



Improving fertility, seed composition, and yield in soybean through strategic Diethyl aminoethyl hexanoate (DTA-6) application

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[https://doi.org/ 10.59658/jkas.v12i3.4347](https://doi.org/10.59658/jkas.v12i3.4347)

Received: Apr. 17, 2025	Abstract This study investigated the effect of the growth regulator DTA-6, applied at varying concentrations (30, 60, and 90 mg L ⁻¹) during two critical growth stages—branching (GS-22) and flowering (GS-51)—on the productivity and quality attributes of two locally adapted soybean cultivars (<i>Shaima</i> and <i>Abaa</i>). Results revealed that DTA-6 positively influenced several agronomic traits, including fertility percentage, seed yield, and various seed quality parameters such as oil content and fatty-acid composition. Notably, the highest DTA-6 concentration (90 mg L ⁻¹), when applied at the flowering stage, yielded the most significant improvements in fertility percentage, seed yield, and certain fatty-acid profiles, albeit accompanied by a reduction in protein content. Genetic differences between the two cultivars— <i>Shaima</i> and <i>Abaa</i> —clearly influenced their responses to DTA-6. <i>Shaima</i> excelled in seed yield and exhibited lower seed wrinkling along with higher oil and oleic acid content, suggesting an enhanced genetic capacity for efficient resource allocation and lipid biosynthesis. In contrast, <i>Abaa</i> showed superior fertility percentage and higher protein content, likely due to genetic traits favoring reproductive development and nitrogen assimilation. These findings underscore the importance of selecting suitable cultivars and optimizing the timing of DTA-6 application to maximize agronomic and quality-related benefits. A significant interaction between cultivar, application timing, and DTA-6 concentration was observed, highlighting that the response varied according to the genetic background and treatment combination. Consequently, the strategic integration of DTA-6 into soybean crop management could enhance yield and seed quality, paving the way for more efficient and profitable production in environments like those studied.
Accepted: July 18, 2025	
Published: Sep. 15, 2025	
Keywords: Soybean, DTA-6, Fertility, Seed yield, Oil content.	

Introduction

Soybean (*Glycine max* L.) is one of the most strategically important crops worldwide, serving as a principal source of plant-based protein and oils, thereby playing a crucial role in both the food and feed industries [1]. This significance stems from the ever-increasing global demand for safe, high-quality protein and oil, as well as the crop's contribution to global food security and sustainable agriculture. Notably, soybean exhibits the ability to fix atmospheric nitrogen through root nodules [2], making it an integral component of crop rotations aimed at improving soil structure and fertility [3]. In recent years, scientific research has intensified efforts to boost soybean productivity and quality by using modern approaches in physiological enhancement. Among the most noteworthy tools in this context are plant growth regulators (PGRs)—organic substances (natural or synthetic) that induce noticeable changes in the plant's biological processes [4]. These substances can promote vegetative growth, optimize photosynthetic activity, and regulate stress responses, thus enabling researchers and growers to push yields to higher levels, particularly under diverse environmental and agricultural constraints [5].

DTA-6 (Diethyl Aminoethyl Hexanoate) has gained attention as one of the promising growth regulators for improving several morphological and biochemical traits of soybean [6]. Some studies indicate that DTA-6 may increase plant height, leaf area, and chlorophyll concentration, leading to greater efficiency in photosynthesis [7]. The compound is also believed to enhance the uptake and distribution of nutrients within various plant tissues, which translates into a rise in overall biomass [8]. Chemically, DTA-6 is considered a cytokinin-like compound, acting in ways that mimic natural cytokinins. It promotes cell division, enhances nutrient mobilization, and supports chlorophyll biosynthesis and reproductive development. These findings are in line with observations by [9], who noted that contemporary growth regulators, including DTA-6, may substantially improve plant tolerance to environmental stress while also elevating final seed yield. On the other hand, differences among soybean cultivars constitute a pivotal factor in determining the extent of plant benefits from growth regulators. Genetic variation significantly influences crop responsiveness to stimulating compounds [10]. Certain cultivars may benefit from DTA-6 through enhanced flowering, greater pod set, or increased oil percentage, whereas another cultivar might excel in protein content or vegetative characteristics. Therefore, studying the response of two different cultivars is a necessary step for understanding the physiological variation between them, thus identifying the best genetic background for local environmental and input conditions [11]. Furthermore, the timing of application plays a key role in determining the efficacy of a growth regulator. According to some investigations, spraying during the branching stage (GS-22) might support vegetative growth, whereas application during the flowering stage (GS-51) could improve pod setting and yield-related attributes [12]. It is also anticipated that the concentration of DTA-6 (e.g., 30, 60, or 90 mg L⁻¹) will differentially influence productivity traits; higher concentrations typically induce more

pronounced metabolic processes, yet they may pose a risk of negative impacts if the threshold is exceeded [6].

Considering these factors, it becomes evident that research is needed to elucidate the role DTA-6 may play in raising yield levels and enhancing the biochemical properties of soybean seeds, while accounting for cultivar variation and determining optimal application timing and concentration. Results from such research could offer practical guidelines for farmers and policymakers, enabling the adoption of modern management strategies to meet the growing demand for high-quality agricultural products while ensuring sustainability in production systems.

Materials and Methods

Experimental Site

The field experiment was conducted during the 2024 growing season at the Mashkab Research Station, Al-Mashkab District, Agricultural Research Department, Najaf Al-Ashraf Governorate, located at 31°53'22"N, 44°30'00"E. The study aimed to evaluate the effect of the growth regulator DTA-6 (Diethyl Aminoethyl Hexanoate) on the physiological, biochemical properties, and yield of two soybean cultivars (*Shaima* and *Abaa*), obtained locally from the Agricultural Research Department under the National Program for Elite Soybean Seed Conservation.

Soil samples were collected from a depth of 0–0.40 m and analyzed in the Central Laboratories Division of the Agriculture Directorate in Najaf Al-Ashraf Governorate following standard procedures [13]. Key soil properties are summarized in Table 1.

Table (1): Chemical and Physical Properties of the Field Soil

Parameter	Unit	Value
Sand	%	87.5
Silt	%	7.5
Clay	%	5
Texture		Sandy loam
Organic Matter	%	2.069
Nitrate	mg/kg	0
Available Nitrogen	mg/kg	41
Available Phosphorus	mg/kg	15
Available Potassium	Ppm	174.8
Electrical Conductivity	ds/m	0.7
pH		7.94

Land Preparation, Experimental Design, and Treatments

The field was plowed twice using a reversible rotary tiller and leveled with disc harrows. After leveling, the field was divided into plots following a Randomized Complete

Block Design (RCBD) with three replications in a split-plot arrangement. The main plots were assigned to the soybean cultivars (*Shaima* and *Abaa*).

A. DTA-6 Foliar Spray Treatments

The following treatments were applied using the growth regulator DTA-6 (cytokinins):

- Water spray only (control).
- DTA-6 at 30 mg L⁻¹ applied at the branching stage (GS-22).
- DTA-6 at 60 mg L⁻¹ applied at the branching stage (GS-22).
- DTA-6 at 90 mg L⁻¹ applied at the branching stage (GS-22).
- DTA-6 at 30 mg L⁻¹ applied at the flowering stage (GS-51).
- DTA-6 at 60 mg L⁻¹ applied at the flowering stage (GS-51).
- DTA-6 at 90 mg L⁻¹ applied at the flowering stage (GS-51).

Spraying was performed early in the morning until complete wetting, with a 1-meter spacing maintained between replications and experimental units. The scale described by [14] was used to determine the growth and development stages of soybean.

Crop Management Practices

Seeds were sown on 01/06/2024 at a depth of 3 cm [14] in plots measuring 4 × 4 m containing five rows, with 75 cm between rows and 20 cm between plants (plant density: 66,667 plants ha⁻¹). Crop management practices included:

- Manual weeding.
- Irrigation as needed.
- A single pre-plant application of phosphate fertilizer (120 kg P₂O₅ ha⁻¹).
- Split applications of nitrogen fertilizer (225 kg N ha⁻¹ as 46% urea) in three doses: post-emergence, at the onset of flowering, and during pod formation.
- Pest control using pesticides (Solution and Disis Expert), with re-application after five days.
- Harvesting on 15/11/2024, when leaves had yellowed and fallen, pods had turned brown, and seed moisture had reached 14%.

Measured Parameters

- **Pod Fertility (%):** Calculated as:

$$\text{Pod Fertility (\%)} = \frac{\text{Number of seeds per pod}}{\text{Number of ovules per pod}} \times 100$$

- **Percentage of Wrinkled Seeds (%):** Determined by calculating the ratio of wrinkled seeds to the total number of seeds and multiplying by 100.
- **Total Seed Yield (Mg ha^{-1}):** Determined from two central rows plus five additional plants; the average yield was calculated and expressed in Mg ha^{-1} .
- **Seed Protein Content (%):** The nitrogen content was determined using the Micro-Kjeldahl method [15] and multiplied by a conversion factor of 6.25 to obtain the protein percentage [16].
- **Seed Oil Content (%):** Determined using Soxhlet extraction with petroleum ether (boiling range: 40–60 °C) according to the standard method [15].
- **Fatty Acid Profile (%):** Proportions of oleic, linoleic, and linolenic acids were determined by gas chromatography (GC) following oil extraction from the samples. The fatty acids were converted to fatty acid methyl esters (FAMES) via BF_3 -enhanced transesterification, and the resulting retention times and peak areas were analyzed.

Statistical Analysis

Data were analyzed using Genstat software through Analysis of Variance (ANOVA) under an RCBD with a split-plot arrangement. Treatment means were compared using the Least Significant Difference (LSD) test at the 5% significance level [17].

Results and Discussion

Fertility Percentage (%)

The findings (Table 2) showed a significant effect of the combinations of DTA-6 regulator spray concentrations and timings, as well as soybean cultivars and their interaction, on fertility percentage. Results in Table 2 indicated that the cultivar *Abaa* significantly outperformed *Shaima* in fertility percentage, with *Abaa* recording an average fertility of 63.03%, whereas *Shaima* recorded 50.97%. This difference can be attributed to genetic variations between the two cultivars, as *Abaa* may possess genes responsible for enhancing pollination and fertilization efficiency, thereby increasing the pod-setting rate compared to *Shaima*. Genetic factors play a decisive role in stimulating fertilization mechanisms within the flowers, contributing to improved pod-setting and embryo growth inside pods, ultimately leading to a higher success rate of seed formation [18]. Alongside genetic factors, the superiority of certain soybean cultivars may also be due to their maternal lines' capacity to efficiently exploit environmental conditions, combined with genetic factors. This efficiency in resource allocation is essential for improving growth and productivity [19].

Regarding the effect of different DTA-6 concentrations and application timings, the results showed that using DTA-6 led to a significant increase in fertility percentage (Table 2), especially when using the higher concentration (90 mg L^{-1}) during the flowering stage (GS-51), achieving the highest fertility percentage of 86.94% compared to the water-spray control at 39.78%. Overall, the increase in fertility was more evident when applying DTA-6 at the flowering stage (GS-51) rather than at the branching stage

(GS-22). The superiority of applying DTA-6 during flowering over branching in increasing fertility percentage may be explained by the fact that the flowering stage is the pivotal point determining successful pollination and flower set, when the plant is at its peak physiological response to growth regulators that promote fertilization and seed stabilization processes. During this stage, applying DTA-6 improves the production of plant hormones that support pollination, such as auxins and gibberellins, thereby stimulating ovary growth and increasing the rate of flowers turning into pods and seeds [20]. Conversely, applying DTA-6 during the branching stage could stimulate more vegetative growth rather than reproductive development, which may reduce fertilization efficiency and negatively affect pod-setting compared to applying it during flowering. The increase in fertility percentage with higher DTA-6 concentrations can be explained by the direct influence on physiological processes related to flowering, such as enhancing pollen activity, improving flower response to fertilization, and increasing nutrient flow to reproductive parts. Higher concentrations also reduce the flower abortion rate, increasing the proportion of flowers that develop into full pods. This mechanism aligns with what was observed in terms of seeds per pod, as using a higher DTA-6 concentration during flowering enhanced seed formation and overall pod-setting efficiency.

There was also a significant effect of the interaction between cultivars and DTA-6 concentrations/timings on fertility percentage, where the treatment of spraying at 90 mg L⁻¹ during the flowering stage (GS-51) recorded the highest fertility percentage of 98.67% in *Shaima* and 75.22% in *Abaa*. In contrast, the lowest values appeared under the water-spray treatment, registering 44.78% in *Shaima* and 34.78% in *Abaa*.

Table (2): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on soybean fertility percentage (%).

DTA-6 Concentration & Application Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	34.78	44.78	39.78
DTA-6 at 30 mg L ⁻¹ (Branching stage, GS-22)	41.67	51.11	46.39
DTA-6 at 60 mg L ⁻¹ (Branching stage, GS-22)	57.78	64.44	61.11
DTA-6 at 90 mg L ⁻¹ (Branching stage, GS-22)	34.33	38.89	36.61
DTA-6 at 30 mg L ⁻¹ (Flowering stage, GS-51)	48.56	61.67	55.11
DTA-6 at 60 mg L ⁻¹ (Flowering stage, GS-51)	64.44	81.89	73.17
DTA-6 at 90 mg L ⁻¹ (Flowering stage, GS-51)	75.22	98.67	86.94
Mean (%)	50.97	63.03	

L.S.D._{0.05} for soybean cultivars = 1.1650

L.S.D._{0.05} for growth regulator combination = 0.7389

L.S.D._{0.05} for interaction = 1.1360

Percentage of Wrinkled Seeds (%)

The findings (Table 3) indicated a significant effect of the combinations of DTA-6 regulator spray concentrations and timings, as well as soybean cultivars and their interaction, on the percentage of wrinkled seeds. Results in Table 3 revealed that *Shaima* significantly outperformed *Abaa* in reducing the percentage of wrinkled seeds, with *Shaima* having an average wrinkled-seed percentage of 13.27%, whereas *Abaa* recorded 18.87%. This difference in seed quality between the two soybean cultivars, particularly *Shaima*, can be attributed to genetic differences that enhance seed production and minimize deformations. Genetic traits have a substantial impact on seed morphology and biochemical characteristics, both of which are crucial for breeding programs aimed at improving crop quality and yield [21]. In addition, *Shaima* may be more efficient in distributing resources within the plant, enabling it to allocate more energy and nutrients to producing healthy, well-filled seeds. This is reflected in a lower percentage of wrinkled seeds and an overall improvement in crop quality. These findings also align with what was reported in Table 19, where *Shaima* outperformed *Abaa* in hundred-seed weight, implying that better seed quality is also associated with larger, heavier seeds.

Regarding the effect of various DTA-6 concentrations and timings, the results showed that using DTA-6 led to a significant reduction in the percentage of wrinkled seeds, especially at the higher concentration (90 mg L^{-1}) applied during the flowering stage (GS-51), which produced the lowest wrinkled-seed percentage of 13.27%. This was superior to the control (water spray), which recorded 19.12%. Overall, the reduction in wrinkled seeds was more pronounced when DTA-6 was applied at the flowering stage (GS-51) than at the branching stage (GS-22). The reason behind the superiority of DTA-6 application during flowering over branching in reducing wrinkled seeds may be that flowering is the critical stage at which seed quality is established, with the physiological processes related to seed filling peaking at this time. During this period, the application of DTA-6 enhances hormonal interactions that encourage nutrient uptake and increase the flow of organic compounds to seeds, thereby improving their filling and reducing the likelihood of wrinkling [22]. In contrast, applying DTA-6 during the branching stage may boost vegetative growth without directly improving seed quality, making the later response during maturity stages less effective in reducing wrinkles. The decrease in wrinkled seeds as DTA-6 concentration increases can be explained by the strong enhancement in hormonal balance within the plant—particularly auxins and cytokinins—leading to improvements in seed quality and development. These hormones regulate critical processes such as water and nutrient distribution, cell-wall structure, and metabolic activity, all essential for optimal seed filling and minimizing wrinkles [23].

A significant effect of the interaction between cultivars and DTA-6 spray concentrations/timings on the percentage of wrinkled seeds was also observed. The treatment of applying 90 mg L^{-1} during the flowering stage (GS-51) recorded the lowest wrinkled-seed percentage of 6.27% in *Shaima* and 11.63% in *Abaa*. Conversely, the highest

wrinkled-seed percentage was noted under the water-spray treatment, with 16.63% in *Shaima* and 21.82% in *Abaa*.

Table (3): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on the percentage of wrinkled seeds in soybean (%).

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	16.63	21.82	19.12
DTA-6 at 30 mg L ⁻¹ , Branching Stage (GS-22)	16.93	21.74	19.33
DTA-6 at 60 mg L ⁻¹ , Branching Stage (GS-22)	16.73	21.51	19.12
DTA-6 at 90 mg L ⁻¹ , Branching Stage (GS-22)	15.64	21.66	18.65
DTA-6 at 30 mg L ⁻¹ , Flowering Stage (GS-51)	12.14	18.62	15.38
DTA-6 at 60 mg L ⁻¹ , Flowering Stage (GS-51)	8.59	15.13	11.86
DTA-6 at 90 mg L ⁻¹ , Flowering Stage (GS-51)	6.27	11.63	8.95
Mean (%)	13.27	18.87	

L.S.D._{0.05} for soybean cultivars = 2.962

L.S.D._{0.05} for growth regulator combination = 3.099

L.S.D._{0.05} for interaction = Non-significant

Seed Yield (Mg ha⁻¹)

The findings (Table 4) showed that *Shaima* excelled in seed yield compared to *Abaa*, with *Shaima* registering a mean seed yield of 2.338 Mg ha⁻¹ versus 1.554 Mg ha⁻¹ for *Abaa*. The difference in soybean productivity between cultivars such as *Shaima* can be ascribed to genetic variations that affect resource allocation toward seed formation. Genetic potential is essential for yield improvement, influencing various traits associated with seed development and overall plant growth [24].

As for the effect of different DTA-6 concentrations and timings, the use of this regulator significantly increased seed yield, especially at the highest concentration (90 mg L⁻¹) applied during the flowering stage (GS-51), giving the highest seed yield of 2.970 Mg ha⁻¹ compared to 1.193 Mg ha⁻¹ under the water-spray control. The rise in seed yield was generally more evident when applying DTA-6 during the flowering stage (GS-51) than at the branching stage (GS-22). This can be explained by the plant's heightened physiological response to growth regulators at the flowering stage, which improves nutrient accumulation and seed-filling processes, thus increasing the final yield [25].

The interaction between soybean cultivars and the combinations of DTA-6 concentrations and application timings showed a significant effect on seed yield (Table 4). The highest seed yield was recorded in *Shaima* (3.463 Mg ha⁻¹) when DTA-6 was applied at 90 mg L⁻¹ during the flowering stage (GS-51), which was significantly superior to all other treatments. This was followed by *Shaima* under 60 mg L⁻¹ at flowering (2.940 Mg ha⁻¹) and 60 mg L⁻¹ at branching (2.630 Mg ha⁻¹). Conversely, the lowest

seed yield was observed in *Abaa* (0.843 Mg ha^{-1}) when treated with 90 mg L^{-1} DTA-6 at the branching stage. These results demonstrate that *Shaima* was more responsive to DTA-6, particularly at the flowering stage, while *Abaa* showed relatively modest improvements across treatments. The significance of the interaction indicates that the effectiveness of DTA-6 on yield enhancement is closely tied to both the genetic background and the timing/concentration of application.

Table (4): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on seed yield of soybean (Mg ha^{-1}).

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (Mg ha^{-1})
Water spray (Control)	1.533	0.853	1.193
DTA-6 at 30 mg L^{-1} , Branching Stage (GS-22)	1.920	1.153	1.537
DTA-6 at 60 mg L^{-1} , Branching Stage (GS-22)	2.630	1.857	2.243
DTA-6 at 90 mg L^{-1} , Branching Stage (GS-22)	1.540	0.843	1.192
DTA-6 at 30 mg L^{-1} , Flowering Stage (GS-51)	2.340	1.550	1.945
DTA-6 at 60 mg L^{-1} , Flowering Stage (GS-51)	2.940	2.143	2.542
DTA-6 at 90 mg L^{-1} , Flowering Stage (GS-51)	3.463	2.477	2.970
Mean (Mg ha^{-1})	2.338	1.554	

L.S.D._{0.05} for soybean cultivars = 0.28364

L.S.D._{0.05} for growth regulator combination = 0.02633

L.S.D._{0.05} for interaction = 0.26220

Protein Percentage (%)

Table 5 indicates that *Abaa* significantly surpassed *Shaima* in protein percentage across all treatments, with *Abaa* averaging 40.05% protein compared to *Shaima* at 36.95%. This difference can be explained by genetic variations between the two cultivars, as *Abaa* may have a greater capacity for protein synthesis, making it more efficient in producing seeds with high protein content. It is also possible that *Abaa* allocates more resources to protein synthesis at the expense of vegetative growth or oil formation, thus providing a nutritional advantage over *Shaima* [26].

Regarding the effect of DTA-6 concentrations and timings, using this regulator resulted in a significant decrease in protein percentage, particularly at the highest concentration (90 mg L^{-1}) during the flowering stage (GS-51), which recorded the lowest protein content of 31.64% compared to 41.82% under the water-spray control. The decrease in protein content was generally more pronounced when applying DTA-6 at flowering (GS-51) rather than at the branching stage (GS-22).

When DTA-6 is applied during the flowering stage in soybean, it may substantially boost seed production while simultaneously reducing protein content. This phenomenon is attributed to the physiological changes occurring at this critical growth stage,

whereby nutrient allocation shifts toward oil production at the expense of protein synthesis [27].

Table (5): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on protein percentage in soybean (%).

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	40.99	42.65	41.82
DTA-6 at 30 mg L ⁻¹ , Branching Stage (GS-22)	39.63	41.40	40.51
DTA-6 at 60 mg L ⁻¹ , Branching Stage (GS-22)	37.65	39.66	38.66
DTA-6 at 90 mg L ⁻¹ , Branching Stage (GS-22)	41.54	42.57	42.06
DTA-6 at 30 mg L ⁻¹ , Flowering Stage (GS-51)	37.69	40.26	38.98
DTA-6 at 60 mg L ⁻¹ , Flowering Stage (GS-51)	33.53	38.17	35.85
DTA-6 at 90 mg L ⁻¹ , Flowering Stage (GS-51)	27.62	35.66	31.64
Mean (%)	36.95	40.05	

L.S.D._{0.05} for soybean cultivars = 0.693

L.S.D._{0.05} for growth regulator combination = 0.786

L.S.D._{0.05} for interaction = 1.077

Oil Percentage (%)

As indicated by the findings (Table 6), *Shaima* significantly outperformed *Abaa* in oil percentage, with *Shaima* recording an average of 20.10% oil compared to *Abaa* at 16.94%. This difference can be attributed to genetic variations between the two cultivars, as *Shaima* may possess genes responsible for enhancing oil-synthesis pathways in the seeds, making it more efficient at forming seeds with a high oil content relative to *Abaa*. Studies show that some cultivars demonstrate a distinct genetic response in allocating resources to fatty-acid synthesis rather than using energy for vegetative growth or protein synthesis, which may be noted in *Shaima*'s high efficiency in forming and accumulating oil in its seed tissues [28].

Concerning the effect of cultivars and different DTA-6 concentrations and timings on oil percentage in soybean, there was a significant rise in oil content at the highest concentration (90 mg L⁻¹) during the flowering stage (GS-51). This treatment achieved the highest oil percentage of 21.87% compared to the water-spray control, which had the lowest at 11.84%. The increase in oil content was generally more evident when using the regulator at the flowering stage (GS-51) than at the branching stage (GS-22). Foliar-application timing exerts a strong influence on soybean's oil production response, particularly during flowering—this critical period for resource allocation directs nutrients toward seed formation, enhancing the accumulation of fats and oils [29].

Table (6): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on oil percentage in soybean (%).

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	15.55	8.14	11.84
DTA-6 at 30 mg L ⁻¹ , Branching Stage (GS-22)	18.70	13.47	16.08
DTA-6 at 60 mg L ⁻¹ , Branching Stage (GS-22)	19.63	17.57	18.60
DTA-6 at 90 mg L ⁻¹ , Branching Stage (GS-22)	20.22	17.67	18.94
DTA-6 at 30 mg L ⁻¹ , Flowering Stage (GS-51)	21.86	19.30	20.58
DTA-6 at 60 mg L ⁻¹ , Flowering Stage (GS-51)	22.32	21.04	21.68
DTA-6 at 90 mg L ⁻¹ , Flowering Stage (GS-51)	22.37	21.37	21.87
Mean (%)	20.10	16.94	18.52

L.S.D._{0.05} for soybean cultivars = 0.2898

L.S.D._{0.05} for growth regulator combination = 0.6480

L.S.D._{0.05} for interaction = 0.8578

Oleic Acid Percentage (%)

As shown by the results (Table 7), *Shaima* excelled in oleic acid percentage compared to *Abaa*, with an average oleic acid content of 27.06% in *Shaima*'s oil versus 23.82% in *Abaa*. This difference is explained by genetic variations between the two cultivars, as *Shaima* exhibits enhanced genetic capability to produce unsaturated fatty acids, particularly oleic acid, which is important for human health and oil quality. Studies indicate that variation in the fatty-acid profile of soybean is related to the influence of regulatory genes responsible for lipid synthesis and metabolism, which affect the activity of enzymes involved in fatty-acid synthesis and modify their composition within seeds [30].

Regarding the effect of DTA-6 concentrations and timings, using this regulator led to a significant increase in oleic acid percentage, especially at the highest concentration (90 mg L⁻¹) during flowering (GS-51). That treatment yielded the highest proportion of 31.88% oleic acid compared to 22.12% under the water-spray control. The rise in oleic acid content was more evident with DTA-6 application at flowering (GS-51) than at branching (GS-22). The reason for the superiority of the higher concentration of DTA-6 during flowering over other concentrations in boosting oleic acid percentage is that this stage is crucial in regulating metabolic pathways that control fatty-acid formation within seeds. At this time, plants exhibit their highest responsiveness to growth regulators that influence resource allocation for both oils and proteins [31].

Table (7): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on oleic acid in soybean (%).

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	22.81	21.43	22.12
DTA-6 at 30 mg L ⁻¹ , Branching Stage (GS-22)	24.59	22.37	23.48
DTA-6 at 60 mg L ⁻¹ , Branching Stage (GS-22)	26.62	24.30	25.46
DTA-6 at 90 mg L ⁻¹ , Branching Stage (GS-22)	22.90	21.63	22.26
DTA-6 at 30 mg L ⁻¹ , Flowering Stage (GS-51)	26.49	23.19	24.84
DTA-6 at 60 mg L ⁻¹ , Flowering Stage (GS-51)	30.74	25.34	28.04
DTA-6 at 90 mg L ⁻¹ , Flowering Stage (GS-51)	35.29	28.47	31.88
Mean (%)	27.06	23.82	

L.S.D._{0.05} for soybean cultivars = 0.080

L.S.D._{0.05} for growth regulator combination = 0.863

L.S.D._{0.05} for interaction = 1.130

Linoleic Acid Percentage (%)

As illustrated by the results (Table 8), *Abaa* produced a higher percentage of linoleic acid compared to *Shaima* across all treatments, with an average of 53.14% for *Abaa* compared to 50.05% for *Shaima*. This difference can be explained by genetic variations, where certain genes responsible for fatty-acid synthesis directly affect the proportion of polyunsaturated fatty acids, including linoleic acid, in soybean seeds. Several studies report that the genetic makeup of specific cultivars provides them with higher efficiency in converting primary lipids into unsaturated fatty acids, thereby causing noticeable differences in linoleic acid levels among different cultivars [32].

Additionally, regarding the impact of DTA-6 concentrations and timings, the use of this regulator led to a significant decrease in linoleic acid percentage, especially at the highest concentration (90 mg L⁻¹) applied during the flowering stage (GS-51). That treatment recorded the lowest linoleic acid proportion of 45.17% compared to 54.86% under the water-spray control. The reduction in this acid was generally more pronounced when DTA-6 was used at the flowering stage (GS-51) rather than at branching (GS-22). The explanation for the decline in linoleic acid percentage with increased regulator concentration during flowering is that this stage represents a key turning point in nutrient distribution within the plant. Metabolic energy is redirected to support seed formation, affecting the balance between synthesizing proteins and fatty acids [33].

The interaction between cultivars and DTA-6 treatment combinations significantly affected linoleic acid content in soybean seeds (Table 8). The highest linoleic acid percentage was observed in *Abaa* under the water-spray control (55.44%) and under 90 mg L⁻¹ DTA-6 at the branching stage (55.49%), both showing minimal deviation from each other. In contrast, the lowest value (41.66%) was recorded in *Shaima* when 90 mg L⁻¹ DTA-6 was applied during the flowering stage (GS-51), followed by the same

treatment in *Abaa* (48.68%). These results demonstrate that linoleic acid content tends to decrease more substantially in *Shaima* than in *Abaa* with increasing DTA-6 concentration at the flowering stage. This indicates that *Shaima* is more sensitive to DTA-6-induced shifts in fatty acid composition, particularly under high-concentration application during reproductive development. The significant interaction effect reinforces the need to tailor DTA-6 application strategies based on cultivar-specific metabolic responses.

Table (8): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on linoleic acid in soybean (%)

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	54.27	55.44	54.86
DTA-6 at 30 mg L ⁻¹ , Branching Stage (GS-22)	52.44	54.72	53.58
DTA-6 at 60 mg L ⁻¹ , Branching Stage (GS-22)	50.72	52.67	51.69
DTA-6 at 90 mg L ⁻¹ , Branching Stage (GS-22)	54.21	55.49	54.85
DTA-6 at 30 mg L ⁻¹ , Flowering Stage (GS-51)	50.56	53.51	52.03
DTA-6 at 60 mg L ⁻¹ , Flowering Stage (GS-51)	46.49	51.46	48.97
DTA-6 at 90 mg L ⁻¹ , Flowering Stage (GS-51)	41.66	48.68	45.17
Mean (%)	50.05	53.14	

L.S.D._{0.05} for soybean cultivars = 0.2346

L.S.D._{0.05} for growth regulator combination = 0.5682

L.S.D._{0.05} for interaction = 0.7509

Linolenic Acid Percentage (%)

According to the results (Table 9), *Abaa* recorded a higher proportion of linolenic acid compared to *Shaima*, reaching an average of 7.18% for *Abaa* versus 4.83% for *Shaima*. This difference can be attributed to genetic variations, as the genes responsible for fatty-acid synthesis directly influence the proportion of this acid in the seeds. Research suggests that the genetic makeup plays a major role in some soybean cultivars by regulating metabolic processes responsible for converting primary lipids into unsaturated fatty acids, leading to clear differences in linolenic acid levels among cultivars [34].

As for the effect of various DTA-6 concentrations and timings, its use resulted in a significant decrease in linolenic acid percentage, particularly when the highest concentration (90 mg L⁻¹) was applied at the flowering stage (GS-51), yielding the lowest linolenic acid percentage of 1.78% compared to 9.08% under the water-spray control. Generally, the reduction in linolenic acid was more evident when DTA-6 was applied during flowering (GS-51) rather than branching (GS-22). The explanation for this decrease in linolenic acid with higher DTA-6 concentrations at flowering is that this stage is critical in determining the seed's oil components. The proportion of fatty acids is influenced by redirecting metabolic energy toward protein synthesis or

monounsaturated fatty acids such as oleic acid, rather than polyunsaturated fatty acids like linolenic acid [35].

Table (9): Effect of cultivars and combinations of DTA-6 regulator spray concentrations and timings on linolenic acid in soybean (%)

DTA-6 Concentration & Timing	<i>Shaima</i>	<i>Abaa</i>	Mean (%)
Water spray (Control)	8.53	9.63	9.08
DTA-6 at 30 mg L ⁻¹ , Branching Stage (GS-22)	6.48	8.26	7.37
DTA-6 at 60 mg L ⁻¹ , Branching Stage (GS-22)	4.20	6.79	5.49
DTA-6 at 90 mg L ⁻¹ , Branching Stage (GS-22)	7.84	9.47	8.66
DTA-6 at 30 mg L ⁻¹ , Flowering Stage (GS-51)	4.46	7.72	6.09
DTA-6 at 60 mg L ⁻¹ , Flowering Stage (GS-51)	1.46	5.65	3.55
DTA-6 at 90 mg L ⁻¹ , Flowering Stage (GS-51)	0.83	2.72	1.78
Mean (%)	4.83	7.18	

L.S.D._{0.05} for soybean cultivars = 0.5584

L.S.D._{0.05} for growth regulator combination = 0.7457

L.S.D._{0.05} for interaction = 1.0083

These findings confirm the potential use of DTA-6, at various concentrations and specific growth stages, to enhance yield and quality traits in soybean while accounting for genetic variation between cultivars. The highest concentration applied during flowering showed the greatest efficacy in increasing fertility percentage and improving seed quality. Consequently, integrating DTA-6 into crop management practices for the tested cultivars can lead to higher yields and better seed quality.

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