 22S,23S-homobrassinolide (Homo-Br) and gibberellic acid (GA_3) were applied with a handgun sprayer until runoff at full bloom and at the beginning of fruit development for a two-year period (2012 and 2013). The substances were sprayed on windless days using an average of 3.8 ±0.29 L of the solutions per tree. Distilled water was sprayed on the control trees. GA_3 was applied in concentrations of 25, 50, and 100 mg L^{-1} and Homo-Br was applied in concentrations of 0.05–0.1 and 0.5 mg l^{-1}. A combination application of 100 mg L^{-1} GA_3 + 0.1 mg L^{-1} Homo-Br was also applied.

Measurements. Fruit from all of the selected branches of '0900 Ziraat' were harvested and taken to the laboratory for fruit quality analyses. Data were collected on fruit weight (g), size as width and length (mm) and firmness (N) from 50 fruits. Color measurement (the surface color of sweet cherry) was measured with a Minolta colorimeter

(Chroma Meter Model CR-400, Minolta, Japan) on both sides of 50 fruit per treatment and expressed as chroma. Stem resistance (N) was assessed by a Chatillon dinamometer with a pulling plug.

Flesh to seed ratio (%) was assessed by weighing a whole fruit and its extracted seed. Total soluble solid content (%) of the fruits were measured with a refractometer (Atago, ATC-1, Japan). Titratable acidity (g malic acid per 100 ml juice) was determined with a pH meter (Mettler Toledo MP220, Germany). 50 fruits were used for these measurements.

On the selected branches in each year, the total number of fruits and fruits with doubling, cracking and pitting were counted before harvest and the percentages were calculated in order to determine the level of physiological disorders.

Statistical analysis. The experiment was designed as a randomized parcels design with 3 single tree replications. Data were evaluated with SPSS for Windows (Chicago, USA, v. 13.0) statistical package program and significance between the means was determined by Duncan's multiple range tests ($p \leq 0.05$). Differences within the years and the treatments were tested. An arc sinus transformation for comparison of proportions was done.

RESULTS

Effects on fruit quality. Effects of GA_3 and Homo-Br on fruit weight were evident for the concentrations applied and between the seasons (tab. 1). No interactions were observed. There was a slight tendency for fruits to be heavier when exposed to the growth regulators, although the extent was not distinct. There was a 5% decrease in the second year. Application of 25 mg l^{-1} GA_3 significantly increased the fruit weight by 16% compared to the untreated fruit. Growth regulators had different effects on fruit size. Fruit lateral width was under the influence of an interaction between growth regulators and the seasons. In the first season, there were no clear differences in the effects, however, in the second season they began to appear. Especially between the highest concentration of Homo-Br (0.5 mg l^{-1}) and the combination application of both regulators with the lowest GA_3 concentration, the difference was the greatest (2.3–2.6 mm). Seasonal differences were only at the 25 mg l^{-1} GA_3 and the difference was 3.5 mm. Length of the fruit was independently affected by the season and the concentrations of the substances. There was 0.5 mm decrease in the second year. The best application for increasing the fruit length was mainly the use of Homo-Br with GA_3. In general all Homo-Br applications increased the length of the fruits comparably better than GA_3 at low and medium concentrations.

Statistical differences were not observed in fruit firmness and stem resistance (tab. 2). Flesh to seed ratio was affected by the treatments and the seasons. Only the 100 mg L^{-1} GA_3 resulted in significant differences with the 0.1 mg L^{-1} Homo-Br and the control group. The ratio in the first year was higher than the second year.

Color of fruits was unaffected by treatments (tab. 3). Total soluble solid content (SSC) were interactively influenced by the growth regulators and the season. Seasonal differences were only observed in the fruits treated with 100 mg l^{-1} GA_3 and the combi-

Table 1. Effect of 22S, 23S-homobrassinolide (Homo-Br) and gibberellic acid (GA_3) on fruit weight and size of [*Prunus avium* cv. 0900 Ziraat] at harvest

Treatment	Fruit weight (g)			Fruit size (mm)					
				width			length		
	2012	2013	mean	2012	2013	mean	2012	2013	mean
25 mg L^{-1} GA_3	7.62	6.87	7.25 A***	27.8 Aa*	24.3 Bb	26.1	25.8	24.6	25.2 C**
50 mg L^{-1} GA_3	6.85	6.62	6.74 AB	27.9 Aa	26.1 ABa	27.0	25.6	25.6	25.7 BC
100 mg L^{-1} GA_3	6.98	6.63	6.81 AB	28.0 Aa	26.4 ABa	27.2	26.5	26.1	26.3 AB
0.05 mg L^{-1} Homo-Br	6.40	6.37	6.39 B	27.3 Aa	26.4 ABa	26.9	26.2	26.0	26.1 AB
0.1 mg L^{-1} Homo-Br	6.78	6.35	6.57 AB	27.2 Aa	26.5 ABa	26.8	26.1	26.2	26.1 AB
0.5 mg L^{-1} Homo-Br	6.99	6.43	6.71 AB	27.1 Aa	26.6 Aa	26.8	26.3	26.0	26.2 AB
100 mg L^{-1} GA_3 + 0.1 mg L^{-1} Homo-Br	7.02	6.75	6.89 AB	27.4 Aa	27.1 Aa	27.2	26.5	26.7	26.6 A
Untreated	6.40	6.06	6.24 B	26.5 Aa	25.2 ABa	25.9	26.1	24.5	25.3 C
Mean	6.88 A***	6.51 B	–	27.40	26.07	–	26.2 A*	25.7 B	–

Means followed by the same small letter in rows and same capital letters in columns are not statistically different (p values, * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001)

Table 2. Effect of 22S, 23S-homobrassinolide (Homo-Br) and gibberellic acid (GA_3) on fruit stem resistance, flesh/seed ratio and firmness of *Prunus avium* cv. 0900 Ziraat at harvest

Treatment	Firmness (N)			Flesh/seed ratio (%)			Stem resistance (N)		
	2012	2013	mean	2012	2013	mean	2012	2013	mean
25 mg L^{-1} GA_3	1.00	0.94	0.97	8.66	7.54	8.10 AB***	5.53	5.35	5.44
50 mg L^{-1} GA_3	0.96	0.95	0.96	8.39	7.74	8.07 AB	5.65	5.25	5.45
100 mg L^{-1} GA_3	0.95	0.98	0.97	8.46	7.85	8. 16 A	5.51	5.05	5.28
0.05 mg L^{-1} Homo-Br	0.97	0.99	0.98	8.04	7.49	7.77 AB	5.53	5.12	5.32
0.1 mg L^{-1} Homo-Br	0.97	0.99	0.98	8.02	6.78	7.40 B	5.59	5.42	5.51
0.5 mg L^{-1} Homo-Br	0.94	1.02	0.98	8.09	6.86	7.48 AB	5.49	5.53	5.51
100 mg L^{-1} GA_3 + 0.1 mg L^{-1} Homo-Br	0.98	1.02	1.00	8.23	7.01	7.62 AB	5.75	5.65	5.70
Untreated	0.95	0.97	0.96	7.70	7.01	7.38 B	5.50	6.24	5.87
Mean	0.97	0.98	–	8.20 A***	7.29 B	–	5.57	5.45	–

Means followed by the same small letter in rows and same capital letters in columns are not statistically different (p values, * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001)

Table 3. Effect of 22S, 23S-homobrassinolide (Homo-Br) and gibberellic acid (GA_3) on fruit colour, soluble solids and titratable acidity of *Prunus avium* cv. 0900 Ziraat at harvest

Treatment	Fruit colour (chroma)			Soluble solids (%)			Titratable acidity (%)		
	2012	2013	mean	2012	2013	mean	2012	2013	mean
25 mg L^{-1} GA_3	40.5	40.9	40.7	11.86 Ba	12.06 ABa	12.0	0.79	0.75	0.77 AB***
50 mg L^{-1} GA_3	41.1	41.2	41.2	12.01 Ba	12.13 Aa	12.1	0.76	0.75	0.76 AB
100 mg L^{-1} GA_3	41.4	41.5	41.4	12.86 Aa	12.20 Ab	12.5	0.72	0.68	0.71 B
0.05 mg L^{-1} Homo-Br	41.0	40.8	40.9	11.95 Ba	11.62 BCa	11.8	0.78	0.76	0.77 AB
0.1 mg L^{-1} Homo-Br	41.1	40.8	40.9	12.01 Ba	11.58 BCa	11.8	0.81	0.77	0.79 A
0.5 mg L^{-1} Homo-Br	40.9	40.3	40.6	11.93 Ba	11.56 BCa	11.7	0.79	0.80	0.79 A
100 mg L^{-1} GA_3 + 0.1 mg L^{-1} Homo-Br	41.5	40.2	40.8	11.72 Ba	11.22 Cb	11.5	0.80	0.81	0.81 A
Untreated	40.3	40.8	40.6	11.94 Ba	11.96 ABa	11.9	0.78	0.77	0.77 A
Mean	41.0	40.9	–	12.0	11.8	–	0.78 A*	0.76 B	–

Means followed by the same small letter in rows and same capital letters in columns are not statistically different (p values, * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001)

Table 4. Effect of 22S, 23S-homobrassinolide (Homo-Br) and gibberellic acid (GA_3) on sweet cherry fruit cracking, double fruit and pitting of *Prunus avium* cv. 0900 Ziraat at harvest

Treatment	Fruit with cracked (% by number)			Fruit with double (% by number)			Fruit with pits (% by number)		
	2012	2013	mean	2012	2013	mean	2012	2013	mean
25 mg L^{-1} GA_3	0.89	0.44	0.67	0.89	0.44	0.67	0.44	0.44	0.44
50 mg L^{-1} GA_3	1.33	0.89	1.11	0.89	0.44	0.67	0.44	0.44	0.44
100 mg L^{-1} GA_3	2.22	0.44	1.33	0.89	0.44	0.67	0.89	0.44	0.67
0.05 mg L^{-1} Homo-Br	0.89	0.44	0.67	0.89	0.89	0.89	0.89	0.44	0.67
0.1 mg L^{-1} Homo-Br	1.33	0.44	0.89	0.89	0.44	0.67	0.89	0.44	0.67
0.5 mg L^{-1} Homo-Br	0.89	0.44	0.67	1.78	0.44	1.11	1.33	0.89	1.11
100 mg L^{-1} GA_3 + 0.1 mg L^{-1} Homo-Br	1.33	1.89	1.61	1.33	0.44	0.89	0.44	0.44	0.44
Untreated	1.78	1.33	1.56	1.33	0.89	1.11	1.33	0.44	0.89
Mean	1.73 A*	0.67 B	–	1.11	0.56	–	0.83	0.5	0.67

Means followed by the same small letter in rows and same capital letters in columns are not statistically different (p values, * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001) nation application. In 2012, GA_3 applied at the highest concentration (100 mg l^{-1}) caused the fruits to have more SSC than the rest of the treatments. However, in the second year, differences appeared to be distinctive. Homo-Br applications resulted in the lower SSC compared with the GA_3 treatments. Combination of the two growth regulators caused fruits to have comparably less soluble solids. 100 mg l^{-1} GA_3 + 0.1 mg l^{-1} Homo-Br had the least amount of soluble solids in both seasons. All GA_3 applications reduced titratable acidity (TA) in the second year. TA was generally at a similar level in all the applications except for the 100 mg l^{-1} GA_3.

Effects on physiological disorders. Formation of double and pitted fruits was not affected by the treatments (tab. 4). Cracking, on the other hand, was under the influence of seasons and reduced around 50% in the second year. Although no statistical importance was observed in the formation of double or pitted fruits, they were also reduced 40–50% in the second year.

DISCUSSION

This investigation describes the effects of GA_3 and 22S, 23S-homobrassinolide on fruit quality and occurrence of physiological disorders in '0900 Ziraat' sweet cherry cultivar. The results show that both growth regulators had similar effects on increasing fruit weight. However, using the lowest concentration of gibberellin, followed by the combination treatment produced fruits with heaviest fruits. Bhat et al. [2011] concluded that both brassinosteroid (0.4 ppm) and CPPU (4 ppm) along with brassinosteroid (20 ppm) applied to the grapes by dipping produced maximum bunch and berry weight. Tambe [2002] and Warusavitharana et al. [2008] used brassinosteroid with GA_3 at 3–4 mm grape berry stage and concluded that they both increased cell elongation and division. Watanabae et al [1997] also reported that 0.001 ppm brassinolide applied at bloom increased grape berry and cluster weights.

The fruit size is one of the most important quality parameter in cherries. According to Cline and Trought [2007] and Zeman et al. [2012] gibberellic acid increased fruit size of sweet cherry. In this research, there were significant differences in suture diameter between treatments. Homo-Br exerted inducing results in producing longer fruits. The result from the application of both growth regulators produced the longest fruits might suggest that GA_3 and Homo-Br seemed to increase cell elongation, which was mentioned in Yokota [1997].

Fruit firmness and total soluble solids are considered to be an important parameter of quality of sweet cherry fruits. The use of GA_3 did not result an increase in fruit firmness at harvest, contradicting with the results of Choi et al. [2002], Zilkah et al. [2008], Canlı and Orhan [2009] and Eihorn et al. [2013]. In sweet cherry, an increased fruit firmness different application of gibberellic acid is consistent with the other research [Facteau et al. 1989, Özkaya et al. 2006]. From the data presented in this research, indicated that GA_3 applications were not effective on total soluble solids. This result contradicted with Huang and Huang [2005] who reported that by application of gibberellic acid increase the total soluble solids in citrus species. This might be caused by only species differences. Having some effects on the soluble solids content of the treated fruit was not supported with the findings of Gomes et al. [2006] on passion fruit, Zeman et al. [2013] on sweet cherry and Watanabae et al. [1997], Symons et al. [2006] and İşçi and Gökbayrak [2015] on grapes. However, our results supported the findings of Vardhini and Rao [2002] in tomato and of Yu et al. [2004] in cucumber, who reported increases in sugars in fruits.

The effects of the two growth regulators 22S, 23S-homobrassinolide and GA_3 on fruit color was not observed. Horvitz et al. [2003] reported no change in color of sweet cherries after gibberellin application. Einhorn et al. [2013] reported that GA_3 applications retarded skin color development in sweet cherries. Fruits exposure to brassinosteroids produced bright color fruits. This effect of brassinosteroids on fruit color has been documented on strawberry [Chai et al 2013]. Although Symons et al. [2006] reported that epibrassinolide accelerated the berry coloring in grapes, Watanabae et al. [1997] showed that brassinolide did not improve coloring in grapes. No effect of the 22S, 23S-homobrassinolide on grape berry color was shown in the study of İşçi and Gökbayrak [2015].

Titratable acidity percentage was significantly reduced by the application of GA_3. From the data presented in this research are in agreement with Nguyen and Yen [2013] who reported that titratable acidity percentage was reduced by the application of GA_3 in waxapple. İşçi and Gökbayrak [2015] reported no effects of the brassinosteroid application on titratable acidity in grapes. Watanabae et al. [1997] also reported increases in berry and cluster weights and no change in acidity.

Increase in flesh to seed ratio was due to the fact that seeds were smaller or flesh was thicker is not clear. However, gibberellic acid generally provided better ratio. Stem resistance was not effected two growth regulators treatments.

The ratio of fruits with doubling, cracking and pitting was not directly under the influence of applications of GA_3 and 22S,23S-Homobrassinolide. Investigations describe the effects of GA_3 application on sweet cherry cultivars that are reported to differ in cracking susceptibility. Horvitz et al. [2003] and Usenik et al. [2005] found GA_3 reduced cracking, which contradicts the findings of Cline and Trought [2007] and Rasmussen and Grauslund [1983] who found GA_3 sprays increased fruit cracking. In addition, gibberellic acid decreased the cracking in fruit by delaying maturity time of fruits and getting over critical rain period [Usenik et al 2005]. Our observation that fruit cracking was not affected by the applications of GA_3 and 22S,23S-homobrassinolide. The frequency of fruit cracking in 2012 was higher than in 2013 because of rain around the harvest. Environmental conditions have important role in cracking of cherries. Simon [2006] reported that the cracking resulting from the rain closer to the harvest time is a significant factor affecting the quality of the sweet cherry fruit. Another factor affecting the fruit cracking is the genetic characteristics of sweet cherry varieties. The data presented here showed that cultivar of '0900 Ziraat' had low fruit cracking. Whether a sweet cherry fruit will be double or not is determined the summer previous to fruiting when formation of flower buds takes place. During this period, the buds are sensitive to any type of stress such as high temperature and drought [Beppu and Kataoka 2011]. Cline and Trought [2007] reported that GA_3 applied at the beginning of fruit growth reduced fruit pitting in 'Bing' sweet cherry.

CONCLUSION

These results suggest that the quality components of the sweet cherry fruits were affected both by GA_3 and 22S, 23S-homobrassinolide applications. However, the extent of these effects varies depending on the concentration and seasonal differences. When there is a statistically important effects of the growth regulators, gibberellin seems to be the one to which the cultivar "0900 Ziraat" gives the most response. Although application of gibberellins in sweet cherry production is quite common with varying results, further studies should be carried out to determine effects of growth regulator combinations before any commercial recommendations to be made.

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WPŁYW 22S, 23S-HOMOBRASSINOLIDU I GA_3 NA JAKOŚĆ OWOCÓW CZEREŚNI '0900 ZIRAAT' ORAZ NA ZABURZENIA FIZJOLOGICZNE

Streszczenie. Uzyskanie wysokiej jakości w produkcji czereśni ma ogromną wagę. Regulatory wzrostu roślin używane były do zwiększenia plonu i jakości w produkcji czereśni. Stwierdzono, że brassinosteroidy, stosunkowo nowa grupa regulatorów wzrostu roślin, ma ciekawy wpływ na wzrost i rozwój roślin. Badanie przeprowadzono w celu oceny roli brassensteroidów i giberelin dla jakości owoców i występowania zaburzeń fizjologicznych u czereśni '0900 Ziraat'. Przez okres 2 lat stosowano kwas giberelinowy (GA_3) oraz 22S, 23S-homobrassinolid jako oprysk w pełni kwitnienia i na początku rozwoju owoców. GA_3 stosowano w stężeniach 25, 50 i 100 mg l^{-1} a 22S, 23S-homobrassinolid – w stężeniach 0,05; 0,1 oraz 0.5 mg l^{-1}. Stosowano też połączone działanie 100 mg l^{-1} GA_3 + 0,1 mg l^{-1} 22S, 23S-homobrassinolidu. Zastosowanie regulatorów wzrostu roślin spowodowało zwiększenie stosunku masy owoców i miąższu do pestek oraz zmniejszenie długości owoców. Efekt ten był głównie spowodowany gibereliną. Hormony i pora roku miały wpływ na całkowitą zawartość stałych substancji rozpuszczalnych oraz kwasowość oznaczoną. Żaden z regulatorów wzrostu nie miał wpływu na występowanie zaburzeń fizjologicznych. W drugim sezonie były one na mniejszym poziomie.

Słowa kluczowe: brassinosteroid, gibereliny, *Prunus avium*, jakość, zaburzenie

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