Improving seed germination and seedling growth of true seed shallot (TSS) using plant growth regulator seed priming

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Abstract. Seeding is the most important and quite challenging stage in seed/TSS cultivation. Plant growth regulator (PGR) seed priming has the potential to enhance the quality of TSS seedlings. The research had been conducted in the greenhouse of Agriculture Faculty, UGM, from February to April 2020. The factorial treatments of shallot cultivars (Tuk-Tuk, Lokananta and Sanren) and seed treatments (soaking seed with GA3 100 ppm and NAA 50 ppm for 12 hours and untreated seeds as control) were assigned in the RCBD with four replications. Each experimental unit was consisted of 728 seeds per cultivar. Both treated and untreated seeds were sown in soil blocks. The data were analyzed using ANOVA and continued with Tukey HSD procedure at α=0.05. The results showed that PGR priming on seeds significantly increased the germination percentage, plant height, leaf number, leaf area, and hypothetical vigor index of the three cultivars at six weeks after sowing. However, there was no significant difference in the fresh weight and dry weight of seedlings. This research implied that soaking seeds in GA3 100 ppm and NAA 50 ppm for 12 hours could improve seed germination and TSS seedling growth. Additional fertilizers are perhaps needed in soil blocks to increase the effect of hormones on the seedlings.

1. Introduction
Shallot (Allium cepa L.Aggregatum group) is categorized as the major condiment in Indonesia that cannot be substituted. It is also a strategic-valued commodity of vegetables that may affect inflation [1,2]. Efforts to increase shallot productivity and production continuity become important to avoid inflation. The use of true seed shallot/TSS potentially enhances the productivity of shallots by >20 tons ha⁻¹ from the currently existing productivity (< 10 ton ha⁻¹) by bulb propagation. TSS also has a long shelf life (2 years), easy to store, handling and distribute so that it can become a seed reserve in each growing season [3,4].

Seeding is the most crucial step in TSS cultivation, and it often comes with obstacles. Generally, seeding needs between 30-45 days age before transplanting. The composition of planting media, seeding technique, fertilization, and seed treatment will affect the bulb yield. Good quality of seeding growth may increase the planting success rate in the field and enhance the plant’s productivity [5–7]. Adiyoga
et al. [1] reported that TSS seeding in soil blocks produced the best yield compared to the direct seeding or seeding in soil plots. The use of soil blocks also helps monitored seedling growth until the transplanting stage since the seeds grew harmoniously in uniform seeding holes.

Seed priming is an effective and practical technique to improve seed growth speed and increase the uniformity of seed growth and plant growth [8]. Plant growth regulator (PGR) seed priming may enhance the plant seedling's germination and growth ability. PGR application in seed germination is considered the prior process in plant growth [9]. Gibberellin is the key hormone that plays a significant role in seed germination [9–11]. Gibberellin induces various genes related in producing amylase, including α-amylase, protease, and β-glucanase. These enzymes act by breaking down food reserve compounds into smaller compounds, such as converting starch into sucrose and produce energy for high cellular respiration during germination [9,12].

Treatment by soaking the seeds in gibberellin (GA3) 100 ppm is described to improve growth speed, growth percentage, and seed viability in various plants [11,13–15], including onion [16,17] and shallot [18]. Gibberellin also plays a role in inducing cell division. Wen et al. [19] reported that cell division activity supported successful seed germination processes.

The generally regulated genes influence plant growth activity by more than one growth hormone [20]. Auxin indirectly induces signals that activate gibberellin accumulation in the process of germination [21]. In the advanced process after germination, auxin plays a significant role in the growth of young seedlings [22].

Sudaryono [22] reported that soaking TSS seeds of Trisula cultivars in auxin and gibberellin solution of 200 ppm overnight resulted in better plant growth and yield than the soaking treatment of auxin with cytokinin as well as the combination of auxin, gibberellin, and cytokines. The control plant was not used to compare, and the effect of treatment towards TSS seedling growth before transplanting was not reported. Therefore, this current research aimed to obtain the effect of soaking TSS Tuk Tuk, Lokananta, and Sanren cultivars treated by gibberellin and auxin PGR on seed morphology, germination, and seedling growth using soil block as a sowing before transplanting.

2. Methods
The research has been carried out in the Faculty of Agriculture experimental greenhouse, Universitas Gadjah Mada, Banguntapan, Bantul, Yogyakarta-from February to April 2020. This research used a two-factors arranged in a randomized complete block design with four replications. The first factor was TSS of cultivar Tuk Tuk (expired date Mei 2020), Lokananta (expired date July 2020), and Sanren (expired date Augustus 2020) (PT East-West, Indonesia). The second factor was seed priming before sowing by soaking the seeds for 12 hours in gibberellic acid (GA3) (Merck, Germany) 100 ppm + Naphthalene Acetic Acid/NAA (Serva, USA) 50 ppm solution and untreated seeds as a control. Each experimental unit consisted of 728 seedlings. The total population used was $3 \times 2 \times 4 \times 728 = 17,472$ seedlings. Environmental conditions were characterized by the average, maximum, minimum, and mean temperature of 34.3; 27.9; 32.1°C, respectively, and the photoperiod of 12 h, the light intensity of 31,119 lux, and relative humidity 75.8%.

2.1. Seed priming
Seed priming before sowing was carried out by soaking the three cultivars in the mixture solution of GA3 solution 100 ppm and NAA 50 ppm PGR mixture for 12 hours. The ratio between seed weight and PGR solution volume was 20% (w/v). After priming, the seeds were strained and dried on tissue paper. The seeds were then treated by a powdered fungicide with 80% mancozeb as an active ingredient (PT Dow AgroSciences, Indonesia). The fungicide was applied to reduce the risk of damping off seedlings [23].

2.2. Sowing
The seeds were deep in soil blocks with a size of 2 x 2 x 2.5 cm. The soil blocks were made from cocopeat, compost, manure, guano, and dolomite mixtures in a ratio of 2: 2: 2: 1 (v / v / v / v / v). The soil blocks were arranged in wooden trays, as many as 364 soil blocks per tray, and hollowed out ± 0.8
cm as planting hole. The seeds inserted into the planting hole as much as two seeds per hole. The soil block was then covered with a mixture of cocopeat, manure, and husk charcoal 1:1:1 (v/v/v) of ± 1 cm thick. The seedlings were then sprinkled with water using a low-pressure sprayer with fine droplets.

2.3. Seedling Nursery
Watering was every 1-2 days to keep the soil block moist. Fungicide (mancozeb 80%) was applied at 10 and 28 days after sowing (DAS) as much as 2 g L⁻¹ to prevent disease. Additional fertilization was applied at 28 DAS using NPK 16:16:16 (Saprotan Utama, Indonesia) as much as 5 g L⁻¹ per tray by leaking it into the soil block. Weed were controlled manually by hand.

2.4. Seed Morphology
Before and after PGR soaking treatment, the condition of seeds was observed by measuring seed weight and seed morphology (Digital microscope 3D, Kayence VHX-6000, USA). Tetrazolium staining with 1% tetrazolium solution was used in longitudinal sections of mature seeds with viable embryo observation. The observation of seed germination was conducted upon the number of seeds with normal germination on 4, 7, 10, and 14 of DAS. The criteria of normal germination used in the measurement were a seedling with a 2 cm long radicle and 1 cm long cotyledon (cotyledon appeared on the soil block's surface).

2.5. Seedling morphology
Seedling height and the number of leaves were measured in 2, 4, and 6 weeks after sowing (WAS) of the 80 seedling samples per experimental unit. Seedling height was measured from the soil block's surface to the cotyledon's tip or the highest leaf. Seedling fresh weight and dry weight (dry weight was measured after drying process in an oven at 80°C temperature for 72 hours), leaf width, root length (Image Analysis Sistem WinDIAS 3, Delta-T-Devices Ltd, Cambridge UK), chlorophyll a, chlorophyll b and total chlorophyll were measured at 6 WAS (seedling were ready to transplant). Every destructive observation sample unit consists of three seedlings.

Chlorophyll was analyzed using the spectrophotometer method with 80% acetone solvent [24]. A total of 1 g leaf sample was crushed and then mixed with 20 ml acetone 80%. It was then strained using a paper filter. The solvent absorbed was measured using spectrophotometer Uv-Vis (Genesis 10S, China) with a wavelength of 645 nm and 663 nm. Chlorophyll concentration of the leaf was calculated using the formula below:

\[
\text{Chlorophyll a} = 0.0127 \times A_{663} - 0.00269 \times A_{645}
\]

\[
\text{Chlorophyll b} = 0.0229 \times A_{645} - 0.00468 \times A_{663}
\]

\[
\text{Total chlorophyll content} = (1) + (2)
\]

Seedling quality was analyzed using germination percentage (GP) and hypothetical vigor index (HVI) values. The germination percentage was calculated using the following formulas [11,25]:

\[
\text{GP} (%) = \frac{G}{S} \times 100\%
\]

Where GP is a germination percentage
G is a number of normal germinated seeds
S is a number of total seeds

Hypothetical vigor index (HVI) describes seedling growth for all growth variables components, including seedling height, leaf area, leaf number, fresh weight, and dry weight of seedlings. HVI was calculated using the following equation [26,27]:

(5)
\[ HVI = \frac{\log N + \log A + \log H + \log R + \log G}{\log T} \]

where \( V \) is a hypothetical relative index of vigor;
- \( A \) is leaf area per seedling \((\text{cm}^2)\);
- \( N \) is leaf number per seedling;
- \( H \) is the seedling height \((\text{cm})\);
- \( R \) is the fresh seedling weight \((\text{g})\);
- \( G \) is the dry seedling weight \((\text{g})\);
- \( T \) is seedling age at the time the measurements were taken \((\text{weeks after germination})\).

2.6. Data analysis

The data collected were analyzed statistically using variance analysis performed in the Statistical Analysis Software (SAS version 9.4). Tukey HSD test was used at a significance level of \( p<0.05 \) when there were any significant differences in anova.

3. Results and discussion

3.1. The effect of plant growth regulator (PGR) seed priming on seed morphology and seed germination

PGR seed priming influenced the germination process in shallot seed. Figures 1.A to 1.D describes the condition of true seed shallot before and after PGR seed priming. The normal mature seed anatomy displayed more information about how the germination process occurs inside the seed.

Figure 1.A shows a shallot seed in the shape of ovate to triangular; one side convex, and the other tends to be flat with a black and granular-textured seed coat that looks like small warts (verruca). Shallot seed anatomy with normal germination was shown in Figure 1.B. The embryo of shallot seed was had a curvy shape with a spiral tip. The embryo was consisted of the radicle (R), meristem tip (SA), that will grow as the first/true leaf, procambium (P), that will grow as the primary vessel connective tissue, placed extending from the radicle tip to the end length of the embryo, cotyledon (C), a seed food storing organ, and at the end of the embryo was haustorium (H), used as the organ that absorbs food reserves from endosperm during the germination process. Endosperm (E) was the main food reserved for the seed with the main constituent of carbohydrates, a small quantity of protein, and fat. The structure of this shallot seed anatomy was identical with what De Mason [28] described as onion seed structure as an interpretation of a study written by Sachs (1863). Shallot coat (SC) was a black-colored and rough coat with a wart-like wavy texture. Under the coat was a layer of \( \pm 0.08 \text{ mm thick aleurone} \) (AL). Aleurone was the outermost layer of protein-rich endosperm as a synthesis place of enzymes for the germination process. The layers’ structure and characteristics were similar to leek, onions, tomatoes, and pepper [29].

Shallot seed priming with GA3 100 ppm + NAA 50 ppm solution for 12 hours promoted hydrolytic enzyme secretion to weaken the seed coat/testa [30]. The weakened testa accelerated the imbibition process and produced physical changes in the seed, such as swelling and cracking of the seed coat (Figure 1.C). This water uptake caused the three shallot seed cultivars’ weight after the soaking treatment to increase (Table 1).
Figure 1. **1.A.** Shallot seed/control; **1.B.** Longitudinal section of mature seed with viable embryo containing radicle (R), shoot apex (SA), procambium (P), long cotyledon (LC), haustorium (H), endosperm (E), aleurone layer (AL), nucellus (N) and testa/seed coat (SC) (tetrazolium staining); **1.C.** Shallot seed after PGR seed priming resulting in a swelled seed with cracks on the seed coat (CR); **1.D.** Radicle protrusion (R) and the occurrence of germination. Scale bar = 0.1 mm. Lens Z20X:100

Cracks on the seed coat may activate the gas circulation, especially oxygen, activate metabolism, and synthesize endogenous gibberellin that was transferred into the aleurone layer. Exogenous gibberellin may accelerate the imbibition process and increased the gibberellin’s content to be transferred into the aleurone layer [28]. After that, gibberellin will bind to the GID1 protein that interacts with protein DELLA, thus becoming the transcription factors binder that triggers gene transcription. The protein DELLA degradation will occur that caused the transcription factors were released so that gibberellin-responsive genes can be expressed, producing protein and hydrolytic enzyme synthesis, especially α-amylase, proteases, glucanases, and phosphatases. These enzymes may break down the food reserve compounds into smaller compounds, such as turning starch into sucrose and produce substrate for cellular respiration. That mechanism may stimulate faster radicle protrusion from the seed [29] (Figure 1.D). The process in Figure 1.D occurred during the seed germination process in the soil block. This led to the faster germination showed by a higher seedling germination percentage of the three shallot cultivars with PGR seed priming (Table 2).
Table 1. Characters of three TSS cultivars seeds after soaking with GA3 100 ppm and NAA 50 ppm.

| Cultivars | Number of seed per 1000 mg | Fresh weight per seed before soaking (mg) | Fresh weight per seed after soaking (mg) | Percentage of seed weight increase by soaking treatment (%) |
|-----------|---------------------------|------------------------------------------|------------------------------------------|--------------------------------------------------------|
| Tuk Tuk   | 370.75±0.96               | 2.70±0.01                                | 4.26±0.06                                | 57.78±2.27                                            |
| Lokananta | 285.25±1.26               | 3.51±0.02                                | 5.48±0.06                                | 56.28±1.12                                            |
| Sanren    | 264.50±1.30               | 3.78±0.02                                | 6.05±0.06                                | 60.08±2.20                                            |

The three shallot cultivars had different percentages of seed weight gain after PGR seed priming, as shown in Table 1. Sanren cultivar had the highest percentage of weight gain with 60.08%, followed by Tuk Tuk cultivar with 57.78%, and Lokananta with 56.28%. The estimated weight gain for these three seed cultivars was 0.6 times the seed weight. This weight-added value illustrated the ability of live seeds to absorb water imbibition. Yudono [30] stated that the amount of water uptake in the living seeds was influenced by the size of the seeds and their chemical composition, where the available range is 0.5 to 2 times the weight of the dry seeds. The larger the seed size, the more endosperm content was presented, so that the ability to absorb water during imbibition was greater than the small seeds. Sanren cultivar had the most massive seed weight with 3.78 mg, this may cause the largest increased weight added compared to the other cultivars. However, other factors such as differences in seed composition between cultivars or the embryos’ size are also suspected in further research.

There was no interaction between the TSS cultivars with PGR seed priming in the germination percentage variable four days after sowing (DAS), 7 DAS, 10 DAS, and 14 DAS, as shown in Table 2. PGR seed priming significantly contributed to the increased germination percentage compared to control (untreated seedling). The seed germination percentage given consecutive treatment was 5.75%; 66.85%; 77.77% and 80.22% at 4 DAS, 7 DAS, 10 DAS and 14 DAS and control seedling had lower germination percentage of 0.03%, 56.78%, 69.51%, and 75.71% respectively. Based on TSS minimum technical requirements, TSS seeds are said to be of good quality if they have a minimum germination percentage of 70% [31], and this value was achieved all treatments at the end of germination observation (14 DAS). However, TSS with PGR seed priming acquired 70% germination faster and produced the highest germination percentage at the final observation. This result was in line with what was found in rice germination [15], guava germination [11], onion germination [16,17] as well as TSS germination [18], where the used of gibberellin 100 ppm may increase the seed germination better than control.

Table 2. Germination percentage (GP) of some TSS cultivars with PGR seed priming using GA3 100 ppm and NAA 50 ppm

| Treatment                  | GP 4 DAS (%) | GP 7 DAS (%) | GP 10 DAS (%) | GP 14 DAS (%) |
|----------------------------|--------------|--------------|---------------|---------------|
| Tuk Tuk                    | 2.16 a       | 53.13 c      | 69.51 b       | 74.83 b       |
| Lokananta                  | 2.99 a       | 61.75 b      | 74.76 a       | 79.92 a       |
| Sanren                     | 3.50 a       | 70.57 a      | 76.65 a       | 80.22 a       |
| Seed priming (GA3 100 ppm+NAA 50 ppm, 12 h) |               |              |               |               |
| Without                    | 0.03 y       | 56.78 y      | 69.51 y       | 75.71 y       |
| With                       | 5.75 x       | 66.85 x      | 77.77 x       | 80.93 x       |
| Interaction                | (-)          | (-)          | (-)           | (-)           |

Note: Value with the same letters is not significantly different based on HSD Tukey, $\alpha=0.05$; (-) no interaction between the cultivars and seed priming  HVI: hypothetical vigor index; *: transformation data with $\sqrt{x}+0.5$.  


NAA 50 ppm addition as an exogenous auxin was related to auxin's function in preventing the possibility of a defect in seedling shape or slow growth in seedling production. Furthermore, auxin plays a role in creating lateral roots in the advanced germination stage and initial seedling growth [32], thus increasing seedlings' germination [22]. The accumulation of auxin in cotyledons was the primary source for auxin to proceed to seedling growth [9]. The synergy between auxin and gibberellin could be seen in the advanced growth after the germination process. That was shown by the increased value of the seedling growth variables described in Table 3.

3.2. The effect of plant growth regulator seed priming towards seedling growth

The interaction between TSS with PGR seed priming was not found in the plant height, root length, number of leaves, leaf area, fresh weight, dry weight, and hypothetical vigor index after six WAS, as shown in Table 3.

Sanren cultivar had the best seedling growth as seen from the variables of plant height, root length, leaf area, and its hypothetical vigor index value, while the lowest growth rate was found in Tuk Tuk cultivar. PGR seed priming significantly affected the increasing seedling plant height, leaf number, and leaf area of the three TSS cultivars. However, there was no significant difference in root length, fresh weight, and seedling dry weight. The analysis of chlorophyll a, b, and total chlorophyll content in Table 4 revealed an interaction between cultivar/genetic factors and seed priming. In Tuk Tuk and Lokananta cultivars, although the chlorophyll content of the seedlings treated with PGR priming was lower than the control, the difference was not significant (P <0.05). In contrast, in the Sanren cultivar, there was a significantly lower difference in the chlorophyll content. The tendency of lower chlorophyll content in leaves treated with PGR priming was the cause of the similar value in fresh weight and dry weight of control seedlings, even though they had higher plant height, leaf number, and leaf area than control seedlings.

| Table 3. Character of seedlings in three TSS cultivars with PGR seed priming using GA3 100 ppm and NAA 50 ppm at transplanting stage (6 weeks after sowing) |
|-----------------------------------------------|
| Treatment | Plant Height (cm) | Root length (cm) | Number of leaves | Leaf area (cm²) | Fresh weight (g) | Dry weight (g) | HVI |
|-----------|--------------------|------------------|------------------|----------------|-----------------|----------------|-----|
| **Cultivars** |
| Tuk Tuk   | 22.51 b            | 20.07 ab         | 3.01 a           | 13.83 b        | 0.52 a          | 0.045 a        | 1.66 b |
| Lokananta | 23.87 a            | 16.44 b          | 3.05 a           | 16.53 a        | 0.58 a          | 0.043 a        | 1.87 ab |
| Sanren    | 24.49 a            | 21.67 a          | 3.10 a           | 18.58 a        | 0.66 a          | 0.055 a        | 2.17 a |
| **Seed Priming (GA3 100 ppm+NAA 50 ppm, 12 h)** |
| Without   | 22.44 y            | 20.50 x          | 2.97 y           | 15.23 y        | 0.56 x          | 0.043 x        | 1.75 y |
| With      | 24.80 x            | 18.29 x          | 3.13 x           | 16.96 x        | 0.62 x          | 0.051 x        | 2.04 x |
| Interaction | (-)                | (-)              | (-)              | (-)            | (-)             | (-)            | (-)  |
| CV (%)    | 5.37               | 16.05            | 2.98             | 11.01          | 5.87*           | 1.02*          | 17.10 |

Note: Value with the same letters is not significantly different based on HSD Tukey, α=0.05; (-) no interaction between the cultivars and seed priming; HVI: hypothetical vigor index; *: transformation data with √x+0.5.

Gibberellin could increase seedling height and leaf width by increased cell division, extension, and replication [15]. However, the leaves may become thinner because chlorophyll's formation on the leaves as the main engine of photosynthesis was not following cell division's active process and stretching [33].
Table 4. Chlorophyll content of three TSS cultivars with PGR seed priming (GA3 100 ppm + NAA 50 ppm, 12 h) at transplanting stage (6 weeks after sowing)

| Variable          | Seed Treatment | Cultivar   | Average | CV  |
|-------------------|----------------|------------|---------|-----|
| Chlorophyll a (mg. g⁻¹) | Without/Control | Tuk Tuk    | 0.481 a | 0.447 |
|                   |                | Lokananta  | 0.422 ab| 0.370 |
|                   |                | Sanren     | 0.531 a | 0.394 |
|                   | With           | Tuk Tuk    | 0.414 ab|        |
|                   |                | Lokananta  | 0.319 bc|        |
|                   |                | Sanren     | 0.257 c |        |
|                   | Average        | Tuk Tuk    | 0.478   | (+)  |
|                   |                | Lokananta  | 0.330   | (+)  |
| Chlorophyll b (mg. g⁻¹) | Without/Control | Tuk Tuk    | 0.162 xy| 0.168 |
|                   |                | Lokananta  | 0.203 xy| 0.171 |
|                   |                | Sanren     | 0.259 x | 0.186 |
|                   | With           | Tuk Tuk    | 0.174 xy|        |
|                   |                | Lokananta  | 0.140 y |        |
|                   |                | Sanren     | 0.113 y |        |
|                   | Average        | Tuk Tuk    | 0.208   | (+)  |
|                   |                | Lokananta  | 0.142   | (+)  |
| Total Chlorophyll (mg. g⁻¹) | Without/Control | Tuk Tuk    | 0.643 uv| 0.615 |
|                   |                | Lokananta  | 0.624 uv| 0.541 |
|                   |                | Sanren     | 0.790 u | 0.580 |
|                   | With           | Tuk Tuk    | 0.587 uv|        |
|                   |                | Lokananta  | 0.459 vw|        |
|                   |                | Sanren     | 0.370 w |        |
|                   | Average        | Tuk Tuk    | 0.686   | (+)  |
|                   |                | Lokananta  | 0.472   | (+)  |

Note: Means in each variable with the same letters are not significantly different based on HSD Tukey, α=0.05; (+) an interaction between cultivars and seed priming; *=: transformation data with √x+0.5.

The decreased chlorophyll content in seedlings with PGR seed priming (Table 4) caused no increase in photosynthate in plants. Rogach et al. [33] stated that priming with GA3 50 ppm caused decreased in cytokinin content by 24.5% in eggplant. Cytokinin plays a role in the synthesis of chlorophyll in plants [32–35]. Decreased cytokines caused a decrease in chlorophyll synthesis in the leaves. The amount of decrease depends on the cultivar/genetic factor. The chlorophyll content increased can be made using two types of treatment, i.e., cytokinin's addition by spraying seedlings during the nursery or adding fertilizer, especially nitrogen fertilizer. The nitrogen fertilizer addition was strongly recommended since cytokinin may lead to gibberellin function decrease [36,37]. The nitrogen application was reported to have increased photosynthetic pigment content, synthetic enzyme, and chloroplast membrane system [38].

Although there was no significant difference in seedlings' root length, fresh weight, and dry weight, the hypothetical vigor index of the seedlings treated with PGR priming was higher (2.04) and significantly different from the control plant (1.75), as shown in Table 3. Hypothetical vigor index describes seedling quality as the accumulation of all plant growth components, i.e., plant height, root length, number of leaves, leaf area, fresh seedling weight, and dry weight. Vigor is defined as a seed or seedling's ability to grow normally and quickly in suboptimal environmental conditions [25]. Vigor relates to seed production ability, where the seedlings with high vigor content will produce high production as well [27,38]. Bettoni et al. [5] stated that onion seedlings with high vigor determined plant growth and bulbs' yield quality. The higher hypothetical index vigor value resulted from seed soaking treatment in GA3 100 ppm and NAA 50 ppm for 12 hours in this study was expected to improve seedlings' viability during the field's transplanting stage and yield of shallot bulbs.

4. Conclusion  
Seed priming using a mixture of plant growth regulators GA3 100 ppm and NA 50 ppm could increase seed germination by value of 10.07 and hypothetical vigor index seedling by 2.04. The Sanren cultivars showed the best percentage of germination and seed growth, followed by Lokananta and Tuk Tuk cultivars.
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