

Impact of Gibberellin Foliar Spray on Fruit and True Seed Production in Two Potato Cultivars: Naima and Eclat

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Abstract - The study was carried out on two potato varieties, Naima and Eclat, in an agricultural field located in the Ram Hamdan area, a key region for potato cultivation in Idlib Governorate. The plants were treated with a gibberellin solution at concentrations of 0, 10, and 20 ppm. Applications were administered every 15 days following plant emergence above the soil surface and continued until the flowering stage. The experiment was designed using a Completely Randomized Design (CRD).

The results demonstrated that the Naima variety exhibited superior performance over the Eclat variety in terms of leaf area (185.66 cm²), number of days to flowering (41.8 days), and fruit weight (4.99 g). Conversely, the Eclat variety outperformed Naima in the number of flowers per plant (63.06 flowers/plant), number of fruits per plant (23.9 fruits/plant), number of true seeds per fruit (166.12 seeds/fruit), seed yield per plant (2.11 g), and seed yield per dunum (8.44 kg/dunum). No significant differences were observed between the two varieties in fruit yield per plant (average 98 g/plant) or the germination rate of true seeds (average 66.8%).

Concerning gibberellin treatments, the sprayed treatments significantly surpassed the control in leaf area, number of days to flower, number of flowers per plant, number of fruits per plant, fruit weight, fruit yield per plant, seed yield per plant, seed yield per dunum, and seed germination rate. However, no significant differences were detected between the gibberellin treatments and the control in the number of true seeds per fruit.

Moreover, the gibberellin treatment at a concentration of 20 ppm significantly outperformed the 10 ppm concentration in leaf area (197.8 cm²), number of days to flowering (38.9 days), number of flowers per plant (65.14 flowers/plant), number of fruits per plant (26.2 fruits/plant), fruit yield per plant (120 g/plant), seed yield per plant (1.99 g/plant), and seed yield per dunum (7.96 kg/dunum). No significant differences were observed between the 20 ppm and 10 ppm concentrations in fruit weight (average 4.57 g), number of true seeds per fruit (149.7 seeds/fruit), or seed germination rate (68.8%).

Keywords: True Potato Seeds, Fruits, Foliar Spraying, Gibberellin, Productivity.

I. INTRODUCTION

Potato (*Solanum tuberosum* L.), belonging to the Solanaceae family, is one of the most important vegetable crops in many countries worldwide. It is a staple commodity used to feed the global population (Mathur, 2003) and is a fundamental part of the diet in European countries, where it is consumed either fresh or processed in increasing quantities (Brown, 2005). It is also used in various primary industries (Iritani, 1981). Potatoes are considered a balanced food, rich in energy, protein, vitamins, and minerals (Mehdi *et al.*, 2008). Potato flowers are borne in simple or compound inflorescences. The flowers are hermaphroditic, and self-pollination is predominant. Potato varieties differ in their ability to flower; some flower abundantly, while others flower sparingly, and some varieties produce only floral buds (Gopal, 1994). Most modern potato varieties are self-fertile, and some produce fruits abundantly (Brown, 1993). The potato fruit is a spherical berry, typically 12-25 mm in diameter, and is usually green in color, though it may turn crimson or black upon maturity. The fruits resemble tomatoes but are not suitable for consumption due to the presence of toxic compounds, primarily solanine (Krtkova *et al.*, 2011). The fruit contains numerous seeds attached to the placenta, with the number of seeds per fruit ranging from 0 to 300, depending on the variety. The seeds are flat, oval, or kidney-shaped, and their color ranges from yellow to yellowish-brown (Draie, 2019).

Foliar spraying is one of the most common methods used to deliver essential nutrients to plants at appropriate concentrations, improve their nutritional status, and enhance yield and quality (Smoleń, 2012). Foliar spraying can also be used for various purposes, including mitigating the negative effects of environmental stresses (such as heat, drought, frost, etc.), applying different nutritional compounds, growth regulators, amino acids, peptide chains, pesticides, and nanomaterials (Smoleń, 2012; Shalaby and El-Ramady, 2014; Simões *et al.*, 2017). Many water-soluble fertilizers can be applied directly to the aerial parts of plants. The applied nutrients can enter the leaves either through epidermal

penetration or stomatal uptake before being utilized in plant metabolism (Oosterhuis and Weir, 2010). Foliar fertilization has the potential to improve the efficiency and speed of nutrient uptake, providing plants with urgently needed nutrients to maximize growth and yield (Oosterhuis, 1995).

Gibberellins are highly effective in promoting cell growth, breaking seed and bud dormancy, eliminating dwarfism, overcoming chilling requirements, enhancing germination, and increasing longitudinal growth and branching. They also have physiological effects on plant growth, including stimulating flowering, fruit set, and overall growth. Gibberellins play a role in photosynthesis and activate other biological processes within plant cells, such as cell division, cell elongation, increased plant height, leaf size, and root system development. Collectively, these effects contribute to increased productivity. Additionally, gibberellins play a significant role in plant growth and the improvement of natural products. Numerous studies indicate that treating plants with growth regulators improves plant structure and crop quality. Gibberellins, one of the plant hormones, are synthesized and produced within various plant tissues, including shoot tips, roots, and developing embryos (AL-Khafaji, 2014; Algul *et al.*, 2016).

Otroshy and Struik (2008) found that a concentration of 5 mg/L of gibberellin significantly increased the number of stems per plant and plant height. On the other hand, Geletie (2016) applied gibberellin at concentrations of 0, 0.1, 0.2, and 0.3 mM to potato plants and observed a significant increase in plant height (126.40 cm/plant) at a concentration of 0.2 mM compared to the control, which recorded 85.10 cm/plant. In an experiment conducted by Al-Sahlan (2008), true potato seeds of the Desiree variety were treated with different concentrations of gibberellin (0, 500, 1000, and 1500 ppm). The results showed that gibberellin treatment significantly affected germination rates, with the 500-ppm treatment achieving the highest average germination rate of 58.66%. Similarly, Cha *et al.* (2011) experimented to study the effect of gibberellin on the germination of true potato seeds at concentrations of 0, 500, 1500, and 4500 ppm for 24 hours. The results demonstrated that seeds treated with 4500 ppm exhibited the highest germination percentage (77.2%), compared to the control, which recorded the lowest germination percentage (53.2%). Jansky *et al.* (2012) studied the effect of gibberellin at a concentration of 1500 ppm for 24 hours on the germination of true potato seeds. They found that gibberellin treatment significantly improved seed germination, with treated seeds showing higher average germination rates compared to untreated seeds.

Roy *et al.* (2016) experimented using gibberellin at a concentration of 100 ppm. They found that it significantly

affected plant height, the production of the highest number of flowers, and the yield of true seeds. The results also showed that the application of 200 ppm of gibberellic acid to flower buds and female inflorescences was the most effective in reducing flower drop and achieving a higher yield of hybrid TPS (118 kg/ha). Montwill (1975) reported that the application of 40 ppm of gibberellin increased the percentage of flowering plants and the number of flowers per plant in potatoes. Rashid *et al.* (1987) found that varieties differed significantly in their response to gibberellin application, with only 7 out of 19 varieties retaining some fruits. Pallais *et al.* (1984) and Sikka *et al.* (1990) observed that the number of flowers per plant increased when sprayed with gibberellin at doses of 25, 50, 75, and 200 ppm. Gibberellic acid at rates of 1000 and 2000 ppm was among the most effective treatments in stimulating flowering, producing approximately ten times the number of flowers (CIP, 1985).

El-Gizawy *et al.* (2006) demonstrated that spraying potato plants with gibberellic acid at concentrations of 0, 50, and 100 ppm resulted in significant varietal differences in flowering and fruit-setting characteristics. Foliar application of gibberellin stimulated flowering by reducing the time required for flowering, extending the flowering period, and increasing the number of flowers per plant. However, no significant differences were observed between the gibberellin levels in terms of fruit-setting percentage, number of fruits per plant, fruit weight per plant, fruit size, number of seeds per fruit, or the weight of 1000 true potato seeds (TPS). On the other hand, the higher concentration of gibberellic acid significantly enhanced the germination of TPS. Additionally, Bodlaender *et al.* (1989) found that gibberellin application at rates of 50 or 100 g/hectare stimulated flowering in the Spunta variety. Khan *et al.* (1994) reported that a single spray of gibberellin at 50 ppm resulted in a minimal flowering response in the Kufri Bahar variety, whereas four weekly repeated sprays produced satisfactory flowering.

In a previous study, flowering under short-day conditions was enhanced by applying a gibberellic acid solution to developing clusters as soon as they appeared (Pallais *et al.*, 1984). Pollen production and fertility were significantly increased in plants treated with three weekly sprays of gibberellin, starting one week after plant emergence. This treatment resulted in a higher percentage of flowering stalks, an increased number of inflorescences, and a greater number of flowers per inflorescence (CIP, 1984). Furthermore, Saldaña and Velázquez (1987) found that spraying potato plants with gibberellic acid reduced the time required for flower emergence and extended the flowering period. Gopal and Rana (1988) demonstrated that the most effective growth regulator for promoting flowering was repeated spraying with gibberellin at a concentration of 150 ppm at 10-day intervals.

Meanwhile, Hoekstra (1988) observed that spraying plants with 100 ppm of gibberellin was sufficient to increase the number of flowers by more than 50%, thereby enhancing true seed production. Taiz and Zeiger (1998) reported that gibberellin has a compensatory effect in accelerating the flowering of long-day plants when grown under relatively short-day conditions.

In a study conducted by Draie and Al-Ali (2021) on three potato varieties (Spunta, Synergy, and Panella) treated with gibberellin at concentrations of 0, 5, 10, and 20 ppm, the study revealed varietal differences in germination speed. The Spunta variety exhibited the fastest germination and produced the highest number of shoots per plant, while the Panella variety outperformed in terms of shoot growth vigor. The treatment with gibberellin at 20 ppm achieved the best results and surpassed the other concentrations in all studied traits. In another study by Draie (2024) on the potato variety Naima, foliar spraying was found to increase the number of aerial shoots and the overall productivity of potato plants.

Alexopoulos *et al.* (2006) found that spraying gibberellic acid during the early growth stages of potato plants (50 days after emergence) in the Chacasina variety resulted in greater plant height when applied once compared to repeated applications. Abdel-Haq *et al.* (2014) reported that spraying potato plants with gibberellin at concentrations of 100 and 200 ppm significantly increased leaf area compared to the control treatment. In a field study conducted in Mosul by Al-Asaaf *et al.* (2011) during the spring season to investigate the effect of gibberellic acid at concentrations of 25, 50, and 100 ppm on the Alaska potato variety, the results indicated that spraying with 100 ppm gibberellin significantly increased plant height and the number of branches. Additionally, the results of a study by Zain Al-Deen and Abdul Rasul (2017) on the Burren potato variety, which included two years of experiments with gibberellin sprays at concentrations of 0, 50, 100, and 200 ppm, showed that the 200-ppm treatment outperformed the others, achieving the greatest plant height (77.36 cm/plant) and the highest leaf area value (2.823 m²/plant).

Despite being one of the most important food and economic crops globally, potato production in developing countries faces constraints such as low soil fertility, pests, diseases, and the lack of high-quality seed tubers. The shortage of high-quality seed tubers is often attributed to the prevailing farming systems. In most developing countries, many farmers either recycle their seeds or obtain seed tubers from informal sources. This practice leads to seed degeneration, the accumulation of tuber-borne diseases, and, consequently, a decline in yield over time. To address the issue of poor-quality seed availability, potato propagation and the production of seed tubers have been attempted using

modern techniques such as tissue culture, hydroponics, or aeroponics. However, these strategies have proven costly for most developing countries and have not achieved the desired outcomes, making them unsustainable. Therefore, the use of true potato seeds (TPS) has emerged as a promising technology that could potentially solve this problem permanently. True potato seeds are inexpensive, easy to handle and transport, can be stored for long periods, and do not transmit most diseases, particularly viral ones. Based on the above, this research aims to study the effect of foliar spraying with various concentrations of gibberellin on the productivity of two potato varieties, Naima and Eclat, in terms of fruit and true seed production in the northwestern region of Syria.

II. MATERIALS AND METHODS

2.1 Research Location

The research was conducted during the 2023-2024 agricultural season in an agricultural field located in the Ram Hamdan area, which belongs to the Idlib Governorate. The site is situated at an altitude of 500 meters above sea level, with coordinates of 36°N latitude and 36°E longitude. The research area is approximately 13 km north of the city of Idlib and is considered one of the most important potato-growing regions in the Idlib Governorate. The area is characterized by an average annual rainfall of approximately 400 mm and an average annual temperature of 15.5°C.

2.2 Plant Material

The study was conducted on two potato varieties, Naima and Eclat, which are among the most important potato varieties cultivated in the northwestern region of Syria (Idlib Governorate).

- Naima: An early-maturing variety with elongated, large tubers. The skin and flesh are white, and it is characterized by high productivity.
- Eclat: An early-maturing variety with white flesh and pale-yellow skin. The tubers are oblong to elongated, very large, and highly uniform at 90 days, with excellent yield. This variety is well-suited for regions with challenging climates.

2.3 Experimental Treatments

The study was conducted on two potato varieties, Naima and Eclat, where the plants were sprayed with gibberellic acid at concentrations of 0, 10, and 20 ppm.

2.4 Agricultural Practices

- Potato tubers were planted in permanent field plots on ridges spaced 70 cm apart, with 35 cm between plants within the same ridge.
- Plants were sprayed with a gibberellic acid solution 15 days after complete germination and emergence of potato plants above the soil surface.
- Foliar spraying was conducted at a rate of one spray every 15 days until the onset of flowering, totaling three sprays: the first spray before flowering (on 15/3/2024), the second spray (on 30/3/2024), and the third spray (on 15/4/2024).
- Gibberellin tablets containing 20% gibberellin (each tablet containing 2 g of gibberellin) were used. To prepare the solution, 1.5 g of gibberellic acid was dissolved in a small amount of ethyl alcohol (50 ml) to ensure complete dissolution. Distilled water was then added slowly to reach a final volume of 1500 ml. The seeds were soaked in the prepared gibberellic acid solution for 24 hours.
- Fruits were collected at full maturity (green mature stage). After collecting, the fruits were mashed, and the mash was placed in water for 24 hours to separate the seeds. The seeds were then washed under tap water to remove the gelatinous material surrounding them. The seeds were dried on filter paper in a shaded, well-ventilated room at 25°C and low relative humidity. Once completely dry, the seeds were stored in an airtight, opaque container for one week at room temperature before being transferred to a refrigerator. One week before planting, the seeds were moved back to room temperature.
- The seeds were then planted in plastic germination trays filled with peat moss and placed in darkness with adequate moisture for 7 days. After this period, the trays were moved to a well-lit area to test the germination rate of the studied varieties.

2.5 Readings and Measurements

1. **Leaf Area (cm²):** The Image-J software on the computer was used to calculate the leaf area. The leaf located on the seventh node of the main stem for all plants and replicates was used for this purpose.
2. **Number of Days to Flowering (days):** The number of days from germination to the onset of flowering was counted for all plants, and the average was calculated for the different treatments.
3. **Number of Flowers per Plant (flower/plant):** Flowers were counted in all inflorescences and all studied plants, and the average per plant was calculated.

4. **Number of Fruits per Plant (fruit/plant):** Fruits were counted in all plants studied, and the average per plant was calculated.
5. **Weight of a Single Fruit (g):** The weight of the fruit was measured using a sensitive balance with an accuracy of 0.001 g.
6. **Fruit Yield per Plant (g/plant):** The fruit yield of all studied plants was calculated, and then the average fruit weight per plant was determined.
7. **Number of True Seeds per Fruit (seed/fruit):** The number of true seeds was counted for all fruits on the plant, and then the average number of seeds per fruit was calculated.
8. **True Seed Yield per Plant (g):** The true seed yield of all studied plants was calculated, and then the average weight of true seeds per plant was determined.
9. **True Seed Yield per Dunum (g):** The average true seed yield per plant was calculated, and then the average yield per unit area (Dunum) was determined.
10. **Seed Germination Percentage (%):** The germination percentage of seeds was calculated using the following formula:

$$\text{Germination Percentage (\%)} = \left(\frac{\text{Number of Germinated Seeds}}{\text{Total Number of Seeds}} \right) \times 100.$$

2.6 Experimental Design and Statistical Analysis

- The experiment was conducted on two potato varieties (Naima and Eclat). The plants were sprayed with gibberellic acid, and three concentrations were used: (0, 10, and 20 ppm). Each planted row of potato plants, with a length of 10 meters, was considered one experimental unit (replicate), and each treatment included five replicates. Thus, the total number of experimental units = 2 varieties × 1 foliar spray material × 3 concentrations × 5 replicates = 30 experimental units.
- A Completely Randomized Design (CRD) was used in this study. The results were analyzed on the computer using the statistical analysis software GenStat V-12, and means were compared using the Least Significant Difference (LSD) test at a significant level of 5%.

III. RESULTS AND DISCUSSION

3.1 Leaf Area

By studying the effect of experimental factors (variety and spray concentration) on the leaf area trait of potato plants, the results shown in Table (1) were obtained.

Table (1): Effect of experimental factors on the leaf area trait (cm²)

Cultivar Concentration	Naima	Eclat	Mean
0	168.0	154.1	161.1 ^c
10	188.6	188.5	188.6 ^b
20	200.4	195.2	197.8 ^a
Mean	185.66 ^a	179.27 ^b	182.47
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	5.48	5.61	11.23

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (1), it is evident that there was no significant superiority of the **Naima** variety over the **Eclat** variety in terms of leaf area for potato plants, with values of 185.66 and 179.27 cm², respectively. The 20-ppm concentration significantly outperformed the 10-ppm concentration, which in turn significantly outperformed the 0-ppm concentration (control), with values of 197.8, 188.55, and 161.1 cm², respectively. Regarding the interaction of the studied factors, the interaction between the **Naima** variety and the 20-ppm concentration achieved the highest leaf area value of 200.4 cm², while the lowest leaf area value was observed when the **Eclat** variety was sprayed with the 0-ppm concentration (control), with a value of 154.1 cm².

These results are consistent with the study by Abdel-Haq *et al.* (2014), which found that spraying potato plants with gibberellin at concentrations of 100 and 200 ppm led to a significant increase in leaf area compared to the control treatment. Additionally, the results reported by Zain Al-Deen and Abdul Rasul (2017) on the potato variety Buren, which involved spraying with gibberellin at concentrations of 0, 50, 100, and 200 ppm, showed that the 200-ppm gibberellin treatment provided the highest leaf area value (2.823 m²/plant).

3.2 Number of Days to Flowering

By studying the effect of experimental factors (variety and foliar spray concentration) on the number of days to flowering in potato plants, the results shown in Table (2) were obtained.

Table (2): Effect of experimental factors on the number of days to flowering (days)

Cultivar Concentration	Naima	Eclat	Mean
0	44.4	49.8	47.1 ^c
10	44.0	42.6	43.3 ^b
20	37.0	40.8	38.9 ^a
Mean	41.8 ^a	44.4 ^b	43.1
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	0.70	0.59	1.20

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (2), it is evident that the **Naima** variety significantly outperformed the **Eclat** variety in terms of the number of days to flowering for potato plants, with values of 41.8 and 44.4 days, respectively. The 20-ppm concentration significantly outperformed the 10-ppm concentration, which in turn significantly outperformed the 0-ppm concentration (control), with values of 38.9, 43.3, and 47.1 days, respectively. Regarding the interaction of the studied factors, the interaction between the **Naima** variety and the 20-ppm concentration achieved the lowest value for the number of days to flowering (37 days), while the interaction between the **Eclat** variety and the 0-ppm concentration resulted in the highest value for the number of days to flowering (49.80 days).

These results align with previous studies on the effect of gibberellin in accelerating the onset of flowering. For instance, Saldana and Velazquez (1987) found that spraying potato plants with gibberellic acid reduces the time required for flowering and extends the flowering period. Additionally, Taiz and Zeiger (1998) reported that gibberellin has a compensatory effect in accelerating the flowering of long-day plants when grown under relatively short-day conditions. Furthermore, El-Gizawy *et al.* (2006) confirmed that all gibberellin spray concentrations (50 and 100 ppm) significantly outperformed the control (0 ppm) in reducing the time required for flowering and extending the flowering period.

3.3 Number of Flowers per Plant

By studying the effect of experimental factors (variety and foliar spray concentration) on the number of flowers per plant, the results shown in Table (3) were obtained.

Table (3): Effect of experimental factors on the number of flowers per plant (flower/plant)

Cultivar Concentration	Naima	Eclat	Mean
0	37.13	39.56	38.46 ^c
10	51.46	71.61	61.18 ^b
20	52.84	78.61	65.14 ^a
Mean	48.22 ^b	63.06 ^a	54.93
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	3.06	2.65	5.30

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (3), it is evident that the Eclat variety significantly outperformed the Naima variety in terms of the number of flowers per plant, with values of 63.06 and 48.22 flowers/plant, respectively. Additionally, the 20-ppm concentration significantly outperformed the 10-ppm concentration, which in turn significantly outperformed the 0-ppm concentration (control), with values of 65.14, 61.18, and 38.46 flowers/plant, respectively. Regarding the interaction of the studied factors, the interaction between the Eclat variety and the 20-ppm concentration achieved the highest number of flowers (78.61 flowers/plant), while the lowest number of flowers was observed when the Naima variety was sprayed with the 0-ppm concentration, with a value of 37.13 flowers/plant.

When comparing the number of flowers in plants treated with gibberellin to those of the control plants, the number increased by 159% at the lower concentration and by 170% at the higher concentration. This highlights the importance of gibberellin spraying in improving the trait of the number of flowers per plant, as gibberellin enhances physiological processes such as cell division and elongation and stimulates flowering (AL-Khafaji, 2014). These results align with previous studies. For instance, Roy *et al.* (2016) found that spraying potatoes with gibberellin at a concentration of 100 ppm resulted in the highest number of flowers compared to the control. Additionally, Pallais *et al.* (1984) confirmed that flowering in potato plants can be enhanced by spraying gibberellic acid solution on flower clusters as soon as they appear. Furthermore, treating plants with three applications of gibberellin at weekly intervals, starting one week after plant emergence, produced the highest number of inflorescences and increased the number of flowers per inflorescence (CIP, 1984). Gibberellic acid at rates of 1000 and 2000 ppm was among the most effective treatments in stimulating flowering, producing approximately ten times the number of flowers (CIP, 1985). Gopal and Rana (1988) also confirmed that the best growth regulator for promoting flowering is repeated spraying with gibberellin at a concentration of 50 ppm at 10-day intervals. Similarly, El-Gizawy *et al.* (2006) found that spraying potato leaves with 200 ppm of gibberellic acid increased the number of flowers per plant. Meanwhile, Hoekstra (1988) observed that spraying plants with 100 ppm of GA3 was sufficient to increase the number of flowers by more than 50%.

3.4 Number of Fruits per Plant

By studying the effect of experimental factors (variety and foliar spray concentration) on the number of fruits per plant in potato plants, the results shown in Table (4) were obtained.

Table (4): Effect of experimental factors on the number of fruits per plant (fruit/plant)

Cultivar Concentration	Naima	Eclat	Mean
0	12.4	17.8	15.1 ^c
10	22.8	25.8	24.3 ^b
20	24.2	28.2	26.2 ^a
Mean	19.8 ^b	23.9 ^a	21.9
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	1.69	1.01	2.02

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (4), it is evident that the Eclat variety significantly outperformed the Naima variety in terms of the number of fruits per plant, with values of 23.39 and 19.8 fruits/plant, respectively. Additionally, the 20-ppm concentration significantly outperformed the 10-ppm concentration, which in turn significantly outperformed the 0-ppm concentration (control), with values of 26.2, 24.3, and 15.1 fruits/plant, respectively. Regarding the interaction of the studied factors, the interaction between the Eclat variety and the 20-ppm concentration achieved the highest number of fruits (28.2 fruits/plant), while the lowest number of fruits was observed when the Naima variety was sprayed with the 0-ppm concentration, with a value of 12.40 fruits/plant.

When comparing the number of fruits in plants treated with gibberellin to those of the control plants, the number increased by 161% at the lower concentration and by 174% at the higher concentration. This highlights the importance of gibberellin spraying in increasing the number of fruits per plant, as gibberellin stimulates various physiological processes in plants, such as flowering and fruit setting (AL-Khafaji, 2014). These results align with previous studies. For instance, Roy *et al.* (2016) found that spraying potato inflorescences with GA3 at a concentration of 100 ppm increased the percentage of flower setting and, consequently, the number of fruits compared to the control. The results also showed that applying 200 ppm of gibberellic acid to buds and inflorescences was the most effective in reducing flower drop. In an experiment conducted by El-Gizawy *et al.* (2006), it was found that varieties differed significantly in their response to the effect of spraying on fruit setting. Additionally, all spray concentrations used significantly outperformed the control in terms of the percentage of fruit setting and the number of fruits formed per plant, although there were no significant differences between the spray concentrations used.

3.5 Fruit Weight

By studying the effect of experimental factors (variety and foliar spray concentration) on the fruit weight trait of potato plants, the results shown in Table (5) were obtained.

Table (5): Effect of experimental factors on the weight of a single fruit (g)

Concentration \ Cultivar	Naima	Eclat	Mean
	0	5.04	3.76
10	4.87	4.22	4.55 ^a
20	5.07	4.11	4.59 ^a
Mean	4.99 ^a	4.03 ^b	4.51
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	0.09	0.08	0.15

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (5), it is evident that the Naima variety significantly outperformed the Eclat variety in terms of fruit weight, with values of 4.99 g and 4.04 g, respectively. Additionally, the 20-ppm and 10-ppm spray concentrations (with no significant differences between them) significantly outperformed the 0-ppm concentration, with values of 4.59 g, 4.55 g, and 4.4 g, respectively. Regarding the interaction of the studied factors, the interaction between the Naima variety and the 20-ppm concentration achieved the highest fruit weight value (5.07 g), while the lowest fruit weight value was observed when the Eclat variety was sprayed with the 0-ppm concentration, with a value of 3.76 g.

In general, all gibberellin spray treatments significantly outperformed control treatment in terms of average fruit weight. However, increasing the concentration from the lower to the higher level did not result in any significant increase in fruit weight. The results highlight the importance of using gibberellin to increase the weight of true potato fruits. These findings align with previous studies, which demonstrated an increase in fruit weight when potato plants were sprayed with gibberellic acid, with the best results observed at a concentration of 100 ppm (Hoekstra, 1988; El-Gizawy *et al.*, 2006).

3.6 Fruit Yield per Plant

By studying the effect of experimental factors (variety and foliar spray concentration) on the fruit yield per plant trait of potato plants, the results shown in Table (6) were obtained.

Table (6): Effect of experimental factors on fruit yield per plant (g/plant)

Cultivar Concentration	Naima	Eclat	Mean
0	60	70	65 ^c
10	110	110	110 ^b
20	120	120	120 ^a
Mean	96 ^a	100 ^a	98
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	5.5	4.8	9.6

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (6), it is evident that there were no significant differences between the Eclat and Naima potato varieties in terms of fruit yield per plant, with values of 100 g and 96 g, respectively. Additionally, the 20-ppm concentration significantly outperformed the 10 ppm and 0 ppm concentrations, and the 10-ppm concentration significantly outperformed the 0-ppm concentration, with values of 120 g, 110 g, and 65 g, respectively. Regarding the interaction of the studied factors, the interaction between both varieties (Eclat and Naima) and the 20-ppm concentration achieved the highest fruit yield per plant value (120 g), while the lowest fruit yield per plant value was observed when the Naima variety was sprayed with the 0-ppm concentration, with a value of 60 g.

The results indicate that gibberellin spraying achieved a significant increase in the fruit yield per plant, as the weight of fruits doubled in the spray treatments compared to the control treatment (170% at the lower spray concentration and 185% at the higher spray concentration, compared to the control). Additionally, it is noted that increasing the spray concentration played a clear role in achieving a significant increase in fruit yield per plant, as the higher concentration significantly outperformed the lower one. These results confirm the role of gibberellin in enhancing cellular activity and physiological processes in plants, which in turn reflects on increased productivity. These findings align with previous studies that demonstrated an increase in fruit yield when gibberellin was applied to plants. For instance, Roy *et al.* (2016) found that spraying potato inflorescences with gibberellin at a concentration of 200 ppm increased yield per unit area. Meanwhile, Hoekstra (1988) observed that spraying plants with 100 ppm of GA3 was sufficient to increase fruit yield.

3.7 Number of True Seeds per Fruit

By studying the effect of experimental factors (variety and foliar spray concentration) on the number of true seeds per fruit in potato plants, the results shown in Table (7) were obtained.

Table (7): Effect of experimental factors on the number of true seeds per fruit (seed/fruit)

Cultivar Concentration	Naima	Eclat	Mean
0	161.18	151.39	156.29 ^a
10	122.56	177.30	149.93 ^a
20	129.26	169.66	149.46 ^a
Mean	137.67 ^b	166.12 ^a	151.89
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	14.08	12.19	24.38

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (7), it is evident that the Eclat variety significantly outperformed the Naima variety in terms of the number of true seeds per fruit, with values of 166.12 and 137.67 seeds/fruit, respectively. There were no significant differences between the spray concentrations used (0, 10, and 20 ppm), with values of 156.29, 149.93, and 149.46 seeds/fruit, respectively. Regarding the interaction of the studied factors, the interaction between the Eclat variety and the 10-ppm concentration achieved the highest number of seeds per fruit (177.3 seeds/fruit), while the lowest number of seeds per fruit was observed when the Naima variety was sprayed with the 10-ppm concentration, with a value of 122.56 seeds/fruit.

The results indicate that gibberellin spraying had no significant effect on increasing the number of seeds per fruit, as there were no significant differences between the spray treatments and the control. This aligns with the study conducted by El-Gizawy

et al. (2006), which found no increase in the number of seeds per fruit in gibberellin spray treatments compared to the control. However, Hoekstra (1988) observed that spraying plants with 100 ppm of gibberellin resulted in an increase in the number of true seeds per fruit.

3.8 True Seed Yield per Plant

By studying the effect of experimental factors (variety and foliar spray concentration) on the true seed yield per plant trait of potato plants, the results shown in Table (8) were obtained.

Table (8): Effect of experimental factors on true seed yield per plant (g/plant)

Cultivar Concentration	Naima	Eclat	Mean
0	1.06	1.68	1.37 ^c
10	1.43	2.30	1.87 ^b
20	1.62	2.36	1.99 ^a
Mean	1.37 ^b	2.11 ^a	1.74
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	0.08	0.07	0.14

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (8), it is evident that the Eclat variety significantly outperformed the Naima variety in terms of true seed yield per plant, with values of 2.11 g and 1.37 g, respectively. Additionally, the 20-ppm concentration significantly outperformed the 10-ppm concentration, which in turn significantly outperformed the 0-ppm concentration (control), with values of 1.99 g, 1.87 g, and 1.37 g, respectively. Regarding the interaction of the studied factors, the interaction between the Eclat variety and the 20-ppm concentration achieved the highest true seed yield value (2.36 g), while the lowest true seed yield per plant was observed when the Naima variety was sprayed with the 0-ppm concentration, with a value of 1.06 g.

3.9 True Seed Yield per Dunum

By studying the effect of experimental factors (variety and foliar spray concentration) on the true seed yield per unit area (dunum) of potato plants, the results shown in Table (9) were obtained.

Table (9): Effect of experimental factors on true seed yield per dunum (kg/dunum)

Cultivar Concentration	Naima	Eclat	Mean
0	4.24	6.72	5.48 ^c
10	5.72	9.20	7.48 ^b
20	6.48	9.44	7.96 ^a
Mean	5.48 ^b	8.44 ^a	6.96
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	0.36	0.27	0.54

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (9), it is evident that the Eclat variety significantly outperformed the Naima variety in terms of true seed yield per dunum, with values of 8.44 kg/dunum and 5.48 kg/dunum, respectively. Additionally, the 20-ppm concentration significantly outperformed the 10-ppm concentration, which in turn significantly outperformed the 0-ppm concentration (control), with values of 7.96, 7.48, and 5.48 kg/dunum, respectively. Regarding the interaction of the studied factors, the interaction between the Eclat variety and the 20-ppm concentration achieved the highest true seed yield per dunum value (9.44 kg/dunum), while the lowest true seed yield per dunum was observed when the Naima variety was sprayed with the 0-ppm concentration, with a value of 4.24 kg/dunum.

The results demonstrate the effective impact of gibberellin spraying in increasing the plant's yield (and thus the total yield per unit area) of true seeds, as all spray concentrations used outperformed the control. Additionally, increasing the spray concentration led to an increase in yield at the plant level, with the higher concentration significantly outperforming the lower one. AL-Khafaji (2014) and Algul *et al.* (2016) confirmed that gibberellins have physiological effects on plant growth, photosynthesis, and the

activation of other biological activities in plant cell components, all of which contribute to increased productivity. These findings align with previous studies. For instance, Roy *et al.* (2016) found that applying 200 ppm of gibberellic acid had a significant impact on obtaining higher TPS yield compared to the control. Meanwhile, Hoekstra (1988) observed that spraying plants with 100 ppm of gibberellin was sufficient to increase plant yield and, consequently, the total yield per unit area of true seeds.

3.10 Seed Germination Percentage (%)

By studying the effect of experimental factors (variety and foliar spray concentration) on the average germination percentage of true seeds in potato plants, the results shown in Table (10) were obtained.

Table (10): Effect of experimental factors on the average seed germination percentage of potato plants

Cultivar Concentration	Naima	Eclat	Mean
0	62.4	63.4	62.9 ^b
10	68.6	67.8	68.2 ^a
20	70.8	68	69.4 ^a
Mean	67.3 ^a	66.4 ^a	66.8
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	1.89	1.64	3.28

* Different letters, for each experimental factor separately, indicate significant differences between the values.

From Table (10), it is evident that there were no significant differences between the Naima and Eclat varieties in terms of seed germination percentage, with values of 67.26% and 66.4%, respectively. However, the 20-ppm and 10-ppm spray concentrations (with no significant differences between them) significantly outperformed the 0-ppm concentration (control), with values of 69.4%, 68.2%, and 62.9%, respectively. Regarding the interaction of the studied factors, the interaction between the Naima variety and the 20-ppm concentration achieved the highest germination percentage value (70.8%), while the lowest germination percentage value was observed when the Naima variety was sprayed with the 0-ppm concentration, with a value of 62.40%.

The previous results demonstrate the positive impact of gibberellin spray treatments in increasing the seed germination percentage compared to the control, as both spray concentrations significantly outperformed the control in germination percentage. However, increasing the concentration did not have any effect on further increasing the germination percentage, as there were no significant differences between the two spray concentrations. These results align with previous studies. For instance, Al-Sahlani (2008) found that gibberellin treatment increased the germination percentage, with the 500-ppm treatment giving the highest average seed germination percentage of 58.66%. Meanwhile, Cha *et al.* (2011) reported that gibberellin treatment at a concentration of 4500 ppm resulted in the highest seed germination percentage of 77.2%, compared to the control treatment, which gave only 53.2%. Additionally, Jansky *et al.* (2012) demonstrated that gibberellin treatment at a concentration of 1500 ppm affected seed germination and

gave the highest average germination percentage compared to the control.

IV. CONCLUSIONS

The Naima variety outperformed the Eclat variety in the traits of leaf area (cm²), number of days to flowering (days), and fruit weight (g). On the other hand, the Eclat variety outperformed the Naima variety in the traits of the number of flowers per plant (flower/plant), number of fruits per plant (fruit/plant), number of true seeds per fruit (seed/fruit), seed yield per plant (g), and seed yield per dunum (kg/dunum). There were no significant differences between the two varieties in terms of fruit yield per plant (g/plant) and true seed germination percentage (%).

On the other hand, gibberellin spray treatments significantly outperformed the control treatment in the traits of leaf area, number of days to flowering, number of flowers per plant, number of fruits per plant, fruit weight, fruit yield per plant, true seed yield per plant, true seed yield per dunum, and seed germination percentage. However, there were no significant differences between gibberellin spray treatments and the control in the trait of the number of true seeds per fruit.

In the same context, the 20-ppm concentration significantly outperformed the 10-ppm concentration in the traits of leaf area, number of days to flowering, number of flowers per plant, number of fruits per plant, fruit yield per plant, true seed yield per plant, and true seed yield per dunum. However, there were no significant differences between the 20-ppm and 10-ppm spray concentrations in the traits of fruit

weight, number of true seeds per fruit, and true seed germination percentage.

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