**RESPONSE OF LIQUID NANO UREA, CLIPPING PRACTICES AND SEED HARDENING ON SESAME (*Sesamum indicum* L.) PRODUCTIVITY AT KARAIKAL REGION**

**ABSTRACT**

A field experiment was conducted in Agronomy Farms at the Department of Agronomy, Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA & RI), Karaikal during the summer season of 2023, to identify an effective seed hardening technique, with and without clipping practice and foliar application in TMV-7 variety of sesame for Karaikal region. The experiment was laid out under Factorial concept of Randomized Block Design (FRBD) with twelve treatments replicated thrice. The treatments consisted of three factors viz., Seed hardening, clipping practice and foliar application. The treatments were of the combination of three factors viz., (i) Seed hardening [No hardening (H0), hardening with plain water (H₁) and hardening with LNU (1000 ml ha-1 of seeds) (H2)], (ii) Clipping practice [without clipping (C0) and with clipping (C1)] and (iii) foliar spray (0.1%) [without foliar spray (F0) and with foliar spray hardening (F1)]. Hardening the seeds with liquid nano urea recorded higher growth and yield parameters. Similarly, the other two factors, clipping practice and foliar application of LNU recorded higher growth and yield attributes. Among clipping practices, the treatment LNU with clipping was superior (752.2 kg ha-1) in comparison to the treatment of LNU without clipping practice in terms of seed yield (544.5 kg ha-1). In the case of foliar application, crops with foliar spray recorded higher seed yield (702.5 kg ha-1) than without foliar spray, Whereas, seed hardening failed to bring up a significant difference for seed yield kg ha-1.

**Keywords:** Sesame, Seed hardening, clipping practices, foliar spray and LNU.

1. **INTRODUCTION**

Sesame (*Sesamum indicum* L.) is one of the oldest and most important [oilseed](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/oilseeds) crop with an oil content of 40-50% popularly known as Til or Gingelly. Sesame is called **“Queen of Oil Seeds”** because of its excellent quality and utility. During 2022, India produced 0.71 million metric tons of sesame. India ranks first in the world with 19.47 lakh ha area and 8.66 lakh tonnes production. Total oilseeds production in the country during 2020-21 was estimated as 36.57 million tonnes which is higher by 3.35 million tonnes than the production during 2019-20 (Ministry of Agriculture and Farmers Welfare, 2020). The nano fertilizer would be more sustainable than conventional urea for the environment and reduce input, logistics and storage costs. It is a boon for India in boosting the economy and farmers’ livelihood while reducing the pollution on mother earth (Kiran and Samal, 2021). The application of nano urea ensured higher nitrogen use efficiency (NUE), higher crop yields, higher profit and a healthy environment (Baboo, 2021). Seed hardening, as highlighted by Parera and Cantliffe (1994), serves as a widely employed method to reduce the duration between seed sowing and seedling emergence. It has proven effective in enhancing seed germination, seedling growth, and the overall crop stand, especially in the face of stress factors in the field. Seed hardening involves a pre-germinative treatment where seeds are subjected to low water potential before sowing, allowing imbibition while preventing premature radicle extension (Bradford, 1986). Clipping means removal or clipping off the terminal bud which activates the dormant lateral buds to produce a greater number of branches. In sesame, the development of auxiliary buds is normally inhibited by Indole Acetic Acid (IAA) produced in the apical meristem. If the source of auxin is removed by excising the apical meristem, the lateral branching gets accelerated. Moreover, terminal clipping arrests the vertical growth of the plant which leads to greater chances for the development of source-to-sink feature relationship in sesame.

1. **MATERIAL AND METHODS**

The experiment was conducted in field number B15 in the Eastern block of Agronomy farms during summer 2023. The college farm is situated at 10º55ʹ N latitude and 79º49ʹ E longitude with an altitude of four meters above mean sea level. Karaikal has a tropical climate with a mean maximum and minimum temperature of 33.1oC and 23.9oC, respectively. The mean annual total rainfall is 1416.9 mm. The total annual evaporation is 2518.2 mm. The mean annual morning and evening relative humidity are 87.4 % and 63.9 %, respectively. A total rainfall of 309.3 mm was observed during the cropping period. The soil of the experimental field was sandy loam in texture with neutral pH (7.65) and normal in EC (0.25 dS m-1). The soil is low in available nitrogen (109.76 kg ha-1), high in available phosphorus (39.69 kg ha-1) and medium in available potassium (144.48 kg ha-1) and the organic carbon (4.5 g kg-1) was found to be low in initial soil. The field experiment was conducted during the summer season - February to May 2023 and the crop was sown during Maasipattam [23rd MSW]. The experiment was laid out under the Factorial concept of Randomized Block Design (FRBD) with three replications.

The treatments consisted of three factors viz., T1- Sowing of non-hardened seed without clipping practice without FS, T2- Sowing of non-hardened seed without clipping practice + FS with LNU, T3- Sowing of non-hardened seed followed by clipping practice without FS, T4- Sowing of non-hardened seed followed by clipping practice + FS with LNU, T5- Sowing of hardened seed with plain water without clipping practice without FS, T6- Sowing of hardened seed with plain water without clipping practice + FS with LNU. T7- Sowing of hardened seed with plain water followed by clipping practice without FS, T8- Sowing of hardened seed with plain water followed by clipping practice + FS with LNU, T9- Sowing of hardened seed with LNU without clipping practice without FS, T10- Sowing of hardened seed with LNU without clipping practice + FS with LNU, T11- Sowing of hardened seed with LNU followed by clipping practice without FS and T12- Sowing of hardened seed with LNU followed by clipping practice + FS with LNU. The size of the gross plot was 5 m x 3.9 m and the net plot was 3.3 m x 2.7 m. At the time of sowing, seeds underwent a 30-minute soaking in liquid nano urea, followed by a 30-minute shade drying period. A similar procedure was implemented, employing plain water instead. Clipping was done by excising the terminal leaves of the sesame crop at 35 DAS. The foliar spray was given twice *viz*; first at the branch formation stage and second spray at 15 days after the first spray. In each spray, 500 ml of LNU was mixed with 500 ml of water and sprayed using a hand sprayer. The Sesame seeds of the variety TMV-7 were used with all the crop management practices pertaining to Sesame were followed as per crop production guide.

1. **RESULTS AND DISCUSSION**

**3.1 Growth Attributes**

Liquid nano urea and clipping practices and significantly influenced on the growth attributes viz., plant height, leaf area index and dry matter production (Table 1).

Among seed hardening techniques hardened with LNU (H2) registered the taller height of 103.9 cm, highest dry matter accumulation (6035.3 kg ha-1) and highest dry matter accumulation (6035.3 kg ha-1) of sesame. The application of conventional nitrogen with the combination of liquid nano urea enhanced the plant height at various stages of the crop as compared to other treatments, where the increased nitrogen application that increased the nitrogen availability to the crop might have enhanced cell division and cell elongation resulting in taller plants. Similar findings by Manikandan and Subramanian (2015) in maize showed that the application of nano- zeourea increased the plant height dominantly when compared to conventional urea. Also, the application of LNU not only increased the number of leaves plant-1 but also the size of the individual leaf in terms of length and width. These results were in agreement with the findings of Nouraein (2019) in maize. Here the seed hardening with liquid nano urea enhanced nutrient availability which favoured chlorophyll formation, keeping the leaves green for a long period which helps to actively participate in the photosynthesis which in turn increased the photosynthesis rate, dry matter production and improved overall growth of the plant. Similar results were emanated by Elavarasan *et al.* (2021) in rice.

Among the clipping practices plants with clipping practice (C1) recorded the highest LAI (2.9) at 60 DAS, dry matter accumulation (7096.9 kg ha-1) and Plants without clipping practice produced the tallest plant (109.2cm). Considering the clipping practices, a higher plant height was observed in plants without clipping (C0) which may be due to the continuous supply of auxin to apical meristematic tissues while a lesser plant height was observed in plants with clipping (C1) where top most shoots from the plant were arrested to avoid vertical growth. Kokilavani *et al.* (2007) and Siro *et al*. (2021) also observed reduced plant height in sesame due to clipping practice. Clipping of terminal leaves activates the dormant lateral buds to produce more branches which was similar to the conclusions made by Kathiresan (1997) and Siro *et al*. (2021). The dry matter accumulation in plant-1 was significant at various stages and higher DMP was recorded in plants with clipping when compared to plants without clipping. This may be because of DMP which depends on leaf area, photosynthetic rate and dry matter partition. The positive increase in the number of branches plant-1 might have offered a higher chance for the increased production of leaves plant-1, which subsequently resulted in higher dry matter accumulation plant-1 due to clipping. This result is in confirmation of the outcome of Venkadachalam (2003).

The application of liquid nano urea through foliar spray has been shown to positively impact plant height, recorded the highest LAI (3.7) at 60 DAS and superior dry matter accumulation (6402.2 kg ha-1). Bahmaniar and Sooaee Mashaee (2010) in rice and Drostkar (2016) in chickpea, both indicating that the foliar spray of nano urea positively influences plant height by promoting increased cell growth. Various studies have highlighted that the external use of nanoparticles can notably enhance overall plant growth, as demonstrated in rice by Mandeh *et al.* (2012). Navya *et al*. (2022) observed in rice that residual nutrients stored in plant parts could be utilized gradually as needed, contributing to the overall augmentation of LAI. The foliar application of liquid nano urea led to elevated dry matter production. This outcome can be attributed to the increased absorption rate facilitated by the application of liquid nano urea, which in turn contributed to the formation of higher dry matter (Liu and Liao, 2008).

The interaction effect of hardened seeds with liquid nano urea (LNU) without clipping along with foliar spray (H2C0F1), significantly resulted in taller plant height (121.9 cm at harvest) surpassing other combinations, Higher leaf area index (3.8) by hardening with LNU in clipped plants (H2C1) and the combination of liquid nano urea seed hardening with clipping practice and foliar spray (H2C1F1) significantly recorded a higher dry matter accumulation (8067.8 kg ha-1).

**3.2 Yield and Yield attributes:**

Liquid nano urea and clipping practices and significantly influenced on the yield and yield attributes viz., number of capsules plant-1, number of seeds capsule-1, test weight, harvest index, seed yield and stover yield. (Table 2).

Among seed hardening factors, hardened seeds with liquid nano urea (H2) remarkably raised the number of capsules by recording 91.3 capsules plant-1, highest harvest index (0.6), highest stover yield (1250.4 kg ha-1), other parameters like number of seeds capsule-1, test weight and seed yield was not significantly influenced by seed hardening techniques. Improvement in yield attributing characters of sesame by hardening with liquid nano urea might be due to the high production of photosynthates with increased nitrogen application and their effective translocation from source to sink which led to the proper formation of grains. This was visualized under the findings of Kumar *et al.* (2011) in maize and Elavarasan *et al.* (2021). The stover yield was also highest when seed treatment with liquid nano urea was done (19.5 percent) compared to no hardening. This might be due to the reason that the application of nitrogen enhanced plant height, LAI, and no of branches plant-1 in sesame which increased photosynthetic activity and dry matter production that led to the increased stover yield. Similar results were also reported by Mehta *et al.* (2019) in wheat.

The clipping practice (C1) significantly influenced the number of capsules plant-1 (98.3 capsules plant-1), increased (50.4) the seeds capsule-1, highest harvest index of (0.6), seed yield (752.2 kg ha-1) and highest stover yield (1263.6 kg ha-1). The probable reason for the dispersion of carbohydrates towards auxiliary vegetative buds below the clipped portion had in turn helped in the production of the maximum number of capsules plant-1 which is directly attributed to more seed yield and other yield attributes as also evidenced by Vasanthan *et al.* (2019) and Vinoth (2020). However, the effect of terminal bud clipping on test weight (g) was found to be non-significant due to genetic coefficients.

Foliar spray (F1) which was significantly superior in increasing the capsule number (92.7 capsules plant-1), superior in seed yield (702.5 kg ha-1), higher stover yield (1268.3 kg ha-1) and greater harvest index (0.6) and other parameters was non significant. The foliar application of liquid nano urea has resulted in a noticeable improvement in yield attributes. The enhanced total number of seeds per capsule can be attributed to increased photosynthate assimilation and improved translocation of photosynthates from source to sink, contributing to the augmentation of seed production per capsule. This phenomenon aligns with observations made by Navya *et al*. (2022) and Raghuvanshi (2018) in mustard. This enhancement can be attributed to the improved nutrient uptake by the plant, fostering optimal growth of plant components and metabolic processes, including photosynthesis. The consequential outcome is the maximum accumulation and translocation of photosynthates to the economically valuable parts of the plant (Bhakher *et al*., 2023).

1. **CONCLUSION:**

The results revealed that both hardening seeds with liquid nano urea (LNU) and implementing clipping practice along with foliar application (H2C1F1) were equally effective in enhancing both grain and straw yield in sesame. Additionally, these treatments proved to be equally profitable. The study's findings suggest that seed hardening with LNU (1000 ml ha-1 of seeds) and employing clipping practice along with foliar spray (0.1%) are equally effective in improving grain yield, straw yield, and economic aspects of sesame cultivation. Consequently, sowing of sesame (TMV-7) with this combination shall be considered optimum for the cultivation of sesame in summer under irrigated conditions in the Karaikal region.

1. **DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

1. **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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**Table 1. Effect of seed hardening with liquid Nano urea and clipping practice along with and without foliar spray on the growth attributes of sesame crop**

|  |  |  |
| --- | --- | --- |
| **Treatments** |  |  |
| **Plant height (cm)** | **LAI** | **DMP (Kg ha-1)** |
| **Seed hardening (H)** |  |  |  |
| H0 (No hardening) |  92.8 | 1.5 | 5642.4 |
| H1 (plain water) |  100.7 | 2.8 | 5805.2 |
| H2 (LNU) |  103.9 | 3.1 | 6035.3 |
| **S Ed** |  3.21 | 0.25 | 80.4 |
| **CD (p=0.05)** |  6.66 | 0.52 | 166.8 |
| **Clipping practice (C)** |  |  |  |
| C0 (without clipping) |  104.8  | 2.4 | 4558.3 |
| C1 (with clipping) |  93.4  | 2.9 | 7096.9 |
| **S Ed** | 2.62  | 0.21 | 65.7 |
| **CD (p=0.05)** | 5.44  | 0.50 | 136.2 |
| **Foliar spray (FS)** |  |  |  |
| F0 (without FS) |  95.6  | 2.6 | 5253.0 |
| F1 (with FS) |  102.7  | 3.7 | 6402.2 |
| **S Ed** | 2.62  | 0.21 | 65.6 |
| **CD (p=0.05)** |  5.44  | 0.46 | 136.2 |
| **H x C** |  |  |  |
| **S Ed** |  2.10  | 0.35 | 0.18 |
| **CD (p=0.05)** | NS  | 0.74 | NS |
| **H x F** |  |  |  |
| **S Ed** | 2.10  | 0.35 | 0.18 |
| **CD (p=0.05)** | NS  | NS | NS |
| **C x F** |  |  |  |
| **S Ed** |  1.71  | 0.29 | 0.14 |
| **CD (p=0.05)** |  NS  | NS | NS |
| **H x C x F** |  |  |  |
| **S Ed** | 2.97  | 0.50 | 0.26 |
| **CD (p=0.05)** |  NS  | NS | NS |

**Table 2. Effect of seed hardening with liquid Nano urea and clipping practice along with and without foliar spray on the yield and yield attributes of sesame**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Number of capsule plant-1** | **Number of seeds capsule-1** | **Test weight (g)** | **Harvest index** | **Seed yield (Kg ha-1)** | **Stover yield (Kg ha-1)** |
|
| **Seed hardening (H)** |  |  |  |  |  |  |
| H0 (No hardening) | 79.3 | 41.9 | 4.9 | 0.5 | 608.3 | 1046.6 |
| H1 (plain water) | 85.3 | 49.7 | 5.3 | 0.5 | 633.8 | 1099.2 |
| H2 (LNU) | 91.3 | 50.2 | 5.5 | 0.6 | 702.9 | 1250.4 |
| **S Ed** | **2.02** | **0.78** | **0.28** | **0.01** | **61.9** | **43.86** |
| **CD (p=0.05)** | **4.20** | **NS** | **NS** | **0.02** | **NS** | **90.95** |
| **Clipping practice (C)** |  |  |  |  |  |  |
| C0 (without clipping) | 72.7 | 48.9 | 4.7 | 0.5 | 544.5 | 1000.5 |
| C1 (with clipping) | 98.3 | 50.4 | 5.0 | 0.6 | 752.2 | 1263.6 |
| **S Ed** | **1.65** | **0.64** | **0.23** | **0.009** | **50.5** | **35.80** |
| **CD (p=0.05)** | **3.43** | **1.33** | **NS** | **0.02** | **104.8** | **74.26** |
| **Foliar spray (FS)** |  |  |  |  |  |  |
| F0 (without FS) | 78.2 | 49.2 | 5.0 | 0.5 | 594.3 | 995.7 |
| F1 (with FS) | 92.7 | 50.1 | 5.3 | 0.6 | 702.5 | 1268.3 |
| **S Ed** | **1.65** | **0.64** | **0.23** | **0.009** | **50.5** | **35.80** |
| **CD (p=0.05)** | **3.43** | **NS** | **NS** | **0.02** | **104.8** | **74.26** |
| **H x C** |  |  |  |  |  |  |
| **S Ed** | **2.86** | **1.11** | **0.40** | **0.01** | **16.4** | **62.02** |
| **CD (p=0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **H x F** |  |  |  |  |  |  |
| **S Ed** | **2.86** | **1.11** | **0.40** | **0.01** | **16.4** | **62.02** |
| **CD (p=0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **C x F** |  |  |  |  |  |  |
| **S Ed** | **2.34** | **0.90** | **0.33** | **0.01** | **13.4** | **50.64** |
| **CD (p=0.05)** | **4.86** | **NS** | **NS** | **NS** | **27.7** | **NS** |
| **H x C x F** |  |  |  |  |  |  |
| **S Ed** | **4.05** | **1.57** | **0.57** | **0.02** | **23.2** | **87.71** |
| **CD (p=0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |