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EFFECTS OF AMINOETHOXYVINILGLYCINE (AVG) AND GIBBERELLIC ACID (GA_3) TREATMENTS ON PRE-HARVEST FRUIT DROP AND QUALITY OF HAKKO PEAR CULTIVAR

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Abstract: This study was conducted to determine the effects of pre-harvest Aminoethoxyvinylgylcine (AVG) and Gibberellic acid (GA_3) applications on the pre-harvest fruit drop amount and fruit quality in the 'Hakko' pear (*Pyrus pyrifolia*) cultivar grafted on BA29 rootstock in a private orchard in the Bala district of Ankara in 2021-2022. It was conducted in an orchard belonging to a producer. 50-100-150 mg/l AVG and 25-50-75 mg/l GA_3 were applied 4 weeks before the estimated harvest date. Fruits are harvested at full maturity date; Pomological properties including cumulative drop percentage, yield per tree, fruit weight, fruit width and length, fruit stem width and length, fruit firmness, fruit color, as well as chemical properties such as soluble solid content (SSC), pH and titratable acidity (TA) were evaluated. It was observed that all doses of AVG and GA_3 during the harvest period reduced the cumulative drop rate compared to the control application (6.78%). In general, the yield per tree was found to be high in GA_3 applications. Both AVG and GA_3 applications had statistically significant effects on fruit weight, fruit width and length, fruit flesh firmness, SSC, and pH. It was observed that both AVG and GA_3 applications reduced pre-harvest fruit drop and improved fruit quality characteristics compared to the control.

Keywords: Preharvest drop, Fruit quality, Growth regulators

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1. Introduction

Pear is a type of fruit spread in the temperate climate regions of the world. It generally likes temperate regions and sunny areas. It is grown in a wide area around the world. The place of pear in the plant kingdom; It belongs to the order *Rosales*, family *Rosaceae*, subfamily *Pomoideae,* genus *Pyrus*. There are about 20 species of the genus *Pyrus* in the world. They are native to Asia, Europe and North America (Özçağıran et al., 2011).

Pear cultivation in the world produces 25,658,713 tons of pear in a total area of 1,399,484 ha (Anonymous, 2023). China ranks first in the world both in terms of area of 981,485 hectares and with production of 18,875,900 tons. This country is followed by Türkiye in the 4th place after India and Italy in terms of area. Although Türkiye is ahead in world pear production in terms of area, it ranks lower in terms of production (Table 1 and Table 2).

Table 1. Pear production (tons) amounts of countries by years

No	Countries	Production Amount (tons)				
		2017	2018	2019	2020	2021
1	China	16.527.694	16.196.649	17.404.532	16.101.450	18.875.900
2	United States	669.000	730.740	648.637	609.628	636.390
3	Italy	772.578	752.590	429.290	619.470	273.450
4	Argentina	517.754	565.697	600.000	600.000	634.000
5	Türkiye	503.004	519.451	530.723	545.569	530.349
6	Holland	330.000	402.000	373.000	400.000	400.000
7	South Africa	416.215	397.555	407.212	431.000	459.532
8	Belgium	301.818	368.830	332.420	392.590	355.680
9	Spain	360.957	332.320	330.670	323.730	316.270
10	India	346.000	318.000	300.000	306.000	276.000
	Total	20.745.020	20.583.832	21.356.484	20.329.437	22.757.571
	World	23.834.525	23.717.204	24.279.481	23.109.219	25.658.713

Table 2. Pear production areas (hectares) of countries by year

No	Countries	Production Area (ha)				
		2017	2018	2019	2020	2021
1	China	928.097	948.694	961.358	869958	981.485
2	India	44.000	44.000	42.000	42.000	42.000
3	Italy	31.729	31.340	28.710	26.600	26.790
4	Türkiye	26.000	26.389	26.299	26.071	25.155
5	Argentina	20.879	24.553	26.244	25.737	24.802
6	Algeria	26.090	22.592	20.240	19.979	18.704
7	Spain	21.888	21.330	20.620	20.220	20.020
8	United States	18.700	18.740	18.009	17.604	16.876
9	Korea	14.198	14.224	14.258	14.292	14.109
10	Bosnia and Herzegovina	5.582	13.061	10.957	13.243	8.980
	Total	1.137.163	1.164.923	1.168.695	1.075.704	1.178.921
	World	1.353.933	1.382.356	1.388.514	1.292.709	1.399.484

In recent years, cultivars of the *Pyrus pyrifolia* species, known as the Asian pear, have been introduced to Türkiye and pear orchards have begun to be established with these cultivars. However, some problems have begun to emerge for Türkiye regarding the production of these new cultivars. The high yields of these cultivars also cause significant losses in fruit quality. In this regard, practices that increase the size and quality of fruits are of great importance (Budak, 2017). Growth regulators play different roles in plants. Auxins, cytokinins and gibberellin act as growth stimulants, ABA as inhibitors and ethylene as regulators of fruit ripening (Fırat, 1998; Sutyemez, 2000). Whether growth hormone is a promoter or an inhibitor, it can also have different effects on the known general properties of certain plants under certain physiological conditions.

One of the problems that negatively affects the productivity and quality of production in commercial orchards where pears are grown is the excessive pre-harvest drop in pears. These droping are frequently encountered in the Hakko pear cultivar, especially in some pear cultivars. In addition, the Hakko pear cultivar is a self-productive cultivar and produces medium-sized fruits. However, the Hakko pear cultivar is a cultivar that has a large growth problem. The effect of GA_3 on fruit size and the effect of AVG on pre-harvest drop have been determined In previous studies (Budak, 2017; Öztürk, 2018; Boyacı, 2022). For this reason, it was aimed to reduce pre-harvest drop, which negatively affects fruit yield, and to improve fruit quality characteristics in the Hakko pear cultivar, which is frequently preferred by pear growers.

This study was conducted to determine the effects of different doses of Aminoethoxyvinylglycine (AVG) and Gibberellic Acid (GA_3) applications on pre-harvest drop amount and fruit quality in Hakko pear cultivar grafted on BA29 rootstock grown in Ankara/Bala.

2. Materials and Methods

2.1. Materials

This study was carried out in 2021-2022 on the Hakko pear cultivar grafted on BA29 rootstock in an orchard owned by a private producer in the Bala district of Ankara Province. The trees selected were healthy and regularly maintained. Hakko pear cultivar is a self-productive cultivar, and the distances between rows and on rows are 1 x 3.5 m. Laboratory analyzes were carried out in the Pomology laboratory of Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Horticulture.

2.1.1. Geographic location and characteristics of the research orchard

The research orchard is located between latitudes 39°29'29"N 33°16'52"E. This orchard where the study was carried out has a loamy structure, the plant nutritional element content is unsalted, slightly alkaline and has very low organic matter content. While the available P and available K levels of the soil sample are high, the extractable Ca and Mg levels are also sufficient (Table 3). During the trial period, fertilization was done in the orchard where the study was carried out, taking into account the soil analysis. A drip irrigation system was used in the orchard. In addition, annual maintenance work such as fighting against diseases and pests, pruning and tillage continued regularly. Irrigation started at the beginning of April and was watered for 1 hour, 2 hours or 3 hours every day, every other day or every 3 days, depending on temperature and rainfall. Soil physical and leaf analysis results of the research orchard are given in Table 3 and Table 4.

Table 3. Some physical and chemical properties of the orchard soil where the study was conducted (2021)

Parameters Examined	Results (07/07/2021)	Evaluation	Results (05/11/2021)	Evaluation
pH	7.7	Slightly Alkaline	7.6	Slightly Alkaline
Lime (%)	27.5	Very lime	23.6	Very lime
Organic Matter (%)	0.60	Very little	0.95	Very little
Texture (%)	43	Loamy	45	Loamy
Salinity (%)	0.039	Without salt	0.041	Without salt
Total nitrogen (%)	0.098	Sufficient	0.102	Sufficient
Phosphorus (kg/da)	21.69	Sufficient	47.93	Very high
Potassium (kg/da)	86.1	More	167.4	More
Calcium (mg/kg)	1532.7	More	1576.1	More
Magnesium (mg/kg)	97.7	Sufficient	148.7	Sufficient
Iron (mg/kg)	4.12	Middle	4.04	Middle
Zinc (mg/kg)	4.76	More	5.00	More
Manganese (mg/kg)	9.03	More	3.90	Sufficient
Copper (mg/kg)	1.76	More	1.91	More

Table 4. Leaf analysis results of the orchard where the study was conducted (2021)

Parameters Examined	Results (07/07/2021)	Evaluation
Nitrogen (%)	3.69	More
Phosphorus (%)	0.17	Sufficient
Potassium (%)	1.21	Sufficient
Calcium (%)	2.26	More
Magnesium (%)	0.42	Sufficient
Iron (mg/kg)	217.8	More
Zinc (mg/kg)	152.0	More
Manganese (mg/kg)	63.6	Sufficient
Copper (mg/kg)	26.5	More

2.2. Methods

4 weeks before the estimated harvest date for Hakko pear cultivar; Control (water + tween 20), 50-100-150 mg/l AVG and 25-50-75 mg/l GA_3 plant growth regulator applications were made. To increase the effectiveness of the applied substance in BBDM solutions before application, Tween 20 (0.5%) was added as a spreading adhesive that reduces surface tension. Applications were made in a controlled manner with a mechanical back sprayer in a time when sunlight was weak (1 hour before sunset) and there was no wind. Each application was carried out in 3 replications, with 5 trees in each replication. 3 out of every 5 treated trees were used in sampling to determine fruit quality characteristics. Two trees were used only to follow the drop, and no fruit was harvested from these trees until the normal harvest time. The Hakko cultivar was harvested on 05.09.2021, and the cumulative drop percentage and yield per tree were first measured in the harvested pear fruits. Pomological analyzes are; The weights of fruits picked up randomly from each replicate at the anticipated harvest date was determined using a precision scale sensitivity with 0.01g sensitivity; the firmness of fruits was measured with the 11.1mm tip of the penetrometer (Force Gauge brand, model PCE-PTR 200). Soluble solids concentration of fruits was analyzed using a digital refractometer (Hanna HI 96801), and pH was measured with a digital pH meter (Hanna, model HI9321). For titratable acidity (TA), 10ml of deionized water was added on 10ml of fruit juice. The aliquots were titrated to pH 8.2 using 0.1N sodium hydroxide (NaOH), and the malic acid concentration (g Malic acid/100 g) was calculated using the amount of NaOH spent in the titration. Color measurement of fruits picked up randomly from each replicate at harvest date was carried out using a colorimeter (Konica-Minolta CR-410). The CIE L*, a*, b* values for color measurement were determined by after the calibration process based on a white plate.

The data obtained at the end of the study were analyzed with variance analysis using the SPSS 22.0 statistical package program according to the random parcel trial design; Differences between the means were checked with the Duncan multiple comparison test (Yurtsever, 1984).

3. Results and Discussion

3.1. Cumulative Drop Percentage and Yield per Tree

In the study, the effects of different doses of AVG and GA_3 applications on the cumulative drop percentage and yield per tree are given in Table 5. However, the percentage of breakdown between groups was found to be very significant. While the highest drop percentage was obtained from the control application with 6.78%, the lowest drop percentage was obtained from the 100 mg/l

AVG application with 1.64%. All doses of AVG and GA_3 during the estimated harvest period were observed to reduce the cumulative drop rate compared to the control treatment (6.78%).

Butar and Çetinbaş (2015) applied AVG by spraying to pear trees at doses of 0, 100, 125, 150 mg/l 7, 21 and 30 days before the estimated harvest time, in order to examine the effect of AVG applications on pre-harvest drop. They reported that AVG applications significantly reduced fruit drop by 38-100%. Karaçalı (2009) reported that pre-harvest drop depends on the plant type and cultivar. Hot or cold weather conditions, late fertilization with high nitrogen content, drought and high soil water level, and low boron and magnesium levels in the soil increase the pre-harvest drop rate. Cultural practices are not sufficient to prevent pre-harvest drop. Plant growth regulators should be used to prevent pre-harvest drop. In our study, in line with the results of many researchers (Greene 2006; Kang et al., 2007; Whale et al., 2008), it was revealed that both AVG and GA_3 prevented or reduced pre-harvest fruit drop. In terms of yield per tree, the highest value was obtained from the 75 mg/l GA_3 application with 15 kg, while the lowest value was obtained from the 50 mg/l AVG application with 9.62 kg. In general, yield per tree was found to be high with GA_3 applications. However, the yield per tree was found to be statistically very significant. Çetinbaş (2018) reported in his study that he applied doses of AVG (0, 100, 125, 150 ppm) 7, 21 and 30 days before harvest on Akça pear cultivar, that the applications had no effect on yield.

Table 5. Effect of AVG and GA_3 applications on cumulative drop percentage and yield per tree in Hakko pear cultivar

Treatments	Cumulative Drop Percentage (%)	Yield per tree (kg)
Control	6.78±1.38a	11.95±1.00bc
50 mg/l AVG	2.96±0.75b	9.62±1.23c
100 mg/l AVG	1.64±0.36b	12.26±1.20bc
150 mg/l AVG	3.31±0.68b	10.96±0.82c
25 mg/l GA_3	3.83±0.75b	14.80±0.71ab
50 mg/l GA_3	2.60±0.68b	14.02±0.63ab
75 mg/l GA_3	3.50±0.35b	15.83±0.42a

3.2. Pomological Analysis

The effect of AVG and GA_3 applications on pomological characteristics in Hakko pear cultivar is given in Table 6. The effect of AVG and GA_3 applications on fruit weight, fruit width and length was found to be statistically significant. While the highest fruit weight of 128.07 g and 25 mg/l GA_3 was obtained, the lowest fruit weight was obtained from the control application with 88.72 g. The highest value in terms of fruit width and length was obtained from 25 mg/l GA_3 application with 62.04-57.54, while the lowest value was obtained from 150 mg/l AVG application with 53.51-49.06.

Table 6. Effect of AVG and GA_3 applications on pomological characteristics of Hakko pear cultivar

	Treatments						
Pomological properties	Control	50 mg/l AVG	100 mg/l AVG	150 mg/l AVG	25 mg/l GA_3	50 mg/l GA_3	75 mg/l GA_3
Fruit weight (gr)	88.72±2.73d	98.76±2.56cd	103.38±2.95c	89.26±2.51d	128.07±5.57a	115.75±3.87b	121.99±5.15ab
Fruit width (mm)	54.74±0.55cd	55.57±0.53cd	56.63±0.62c	53.51±0.96d	62.04±0.85a	59.87±0.68b	59.64±0.87b
Fruit size (mm)	49.45±0.90e	52.56±0.98d	52.95±0.50cd	49.06±0.90e	57.54±0.83a	55.09±0.65bc	56.81±0.74ab
Stalk length (mm)	36.14±0.61ab	34.23±0.90b	35.56±0.80ab	36.31±0.60ab	35.70±0.84ab	36.50±0.71ab	36.85±0.70a
Stalk tickness (mm)	2.75±0.06c	2.85±0.06c	2.87±0.07c	2.86±0.06c	3.30±0.08a	3.08±0.07b	2.78±0.10c
Flesh firmness (kg/cm^2)	3.84±0.14c	4.56±0.11b	5.89±0.14a	4.42±0.15b	5.87±0.15a	5.57±0.12a	3.94±0.12c
Color L	67.98±1.48a	72.30±1.93a	70.56±1.69	60.35±1.20b	70.65±2.30a	70.40±2.05a	67.25±1.77
Color a	9.48±1.06ab	7.57±0.72a	a9.79±0.64c	9.50±0.24ab	9.56±0.85ab	10.64±0.51c	a10.07±0.76c
Color b	42.86±0.84a	44.54±1.06a	42.27±1.10a	37.47±0.72b	42.46±1.24a	43.39±1.11a	43.82±1.10a

*The difference between values marked with different letters is significant at P<0.05 level.

Stern (2008) reported that GA_3, 2,4-D and NAA applications significantly increased fruit size in 'Cossica' and 'Spadona' pear cultivars. Çetinbaş (2010) stated that GA_3, AVG and CC applications increased fruit yield and especially GA_3 applications were more effective than other applications. When studies were examined, it was shown that gibberellin applications in pears increased fruit size (Jackson, 2003; Stern et al., 2007; Chen et al., 2012). In this study, it was determined that fruit weight increased especially in GA_3 applications compared to the control and AVG applications.

Since fruit size is one of the reasons for preference in pears, especially in summer cultivars, fruit size is important in examining quality criteria (Flaishman et al., 2001; Stern et al., 2007). Although the Hakko pear cultivar is of high quality, it produces smaller fruits than other early cultivars. Considering this situation, fruit size in pears is important in terms of increasing profitability (Yehia and Hassan, 2005; Zhang et al., 2007).

It has been reported that plant growth regulators such as gibberellic acid and AVG are an important cultural practice to obtain a regular yield increase and quality fruit in pear orchards (Lafer, 2008). While stalk length was found to be statistically insignificant in AVG and GA_3 applications, stem thickness was found to be very important. While the highest value in terms of stalk length was obtained from the 75 mg/l GA_3 application with 36.85 mm, the lowest value was obtained from the 25 mg/l GA_3 application with 35.70 mm. In terms of stalk thickness, the highest value was obtained from the 25 mg/l GA_3 application with 3.30 mm, while the lowest value was obtained from the control application with 2.75. Budak (2017) The effect of Oxalic acid and GA_3 applications on fruit stalk length in Cosiu and Hakko pear cultivars was found to be statistically insignificant.

The effect of the treatments on fruit flesh firmness was found to be statistically very significant. While the highest flesh firmness value of 5.89 kg/cm^2 was obtained from the 100 mg/l AVG application, the lowest flesh firmness value of 3.84 kg/cm^2 was obtained from the control application.

Canlı and Pektaş (2015) BA, BA + GA_{4+7} applications they reported that fruit flesh firmness in Akça and B.P. Morettini pear cultivars increased significantly compared to the control. It was determined that pre-harvest AVG and GA_3 applications increased fruit flesh firmness. While the effect of the applications on Color L, b was found to be statistically very significant, its effect on Color a was found to be insignificant. The highest L value, which expresses brightness in fruits, was obtained from 72.30 and 50 mg/l AVG application, and the lowest L value was 60.35 and 150 mg/l AVG application. The highest a* value, where positive values indicate red and negative values indicate green, was obtained from 50 mg/l GA_3 application with -10.64, while the lowest value was obtained from 50 mg/l AVG application with -7.57. The highest b* value, whose positive value indicates jaundice and whose negative value indicates blueness, was obtained from 50 mg/l AVG application with 44.54, while the lowest b value was obtained from 150 mg/l AVG application with 37.47.

Pektaş (2009) reported that BA and BA + GA_{4+7} applications increased the L value in 'Akça' pear cultivar and darker fruits were obtained compared to the control, which is in agreement with the findings of the study. Again, Pektaş (2009) reported that fruits with the highest a value were obtained in 'Akça' pear cultivar with 50 ppm BA application.

Budak (2017) determined that the effect of BBDM applications on the b value, which expresses the change of fruit color between blue and yellow, is significant. The study reported that the highest b* value was obtained in Hakko cultivar with 4 mM OA (41.69) and in Kosiu cultivar with 3 mM OA (31.15) applications. Durham et al. (2005) stated that the ideal fruit peel color of pear fruits is light yellow and that fruit brightness is important in meeting consumer demand. The effects of AVG and GA_3 applications on some chemical properties of Hakko pear cultivar are given in Table 7.

Table 7. Effect of AVG and GA_3 applications on some chemical properties of Hakko pear cultivar

	Treatments						
Chemical properties	Control	50 mg/l AVG	100 mg/l AVG	150 mg/l AVG	25 mg/l GA_3	50 mg/l GA_3	75 mg/l GA_3
SSC (%)	13.82±0.1b	13.20±0.2e	13.27±0.0de	14.10±0.0a	13.57±0.1c	13.10±0.0e	13.47±0.1cd
pH	4.24±0.0g	4.36±0.0e	4.44±0.0c	4.30±0.0f	4.60±0.0a	4.41±0.0d	4.52±0.0b
TA	0.31±0.0a	0.23±0.0c	0.24±0.0c	0.31±0.0a	0.24±0.0c	0.29±0.0b	0.21±0.0d

*The difference between values marked with different letters is significant at P<0.05 level.

The SSC level varies depending on the ripeness of the fruit, as an indicator of the sugar content. The level of SSC increases as starch breaks down into sugar (Stover et al., 2003). It has been determined that AVG reduces the SSC content of the fruit by delaying starch degradation (Silverman et al., 2004; Yuan and Carbaugh, 2007; Brackmann et al., 2015; Öztürk et al., 2015). In the study, the highest SSC value was obtained from 150 mg/l AVG application with 14.10%, and the lowest SSC value was obtained from 50 mg/l GA_3 application with 13.10%. The effect of the applications on pH was found to be statistically very significant. The highest pH content was obtained from the 25 mg/l GA_3 application with 4.60, and the lowest pH content was obtained from the control application with 4.24. The effect of the applications on titratable acidity was found to be statistically very

significant. While the highest TA values were obtained from control and 150 mg/l AVG applications, the lowest TA value was obtained from 75 mg/l GA_3.

Polat and Bağbozan (2017), in their study on early native pears, found the SSC value between 10.58-16.33% and the titratable acid amount between 0.10-0.94%. Mete (2019) reported in his study that the SSC value was between 15.62-12.45% and the titratable acid amount was between 0.28% and 0.66%. In our study, although SSC was found to be statistically insignificant, it was found between 11.45% and 13.10%, which is similar to previous studies. Clayton et al. (2000) reported that AVG applications increased the amount of SSC and decreased the amount of TA, and this was also observed in our results.

4. Conclusion

This study was carried out on the Hakko pear cultivar grafted on BA29 rootstock in the Bala district of Ankara in 2021-2022 to examine whether pre-harvest fruit drop and fruit size can be increased with BBGM applications in the Hakko pear cultivar, which continues to increase over the years in pear production in Türkiye. The effects of different doses of AVG and GA_3 on pre-harvest fruit quality in Hakko pear cultivar were examined 4 weeks before the estimated harvest date. When the pre-harvest drop is evaluated, it is noted that both AVG applications and GA_3 applications reduce the pre-harvest drop compared to the control, and especially the 100 mg/l AVG application is effective in reducing the drop compared to the control trees. It was determined that the yield per tree was higher in GA_3 applications than in the control and AVG applications. It is known that plant growth regulators such as gibberellic acid and AVG are an important cultural practice to obtain a regular yield increase and quality fruit in pear orchards. Fruit size is an important quality criterion for pears. The effect of different doses of AVG and GA_3 applications on fruit sizes was found to be very significant. It was determined that especially 25 mg/l GA_3 application resulted in larger fruits than both control and AVG applications.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	Y.A.	S.B.
C	20	80
D	25	75
S	20	80
DCP	80	20
DAI	30	70
L	50	50
W	70	30
CR	40	60
SR	40	60
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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