Improving the Productivity and Reducing the Drop Percentages of Fruits in Pear by the External Application of Some Plant Growth Regulators

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Fruit drop from pear trees causes serious losses in income. However, the application of plant bio-regulators improves the internal physiology of developing fruit by ensuring that they receive an adequate supply of water, nutrients, and other compounds necessary for their proper growth and development, which leads to improved size, quality, and ultimately better yield in a variety of fruit crops. This study investigated the foliar application of three plant growth regulators: CPPU at 10, 15, and 20 ppm, GA_3 at 25, 50, and 75 ppm and NAA at 25, 50, and 75 ppm. The pear trees were sprayed four times: before flowering, full bloom, after three weeks, and after six weeks. The results showed that the spray of GA_3 at 50 and 75 ppm gave the highest effect in increasing the shoot length, shoot thickness, leaf area, and leaf total chlorophyll. The spraying of NAA at 50 and 75 ppm was the best treatment in increasing the fruit set percentages, fruit yield, fruit weight, and fruit dimensions as well as the fruit content from soluble solids, and fruit sugars, while they reduced the fruit drop percentages comparing with the other applied treatments.

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INTRODUCTION

Pear (*Pyrus communis* L.) belongs to the Rosaceae family and the *Pyrus* genus, which includes twenty-two species found in Asia, Europe, and northern Africa. 'Le-Conte' is the essential pear cultivar grown in Egypt and it resulted from a hybridization between *Pyrus communis* x *Pyrus serotina*. It is one of the most important pear trees in the world, and it is cultivated in whole temperate-zone countries. The cultivated area in Egypt is approximately 5154 hectares, which has resulted in approximately 74,000 tons (FAO 2021). The productivity of pear cv. 'Le-Conte' in Egypt changes from year to year, and this may be as a result of a reduction in ovules viability and stigma receptivity, pollen development rates, ovule abortion, increased flower abscission, and reduced fruit reservation (Yehia and Hassan 2005). In general, pear is the 3rd largest crop from the cultivated area among the deciduous fruit trees.

Plant growth regulators (PGRs) play a vital part in improving horticultural crops' yield and fruit quality (Velasquez *et al*. 2016). The exogenous spraying of PGRs is used often to improve the fruit size, increase the cell division, and minimize the fruit number by encouraging flower formation and reducing the flower and fruit shedding (Davenport 2011; Agustí *et al*. 2022). Additionally, they are organic chemical compounds, which regulate the plant's physiological processes when they are applied in small concentrations, where they can induce the fruit set, minimize the fruit drop and raise the productivity and quality characteristics (Bons and Kaur 2020). PGRs are also signaling molecules that influence fruit growth, blooming rates, and plant cell division (Cutler and Nelson 2017; Talat *et al*. 2020).

CPPU (Sitofex) is a synthetic cytokinin that plays a paramount role in increasing fruit size by inducing cell division or cell increase in many fruits such as sweet cherry, apple, kiwifruit, grape, and pear (Zhang and Whiting 2011). Cytokinins have the ability to increase the fruit soluble solids and reduce the coloration of the exocarp. As cytokinins induce the growth of the floral meristem, it increases the flower number (Li *et al*. 2019). Aremu *et al*. (2020) found that cytokinins are critical for enhancing fruit development, floral and fruit growth, and fruit weight. They also help to preserve and enhance the texture, flavour, and aroma of fruit in a variety of fruits, including raspberries, kiwis, litchi, grapes, sweet cherries, and strawberries.

Gibberellins have the ability to ameliorate the fruit set percentages and growth in apple (Watanabe *et al*. 2008). Moreover, they are mostly applied to reduce the drop percentage and to increase the quality of fruit (Kumari *et al*. 2018). Aremu *et al*. (2020) reported that gibberellins enhance physiological functions such as fruit production, flower initiation, leaf elongation, and stem development. By promoting photosynthetic enzymes and increasing the efficacy of mineral utilization, they also enhance the process of photosynthesis. Additionally, they noticed that in grapes, sweet cherries, strawberries, kiwifruit, and raspberries, gibberellins improve fruit set percentages, growth, size, fruit preservation, and fruit quality attributes, such as fruit weight, hardness, length, and diameter.

As a broad-spectrum regulator of plant growth, NAA is an auxin analogue that stimulates cell division and expansion (Gill and Bal 2009). The synthetic auxin NAA helps to promote root development, vascular tissue differentiation, cell lengthening, apical control, fruit setting percentage, and the prevention of leaf or fruit loss (Mehraj *et al*. 2015). Additionally, the foliar spraying of NAA at 25 to 50 ppm on apple markedly enhanced the fruit set and retention (Osama *et al*. 2015). It is mostly utilized to improve the production of strawberries like improving the fruit from total sugars, ascorbic acid, and on the opposite side to lessen the titratable acidity (Bhople *et al*. 2020). So, the purpose of this study was to find out how foliar application of CPPU, GA_3, and NAA could improve vegetative growth, and increase fruit set percentages, productivity, and quality while decreasing fruit drop percentages.

EXPERIMENTAL

Treatments, Location and Design

The experiment was conducted in 2022 and 2023 on 10-year-old pear trees (*Pyrus communis* L.) budded on *Pyrus betulifolia* rootstock. The trees were planted at 4*4 meters in sandy soil within a private orchard under drip irrigation, in Nubaria region, El-Beheira governorate, Egypt. The analysis of the soil is shown in Table 1 (Sparks *et al*. 2020).

Table 1. Physiochemical Soil Analysis

<table>
<tr><td colspan="8">Mechanical Analysis</td></tr>
<tr><td>Clay %</td><td>Silt %</td><td colspan="2">Sand %</td><td colspan="2">Soil texture</td><td colspan="2">pH</td></tr>
<tr><td>3 %</td><td>4.5 %</td><td colspan="2">92.5 %</td><td colspan="2">Sandy</td><td colspan="2">8.3</td></tr>
<tr><td>EC dsm^{-1} (1:5)</td><td>Total $CaCO_3^{-2}$</td><td colspan="2">Organic matter</td><td colspan="4">Available macronutrients (mg/ kg soil)</td></tr>
<tr><td rowspan="2">0.812</td><td rowspan="2">4.8</td><td colspan="2" rowspan="2">0.275</td><td>N</td><td>P</td><td colspan="2">K</td></tr>
<tr><td>117.5</td><td>9.2</td><td colspan="2">297.5</td></tr>
<tr><td colspan="4">Soluble Anions (%)</td><td colspan="4">Soluble Cations (%)</td></tr>
<tr><td>HCO_3^-</td><td>Cl^-</td><td colspan="2">SO_4^{-2}</td><td>Na^+</td><td>Mg^{2+}</td><td>K^+</td><td>Ca^{2+}</td></tr>
<tr><td>2.12</td><td>3.1</td><td colspan="2">3.3</td><td>3.66</td><td>1.5</td><td>0.425</td><td>2.7</td></tr>
</table>

Sixty uniform trees, selected for their similar growth and size, received consistent agricultural practices throughout the two-year experiment. The trees were sprayed four times: before flowering, during full bloom, three weeks after the full bloom spray, and three weeks after the third spray, using water as the control, 10, 15 and 20 ppm CPPU, 25, 5 and 75 ppm GA_3 and 25, 50, and 75 ppm NAA. The trees were randomly distributed and arranged in a Randomized Complete Block Design (RCBD) in six replicates (six trees).

Vegetative Parameters

At the end of the vegetative time, the shoot diameter was in cm and the shoot thickness was measured by using a vernier caliper. Total chlorophyll (SPAD) was measured in fresh leaves by taken from 10 mature leaves located in the middle section of the shoots surrounding the trees. The average leaf area (cm²) was determined using the below equation (Mosa *et al*. 2022),

$$LA = 0.70\,(L \times W) - 1.06 \tag{1}$$

where LA is the leaf area, L is the leaf length, and W is the leaf width.

Fruit Set Percentages and Fruit Drop Percentages

In March of 2022 and 2023, four carefully selected branches from each side of the experimental trees were labeled, and the number of blooms on each branch was recorded. The fruit set percentage was then calculated using Eq. 2 (El-Hady *et al*. 2007).

$$\text{Fruit set \%} = \frac{\text{Number of fruit setting}}{\text{Total number of flowers}} \text{ X } 100 \tag{2}$$

By computing the quantity of dropped fruits from fruit planting until the harvesting date in June of each year, pre-harvest fruit drops were estimated. Next, the fruit drop's proportion was determined using the formula below.

$$\text{Fruit drop \%} = \frac{\text{Number of fruit setting} - \text{Number of mature fruits}}{\text{Number of fruit setting}} \text{ X } 100 \tag{3}$$

Fruit Yield

During the July 2022 and 2023 seasons, the yield in kg for each tree was weighted and then by multiplying the yield of the tree * the number of trees in a hectare to calculate the yield of hectare in ton.

Fruit Quality

Fruit physical characteristics

Thirty fruits were randomly selected from each replicate (tree). Measurements were made of the average of their weight (g), fruit length, and fruit diameter by using a vernier caliper. Fruit firmness (Ib/inch^2) was determined using a Magness and Taylor pressure tester equipped with a 7/18-inch plunger. Fruit size (cm^3) was assessed by measuring the volume of displaced water after immersing the fruit.

Fruit chemical characteristics

Total soluble solids percentages were measured by using the hand refractometer (ATAGO Co. LTD., Tokyo, Japan). Ascorbic acid content (VC) in the juice was assessed through titration with 2,6-dichloro phenol-indo-phenol and expressed in milligrams per 100 mL of juice. Total and reducing sugars were quantified calorimetrically using the Nielsen's method (Nielsen 2010). Non-reduced sugars percentage is the difference between total sugars and reduced sugars. Fruit acidity, expressed as a percentage of malic acid content, was determined in fruit juice through titration with 0.1 N sodium hydroxide, using phenolphthalein as an indicator (A.O.A.C. 2005).

Mineral content in the apricot leaves

From the middle part of the shoots, 30 leaves were collected in July after fruit picking from each tree (Arrobas *et al.* 2018) to analyze macronutrients (nitrogen, phosphorus, potassium) and micronutrients (iron, zinc, manganese, boron). The leaves were washed with tap water, then distilled water, and dried in an oven at 70 °C until they reached a consistent weight before being thoroughly crushed. The samples were then digested using 2 mL of H_2SO_4 and H_2O_2. The nitrogen content in the leaves was measured using the micro-Kjeldahl method (Wang *et al.* 2016). Phosphorus was determined by the Vanadomolybdate method (Weiwei *et al.* 2017), and potassium was assessed using a flame photometer (SKZ International Co., Ltd., Jinan Shandong, China) (Chapman 2021). The concentrations of zinc, manganese, and iron were measured with an Atomic Absorption Spectrophotometer, while boron was quantified using a spectrophotometer at 430 nm.

Statistical analysis

The results were statistically analyzed using One Way ANOVA for a Randomized Complete Block Design (RCBD). The means of the treatments were compared using the Least Significant Difference at 0.05 ($LSD_{0.05}$) (Snedecor and Cochran 2021).

RESULTS AND DISCUSSION

Vegetative Growth Parameters

Table 2 reveals that external application of CPPU, GA_3, and NAA on pear trees can enhance shoot length, thickness, leaf area, and total chlorophyll content compared to unsprayed trees. The highest significant improvements were observed with foliar spraying of GA_3 at 75 ppm, followed by 50 ppm. Moreover, spraying pear trees with 75 ppm NAA and CPPU at 20 ppm significantly increased these vegetative parameters. The differences between the influence of 75 and 50 ppm from GA_3 were not significant in the shoot length and leaf total chlorophyll in both seasons and also there were insignificant differences between them in the first season in shoot thickness, and leaf are but in the second seasons the differences were significant.

Table 2. Effect of the Foliar Spraying of CPPU, GA_3, and NAA on Shoot Length, Shoot Thickness, Leaf Area, and Leaf Total Chlorophyll of Pear Trees during 2022 and 2023

Treatments		Shoot Length (cm)		Shoot Thickness (cm)		Leaf Area (cm^2)		Total Chlorophyll (SPAD)	
		2022	2023	2022	2023	2022	2023	2022	2023
Control	0	68.82d	71.80d	0.76e	0.79e	38.16d	38.46e	43.18e	44.92f
CPPU	10 ppm	71.02d	72.40cd	0.80de	0.81de	38.22d	38.11e	44.10e	47.74e
	15 ppm	75.28c	73.42cd	0.84cd	0.82de	41.18c	41.49d	48.20d	49.46de
	20 ppm	81.01b	82.38ab	0.94b	0.96c	45.79ab	44.37bc	51.10bc	51.48bc
NAA	25 ppm	70.42d	73.10cd	0.8de	0.80e	40.22c	38.67e	43.72e	49.34de
	50 ppm	74.96c	74.64c	0.88bc	0.83de	44.79b	41.65d	48.84d	49.78cd
	75 ppm	80.84b	80.78b	0.94b	0.99bc	44.32b	43.29cd	50.00cd	52.12b
GA_3	25 ppm	73.70c	75.14c	0.84cd	0.86d	42.05c	39.16e	45.00e	45.42f
	50 ppm	83.34a	84.16a	1.04a	1.03b	46.20ab	45.70b	53.16ab	54.22a
	75 ppm	83.70a	84.86a	1.05a	1.09a	47.06a	47.62a	54.42a	55.38a
$LSD_{0.05}$		2.31	2.52	0.06	0.05	1.76	1.74	2.07	1.88

The treatments with the same letters in each column do not significantly differ from one another.

Fruit Set and Fruit Drop Percentages, and Fruit Number

Table 3 indicates that the application of plant growth regulators such as NAA, GA_3, and CPPU enhanced both the fruit set percentages and the number of fruits while decreasing the rate of fruit drop across both experimental seasons. Furthermore, the application of 75 ppm NAA resulted in the most obvious increases in both fruit set percentages and fruit numbers, proving to be the most effective treatment across both experimental seasons.

Table 3. Effect of the Foliar Spraying of CPPU, GA_3 and NAA on Fruit Set and Fruit Drop Percentages and Fruit Number per Tree of Pear Trees during 2022 and 2023

Treatments		Fruit Set %		Fruit Drop %		Fruit Number	
		2022	2023	2022	2023	2022	2023
Control	0	4.418e	4.26f	83.68a	82.23a	157.60e	157.00f
CPPU	10 ppm	4.938de	4.76de	78.49bc	78.20b	162.20e	164.00e
	15 ppm	5.092d	5.17cd	76.25d	74.02c	169.80d	179.20cd
	20 ppm	6.356b	6.56b	74.17e	72.14c	183.20b	185.20bc
GA_3	25 ppm	4.82de	4.56ef	79.78b	76.69b	157.20e	159.40ef
	50 ppm	5.04d	5.24c	76.13d	73.92c	169.20d	164.80e
	75 ppm	5.63c	6.20b	74.09e	73.93c	177.20c	176.00d
NAA	25 ppm	4.968de	4.8de	77.26cd	76.17b	169.40d	180.20cd
	50 ppm	6.61b	6.59b	72.36ef	68.94d	180.80bc	191.00b
	75 ppm	7.17a	7.67a	70.91f	67.47d	190.00a	200.60a
$LSD_{0.05}$		0.53	0.40	1.88	2.00	5.66	5.84

The treatments with the same letters in each column do not significantly differ from one another.

This treatment also notably reduced the percentage of fruit drop during the two testing periods. Additionally, significant improvements in fruit quantity and fruit set ratio were achieved compared to untreated trees through the foliar applications of 50 ppm NAA, as well as 75 and 50 ppm GA_3, and 20 ppm CPPU throughout both seasons. The reduction in fruit drop percentage by 50 and 75 ppm NAA was similarly effective across the two seasons.

Fruit Weight and Fruit Yield

Table 4 shows that, across both seasons, foliar applications of 75, 50, and 25 ppm NAA, 75 and 50 ppm GA_3, and 10, 15, and 20 ppm CPPU significantly increased fruit weight and yield, both in kg per tree and tonnes per hectare when compared to untreated trees.

Additionally, the spraying of 75 ppm NAA was the superior treatment that gave the highest notable increments in both studying seasons over the other sprayed treatments. The spraying of 50 ppm NAA, 75 GA_3 and 20 ppm CPPU were more efficient in increasing the fruit weight, and fruit yields in kg or ton rather than the other sprayed treatments.

Table 4. Effect of the Foliar Spraying of CPPU, GA_3, and NAA on Fruit Weight, Fruit Yield in kg and in ton per Hectare of Pear Trees during 2022 and 2023

Treatments		Fruit Weight (g)		Fruit Yield (kg/tree)		Yield (ton/h)	
		2022	2023	2022	2023	2022	2023
Control	0	251.40d	255.40e	39.61f	40.10f	10.14f	10.27f
CPPU	10 ppm	263.40c	262.00de	42.77e	42.96e	10.95e	11.00e
	15 ppm	271.80bc	277.00b	46.15cd	49.64cd	11.81cd	12.71cd
	20 ppm	274.00b	277.60b	50.20b	51.42c	12.85b	13.16c
GA_3	25 ppm	252.60d	253.20e	39.72f	40.37f	10.17f	10.33f
	50 ppm	268.40bc	266.80cd	45.41d	43.97e	11.62d	11.26e
	75 ppm	272.60bc	273.40bc	48.31bc	48.12d	12.37bc	12.32d
NAA	25 ppm	269.40bc	275.80b	45.63d	49.69cd	11.68d	12.72cd
	50 ppm	274.80b	281.60b	49.70b	53.79b	12.72b	13.77b
	75 ppm	287.80a	293.80a	54.68a	58.94a	14.00a	15.09a
$LSD_{0.05}$		8.96	8.43	2.40	2.19	0.61	0.56

The treatments with the same letters in each column do not significantly differ from one another.

Fruit Quality

Physical fruit characteristics

According to Table 5, the application of 75 and 50 ppm NAA, 75 and 50 ppm GA_3, and 20 and 15 ppm CPPU significantly enhanced the physical characteristics of the fruits, including size, length, and firmness, compared to trees that were not sprayed across the two seasons.

The most significant increments in these parameters were significantly noticed when the trees were sprayed at 75 ppm NAA in the two seasons. The fruit diameter was remarkably increased by the spraying of the pear trees with 75, 50, and 25 ppm NAA and 20 ppm CPPU significantly improved it in the two seasons.

Table 5. Effect of the Foliar Spraying of CPPU, GA_3, and NAA on Fruit Size, Length, Diameter and Firmness of Pear Trees during 2022 and 2023

Treatments		Fruit Size (cm^3)		Fruit Length (cm)		Fruit Diameter (cm)		Fruit Firmness ($lb/inch^2$)	
		2022	2023	2022	2023	2022	2023	2022	2023
Control	0	263.60d	268.60ef	8.06d	8.03f	7.72d	7.82d	12.48f	12.38c
CPPU	10 ppm	276.20c	276.00de	8.36d	8.92de	8.16cd	7.93d	12.90ef	12.40c
	15 ppm	286.00bc	292.20b	9.26c	9.64c	8.32cd	8.19cd	13.88cd	14.60b
	20 ppm	286.20bc	290.80b	10.26ab	10.44ab	9.08b	8.90b	14.84b	15.02ab
GA_3	25 ppm	266.00d	267 .00f	8.08d	8.36ef	7.94cd	8.10cd	12.38 f	12.94c
	50 ppm	283.00bc	280.40cd	8.60d	8.9de	8.23cd	8.11cd	14.20bc	14.48b
	75 ppm	287.80b	287.20bc	9.20c	9.26cd	8.30cd	8.52bc	14.64bc	14.72b
NAA	25 ppm	283.00bc	291.00b	9.90b	9.84bc	8.44c	8.30cd	13.34de	12.70c
	50 ppm	288.40b	294.60b	10.70a	10.74a	9.06b	9.42a	14.34bc	15.16ab
	75 ppm	302.20a	306.80a	10.80a	10.76a	9.66a	9.84a	15.70a	15.76a
$LSD_{0.05}$		9.08	7.81	0.57	0.65	0.56	0.49	0.74	0.94

The treatments with the same letters in each column do not significantly differ from one another.

Fruit chemical characteristics

In comparison to the trees that were not sprayed throughout the two seasons, the findings in Table 6 showed that the foliar spraying of NAA, GA_3, and CPPU significantly increased the fruit content from TSS percentages and from vitamin C. Additionally, the treating of pear trees with 75 ppm NAA, 75 ppm GA_3 and 20 ppm CPPU gave the highest remarkable values in the fruit content from soluble solids in the two seasons. The application of 75 and 50 ppm from NAA and also 20 ppm CPPU extremely increased the fruit content from vitamin C during two test seasons. Concerning the fruit content from acidity, it was noticed that it was notably minimized by the spraying of 25, 50, and 75 ppm NAA, 50 and 75 ppm GA_3, and 15 or 20 ppm CPPU with respect to not treated trees.

Table 6. Effect of the Foliar Spraying of CPPU, GA_3 and NAA on Fruit Content from Soluble Solids, Acidity and VC of Pear Trees during 2022 and 2023

Treatments		TSS%		Acidity %		VC (mg/100 mL juice)	
		2022	2023	2022	2023	2022	2023
Control	0	12.20d	11.84e	0.42a	0.39a	9.81b	9.82d
CPPU	10 ppm	13.02c	13.16d	0.394b	0.37ab	10.05b	10.26cd
	15 ppm	13.96b	13.76cd	0.316d	0.29d	10.33b	10.36cd
	20 ppm	14.72a	15.04ab	0.29e	0.28de	11.164a	10.84bc
GA_3	25 ppm	13.58bc	13.54d	0.40b	0.37ab	9.89b	10.4cd
	50 ppm	13.76bc	14.00cd	0.30de	0.34c	10.14b	10.32cd
	75 ppm	14.96a	14.48bc	0.29e	0.28de	10.18b	10.54c
NAA	25 ppm	13.72bc	13.54d	0.37c	0.35bc	10.42b	10.52c
	50 ppm	13.76bc	14.56bc	0.28ef	0.26ef	11.28a	11.24b
	75 ppm	15.38a	15.50a	0.26f	0.24f	11.74a	11.99a
$LSD_{0.05}$		0.69	0.82	0.02	0.02	0.58	0.56

The treatments with the same letters in each column do not significantly differ from one another.

Total and reduced sugars percentages were markedly increased by spraying the pear trees with 50 and 75 ppm NAA, 50 and 75 ppm GA_3, and 15 and 20 ppm comparing with untreated trees in 2022 and 2023 (Table 7). Moreover, the notable and most significant percentages were obtained by the spraying of pear trees with 75 ppm NAA, then by 50

NAA, 75 ppm GA_3, and 20 ppm in both experimental seasons. Moreover, the differences between the effects of 50 ppm NAA, 75 ppm GA_3, and 20 ppm CPPU were not significant on the fruit content from total and reducing sugars content in both testing season. Non-reducing sugars content in pear fruits were not significantly affected by the spraying of the foliar application of the tree applied PGRs compared to untreated trees.

Table 7. Effect of the Foliar Spraying of CPPU, GA_3 and NAA on Fruit Content from Total, Reduced, and Non-Reduced Sugars of Pear Trees during 2022 and 2023

Treatments		Total Sugars %		Reduced Sugars %		Non-reduced Sugars %	
		2022	2023	2022	2023	2022	2023
Control	0	8.59f	8.69e	6.22d	6.27e	2.56ab	2.42a
CPPU	10 ppm	8.81ef	8.99e	6.46d	6.58e	2.34ab	2.41a
	15 ppm	9.34cd	9.35d	7.15c	6.94d	2.19b	2.41a
	20 ppm	10.16b	10.15bc	7.59b	7.97b	2.57ab	2.18b
GA_3	25 ppm	9.05de	8.95e	6.53d	6.54e	2.51ab	2.41a
	50 ppm	9.54c	8.93e	7.38bc	7.27cd	2.16b	2.30ab
	75 ppm	10.13b	10.33b	7.74b	7.82b	2.39ab	2.51a
NAA	25 ppm	9.21cd	9.57d	6.56d	6.45e	2.65a	2.48a
	50 ppm	10.08b	9.88c	7.58b	7.45c	2.50ab	2.44a
	75 ppm	10.56a	11.06a	8.31a	8.58a	2.25ab	2.48a
$LSD_{0.05}$		0.32	0.29	0.34	0.34	0.38	0.20

The treatments with the same letters in each column do not significantly differ from one another.

Mineral Content from Macro and Micronutrients

Leaf mineral content from macronutrients such as nitrogen, phosphorous, and potassium was positively affected by the spraying of NAA, GA_3 and CPPU in the two seasons (Table 8).

Table 8. Effect of the Foliar Spraying of CPPU, GA_3 and NAA on the Leaf Mineral Content from Nitrogen, Phosphorous and Potassium of Pear Trees during 2022 and 2023

Treatments		N %		P %		K %	
		2022	2023	2022	2023	2022	2023
Control	0	2.12e	2.14e	0.27e	0.30c	1.35d	1.40e
CPPU	10 ppm	2.20de	2.24d	0.28de	0.30c	1.37d	1.41e
	15 ppm	2.29cd	2.27cd	0.35a-c	0.32bc	1.44c	1.44de
	20 ppm	2.48ab	2.33bc	0.36ab	0.35ab	1.48b	1.55b
GA_3	25 ppm	2.24de	2.24d	0.30cde	0.30c	1.36d	1.41e
	50 ppm	2.31cd	2.28cd	0.33b-d	0.33abc	1.48b	1.47cd
	75 ppm	2.38bc	2.42ab	0.35a-c	0.36ab	1.59a	1.63a
NAA	25 ppm	2.29cd	2.31cd	0.32b-e	0.32bc	1.42c	1.45de
	50 ppm	2.32cd	2.34bc	0.35a-c	0.34abc	1.50b	1.52bc
	75 ppm	2.53a	2.48a	0.38a	0.36a	1.58a	1.60a
$LSD_{0.05}$		0.12	0.08	0.05	0.03	0.04	0.04

The treatments with the same letters in each column do not significantly differ from one another.

The most significant increment was obtained by the spraying of 75 ppm NAA compared to untreated trees. Spraying the pear trees with 25 and 50 ppm GA_3, 50 and 75 ppm, as well as 15 and 20 ppm significantly increased the leaf content of nitrogen compared to the control. The phosphorous concentration in the leaves of pear was markedly increased by the spraying of 75 ppm GA_3 and 20 ppm CPPU as compared to the control. The potassium percentage was remarkably increased by the spraying of 20 ppm CPPU, 50 and 75 ppm GA_3, and 50 ppm NAA as compared to untreated trees.

Table 9 demonstrates that the foliar application of 50 and 75 ppm NAA, 50 and 75 ppm GA_3, and 20 ppm CPPU significantly enhanced the leaf content from Fe, Zn, Mn, and B compared to untreated trees. The most effective treatment, yielding the best results, was the application of 75 ppm NAA, which outperformed the other treatments. Conversely, the effects of spraying 25 ppm NAA, 25 ppm GA_3, and 15 and 10 ppm CPPU on increasing leaf nutrient content were not significant in the years 2022 and 2023.

Table 9. Effect of the Foliar Spraying of CPPU, GA_3, and NAA on the Leaf Mineral Content from Iron, Zinc, Manganese, and Boron of Pear Trees during 2022 and 2023

Treatments		Fe ppm		Zn ppm		Mn ppm		B ppm	
		2022	2023	2022	2023	2022	2023	2022	2023
Control	0	145.40f	149.40ef	29.60f	30.00d	49.40e	48.20f	43.00e	43.00e
CPPU	10 ppm	145.80f	145.60f	31.20def	32.00cd	52.20de	51.80e	45.00de	44.60de
	15 ppm	152.40de	154.20de	32.40def	34.80bc	55.20cd	54.40e	48.40d	52.60c
	20 ppm	158.40c	165.20bc	40.20b	42.60a	61.00b	70.40c	60.80ab	64.60a
GA_3	25 ppm	147.80ef	149.40ef	33.20de	31.80cd	54.00cd	73.80b	45.80de	46.40de
	50 ppm	155.00cd	159.20cd	34.20cd	34.40bc	55.60c	61.00d	52.00c	52.40c
	75 ppm	169.40b	175.20a	42.60ab	43.00a	68.80a	51.60e	59.80b	60.80b
NAA	25 ppm	148.40ef	148.60ef	30.80ef	30.40d	50.00e	53.20e	46.80d	46.60d
	50 ppm	159.80c	167.16b	36.60c	36.40b	59.80b	60.00d	53.60c	54.40c
	75 ppm	175.40a	179.60a	44.60a	45.00a	71.40a	77.40a	63.40a	67.00a
$LSD_{0.05}$		4.63	6.64	2.81	3.28	2.96	3.10	3.19	3.31

The treatments with the same letters in each column do not significantly differ from one another.

DISCUSSION

The data showed that CPPU, GA_3, and NAA external spraying was beneficial for enhancing pear tree vegetative growth, fruit set percentages, fruit productivity, fruit quality, and nutritional status.

These findings align with those of Guirguis *et al*. (2003), which indicated that applying a 20 ppm CPPU treatment at full bloom significantly increased both the fruit set percentage and fruiting. The treatment of CPPU at 10 mg/L on blueberries cv. 'Elliott' during 10 to 15 days after 50% bloom revealed a remarkable increase in fruit set and berry size (Serri and Hepp 2006). Xiao *et al*. (2007) indicated that the spraying of CPPU at 10 to 25 mg/L after full bloom on Diospyros Kaki cv. 'Zenjimaru' increased the fruit weight, as well as fruit content by reducing TSS content TSS-acid ratio, and starch degradation. CPPU effectively increased fruit weight in pear and kiwifruit by encouraging cell division and growth (Zhang *et al*. 2008). Banyal *et al*. (2013) reported that applying CPPU to Royal Delicious apple trees when the fruit size reaches 10 mm significantly improves fruit set and retention, reduces fruit drop, and maximizes both fruit weight and yield. This treatment also enhances fruit size and overall quality, particularly in terms of fruit weight, compared to other treatments examined in the study. Cytokinin induces the prolongation of inflorescences and the flooring meristems by enhancing the flower number and developing the flower formation as well as raising the sing flower number (Li *et al*. 2019). Banyal and Banyal (2020) stated that CPPU effectively promotes cell division and elongation, leading to increased fruit weight and productivity. Apricot trees of the Zaghinia cultivar, treated with 0, 7.5, and 15 mg/L Sitofex, showed significant increases in fruit set percentage, productivity, fruit weight, firmness, and size. Additionally, there were notable enhancements in the fruit content of TSS, and TSS-TA ratio (Medan and Al Douri 2021).

GA_3 directly organizes the elongation, extension, and development of the plant cells consequently increasing the fruit length and diameter of the olive fruits (Ramezani *et al*. 2010). The external spraying of GA_3 resulted in greater shoots, leaves, stems and roots by stimulating cell expansion and division in numerous plants (Bose *et al*. 2013). The external application of GA_3 ameliorates cell extension (Erogul and Sen 2015) and fosters fruit mineral absorption (Fortes *et al*. 2015), and cell divide (Zhang *et al*. 2020), which consequently increases the fruit weight and its size. Ozkan *et al*. (2016) documented that the use of GA_3 substantially enhanced pollen grain germination and the growth of pollen tubes. The external application of GA_3 affects the hormonal balance in the plants, fruit growth and seed formation (Zang *et al*. 2016). Additionally, the same authors reported that spraying rabbiteye blueberry with GA_3 at 500 mg/L dramatically raised return bloom, inflorescences number, area, leaf fresh weight, photosynthetic rate, fruit weight, and number of fruitful seeds. Additionally, GA_3 can increase the fruit size, fruit firmness, vitamin C, TSS, total sugars, and sweetness indicators of apple (Hajam *et al*. 2017). The usage of GA_3 is very important in the transport from the vegetative to the propagative phase and this consequently is paramount for the development of the flowers, fertilization, and fruit growth (Plackett and Wilson 2018; Prakash *et al*. 2022). GA_3 can stimulate fruit development by precisely promoting cell expansion (Khan *et al*. 2020; Zhang *et al*. 2020). GA_3 promotes cell extension, division, and fruit growth by regulating various cellular activities, including protein synthesis, the efficacy of photosynthesis, nutrient absorption, phytohormonal equilibrium, and antioxidant defense mechanisms (Gacnik *et al*. 2021; Talaat *et al*. 2023). The foliar application of GA_3 on olive promoted cell enlargement and mesocarp development, which reflected in increasing the fruit quality (Yadav *et al*. 2021).

NAA has the ability to encourage cell elongation in mesocarp cells, thus increasing fruit size and yield (Stern *et al*., 2007). Additionally, Agrawal and Dikshit (2008) indicated that the exo spray of NAA raised the fruit's weightiness and productivity because it can activate cell prolongation, vacuole size, and cell wall flexibility. Anawal *et al.* (2015) reported that external spraying of 40 ppm NAA on pomegranate cv. 'Bhagwa' significantly enhanced the fruit weight, number, length, diameter, volume, soluble solids, and total, reducing, and non-reducing sugars compared to untreated trees. NAA has the ability to encourage the rapid formation of roots in the cuttings of many crops such as vines (Rademacher 2015). The effectiveness of NAA on plant growth is largely attributed to increased cellulose production and reduced fruit drop (Suman *et al.* 2017). The foliar spray of NAA can improve the fruit quality and productivity in numerous fruit crops; plums, blueberries, guavas, and berry (Singh *et al*. 2017; Milić *et al*. 2018). Besides, NAA is crucial in preventing preharvest fruit drop percentage, promoting cell division, elongation, and membrane permeability, and enhancing flowering rates, fruit productivity, and fruit size (Thiruppathi 2020).

CONCLUSIONS

1. Spraying of plant growth regulators (PGRs) greatly reduced the fruit drop and thus improved the obtained yield and its productivity per hectare.
2. The most notable influence resulted from the spraying of 75 ppm NAA in improving the fruit set percentages, reducing the fruit drop percentages, and raising fruit productivity in the 2022 and 2023 seasons.
3. The exogenous application of 50 NAA, 75 GA_3 and 20 ppm CPPU were also effective treatments in reducing the fruit drop and raising the fruit yield compared to the not sprayed trees.

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