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Enhancing Fruit and True Seed Production in Potato (*Solanum tuberosum* L.) Through Amino Acid Foliar Application: A Comparative Study of Naima and Eclat Cultivars

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Abstract - **This research was conducted in Ram Hamdan area, which belongs to Idlib Governorate, during the 2023-2024 agricultural season, as this area is considered one of the most important potato cultivation areas in the governorate. The study used two potato cultivars, Naima and Eclat, which are widely spread in the study area, where plants were sprayed with amino acid solutions at concentrations of 0, 10, and 20 g/L, at a rate of one spray every 15 days after plant emergence above soil surface until flowering time. The experiment depended on completely randomized design (CRD).Results showed superiority of Naima cultivar over Eclat cultivar in traits of leaf area (196.3 cm²), days to flowering (43.6 days), fruit weight (5.94 g), number of true seeds per fruit (181.75 seeds/fruit), while Eclat cultivar surpassed Naima cultivar in traits of total number of flowers per plant (59.62 flowers/plant), total number of fruits per plant (22.2 fruits/plant), fruit yield per plant (97.07 g/plant), true seed yield per plant (2.01 g), true seed yield per hectare (80.7 kg/ha), with no significant differences between the two cultivars in true seed germination percentage (overall average 67.24%).On the other hand, amino acid spray treatments significantly outperformed the control treatment in all studied traits. The lowest concentration (10 g/L) achieved significant superiority over the control (0 g/L) in traits of leaf area (196.6 cm²), days to flowering (43.3 days), number of flowers per plant (55.98 flowers/plant), number of fruits per plant (21.5 fruits/plant), fruit weight (5.29 g), fruit yield per plant (110.7 g/plant), number of true seeds per fruit (165.7 seeds/fruit), true seed yield per plant (1.92 g/plant), true seed yield per hectare (7.68 kg/ha), and seed germination percentage (69.1%).Finally, the concentration (20 g/L) achieved significant superiority over the concentration (10 g/L) in traits of total number of flowers per plant (59.01 flowers/plant), single fruit weight (5.75 g), and number of true seeds per fruit (193.23 seeds/fruit), while there was no significant effect of increasing spray concentration on improving the rest of the traits studied.**

Keywords: Potato, Fruits, True Potato Seeds TPS, Amino Acids, Productivity.

I. INTRODUCTION

The potato (*Solanum tuberosum* L.) originated in the Andes region, where it has been cultivated as a staple food crop for over 7,000 years. Research by Spooner *et al*. (2010) identifies the potato's center of origin as the border region between Peru and Bolivia. Globally, the potato ranks as the fourth most widely cultivated food crop after wheat, rice, and maize. It is the most economically significant tuber crop, dominating production volumes among root and tuber crops, with an annual output of approximately 375 million tons harvested from 17.8 million dunams (Draie, 2019a). Potato cultivation spans over 150 countries, extending from latitudes 65°N to 50°S and elevations ranging from sea level to 4,000 meters (Acquaah, 2007). The global average yield stands at 2 tons per dunam, with an annual per capita consumption of 31.3 kg (FAO, 2022).

Although potato propagation via tubers remains the primary method, True Potato Seed (TPS) technology represents one of the most promising alternatives for potato production. This technique requires only a minimal quantity of seeds for planting (approximately 150 grams of TPS per hectare compared to the 2 tons of seed tubers typically needed for the same area). TPS offers significant advantages: its transportation and storage are generally easy and inexpensive, the seeds can be stored long-term, and most diseases transmitted through tubers are not transmitted through true seeds (Rowell *et al*., 1986). The use of TPS reduces production costs by eliminating the need for expensive seed tubers, which can account for 40-70% of total production costs (Accatino and Malagamba, 1982). In warmer climates, the cost of healthy seed tubers may reach 50-70% of total production expenses (Upadhya, 1994). Calculations show that TPS production costs do not exceed 10% of the price of imported seed tubers required for cultivating the same area (CIP, 1985). Furthermore, TPS contributes to food security by making seed tubers available for consumption. Additionally, the genetic diversity of TPS varieties has been shown to

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enhance resistance to late blight (Almekinders and Struik, 1996). Although variations exist among strains, TPS-derived plants typically produce greater numbers of tubers with lower average tuber weights compared to plants grown from standard-sized seed tubers (Wiersema, 1984; Benz *et al*., 1995).Several key factors determine flowering and fruit set in potatoes (genotype, day length, temperature, and mineral nutrition). The fundamental requirement for large-scale TPS production is that TPS varieties exhibit abundant and prolonged flowering. Studies have demonstrated that late-maturing varieties flower more profusely and for longer durations than early-maturing varieties (Gopal, 2003). Optimal flowering and fruit formation occur under long-day conditions (approximately 16 hours) with high humidity and cool temperatures, while TPS production declines in warm tropical conditions (Almekinders and Struik, 1996; Sleper and Poehlman, 2006). High temperatures inhibit flowering, reduce pollen fertility, and consequently limit fruit and seed formation in potatoes (Malagamba and Monares, 1988).

Foliar fertilization is defined as the foliar spraying or application of one or more essential mineral nutrients to above-ground plant parts with the objective of reducing conventional soil fertilizer use (Sabbe and Hodges, 2009). Interest in foliar fertilizers has grown due to their multiple advantages, including rapid and efficient response to plant nutritional requirements, reduced fertilizer quantities needed, and the ability to circumvent unfavorable soil conditions for nutrient uptake. It is well established that supplemental foliar fertilization during crop growth can improve plant mineral status and increase crop yield (Kolota and Osinska, 2001). Furthermore, foliar fertilization demonstrates the capacity to enhance both the efficiency and speed of nutrient utilization when plants require immediate nourishment to maximize growth and productivity (Oosterhuis, 1995).

Amino acids are particularly important for stimulating cell growth. They function as buffers that help maintain appropriate pH values within plant cells, as they contain both acidic and basic groups, while also removing ammonia from the cell. This function is linked to amide formation, thereby protecting plants from ammonia toxicity. Amino acids also inhibit nitrate uptake in plants (Aslam *et al*., 2001). They can serve as a source of carbon and energy while protecting plants from pathogens. Additionally, amino acids play roles in synthesizing amines, purines, pyrimidines, alkaloids, vitamins, enzymes, terpenoids, and other compounds (Goss, 1973). They are recognized as known biostimulants with positive effects on plant growth and productivity, significantly mitigating injuries caused by abiotic stresses (Kowalczyk and Zielony, 2008). They may also function as components of coenzymes or as precursors for certain plant hormones, enhancing plant growth by improving photosynthesis, mRNA transcription, and sugar and protein production (Amin *et al*., 2011).Amino acids primarily form complexes with metal cations through carboxyl (-COO) and amino (-NH2) groups, thereby influencing the biological availability of minerals to plants (Aravind and Prasad, 2005). They reduce the effects of drought and salinity stress through their physiological efficacy by altering the osmotic potential of plant tissue (Aspinall and Paleg, 1981). Increased amino acid levels lead to reduced osmotic potential, which in turn lowers cellular water potential, thereby enhancing the cell's ability to absorb water and dissolved nutrients from the growth medium and subsequently promoting vegetative growth (Claussen, 2004; Amini and Ehsanpour, 2005).Free amino acids serve as an essential nitrogen source for protein and enzyme synthesis, as well as energy provision, which stimulates both vegetative and root growth (Mohamed and Khalil, 1992; Abdel-Aziz and Balbaa, 2007). Their supplementation increases the duration and number of cell divisions and expands them (Idris, 2009). They also inhibit the activity of enzymes responsible for ethylene formation, which become more active when plants are exposed to salt stress conditions (Stewart *et al*., 1977; Stewart and Larher, 1980).

The flowering trait in plants is considered an indicator of yield potential, as it is a genetic characteristic that varies between cultivars or hybrids. The availability of amino acids in plant tissues is essential for pollen production and pollen tube growth (Abdel-Aziz and Balbaa, 2007). Amino acids and sugars present in the stigma promote pollen tube development. Therefore, the external application of free amino acids enhances pollen production and reduces the time required for fertilization. Accelerating the fertilization process improves fruit set, particularly under high temperature conditions (in open-field cultivation) or frost conditions (in unheated protected cultivation) (Mohamed and Khalil, 1992).

Zidan and Dauob (2005) reported that foliar application of two amino compounds (Bulldozer and Aminorevival) on potato plants increased stem number, stem length, and leaf area compared to the control. Draie (2019b) confirmed in his study on the effect of foliar amino acid application on yield and its components in strawberry plants (Novo cultivar) that amino acid spraying positively affected all studied traits (fruit diameter, length, and weight; number and weight of fruits per plant; number and weight of fruits per square meter) compared to the control. In a study conducted by Abbas *et al*. (2020) in Iraq to examine the effect of amino acid spraying (proline and arginine) on potato growth and productivity, which included three spraying levels (0, 150, and 300 ppm), results showed superiority of the 150 ppm amino acid (proline and arginine) treatment in all studied traits and indicators (plant height, number of main stems, leaf area).In an experiment conducted by Abd El-Raheem *et al*. (2020) to study the effect of foliar

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amino acid spraying on growth, productivity, and nutrient balance of potato plants (Spunta cultivar), different concentrations of amino acids (0, 500, and 1000 ppm) were sprayed at 20, 40, 60, and 80 days after planting. Results indicated that the best treatment giving highest yield was with 1000 ppm amino acid spraying. Ahmad *et al*. (1999) found that application of four levels (M3-10, M4-10, M5-10, M6-10) of L-tryptophan on potato plants (PARS-70) during root tube formation stage showed maximum plant height at day 30 (67.10 cm) and day 45 (67.25 cm) after L-tryptophan application at M5-10.In an experiment conducted by Al-Hamdani *et al*. (2017) on locally produced Burren potato cultivar from previous spring season (Super Elite), spraying with amino acid compound at 4 ml/L concentration significantly increased plant height, number of main aerial stems, stem diameter, and total leaf chlorophyll content, while 2 ml/L spraying treatment showed superiority in single leaf area

Despite the significant importance of potatoes as a major global food and economic crop, their production in developing countries faces substantial challenges, including declining soil fertility, widespread pests and diseases, and the unavailability of high-quality seed tubers. The shortage of good-quality seeds is primarily attributed to prevailing traditional farming systems, where most farmers in these countries rely on reusing their local seeds or obtaining tubers from informal sources. This approach leads to seed quality deterioration and the accumulation of tuber-borne diseases, resulting in long-term productivity decline.In this context, True Potato Seed (TPS) technology emerges as a promising solution, as these seeds are characterized by their low cost, ease of transportation, long-term storage capability, and inability to transmit most diseases, particularly viral ones. Based on this background, the current research aims to study the effect of foliar spraying with certain organic compounds, such as amino acids, at different concentrations, on vegetative growth parameters and the productivity of fruits and true seeds in two potato cultivars, Naima and Eclat, cultivated in northwestern Syria.

II. MATERIALS & METHODS

2.1 Research Location:

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

2.2 Plant Material:

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

- **Naima:** An early-maturing variety with elongated, large-sized tubers, white skin and flesh, and high productivity.
- **Eclat:** An early-maturing variety with white flesh and pale-yellow skin. The tubers are rectangular to elongated, very large and uniform at 90 days, with excellent yield potential, making it highly suitable for regions with harsh climates.

2.3 Experimental Treatments:

The study was conducted on the Naima and Eclat potato cultivars. The plants were foliar-sprayed with Amino Pro (a mixture of amino acids) at concentrations of 0, 10, and 20 g/L.

2.4 Agricultural Practices:

- **Planting Method:** Potato tubers were planted in permanent field rows with 70 cm spacing between rows and 35 cm spacing between plants within the same row.
- **Amino Acid Application:** Plants were sprayed with the amino acid solution 15 days after complete emergence (when potato plants were fully visible above the soil surface).
- **Foliar Spray Schedule:** Spraying was conducted every 15 days until flowering initiation, totaling three sprays:
    1. First spray (pre-flowering): March 15, 2024
    2. Second spray: March 30, 2024
    3. Third spray: April 15, 2024
- **Fruit Harvesting and Seed Extraction:**
    - Fruits were collected at full maturity (green-ripe stage).
    - After harvesting, fruits were mashed, and the pulp was soaked in water for 24 hours to separate the seeds.
    - Seeds were then washed under tap water to remove the gelatinous coating.
    - Drying was done on filter paper in a shaded, well-ventilated room at 25°C and low relative humidity.
    - Once fully dried, seeds were stored in light-proof, airtight containers for one week at room temperature, then transferred to cold storage.
    - One week before planting, seeds were moved back to room conditions and soaked in gibberellic acid solution for 24 hours to enhance germination.

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- **Germination Test:**
  - Seeds were sown in plastic germination trays filled with peat moss substrate.
  - Trays were kept in darkness with controlled humidity for 7 days, then moved to lighted conditions to assess the germination rate of the studied varieties.

2.5 Studied Parameters and Measurements:

1. **Leaf Area (cm²):** Measured using Image-J software on a computer. The leaf at the 7th node of the main stem was analyzed for all plants and replicates.
2. **Days to Flowering (days):** Recorded as the number of days from germination to first flowering for all plants. The average was calculated for different treatments.
3. **Number of Flowers per Plant (flower/plant):** Flowers were counted in all inflorescences across studied plants. The average per plant was calculated.
4. **Number of Fruits per Plant (fruit/plant):** Fruits were counted on all studied plants. The average per plant was determined.
5. **Single Fruit Weight (g):** Measured using a precision scale (0.001 g accuracy).
6. **Fruit Yield per Plant (g/plant):** Total fruit weight per plant was recorded. The average fruit weight per plant was calculated.
7. **Number of True Seeds per Fruit (seed/fruit):** True seeds were counted in all fruits per plant. The average number of seeds per fruit was determined.
8. **True Seed Yield per Plant (g):** Total true seed weight per plant was measured. The average seed weight per plant was calculated.
9. **True Seed Yield per Dunam (g): The** average seed yield per plant was extrapolated to yield per dunam (unit area).
10. **Seed Germination Rate (%):** Calculated using the formula:

Germination (%) = (Number of germinated seeds / Total seeds) × 100

2.6 Experimental Design and Statistical Analysis:

- The experiment was conducted on two potato cultivars (Naima and Eclat). Plants were sprayed with amino acids at three concentrations (0, 10, and 20 g/L).
- Each 10-meter-long row of potato plants was considered one experimental unit (replicate), with five replicates per treatment.
- Total experimental units = 2 cultivars × 1 foliar spray treatment × 3 concentrations × 5 replicates = 30 experimental units.
- The study followed a Completely Randomized Design (CRD).
- Data was analyzed using GenStat V-12 statistical software.
- Means were compared using the Least Significant Difference (LSD) test at a 5% significance level.

III. RESULTS

3.1 Leaf Area:

The study examined the effect of experimental factors (potato cultivar and amino acid foliar spray concentration) on the leaf area of potato plants. The results are presented in Table (1).

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

Concentration \ Cultivar	Naima	Eclat	Mean
0	168	154.1	161.1[b]
10	207.4	185.8	196.6[a]
20	213.5	187.9	200.7[a]
Mean	196.3[a]	175.93[b]	186.12
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	6.48	5.61	11.23

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

Table (1) demonstrates the significant superiority of the Naima variety over the Eclat variety in terms of potato leaf area, with values of 196.3 and 175.93 cm² respectively. Both amino acid foliar spray concentrations of 20 and 10 g/L (showing no significant difference between them) significantly outperformed the control (0 g/L), with values of 200.7, 196.6, and 161.1 cm² respectively. Regarding the interaction of studied factors, the combination of the Naima variety with the 20 g/L amino acid concentration achieved the highest leaf area value of 213.5 cm², while the lowest leaf area value was observed in the Eclat variety sprayed with the 0 g/L concentration (control) at 154.1 cm².

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3.2 Days to Flowering:

Following the investigation of the effects of experimental factors (potato cultivar and amino acid foliar spray concentration) on the number of days from germination to flowering initiation in potato plants, the results presented in Table (2) were obtained.

Table (2): Effect of experimental factors on days to flowering initiation (day)

Concentration \ Cultivar	Naima	Eclat	Mean
0	44.4	49.8	47.1[b]
10	42.6	44	43.3[a]
20	43.8	44	43.9[a]
Mean	43.6[a]	45.93[b]	44.77
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 values.***

Table (2) shows the significant superiority of the Naima variety over the Eclat variety in days to flowering of potato plants, with values of 43.6 and 45.93 days respectively. Both amino acid spray concentrations of 10 and 20 g/L (with no significant difference between them) significantly outperformed the control (0 g/L) in days to flower, with values of 43.3, 43.9, and 47.1 days respectively. Regarding the interaction of studied factors, the combination of Naima variety with 10 g/L amino acid concentration achieved the lowest days to flowering (42.6 days), while Eclat variety with 0 g/L concentration showed the highest days to flowering (49.80 days).

3.3 Number of Flowers per Plant:

The study of experimental factors (potato cultivar and amino acid foliar spray concentration) on total flower count per potato plant yielded the results shown in Table (3).

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

Concentration \ Cultivar	Naima	Eclat	Mean
0	37.13	39.56	38.34 [c]
10	45.31	66.64	55.98 [b]
20	45.36	72.66	59.01 [a]
Mean	42.60 [b]	59.62 [a]	51.11
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	0.7	0.59	1.2

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

Table (3) clearly shows the Eclat variety significantly outperformed the Naima variety in total flower count per plant, with values of 59.62 and 42.60 flowers/plant respectively. The 20 g/L amino acid spray concentration significantly exceeded the 10 g/L concentration, which in turn significantly surpassed the control (0 g/L), with values of 59.01, 55.98, and 38.34 flowers/plant respectively. Regarding factor interactions, the combination of Eclat variety with 20 g/L amino acid concentration achieved the highest flower count (72.66 flowers/plant), while Naima variety sprayed with the control concentration (0 g/L) showed the lowest flower count (37.13 flowers/plant).

3.4 Number of Fruits per Plant:

The study of experimental factors (potato cultivar and amino acid foliar spray concentration) on total true fruit count per potato plant yielded the results shown in Table (4).

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

Concentration \ Cultivar	Naima	Eclat	Mean
0	12.40	17.80	15.1[c]
10	19.00	24.00	21.5[a]
20	13.20	24.80	19[b]

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Mean	14.89 b	22.2 a	18.53
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 values.*

Table (4) demonstrates the Eclat variety's significant superiority over Naima in total fruit count per plant, with values of 22.2 and 14.89 fruits/plant respectively. The 10 g/L amino acid concentration significantly outperformed the 20 g/L treatment, which in turn surpassed the control (0 g/L), with values of 21.5, 19, and 15.1 fruits/plant respectively. Regarding factor interactions, the Eclat variety with 20 g/L treatment achieved the highest fruit count (24.8 fruits/plant), while Naima with the control treatment (0 g/L) showed the lowest count (12.40 fruits/plant).

3.5 Fruit Weight:

Following the study of experimental factors (potato cultivar and amino acid foliar spray concentration) on single true fruit weight in potato plants, the results presented in Table (5) were obtained.

Table (5): Effect of experimental factors on true potato fruit weight (g)

Cultivar / Concentration	Naima	Eclat	Mean
0	5.04	3.76	4.4 c
10	5.84	4.73	5.29 b
20	6.94	4.55	5.75 a
Mean	5.94 a	4.34 b	5.14
L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	0.089	0.077	0.15

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

Table (5) shows the Naima variety significantly outperformed the Eclat variety in fruit weight, with values of 5.94 g and 4.34 g respectively. The 20 g/L amino acid spray concentration significantly exceeded the 10 g/L concentration, which in turn surpassed the control (0 g/L), with values of 5.75 g, 5.29 g, and 4.4 g respectively. Regarding factor interactions, the combination of Naima variety with 20 g/L amino acid concentration achieved the highest fruit weight (6.94 g), while Eclat variety sprayed with the control concentration (0 g/L) showed the lowest fruit weight (3.76 g).

3.6 Fruit Yield per Plant:

The study of experimental factors (potato cultivar and amino acid foliar spray concentration) on fruit yield per potato plant yielded the results shown in Table (6).

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

Cultivar / Concentration	Naima	Eclat	Mean
0	59.8	66.0	62.9 c
10	109.0	112.4	110.7 a
20	91.2	112.8	102.0 b
Mean	86.67 b	97.07 a	91.87
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 values.*

Table (6) demonstrates the Eclat variety's significant superiority over Naima in fruit yield per plant, with values of 97.07 and 86.67 g/plant respectively. The 10 g/L amino acid spray concentration significantly outperformed the 20 g/L treatment, which in turn surpassed the control (0 g/L), with values of 110.7, 102, and 62.9 g/plant respectively. Regarding factor interactions, the Eclat variety with 20 g/L treatment achieved the highest fruit yield (112.8 g/plant), while Naima with the control treatment (0 g/L) showed the lowest yield (59.8 g/plant).

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3.7 Number of True Seeds per Fruit:

After studying the effect of experimental factors (potato cultivar and amino acid foliar spray concentration) on the number of true seeds per single potato fruit, the results shown in Table (7) were obtained.

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

Cultivar / Concentration	Naima	Eclat	Mean
0	161.18	151.39	156.29^b
10	162.01	169.39	165.7^b
20	222.06	164.4	193.23^a
Mean	181.75^a	161.73^b	171.73
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 values.***

Table (7) shows the Naima variety significantly outperformed the Eclat variety in number of true seeds per fruit, with values of 181.75 and 161.73 seeds/fruit respectively. The 20 g/L amino acid spray concentration significantly exceeded both the 10 g/L concentration and control (0 g/L) (with no significant difference between these two), with values of 193.23, 165.29, and 156.29 seeds/fruit respectively. Regarding factor interactions, the combination of Naima variety with 20 g/L amino acid concentration achieved the highest seed count per fruit (222.06 seeds/fruit), while Eclat variety sprayed with the control concentration (0 g/L) showed the lowest seed count (151.39 seeds/fruit).

3.8 True Seed Yield per Plant:

The study of experimental factors (potato cultivar and amino acid foliar spray concentration) on true seed yield per potato plant yielded the results shown in Table (8).

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	1.62	2.22	1.92^a
20	1.49	2.15	1.82^b
Mean	1.39^b	2.01^a	1.70
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 values.***

Table (8) demonstrates the Eclat variety's significant superiority over Naima in true seed yield per plant, with values of 2.01 and 1.39 g/plant respectively. The 10 g/L amino acid spray concentration significantly outperformed the 20 g/L treatment, which in turn surpassed the control (0 g/L), with values of 1.92, 1.82, and 1.37 g/plant respectively. Regarding factor interactions, the Eclat variety with 10 g/L treatment achieved the highest true seed yield (2.22 g/plant), while Naima with the control treatment (0 g/L) showed the lowest yield (1.06 g/plant).

3.9 True Seed Yield per Hectare:

The study of experimental factors (potato cultivar and amino acid foliar spray concentration) on average true seed yield per hectare for potato plants yielded the results shown in Table (9).

Table (9): Effect of experimental factors on true seed yield per hectare (g/ha)

Cultivar / Concentration	Naima	Eclat	Mean
0	42.5	6.7.3	54.9 ^c
10	64.8	88.7	76.8 ^a
20	59.6	86.2	72.9 ^b
Mean	55.6 ^b	80.7 ^a	68.2

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L.S.D. (5%)	Cultivar	Concentration	Cultivar × Concentration
	3.1	2.7	5.4

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

Table (9) demonstrates the statistically significant superiority of the Eclat cultivar over the Naima cultivar in terms of average productivity per hectare of true potato seeds, with values reaching 80.7 and 55.6 kg/ha, respectively. The foliar application of amino acids at a concentration of 10 g/L showed statistically significant superiority over the 20 g/L concentration, which in turn significantly outperformed the 0 g/L control, with recorded values of 76.8, 72.9, and 54.9 kg/ha, respectively. Concerning the interaction of the studied factors, the combination of the Eclat cultivar with the 20 g/L amino acid concentration achieved the highest seed productivity per hectare at 88.7 kg/ha, while the lowest productivity of 42.5 kg/ha was observed when the Naima cultivar was treated with the 0 g/L concentration (control treatment).

3**. 10 Percentage of true seed germination:**

The study examined the effects of experimental factors (potato cultivar and foliar amino acid application concentration) on true seed germination percentage, as presented in Table (10).

Table (10): Effect of experimental factors on the percentage of true potato seed germination (%)

Concentration \ Cultivar	Naima	Eclat	Mean
0	62.4	63.4	62.9[b]
10	67	71.2	69.1[a]
20	70	69.4	69.7[a]
Mean	66.47[a]	68[a]	67.2
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 values***

Table (10) shows no statistically significant differences between the Eclat and Naima cultivars in true seed germination percentage, with values of 68% and 66.47%, respectively. The amino acid foliar applications at 20 g/L and 10 g/L (showing no significant difference between them) significantly outperformed the 0 g/L control, with values of 69.7%, 69.1%, and 62.9%, respectively. Regarding factor interactions, the combination of Eclat cultivar with 10 g/L amino acid concentration achieved the highest germination rate (71.2%), while the lowest rate (62.4%) occurred with Naima cultivar treated with 0 g/L concentration.

IV. DISCUSSION

The previous results reveal distinct differences between the two potato cultivars, Naima and Eclat, in the studied traits. The Naima cultivar exhibited approximately 111% larger leaf area, earlier flowering by about two days, 137% greater fruit weight, and 112% more seeds per fruit compared to the Eclat cultivar. In contrast, the Eclat cultivar produced approximately 140% more flowers per plant, 149% more fruits per plant, 112% higher fruit yield per plant, 145% higher seed yield per plant, and 145% higher seed yield per hectare compared to Naima. However, no significant difference was observed between the two cultivars in terms of true seed germination percentage.

The results demonstrated the clear effect of foliar amino acid application in improving all studied traits: leaf area (cm²), days to flowering (day), number of flowers per plant (flower/plant), number of fruits per plant (fruit/plant), single fruit weight (g), fruit yield per plant (g/plant), number of true seeds per fruit (seed/fruit), true seed yield per plant (g), true seed yield per hectare (kg/ha), and seed germination percentage (%). Compared to the control (0 g/L), the 10 g/L amino acid treatment increased leaf area by 122%, reduced days to flowering (earliness) by 91%, increased total flowers per plant by 146%, increased fruits per plant by 142%, increased single fruit weight by 120%, increased fruit yield per plant by 176%, increased true seeds per fruit by 106%, increased true seed yield per plant by 140%, increased true seed yield per hectare by 140%, and improved seed germination rate by 110%. However, increasing the amino acid concentration from 10 g/L to 20 g/L showed negligible effects on trait improvement: total flowers per plant increased by 105%, single fruit weight by 108%, and true seeds per fruit by 116%, while other traits showed either non-significant or slightly negative effects.

The observed results and the positive effects of foliar amino acid application on improving the studied traits can be attributed to the crucial role of amino acids in stimulating cell growth, enhancing plant growth and productivity, and mitigating environmental stress impacts (Kowalczyk and Zielony, 2008; Aslam *et al*., 2001). Amino acids improve plant growth by enhancing photosynthesis (Amin *et al*., 2011)

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and facilitating mineral nutrient uptake (Aravind and Prasad, 2005). They also alleviate drought and salinity stress through physiological activity by reducing plant tissue osmotic potential (Aspinall and Paleg, 1981), thereby lowering cellular water potential and increasing water and mineral absorption capacity, which promotes vegetative growth (Claussen, 2004; Amini and Ehsanpour, 2005). Furthermore, free amino acids serve as a vital nitrogen source for protein and enzyme synthesis, providing energy that stimulates vegetative and root growth (Mohamed and Khalil, 1992; Abdel-Aziz and Balbaa, 2007), and their application increases cell division and expansion (Idris, 2009).

Our results align with previous studies demonstrate the importance of foliar amino acid applications in improving vegetative growth and productivity traits in potato plants. Zidan and Dauob (2005) confirmed that foliar amino acid spraying increased leaf area compared to control treatments. Draie (2019b) reported positive effects on all studied traits (fruit diameter, length, weight, fruit number and weight per plant, and fruit yield per square meter).In another study on the Naima potato cultivar, Draie (2024) found that foliar organic acid applications increased both aerial stem count and total potato productivity. Abbas *et al*. (2020) observed superior performance with amino acid sprays (150 ppm) across all measured traits (plant height, main stem count, leaf area). Abd El-Raheem *et al*. (2020) noted that potato plants (cv. Spunta) treated with amino acids (1000 ppm) achieved the highest yield compared to controls. Similarly, Al-Hamdani *et al*. (2017) documented significant improvements in plant height, main stem number, stem diameter, and total leaf chlorophyll content in the Burren cultivar with amino acid foliar sprays (4 ml/L).

V. CONCLUSIONS

The Naima cultivar outperformed the Eclat cultivar in leaf area (cm²), days to flowering (day), single fruit weight (g), and number of true seeds per fruit (seed/fruit). Conversely, the Eclat cultivar showed superior performance in total flowers per plant (flower/plant), total fruits per plant (fruit/plant), fruit yield per plant (g/plant), true seed yield per plant (g), and true seed yield per hectare (kg/ha). No significant differences were observed between the two cultivars in true seed germination percentage (%).Amino acid foliar applications significantly outperformed the control treatment in all studied traits: leaf area, days to flowering, number of flowers per plant, number of fruits per plant, single fruit weight, fruit yield per plant, number of true seeds per fruit, true seed yield per plant, true seed yield per hectare, and seed germination percentage. Finally, the 20 g/L concentration demonstrated statistically significant superiority over the 10 g/L concentration in total flowers per plant, single fruit weight, and number of true seeds per fruit. However, increasing the application concentration showed no significant effect on improving the remaining studied traits.

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