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Impact of plant growth regulators on yield and quality of Flame Seedless grapevines

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Abstract: This research was carried out over two consecutive seasons (2022 and 2023) to study the impact of jasmonic acid at concentration of (15, 30 and 45 ppm) and naphthalene acetic acid at concentration of (50, 100 and 150 ppm) as well as their interactions at different dosage on 10-year-old Flame seedless grapevines in clay soil at a private farm in Talla village, Minia Governorate. The Results showed that applications of jasmonic acid + naphthalin acetic acid were effective in contrast to the single application and the control for improving yield, cluster parameters and physio-chemical quality of Flame Seedless berries and the best treatment was 45 ppm jasmonic acid + 150 ppm naphthalin acetic acid followed by 30 ppm jasmonic acid + 100 ppm naphthalin acetic acid, with no discernible distinction between the two and considered the middile concentration was the best, which gave the promising results in this respect.

Key words: Flame seedless grapevines, Jasmonic acid, naphthalene acetic acid, yield and cluster quality.

1. Introduction

The grapevine (*Vitis vinifera* L.) is recognized as the world's most economically important crop, ranking second in Egypt. The area around Egypt dedicated to grape cultivation reached 186.735 fed., with productive area reached to 175245 fed., producing a total of 1715410 tons. While, cultivated area in Minia Governorate reached 210809 fed., with productive area reached to 20852 fed., producing a total of 205244 tons **(MALR, 2023**). In Egypt, Flame Seedless is regarded as the primary early-ripening seedless table grape. It is a sturdy grape variety that can bear a lot of fruit and keeps well in storage. According to **Akkurt *et al.* (2019**), it is a hybrid of multiple cultivars of Vitis vinifera, Tifafihi Ahmer x Red Malaga, SultaninaxCardinal, and Muscat of Alexandria x Sultanina. This quick-growing early cultivar yields huge, sweet berries early in the season and is perfect for hot, sunny climates **(Brooks *et al.*, 1997**). Flame Seedless possesses exceptional eating attributes. The fruit has a crispy and firm texture, exceptional flavor, and a high total soluble solids percentage at the time of harvest. It warrants particular attention in Egypt due to its properties that are advantageous for local consumption and exportation. It is advantageous to access the initial market opportunity within the European Union while prices are elevated.

Because growth regulators are so crucial to the growth and development of plants, a number of procedures are carried out, including treatment. As the growth processes are under the control of hormones produced inside the plant, including Auxins and jasmonate, they have a great effect on the growth and development of the plant (**Al-Khafaji and Al-Douri, 2022**).

Jasmonic acid (JA) serves as an internal regulator in plants, enhancing their ability to scavenge free radicals and fortifying their antioxidant systems, thereby influencing both growth and defense mechanisms (**Wang and Lin, 2000**). It also regulates stress responses (**Aubert *et al.*, 2015**). Jasmonic acid plays a crucial role in inducing inhibiting rubisco biosynthesis, stomatal closure, impacting phosphorus and nitrogen uptake, and influencing the transport of glucose and other organic substances (**El-Kenawy, 2018; Gomi, 2020**). Additionally, it enhances the transcription levels of multiple color-associated genes, positively influencing qualitative attributes and promoting the production of anthocyanins and antioxidant activity in various fruit types (**Jia *et al.*, 2016; Wei *et al.*, 2017).** The impact of JA on the quality of horticultural crops has been thoroughly examined. It significantly enhances apple coloration and sugar accumulation in peaches, ultimately leading to a noticeable enhancement in the fruit's nutritional and commercial worth (**Gao *et al.*, 2021; Zhao *et al.*, 2021**). Furthermore, it reduces the indicators of aging, such as elevated peroxidase and protease activity, respiratory rate, and a notable decrease in chlorophyll (**Hussein *et al.*, 2023**). Recent studies indicate that jasmonic acid, when applied as pre- or postharvest treatments, influences fruit ripening and quality parameters at harvest and during storage (**Serrano *et al.*, 2018**).

The objective of the present study was to examine the influence of varying concentrations of jasmonic acid and naphthyl acetic acid, both individually and in combination, on the enhancement of growth, chemical composition, fruit physico-chemical quality, and yield of Flame seedless grapevines grown in the Minia region.

2. Materials and Methods

2.1. Experimental site

This research was carried out over two consecutive seasons (2022 and 2023) to study the impact of jasmonic acid and naphthalene acetic acid as well as their interactions at different dosage on 10-year-old Flame seedless grapevines spaced 2X3 m apart in clay soil (Table A) analyzed as per **Wilde *et al.* (1985**), utilizing a surface irrigation system sourced from the Nile at a private farm in Talla village, Minia Governorate. The chosen vines exhibited uniformity in growth and vigor. Cane pruned was used with a bud load of 80 buds per vine (8 canes X 8 eyes and 8 renewal spurs X 2 eyes). The fertilization program and other agricultural practices were consistent across all vines.

2.2. Examined designs and treatments

The ten vines with three replications and one vine each replication in a Randomized Complete Block design were received treatments of jasmonic acid (JA) and naphthalin acetic acid (NAA) as follows:

1- Control (spray with water).

2- Jasmonic Acid (JA 15 ppm).

3- Jasmonic Acid (JA 30 ppm).

4- Jasmonic Acid (JA 45 ppm).

5- Naphthalin acetic acid (NAA 50 ppm).

6- Naphthalin acetic acid (NAA 100 ppm).

7- Naphthalin acetic acid (NAA 150 ppm).

8- JA (15 ppm) + NAA (50 ppm).

9- JA (30 ppm) + NAA (100 ppm).

10- JA (45 ppm) + NAA (150 ppm).

JA and NAA were both administered three times: at the onset of growth, immediately following fruit set, and one month later.

Table (A). Physio-chemical analysis of the tested soil

Soil characters		2021/2022
Particle size distribution (%)	**Sand**	2.89
	Silt	37.11
	Clay	60.00
	Texture class	Clay
EC ppm (1:2.5 extract)		297
pH (1:2.5 extract)		7.86
Organic matter %		2.32
$CaCO_3$ %		2.54
Soil nutrients	**Total N (%)**	0.18
	Available P (ppm)	5.04
	Available K (ppm)	506.0
	Zn (ppm)	2.6
	Fe (ppm)	2.9
	Mn (ppm)	3.5
	Cu (ppm)	0.13

2.3. Measurements

The following data was recorded during the investigative seasons of 2022 and 2023:

Characteristics of clusters and yield

The following data was determined by harvesting four clusters per vine during the maturation stage: Cluster number/vine, weight (g), length (cm), shoulder (cm) and yield (kg)/vine was assessed in kg for each tree/replicate by the following equation: cluster number × cluster weight as well as berry setting (%) was computed as the following: Prior to blooming, five flower clusters per vine were placed in perforated paper bags; these were released during berry set and were computed as follows:

$$\text{Fruit berry Setting\%} = \frac{\text{Number of berries /cluster}}{\text{Total number of flower /cluster}}$$

Physical characteristic of the berry

- The shot berry proportion was determined by the following equation

$$\text{Shot berry\%} = \frac{\text{The number of shot berries in each cluster}}{\text{The total number of berries/cluster}} \times 100$$

- Berry weight (g), berry dimensions (longitudinal and equatorial).

Chemical characteristics of berries

According to (**A.O.A.C, 2000**): TSS% in berries was determined using a hand-held refractometer, Titrating 5 ml of berry juice against 0.1 N NaOH with phenolphthalein determined the titratable acidity percentage, TSS/acidity ratio of berry juice was calculated, reducing sugar% and the total anthocyanin content in berry skin was assessed using a spectrophotometer, following the methodology outlined by **Yilidz and Dikmen (1990).**

2.4. Statistical analysis

All collected data were systematically organized into tables and analyzed statistically according to the method of **Mead *et al.* (1993**), with treatment means compared using the new LSD test at a significance level of 5%.

3. Results and Discussion

3.1. Yield and cluster characteristic

The impact of foliar application of plant growth regulators, specifically jasmonic acid and naphthalene acetic acid, at varying concentrations on the yield of "Flame" seedless grapevines is assessed through metrics such as berry setting percentage, number of clusters per vine, average cluster weight, yield per vine, and average cluster length and width. These results are compared to the control treatment and are presented in Table (1).

Table (1). Impact of foliar applying with jasmonic acid and naphthalin acetic acid on yield and cluster parameters of Flame Seedless grapevines across 2022 and 2023 seasons

Characteristics / Treatments	Cluster number/vine		Cluster weight (g)		Yield/vine (kg)		Berry setting %		Cluster length (cm)		Cluster shoulder (cm)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Control	30.5	30.5	353.0	355.0	10.8	10.8	11.8	12.1	16.9	17.3	10.8	11.0
JA (15 ppm)	30.5	32.7	365.0	368.0	11.1	12.0	13.3	13.7	18.9	19.2	12.7	13.0
JA (30 ppm)	30.5	34.2	377.0	378.0	11.5	12.9	14.7	15.1	19.8	20.0	13.3	13.6
JA (45 ppm)	30.0	35.5	384.0	384.0	11.7	13.6	15.8	16.3	20.3	20.5	13.7	14.0
NAA (50 ppm)	30.5	34.3	375.0	379.0	11.4	13.0	14.8	15.1	19.7	20.1	13.3	13.7
NAA (100	30.5	35.7	386.0	391.0	11.8	14.0	16.1	16.4	20.4	20.9	14.0	14.3
NAA (150	30.5	36.9	392.0	398.0	12.0	14.9	17.0	17.6	20.8	21.5	14.3	14.6
JA (15 ppm) +	30.5	35.8	387.0	389.0	11.8	13.9	16.2	16.6	20.6	21.1	14.4	14.7
JA (30 ppm) +	30.0	37.2	396.0	400.0	12.1	14.9	17.6	18.0	21.3	21.8	15.0	15.3
JA (45 ppm) +	30.5	38.5	403.0	407.0	12.3	15.7	18.7	19.2	21.8	22.4	15.4	15.7
New LSD at 5%	**N.S**	**1.4**	**8.0**	**8.0**	**0.3**	**1.0**	**1.2**	**1.3**	**0.6**	**0.7**	**0.5**	**0.5**

The treatments implemented exhibited a notable impact on the berry setting percentage, number of clusters per vine, average cluster weight, yield per vine, and average cluster length and width during two seasons and cluster number per vine of Flame seedless grapevines, specifically in the second season, while no significant effect was observed in the first season, as detailed in Table (1). A notable enhancement in the examined characteristics across all implemented treatments, in contrast to the control, was discerned during the 2023 seasons. Nonetheless, the application of JA or NAA at varying concentrations resulted in an increase in mentioned parameters, whereas the first season exhibited a consistent count of cluster. Notably, NAA at 150 ppm yielded the highest cluster count per vine (36.9 in the second season), (392.0- 398.0 g) for cluster weight, (12.0 - 14.9 kg/vine) for yield, (17.0 -17.6%) for berry setting), (20.8- 21.5 cm) for cluster length and (14.3-14.6 cm) for cluster shoulder, closely followed by the vines treated with NAA at 100 ppm, with no significant difference observed between the two treatments. Conversely, the untreated vines exhibited the lowest metrics. The interaction among plant growth regulators revealed that the application of 45 ppm JA combined with 150 ppm NAA resulted in the highest yield parameters, closely followed by the lower concentration, with no significant differences observed. The remaining treatments yielded moderate scores.

In terms of jasmonic acid's impact, **Wang and Lin (2000**) discovered that it strengthens the antioxidant system and scavenges free radicals, both of which improved the cluster's production and physical characteristics. Our findings concur with **Ali and Zayat (2019)** noted that jasmine oil at 4 ml/L is more successful in encouraging fruit set, which greatly raises the quantity of fruits produced by each plant and the yield per plant in Washington Navel Orange. **Mostafa *et al.*, (2020)** found that spraying jasmonic oil at both (3 or 6 cm^3/L) led to a raise in yield weight, bunch weight, and length compared with the untreated vines. **Rizk Alla *et al.* (2024**) reported that sprinkle applications of jasmonic acid at concentrations of 10 or 20 ppm had the most beneficial effects on yield (yield kg/vine, cluster weight and dimensions).

The enhancement effect of NAA on yield properties may be attributed to its ability to increase cell wall flexibility, facilitating enlargement and accelerating the rate of fruit growth, ultimately resulting in increased fruit yield (**Arteca, 1996).** NAA application promotes the expansion of fruit mesocarp cells, thereby enhancing fruit size and overall production (**Stern *et al.*, 2007**). NAA significantly reduced flower abscission, improved productivity, and enhanced fruit quality (**Iqbal *et al.*, 2009**). **Abdelgawad *et al.* (2022)** demonstrated that average yield, and its attributes (average cluster weight and average berry size), were significantly higher in the treatment with NAA at 75 ppm compared to the control. According to **Mohammed *et al.*, (2022**), applying NAA at 75 ppm yielded the best results in terms of improving yield per vine, cluster weight and dimensions.

3.2. Berry physical characteristics

Table 2 illustrate the morpho-physical parameters of the grapevine "Flame seedless," which include shoot berry, average berry weight, longitudinal, and equatorial. The morpho-physical parameters are compared to the control treatments during the 2022 and 2023 seasons to determine the impact of foliar application with JA or/and NAA at variable concentrations. Locally, regionally, or globally, these parameters are crucial for effective marketing.

The data indicated a noteworthy variation in JA and/or NAA concentrations observed for the berry physical quality of Flame seedless grapevines (Table 2). Data concerning the berry weight, longitudinal, and equatorial development in Flame seedless grapevines indicated that the highest measurements (3.69-3.76 g), (1.97 - 1.98 cm) and (1.71- 1.73 cm), respectively were recorded with the application of NAA at 150 ppm, which was comparable to the 100 ppm treatment, revealing no significant differences between the two concentrations. The same treatments recorded the lowest shot berries. The minimum measurements of the berry physical parameters were noted in the control group, which recorded the highest shot berries. The application of NAA proved to be more efficacious than that of JA. The analysis revealed that the highest berry weight, longitudinal, and equatorial measurements (3.85- 3.87 g), (1.99-2.00 cm) and (1.75- 1.77 cm), respectively and reduction in shot berries (5.6- 5.3) were achieved with a combination of 45 ppm JA and 150 ppm NAA, closely followed by lower concentrations, which did not exhibit significant differences across the two seasons.

The enhancement of plant hormones and carbohydrates, which is manifested in the promotion of cell division, may be the cause of the improvement in the characteristics of physical berries in relation to the impact of jasmonic acid (**Avanci *et al.*, 2010**). **Attia (2022)** reported that jasmonic acid enhanced physical characteristics of king ruby berries. **Rizk Alla *et al.* (2024**) reported that sprinkle applications of jasmonic acid at concentrations of 10 or 20 ppm had the most beneficial effects on the physical attributes (average berry weight, size, and dimensions).

It is possible that NAA could behave as auxin, interfering with an enzyme's activity or production in the cell wall or cytoplasm. This process results in the hydrolysis of polysaccharides and the production of osmotically simpler saccharides, such as glucose or fructose. This process is followed by an increase in water accumulation within the cell and the formation of larger cells (**Kumar *et al.*, 2022**). Our findings regarding the enhancement of the fruit's physical attributes as the application of NAA has been found to be beneficial in enhancing fruit size in pomegranate (**Reddy, 2011**). The applying of NAA in muskmelon resulted in a recorded enhancement in fruit length and breadth **(Devi and Madhanakumari, 2015**). NAA significantly enhances the transport of nutrients and minerals from various plant parts to developing fruits, resulting in increased weight and volume (**Arora and Singh, 2014**). These findings align with those documented by **Garasiya *et al.* (2013**) investigated that the addition of NAA enhanced guava fruit weight. **Safaei *et al.* (2015**) demonstrated that the application of NAA enhanced the weight of Mandarin fruit. **Ghosh *et al.* (2016**) observed that the applying of NAA enhanced the weight of pomegranate fruit. **Abdelgawad *et al.* (2022**) demonstrated that berry size greatly higher in the treatment with NAA at 75 ppm compared to the control.

Table (2). Impact of foliar applying with jasmonic acid and naphthalin acetic acid on berries physical quality of Flame Seedless grapevines across 2022 and 2023 seasons

Characteristics / Treatments	Shot berries %		Berry weight (g)		Berry longitudinal (cm)		Berry equatorial (cm)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	8.2	8.0	3.45	3.48	1.78	1.81	1.53	1.55
JA (15 ppm)	7.3	7.2	3.54	3.56	1.84	1.86	1.58	1.61
JA (30 ppm)	6.7	6.6	3.62	3.64	1.89	1.91	1.62	1.65
JA (45 ppm)	6.5	6.2	3.68	3.70	1.91	1.93	1.65	1.67
NAA (50 ppm)	6.8	6.7	3.63	3.65	1.89	1.91	1.63	1.65
NAA (100 ppm)	6.4	6.1	3.71	3.73	1.95	1.96	1.68	1.70
NAA (150 ppm)	6.1	5.7	3.76	3.79	1.97	1.98	1.71	1.73
JA (15 ppm) + NAA (50 ppm)	6.4	6.2	3.70	3.74	1.92	1.94	1.67	1.71
JA (30 ppm) + NAA (100 ppm)	5.9	5.7	3.79	3.81	1.97	1.98	1.72	1.75
JA (45 ppm) + NAA (150 ppm)	5.6	5.3	3.85	3.87	1.99	2.00	1.75	1.77
New LSD at 5%	**0.4**	**0.5**	**0.07**	**0.07**	**0.03**	**0.03**	**0.04**	**0.04**

3.3. Berry chemical quality characteristics

The average values of the chemical quality characters (TSS%, total acidity, TSS/acidity ratio, reducing sugar, and total anthocyanin) of grapevine cv. 'Flame seedless' fruits are presented in Table 3 as a result of the foliar application of JA and / or NAA thrice at varying concentrations during the 2022 and 2023 seasons.

The application of both JA and/or NAA at varying levels significantly increased the TSS%, TSS/acidity ratio, reducing sugar, and total anthocyanin, while decreased total acidity of the berries in comparison to untreated vines, as demonstrated by Table 3. The effects of the highest concentrations were greater than those of the lowest concentrations in both seasons. Furthermore, the TSS%, TSS/acidity ratio, reducing sugar, and total anthocyanin of the berries were significantly increased and total acidity decreased by the application of 150 ppm NAA, with 100 ppm following closely behind, in comparison to the JA concentrations observed across the two seasons. Additionally, the berries chemical quality was substantially impacted by the combination of treatments, as opposed to the unsprayed vines and individual applications. The mean value of TSS%, TSS/acidity ratio, reducing sugar, and total anthocyanin were highest and total acidity was lowest at 45 ppm JA + 150 ppm NAA, with 30 ppm JA + 100 ppm NAA following closely behind. Nevertheless, the variations in these effects were negligible and not statistically significant between the two seasons.

Table (3). Impact of foliar applying with jasmonic acid and naphthalin acetic acid on berries chemical quality of Flame Seedless grapevines across 2022 and 2023 seasons

Characteristics / Treatments	TSS%		Total acidity%		TSS/acidity ratio		Reducing sugar%		Total anthocyanin mg/100g FW	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Control	18.4	18.5	0.720	0.718	25.6	25.8	14.4	14.5	25.1	25.3
JA (15 ppm)	19.0	19.1	0.691	0.690	27.5	27.7	14.9	15.1	25.7	25.8
JA (30 ppm)	19.5	19.7	0.668	0.666	29.2	29.8	15.4	15.6	26.1	26.2
JA (45 ppm)	19.8	20.1	0.650	0.647	29.7	31.1	15.6	15.9	26.4	26.5
NAA (50 ppm)	19.6	19.8	0.669	0.667	29.3	29.7	15.5	15.6	26.2	26.3
NAA (100 ppm)	20.2	20.4	0.645	0.644	31.3	31.7	16.0	16.2	26.7	26.8
NAA (150 ppm)	20.6	20.8	0.626	0.625	32.9	33.3	16.3	16.5	27.0	27.1
JA (15 ppm) + NAA (50 ppm)	20.1	20.5	0.649	0.645	31.0	31.8	15.9	16.1	26.7	26.8
JA (30 ppm) + NAA (100 ppm)	20.7	21.0	0.627	0.622	33.0	33.7	16.4	16.5	27.1	27.3
JA (45 ppm) + NAA (150 ppm)	21.1	21.4	0.609	0.604	24.6	35.4	16.6	16.8	27.4	27.6
New LSD at 5%	**0.5**	**0.5**	**0.02**	**0.02**	**1.7**	**1.8**	**0.4**	**0.4**	**0.4**	**0.4**

The exogenous application of jasmonic acid inhibits respiration, enabling fruit to preserve its energy reserves, resulting in increased total soluble solids and reducing sugar levels in JA-treated plant fruits. The increase in anthocyanins may also contribute to soluble solids (**Huang *et al.*, 2015**). Concerning the influence of jasmonic acid, **Yilmaz *et al.* (2003)** indicate that jasmonic acid and abscisic acid exhibit comparable biological properties. It has been shown to exert a senescence-promoting effect in the leaves of various plant families, as evidenced by a reduction in total acidity and an increase in total soluble solids. Moreover, **Aubert *et al.* (2015)** discovered that the beneficial effect of jasmonic acid on anthocyanin synthesis can be attributed to the improvement of the antioxidant system and the ability to scavenge free radicals. Plant growth regulators such as Jasmonic acid accelerate the accumulation of anthocyanin in grape berry skin (**Shehata, 2024).** Jasmonic acid applied topically to "Flame seedless" berries at 10% berry coloring improved the anthocyanin and TSS levels as well as TSS/TA ratio of the berries (**Samy, 2021**). The findings align with those acquired by **Attia (2022); Hussein *et al.* (2023); Rizk Alla *et al.* (2024).**

AS for the effect of NAA on Flame seedless chemical quality, **Salama and Elsherbeny (2016)** reported comparable outcomes, in which they determined that the lower concentration of NAA was the most effective treatment in this regard, surpassing both the higher treatment and the control. Additionally, according to **He *et al.* (2020),** the application of NAA suppressed anthocyanin accumulation, as naphthalene acetic acid, a synthetic auxin, delays ripening by repressing sugar and anthocyanin accumulation. Comparable outcomes have been documented by **Safaei *et al.* (2015)** demonstrated that NAA treatment enhanced the total soluble solids, weight of mandarin fruit and size. **Khandaker *et al.* (2015**) reported that the total soluble solids of apple fruits increased following NAA treatment. **Palei *et al.* (2016)** found that the yield-enhancing physical and chemical characteristics in strawberries were improved with NAA.

4. Conclusion

From an economic standpoint, the most effective treatment for improving growth, yield, and berry quality was to supply Flame seedless grapevines with a mixture containing 30 ppm jasmonic acid and

100 ppm naphthalin acetic acid three times at the onset of growth, immediately after berry setting, and one month thereafter under the same conditions.

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تأثير منظمات النمو على المحصول و الجوده لعنب فليم سيدلس

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الموجز

أجريت التجربه خلال موسمين متتاليين ٢٠٢٢ و ٢٠٢٣ لدراسة تأثير الجاسمونيك أسيد بتركيز (١٥، ٣٠، ٤٥ جزء فى المليون) و حمض النفثالين أستيك أسيد بتركيز (٥٠، ١٠٠ ، ١٥٠ جزء فى المليون) منفرده و مجتمعه على كروم العنب فليم سيدلس عمرها ١٠ سنوات متشابهة من نفس العمر و النمو و الحجم مزروعه فى تربه طينيه بمزرعه خاصة بقريه تله – محافظة المنيا. أظهرت النتائج أن إستخدام التفاعلات المشتركه بين الجاسمونيك أسيد و النفثالين أستيك أسيد كان الاكثر فعاليه بمقارنه بالمعاملات الفرديه و الكنترول فى تحسين المحصول و معايير العناقيد و الجوده الفيزيائيه و الكيميائية لثمار عنب فليم سيدلس و كانت أفضل المعاملات المستخدمه ٤٥ جزء فى المليون جاسمونيك أسيد+ ١٥٠ جزء فى المليون نفثالين أستيك أسيد مع عدم ملاحظة أى فرق معنوي مع التركيز المتوسط لكلا المادتين ٣٠ جزء فى المليون جاسمونيك أسيد + ١٠٠ جزء فى المليون نفثالين أستيك أسيد و بالتالى يمكن إعتبارها هى الأفضل للحصول على أفضل محصول و عائد.

الكلمات المفتاحية: عنب الفليم – حمض الجاسمونيك – حمض الخليك – المحصول – جودة العناقيد.