Annals of Agricultural & Crop Sciences

Open Access

Austin Publishing Group

Research Article

# Growth and Yield Response of Black Sesame (*Sesamum indicum L.*) to Foliar Spray of Amendments as Plant Growth Regulators and Micronutrients in Field Conditions

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**Received:** May 11, 2021; **Accepted:** June 08, 2021; **Published:** June 15, 2021

**Abstract**

To improve the yield of sesame in Mekong delta of Vietnam, the study was conducted to find out plant growth regulator, micronutrient to increase growth and yield of black sesame. The experiment consisted of six treatments (NT) as follows: NT1: Control as no plant growth regulators and micronutrients, NT2: Spraying brassinolide at 50ppm, NT3: Spraying gibberellin at 100ppm and manganese at 0.05%, NT4: Spraying brassinolide at 1.25ppm, NT5: Spraying boric at 50ppm and molybdenum at 50ppm, NT6: Spraying selenium at 4ppm. The results showed that spraying plant growth regulators and micronutrients as single NAA, BR, Se and combined GA3 plus manganese, boric plus molybdenum at 27 and 35 days after sowing have not increased plant height and height to the first fruit in the first crop. Combination of spraying boric plus molybdenum or single selenium increased the number of capsules per plant, the number of seeds per capsule and resulted in higher sesame yield.

**Keywords:** Plant growth regulator; Black sesame; Yield; Microelements

## Introduction

The frequency and intensity of severe weather conditions such as floods and droughts is increasing due to climate change. The Mekong Delta is one of three mega-deltas in the world that will be seriously and irreversibly affected by climate change in the next 30-50 years [1]. Crop selection for drought tolerance in the dry season can simultaneously reduce the amount of irrigation water used in agriculture and improve productivity. In recent years, sesame has been rotated on rice fields in the spring-summer season in many locations in the Mekong Delta due to its drought-tolerant characteristics [2]. However, the summer-spring season temperatures are often high and affect the reproductive phase of sesame [3]. Plant Growth Regulators (PGRs) such as brassinolide, and micronutrients such as Boron (B), Manganese (Mn) and Selenium (Se) help form cell walls and plasma membranes, increase the fertility of plants and catalyze biological redox processes. At recommended rates, PGRs and micronutrients are reported to enhance plant drought tolerance against abiotic stresses by improving overall plant growth (particularly root growth) and development and important metabolic processes including photosynthesis and respiration [4-6]. Specifically, brassinosteroids are essential for the activation and synthesis of enzymes that are required for chlorophyll formation [7].

Micronutrients are also reported to enhance sesame yield and optimize nutrient acquisition and utilization. For example, the application of 3kg B $ha^{-1}$ increased sesame yield where adequate nitrogen (N) was applied [8] and the supplementation of manganese increased the uptake of N, phosphorus (P) and potassium (K) as well as micronutrients under coastal saline soil conditions [9]. The purpose of this study was to evaluate the plant growth and yield impact of applying PGRs and micronutrients to sesame crops under field conditions in the Mekong Delta, Vietnam.

## Materials and Methods

### Materials

The field trial was conducted on acid sulfate soil from March to June 2017 in Thoi Tan commune, Thoi Lai district, Can Tho City. A local sesame variety was used (Can Tho black sesame) with traits: short duration growth, high height, number of capsule, drought tolerance and yield. Treatments included: PGRs - Naphthalene Acetic Acid (NAA), Gibberellin (GA3) and Brassinolide; and micronutrients - Boron (B), Molybdenum (Mo), Selenium (Se) and Manganese sulfate ($MnSO_4$), in addition to recommended rates of mineral fertilizers - urea (N 46%), single super phosphate (P 16%) and potassium chloride (K 60%). Rates, timing and application methods are provided below.

### Methods

**Experimental design:** The field experiment was arranged in a randomized complete block design including six treatments with five replications. Each plot was $25m^2$. Treatments as follows were applied as a foliar spray:

NT1: Control (No PGRs and no micronutrients).

NT2: Naphthalene acetic acid (50ppm).

NT3: Gibberellin (100ppm) and $MnSO_4$ (0.05%).

NT4: Brassinolide (1.25ppm).

NT5: Boron (50ppm) and molybdenum (50ppm).




**Citation:** Tuan NTQ, Hue NH, Khuong NQ, Huu TN and Thuc LV. Growth and Yield Response of Black Sesame (*Sesamum indicum L.*) to Foliar Spray of Amendments as Plant Growth Regulators and Micronutrients in Field Conditions. Ann Agric Crop Sci. 2021; 6(4): 1083.

NT6: Selenium (4ppm).

**Soil sample collection:** Initial soil samples were collected at 5 sites diagonally in depth of 0-20 cm. Samples were thoroughly mixed and analyzed for: Soil Organic Carbon (SOC), total Nitrogen (Ntot), total Phosphorus (Ptot), total potassium (Ktot), B (mg B $kg^{-1}$), Se (mg Se $kg^{-1}$) and Mo (mg Mo $kg^{-1}$).

**Seed density:** Sesame seed was sown at $4kgha^{-1}$, with seeds mixed with sand at ratio of 2: 1 (sand: sesame) to ensure uniform seed distribution.

**Fertilizers and amendments:** Before planting, mineral fertilizer was applied at the recommended rate of $90N-60P_2O_5-60K_2O$. Total inorganic P fertilizer was added at basal application. For N fertilizer with 30, 40, and 30% applied after sowing at days 15, 30 and 40 respectively. Potassium fertilizer was applied 50% at days 15 and 30 respectively. PGRs and micronutrients were sprayed directly on the total leaf surface area at the stage of forming flower buds (27 DAS) and starting to flower (35 DAS).

**Growth parameters and yield of sesame:** Plant height (cm) was measured from the soil surface to the highest growth peak of 20 plants per plot at 27, 34, 40, 47, 54, 61, 68 and 75 DAS. Height to first fruit (cm) was measured from the soil surface to the position of the first capsules of 20 plants per plot. Length of fruit-bearing trunk segment (cm) was measured from the first capsule to the last capsule. Number of flowers per plant (flower) was assessed at 34, 40, 47, 54 and 61 DAS. Leaf proline content (μmol/g fresh weight): for each experimental plot 10 plants were randomly selected and sampled (taking the $5^{th}$ leaf from the top down) at 55 DAS. Samples were composited for each plot, thoroughly mixed and analyzed for proline content following Bates et al. [10]. Number of capsules per plant (left) was assessed at 47, 54, 61, 68 and 75 DAS. Capsuling rate per plant was calculated as: Capsuling rate per plant (%) = (total number of capsule left on the plant/ total number of flowers) x 100. Number of seeds per capsule (seed) was assessed in 20 randomly selected capsules per replicate. Grain moisture was recorded by dried at $45^0C$ for 72 hours. Weight of 1,000 seeds (g) was recorded at 8% moisture. Yield ($kgha^{-1}$) was calculated using the weight of grain of the $25m^2$ plot at harvest based on 8% moisture.

### Data analysis

The data given in this research are mean values of five replications, unless otherwise stated. All data were analyzed using one-way Analysis of Variance (ANOVA) by SPSS software package version 13.0. All mean values were analyzed using one-way ANOVA and comparison among means for significant differences using Duncan's test at P <0.05.

## Results

### Initial soil characteristics at experiment site

The results in Table 1 shows that content of organic matter (%C) reached 2.54% in the soil of the first sesame crop that is assessed at low level (2-4%) [11], the key mineral elements include: total nitrogen content (0.15%) at low threshold [11], total phosphorus content (0.06%) at poor critical concentration and total potassium content (1.47%) at medium level [12]. In addition, the analysis result of essential trace elements showed that the experimental soil had a B

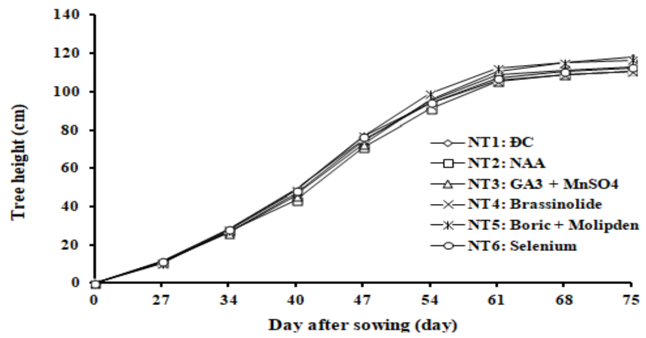


**Figure 1:** The growing of sesame height over times of growth.

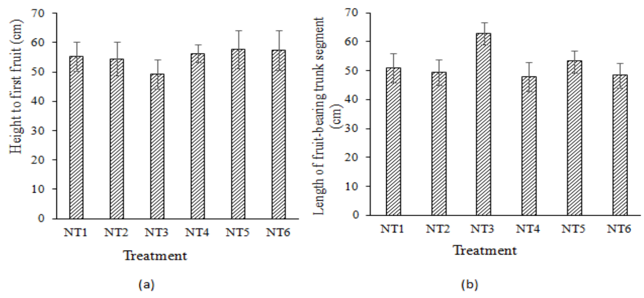


**Figure 2:** Sesame plant growth parameters for the six treatments (a) Height (cm) to first fruit and (b) Length (cm) of fruit-bearing trunk segment. Different lowercase letters in the same column indicate significant differences at P <0.01 (**), <0.05 (*); and ns: no significant difference at P >0.05; NT1: Control; NT2: NAA; NT3: GA3 + $MnSO_4$; NT4: BR; NT5: B + Mo; NT6: Se.

content in the soil at a threshold of $0.71mgkg^{-1}$ of dry soil [13] and Mo content in soils (2.08mgkg dry soil) at medium threshold [13]. Unfortunately, soil Se content did not detected in this experiment.

### Sesame plant growth and yield

**Plant height:** There was no significant difference in plant height between treatments, with height increasing gradually up to 75 DAS. Across all treatments, plant height was stable from 61 DAS in the range of 100 to 120 cm (Figure 1).

**Height of first capsule forming:** The height of the first capsule ranged from 49.4 to 57.8 cm across the six treatments, with the highest value in the B and Mo treatment (57.8cm) and the lowest in the GA3 plus $MnSO_4$ treatment (49.4cm; Figure 2a). Although the height to first fruit of spraying treatment of GA3 plus $MnSO_4$ was recorded lowest, it gave the largest length of fruit-bearing trunk segment (62.8cm, Figure 2b). Length of fruit-bearing trunk segment between all other treatments ranged from 47.8cm to 53.2cm.

**Number of flowers per plant:** Overall there was no significant difference in the number of flowers per sesame plant with treatment, with values ranging from 4.7 to 5.6 flowers per plant at 34 DAS (Table 2). However, there was a significant (P<0.01) treatment effect at 40 DAS, with the highest number of flowers per plant (17.6) in the Brassinolide treatment. By 54 and 61 DAS, the number of flowers per plant was stable among treatments. The GA3 plus $MnSO_4$, Brassinolide, B plus Mo and Se treatments achieved significantly (P<0.05) higher flower numbers compared with the control treatment and sprayed NAA. There was no difference in the number of flowers

**Table 1:** Chemical properties of initial soil sample.

| Parameter / Depth (cm) | SOC (%C) | $N_{tot}$ (%) | $P_{tot}$ (%) | $K_{tot}$ (%) | B (mgkg$^{-1}$) | Se (mgkg$^{-1}$) | Mo (mgkg$^{-1}$) |
|---|---|---|---|---|---|---|---|
| 0-20 | 2.54 | 0.15 | 0.06 | 1.47 | 0.71 | UD | 2.08 |

UD: Undetected.

**Table 2:** Number of flowers in stage of sesame growth.

| Treatment | Days after sowing | | | | |
|---|---|---|---|---|---|
| | 34 | 40 | 47 | 54 | 61 |
| NT1 | 4.9 | 11.7$^{b}$ | 20.7$^{c}$ | 33.7$^{b}$ | 46.3$^{b}$ |
| NT2 | 5.3 | 11.3$^{b}$ | 23.1$^{c}$ | 38.7$^{ab}$ | 50.5$^{ab}$ |
| NT3 | 4.7 | 12.3$^{b}$ | 23.5$^{bc}$ | 44.3$^{a}$ | 59.4$^{a}$ |
| NT4 | 5.5 | 17.6$^{a}$ | 31.5$^{a}$ | 46.5$^{a}$ | 59.8$^{a}$ |
| NT5 | 5.2 | 16.0$^{a}$ | 29.6$^{ab}$ | 47.7$^{a}$ | 62.4$^{a}$ |
| NT6 | 5.6 | 15.8$^{a}$ | 24.9$^{bc}$ | 44.4$^{a}$ | 59.9$^{a}$ |
| F | ns | ** | ** | * | * |
| CV (%) | 13.9 | 17.4 | 17.8 | 14.8 | 14.7 |

Different lowercase letters in the same column indicate significant differences at P <0.01 (**), <0.05 (*); and ns: No Significant difference at P >0.05; NT1: Control; NT2: NAA; NT3: GA3 + $MnSO_4$; NT4: BR; NT5: B + Mo; NT6: Se.

per plant between the Brassinolide, B plus Mo and Se treatments at 40, 54 and 61 DAS (Table 2).

**Proline content in sesame leaf**: There was no significant difference in the proline content of sesame leaves between treatments; however, proline content was highest at 55 DAS in the Brassinolide (4.49µmg$^{-1}$), Se (4.29µmg$^{-1}$) and NAA (4.28µmg$^{-1}$) treatments respectively (Figure 3), and lowest in the control (4.07µmg$^{-1}$).

**Yield components and yield of sesame:** Capsule set on plant (%) was significantly different (P<0.05) between treatments (Table 3), with highest values in the Se treatment (50.4%) and lowest in the control (42.6%). There was no significant difference between the GA3 combined with $MnSO_4$ (46.5%), Brassinolide (46.8%) and B plus Mo (47.2%) treatments. The number of capsules per plant was significantly (P<0.01) different with treatments (Table 3), with GA3 plus $MnSO_4$ (27.7), Brassinolide (27.6), B plus Mo (29.3) and Se (30.1) having the highest values, and the control and NAA having the lowest values. The number of seeds on the left between the treatments was statistically different at the 5% level. The B plus Mo treatment had the highest number of capsules per plant (49), followed by the Se, NAA, GA3 plus $MnSO_4$, Brassinolide and control (41.2) treatments, respectively.

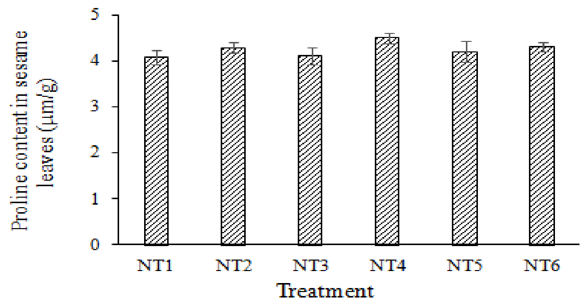


**Figure 3:** Proline content in sesame leaves at 55 days after sowing. Bars: SE; NT1: DC; NT2: NAA; NT3: GA3 + $MnSO_4$; NT4: Brassinolide; NT5: Boric + Molipden; NT6: Selenium.

There was no significant difference in the weight of 1000 grains with treatment, and values ranged 2.80 to 2.82 g. There was a positive and significant difference (P<0.05) in sesame yield between the control (0.98 tons ha$^{-1}$) and all other treatments (Table 3), with the B plus Mo treatment having the highest yield (1.23 tons ha$^{-1}$, Table 3). However, there was no significant difference in yield between the treatments.

## Discussion

Our study demonstrated that PGRs and micronutrients, such as GA3 + $MnSO_4$ and Bo plus Mo, can increase the stem length and number of flowers per plant at harvest for sesame. Shirazy et al. [14] reported similar results in their study using sesame (BARI Til-4) in Bangladesh, where the combination of N and trace elements including Mn increased the height of sesame at 50 DAS. In their study, plant height ranged from 111.6 to 127 cm, with the highest values recorded for 60kg N per ha$^{-1}$ and trace elements at 100ppm per ha$^{-1}$.

In our study, foliar applications of B plus Mo and Se increased the number of capsules per plant, the number of seeds per capsule and sesame yield in the field. Our results agree with Seervi et al. [15], who reported foliar application of Mo ($(NH_4)Mo_7O_{24}.4H_2O$) at 50ppm and Mn ($MnSO_4.H_2O$) at 100ppm to sesame crops increased the number of capsules per plant, number of seeds per capsule, weight of seeds

**Table 3:** Yield component and yield of sesame.

| Treatment | Capsule set/plant (%) | Number of capsules/plant (fruit) | Number of seeds/capsule (seed) | Weight of 1000 seeds (g) | Yield (tons ha$^{-1}$) |
|---|---|---|---|---|---|
| NT1 | 42.6$^{b}$ | 19.7$^{b}$ | 41.2$^{b}$ | 2.81 | 0.98$^{b}$ |
| NT2 | 44.6$^{b}$ | 22.4$^{b}$ | 44.2$^{ab}$ | 2.82 | 1.08$^{ab}$ |
| NT3 | 46.5$^{ab}$ | 27.7$^{a}$ | 43.4$^{ab}$ | 2.8 | 1.14$^{ab}$ |
| NT4 | 46.8$^{ab}$ | 27.6$^{a}$ | 43.2$^{ab}$ | 2.81 | 1.21$^{a}$ |
| NT5 | 47.2$^{ab}$ | 29.3$^{a}$ | 49.0$^{a}$ | 2.81 | 1.23$^{a}$ |
| NT6 | 50.4$^{a}$ | 30.1$^{a}$ | 48.2$^{a}$ | 2.82 | 1.22$^{a}$ |
| F | * | ** | * | ns | * |
| CV (%) | 7.6 | 12.5 | 11.7 | 0.14 | 10.4 |

Different lowercase letters in the same column indicate significant differences at P <0.01 (**), <0.05 (*); and ns: No Significant difference at P >0.05; NT1: Control; NT2: NAA; NT3: GA3 + $MnSO_4$; NT4: BR; NT5: B + Mo; NT6: Se.

per plant and yield compared to the control. Similarly, Elayaraja [16] found that Mo helped to enhance grain and stem yield. Application of PGRS such as Brassinolide can considerably enhance plant growth and development, for example a study where Brassinolide was sprayed on Green Gam (*Vigna radiata L*. Wilczek) before and during flowering increased chlorophyll content of leaves and improved plant productivity [17]. In our study, spraying PGRs and micronutrients as only NAA, combined GA3 and $MnSO_4$, only brassinolide, combined boric and molybdenum and only selenium at 27 and 35 DAS did not increase plant growth parameters, namely plant and first fruit height. During flowering, the plant was produced enough Gibberellin, the flowers grow normally, whereas the lack of petals and pistil Gibberellin resulted in less developed and inactive [18]. Experiments of Al-Mahdawe and Al-Attrakchii [19] on two types of carnation showed that Bo helps extend the life of flowers compared to the control. Besides, brassinolide has also been shown to have an effect on plant reproduction during stress conditions [20]. This suggests that the application of GA3 + $MnSO_4$ at the time of bud formation and flowering is likely to have helped the plant develop the stem bearing fruit segment by extending the cells of GA3 [21]. However, to confirm this, and to more accurately assess the nutritional needs of sesame, the macronutrient and trace mineral content of sesame seeds and plant tissue is required.

## Conclusion

While the application of NAA, brassinolide or selenium and/or combined gibberellin plus manganese, or boric plus molybdenum did not improve sesame plant growth, the application of PGRs such as brassinolide or micronutrients such as selenium or combined boric plus molybdenum increased sesame yield. Only the foliar application of selenium or combined boric plus molybdenum enhanced yield components including number of capsules per plant and number of seeds per capsule.

## Acknowledgement

This project was funded by the Upgrading Project of Can Tho University VN14-P6 with ODA loans from the Japanese Government.

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