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The Effect of Cultivation Media on Matriconditioning Technique and the Concentration of Onion Peel Waste PGR on the Viability and Yield Rice (*Oryza sativa*) Through the Metabolic Activity of the Seed

Alfiyyah Nur Amany [a], Setiyono [b], Ummi Sholikhah [a], Tri Ratnasari [a], Susan Barbara Patricia Sembiring Meliala [b,*], Ayu Puspita Arum [b], Dyah Ayu Savitri [b]

[a] Department of Agrotechnology, Universitas Jember, Jember, Indonesia
[b] Department of Agricultural Science, Universitas Jember, Jember, Indonesia

Abstract. *A major limiting factor for rice production in the tropics is the decline in seed quality due to storage duration and environmental conditions. Rice seeds are often stored for extended periods, making seed expiration unavoidable. Expired seeds frequently undergo quality deterioration. Therefore, an effective approach is needed to mitigate quality decline and sustain rice production. This study aims to evaluate the effectiveness of different matriconditioning techniques and various concentrations of onion peel waste-derived plant growth regulators (PGRs) in maintaining seed viability and rice yield. The research was conducted using a Completely Randomized Design (CDR) with a two-factor experimental setup and three replicates. The first factor was the matriconditioning medium, consisting of three levels:* M_1 *(soil),* M_2 *(soil + husk charcoal), and* M_3 *(soil + husk ash). The second factor was the concentration of onion peel waste-derived PGR, consisting of four levels:* K_1 *(0% – water),* K_2 *(25% – 250 mL onion peel waste PGR per 1000 mL),* K_3 *(50% – 500 mL onion peel waste PGR per 1000 mL), and* K_4 *(75% – 750 ml onion peel waste PGR per 1000 mL). The results showed that matriconditioning with soil and husk charcoal, along with 25% onion peel waste-derived PGR, enhanced rice seed viability. Additionally, a 75% concentration of onion peel waste PGR significantly influenced the weight of 1000 grains and the total harvested grain weight.*

Keywords: *deterioration; matriconditioning; PGR; production.*

Type of the Paper: Regular Article.

1. Introduction

The majority of Indonesians consume rice daily due to its high carbohydrate content (90%) [1]. Rice production decreased by 0,43% compared to the previous year. In 2020, Indonesia produced 54,65 million kilograms of rice; however, in 2021, production declined to 54.42 million dry milled rice, a reduction of 233,911 tons [2].

One of the factors contributing to the decline in rice production in the tropics is the rapid deterioration of seeds during storage, leading to reduced seed quality. Seed deterioration is a gradual and irreversible process caused by physiological changes in the seeds. Seed deterioration is characterized by reduced germination, decreased seed vigor, abnormal seed growth, and inhibited plant growth and development [3]. Changes in seed quality can occur over time due to storage conditions [4]. During seed storage, protein inactivation may occur, leading to seed

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* First corresponding author
Email: susansm.faperta@unej.ac.id

damage due to a decline in cellular metabolism [5].

Rice seeds cannot be used directly by farmers due to issues with the distribution and absorption in certain areas. Prolonged distribution makes seed expiration inevitable. In agricultural shops, rice seeds have a circulation period of six months. After this period, rice seeds expire, leading to a decline in seed quality, commonly referred to as deterioration. Seed vigor and viability decrease during storage, making it difficult to maintain seed quality [6].

Seed deterioration can lead to failed germination or abnormal growth, resulting in defective sprouts. The effects of storage-induced deterioration can be assessed by evaluating seed viability through maximum growth potential measurement [7]. During storage, rice seed quality may decline, as indicated by reduced seed viability. This occurs because shelf life influences seed moisture content and maximum growth potential. A decline in seed viability, which affects growth potential and germination, ultimately impacts rice yields productivity [8]. Therefore, addressing the deterioration of expired rice seeds is crucial, necessitating effective strategies to mitigate seed deterioration.

One approach to mitigating seed deterioration is the use of invigoration techniques [9]. Invigoration is a seed treatment method that enhances the vigor of deteriorated seeds [10]. This ensures that seeds produce normal sprouts capable of developing into healthy plants and achieving optimal yields. One effective invigoration technique is *matriconditioning*, a pre-sowing seed treatment conducted in a medium with high matrix potential. This technique enhances seed quality and germination. Matriconditioning media consist of a moist, dense substrate with high water-holding capacity. By retaining and absorbing water efficiently, *matriconditioning* media facilitate the imbibition process— the initial phase of germination— followed by hormonal activation and enzyme activity. Once hormones and enzymes are activated, the differentiation process progresses, leading to the emergence of the hypocotyl, radicle, and cotyledons. *Matriconditioning* media such as husk charcoal, ash, and sawdust can be used [11].

Additionally, seed invigoration can be enhanced by applying plant growth regulators (PGRs). These organic compounds either promote or inhibit plant growth and influence growth patterns [12]. Growth regulators are also present in agricultural waste, such as onion peels. Shallots contain auxin and gibberellin hormones, which promote plant growth. Phytohormones such as auxin and gibberellin act as endogenous regulators of seed shelf life [13]. Auxin stimulates seed germination by promoting root development, which supports overall plant growth. The auxin hormone present in shallot skin influences seed metabolism, including catabolism and anabolism during germination. Catabolism involves the breakdown of food reserves into energy for germination. Meanwhile, anabolism is the process of protein synthesis for the formation of new embryo cells. Additionally, auxin plays a role in enhancing plant yields by increasing plant weight

[14]. Gibberellins contribute to cell division, breaking seed dormancy, promoting seed germination, and stimulating sprout growth [15]. The gibberellin content in onion peel waste stimulates hydrolytic enzymes involved in breaking down food reserves. This compound accelerates the hydrolysis of amylase into maltose and glucose, thereby influencing plant growth and development [16]. Additionally, onion peel contains auxin and gibberellin hormones, which contribute to plant growth and yield by enhancing cell division and enlargement. Consequently, this leads to improved plant productivity [17].

The application of these two invigorations techniques is expected to enhance rice viability and yield. Therefore, studies on the effects of *matriconditioning* and growth regulators on rice viability and yield are necessary to address this issue and support increased rice production in Indonesia.

2. Materials and Methods

The research was conducted from December 2022 to February 2023 in the Greenhouse of Agrotecnopark, Universitas Jember.

2.1. Tools and Materials

Plastic containers, microscopes, analytical scales, teeth, paper envelopes, ovens, and measuring tapes were all utilized in this investigation. The experiment used expired rice seeds from the M70D generation, along with rubbed ash, husk charcoal, cow dung fertilizer, onion peel PGR, B1+B6 PGR, polybags, soil, urea, SP36, KCl, ZA, dolomite, and labels.

2.2. Experimental Design and Data Collection

This research was conducted using a factorial approach within a Completely Randomized Design (CDR) framework, consisting of two factors with three replications. The first factor was the *matriconditioning* medium, which included three levels: M_1 (soil), M_2 (soil + husk charcoal), and M_3 (soil + husk ash). The second factor was the concentration of onion peel waste PGR, which consisted of four levels: K_1 (0% – water), K_2 (25% – 250 mL onion peel waste PGR per 1000 mL), K_3 (50% – 500 mL onion peel waste PGR per 1000 mL), and K_4 (75% – 750 mL onion peel waste PGR per 1000 mL). Analysis of Variance (F-test) was used to examine the observational data. Duncan's Multiple Range Test (DMRT) was performed at a 5% significance level to determine whether there was a statistically significant difference between treatments. Data processing was conducted using Excel.

2.3. Implementation of Activities

The implementation of activities began with the preparation of onion peel PGR. The process started by creating a 100% onion peel PGR solution, which was made by dissolving 1000 grams of onion peel in 1000 ml of water. The solution was then diluted to concentration of 25%, 50%, and 75%. Once the onion peel PGR was ready, the rice seeds were soaked in the solution at concentrations of 0%, 25%, 50%, and 75% for 12 hours.

The soaked rice seeds were then planted in the prepared *matriconditioning* media, which consisted of husk charcoal and husk ash. To assess seed viability, 100 seeds were planted in each plastic tub. The seeds were grown in plastic tubs for 14 days to evaluate their viability. The viability assessment included germination (%) and maximum growth potential (%) using formulas (1) and (2).

$$\text{Germination (\%)} = \frac{\sum Normal\ sprouts}{\sum Planted\ seed} \text{ x } 100\ \% \quad (1)$$

$$\text{Maximum Growth Potential (\%)} = \frac{Growing\ seed}{Planted\ seed} X\ 100\% \quad (2)$$

After the viability test was conducted, samples from each treatment combination were selected for transplanting into poly bags containing soil mixed with 36 kg of cow manure. Three plants with normal germination criteria were transplanted per treatment.

Transplanted plants in polybags were maintained regularly. Maintenance included watering, weeding, fertilizing, pest and disease control, and the application of onion peel PGR. Watering was carried out once daily using a fanfare. Weeding was performed manually by removing weeds around the plants by hand. Fertilization was carried out using 0.27 kg of urea, 0.18 kg of SP36, and 0.09 kg of KCl. Urea was applied after transplanting and at 50 days after planting. SP36 and KCl were applied only once, immediately after transplanting. Pest prevention in rice plants was carried out through environmental sanitation. Additionally, plants experiencing stress after transplanting were treated with a B1+B6 solution at a concentration of 2 ml/L. The B1+B6 solution contained thiamine mononitrate (0.10%), phosphoric acid (2.0%), pyridoxine, NAA, Cu (0.79%), Mn (0.32%), Mo (0.0043%), Zn (0.078%), and B (0.0041%). Growth regulators are applied again during the plant's generative phase to optimize grain filling.

The final stage is harvesting. Harvesting is performed when 95% of the grains have dried, and the flag leaves have turned yellow. The plants are harvested manually by removing the entire plant.

3. Results and Discussion

The recapitulation of the analysis of variance (F-Count) for all observed variables is shown in (Table 1). The analysis results indicate that the interaction between *matriconditioning* media and onion peel PGR concentration had no significant effect on most observed variables, except for germination (%) and maximum growth potential (%). Meanwhile, the main effect of the *matriconditioning* media factor showed a highly significant effect on germination (%) and maximum growth potential (%). Similarly, the main effect of onion peel PGR concentration had a highly significant effect on germination (%), maximum growth potential (%), 1000-grain weight, and crop grain weight.

Table 1. Recapitulation of the results of analysis of variance (F-Count) on all observation variables

No	Observational Variables	Value of F-Count		
		Matriconditioning Media (M)	Onion Peel PGR (K)	Interaction (M x K)
1.	Germination (%)	228.97 **	113.76 **	2.54*
2.	Maximum Growth Potential (%)	231.77 **	111.49 **	2.82*
3.	Plant Height (cm)	0.97 ns	1.01 ns	0.35 ns
4.	Number of tillers	0.98 ns	2.22 ns	0.84 ns
5.	Fresh Weight of Stover (gr)	1.86 ns	2.34 ns	0.87 ns
6.	Dry Weight of Stover (gr)	1.8 ns	2.44 ns	0.98 ns
7.	1000 Grain Weight (gr)	1.15 ns	20.94 **	0.31 ns
8.	Crop Grain Weight (gr)	0.05 ns	66.55 **	0.23 ns

Notes: (**) very significantly different; (*) significantly different; (ns) = non significant

3.1. Effect of Interaction of Matriconditioning Growing Media and Concentration of Onion Peel Waste PGR on the Viability and Yield Rice

The results of the analysis indicate that the combination of *matriconditioning* growing media and onion peel waste concentration affects seed viability. This is evident from the analysis results on germination and maximum growth potential variables. The combination of *matriconditioning* growing media (soil + husk charcoal) and 25% onion peel waste PGR (M_2K_2) resulted in the highest average germination rate of 93.67% (Table 2).

Table 2. The interaction effect of *matriconditioning* growing media and concentration of onion peel waste PGR on germination (%).

M	K							
	K1		K2		K3		K4	
M1	74.67 C	b	81.33 B	a	74.00 C	B	73.33 B	b
M2	87.33 A	b	93.67 A	A	84.67 A	C	81.00 A	d
M3	84.33 B	b	91.67 A	A	82.00 B	C	80.00 A	c

Notes: Numbers followed by uppercase letters (vertical) compare the effect of planting media factor treatment (M) at the same level of concentration PGR (K), whole numbers followed by lowercase letters (horizontal) compare the effect of concentration PGR (K) at the level of planting medium (M) the same one

A similar trend was observed in the maximum growth potential (%). The combination of *matriconditioning* growing media (soil + husk charcoal) and 25% onion peel waste PGR (M_2K_2) resulted in the highest average maximum growth potential of 95.33% (Table 3).

This is because the *matriconditioning* media functions as a water reservoir and supply for seeds, interacting with the concentration of onion peel waste PGR, which serves as a source of auxin and gibberellin hormones that stimulate plant growth and development. The *matriconditioning* growing media extends the imbibition phase due to its excellent water-holding capacity, thereby increasing the germination percentage of seeds that have undergone quality deterioration [18]. Water is essential for the imbibition process; therefore, its availability in the seed growing environment is crucial. A delay in water absorption can lead to delayed seed germination and slower sprout growth [19]. In addition, the use of onion peel waste PGR also contributes to increasing seed germination. Onion peel waste can serve as a solution that stimulates seed germination due to its auxin and gibberellin content. The auxin hormone plays a role in breaking dormancy and promoting shoot and root growth. This is because the auxin hormone aids in embryo development and seed maturation [20], while the gibberellin hormone stimulates cell elongation, allowing the radicle to penetrate the endosperm, which acts as a barrier to seed growth [21]. The medium has a high water -holding capacity, allowing it to optimize the effectiveness of the applied PGR. Sufficient water availability enhances seed germination.

Table 3. The interaction effect of *matriconditioning* growing media and concentration of onion peel waste PGR on maximum growth potential (%).

M	K							
	K1		K2		K3		K4	
M1	81.00 C	b	84.67 B	a	77.33 C	C	76.33 B	c
M2	91.67 A	b	95.33 A	a	90.33 A	B	83.67 A	c
M3	89.33 B	b	93.67 A	a	86.67 B	C	82.33 A	d

Notes: Numbers followed by uppercase letters (vertical) compare the effect of planting media factor treatment (M) at the same level of concentration PGR (K), whole numbers followed by lowercase letters (horizontal) compare the effect of concentration PGR (K) at the level of planting medium (M) the same one

Matriconditioning growing media, such as of husk charcoal and husk ash, possess high water-holding capacity and large pores, which enhance seed germination. The media's ability to retain water effectively optimizes the imbibition process. Water availability is crucial during germination. Insufficient water supply can hinder seed germination. During this process, water activates embryonic cells, softens the seed to facilitate oxygen absorption, and serves as a medium for transporting nutrients from the cotyledons to the growing point [22].

The 25% onion peel waste PGR concentration yielded the best results, as it provided an optimal balance to promote seed germination. Onion peel, which contains auxin and gibberellin hormones, can have both positive and negative effects on seed germination. Seed germination success depends on the concentration of PGR applied, as variations in concentration influence seed activity [21]. The application of onion peel PGR, which contains auxin and gibberellin hormones, stimulates seed metabolic activity, thereby enhancing the growth of shoots, roots and leaves. This occurs because the addition of auxin stimulates metabolism, which includes both catabolism and anabolism. Meanwhile, gibberellin plays a role in increasing amylase enzyme activity, which facilitates the mobilization of food reserves, thereby promoting seed germination. Auxin and gibberellin hormones are effective at specific concentrations; excessively high levels can inhibit seed germination, while low concentrations may be ineffective [23]. The presence of onion peel waste PGR, which contains auxin and gibberellin, accelerates amylase hydrolysis. The amylase enzyme catalyzes the breakdown of starch (carbohydrates) into maltose. Initially, starch molecules are degraded into shorter glucose chain units called dextrins, which are subsequently converted into maltose and then into glucose. This glucose serves as an energy source for seed germination [24].

The use of PGR to enhance seed germination requires an appropriate concentration and timing. In general, nutrient requirements vary across different phases of plant growth. During the germination phase, a relatively low concentration is sufficient. Administering high concentrations at this stage may, in fact, inhibit germination [25].

3.2. Effect of Matriconditioning Growing Media on the Viability and Yield Rice

The analysis of variance revealed that the *matriconditioning* growing media treatment had a significant effect on germination percentage and maximum growth potential. This treatment helps balance the seed's water potential, thereby stimulating seed metabolism, which in turn promotes the emergence of the radicle, hypocotyl and cotyledon [11]. The *matriconditioning* medium consists of a moist, dense substrate that stimulates the seed imbibition process. Seeds subjected to *matriconditioning* treatment undergo a more controlled imbibition process, allowing for the optimization of internal seed factors necessary to initiate germination. Imbibition, or the entry of water into the seed, is the initial step of seed germination. This process facilitates biochemical reactions essential for supporting seed germination [26]. Consistent with this, a study on black soybean plants found that the use of charcoal husk matriconditioning media resulted in a germination rate of 91.75%, compared to 82.75% in the control treatment [27].

The treatment of *matriconditioning* media had no significant effect on crop yield due to its nutrient content. Beyond the germination period, husk charcoal and husk ash media not only facilitate the imbibition process but must also contribute to nutrient availability to support plant growth. The need for water alone is not enough to increase plant growth, sufficient nutrients are needed to maximize plant growth. The nutrients contained in rice husk charcoal and husk ash are insufficient to encourage the growth of rice plants and do not meet the minimum quality standards of pure solid organic fertilizer [28]. Rice husk charcoal contains nitrogen (0.3%), phosphorus (0.15%), and potassium (0.31%) [29], while husk ash contains nitrogen (1%), phosphorus (0.2%), and potassium (0.58%) [30]. According to Ministerial Decree No. 261/KPTS/SR.310/M/4/2019, the minimum quality standard for pure organic fertilizer in terms of macro nutrients is 2% [9]. Nitrogen is a limiting factor in rice production. To obtain high yields, sufficient N nutrients are needed in the soil. Generally, approximately 2.60% of nitrogen is needed to optimize rice production. Nitrogen plays a crucial role in all stages of plant growth, and its deficiency in the soil leads to reduced rice yields [31].

3.3. Effect Concentration of Onion Peel Waste PGR on the Viability and Yield Rice

The analysis of variance revealed a statistically significant difference in the concentration onion peel waste PGR on the observed variables: germination (%), maximum growth potential (%), 1000-grains weight, and crop grain weight. Onion peel contains the hormones auxin and gibberellin, which facilitate seed germination. The hormones play a crucial role in breaking dormancy and stimulating the growth of shoots, roots, and leaves [32]. Applying the appropriate concentration and soaking duration enhances water absorption, activating enzymes involved in nutrient mobilization, cell division, and cell enlargement, thereby accelerating seed germination. When using PGR to increase seed germination, the appropriate concentration and soaking duration are required. Nutrient requirements vary across different plant growth phases, and during germination, a relatively low concentration is needed. Excessively high concentrations at this stage may inhibit germination [21]. Soaking duration also greatly influences germination. Longer soaking periods increase water absorption, but excessive soaking may lead to seed deterioration or rotting. Generally, an optimal soaking duration ranges for 12-36 hours [33].

The auxin content in onion peel enhances seed metabolic activity, promoting cell division and tissue differentiation. In addition, auxin increases the elasticity of the cell wall, facilitating higher water absorption to encourage germination [34]. Meanwhile, gibberellin stimulates hydrolytic enzymes involved in breaking down stored nutrients. These materials accelerate the hydrolysis of amylose into maltose and glucose, thereby influencing the growth and development of seeds [24].

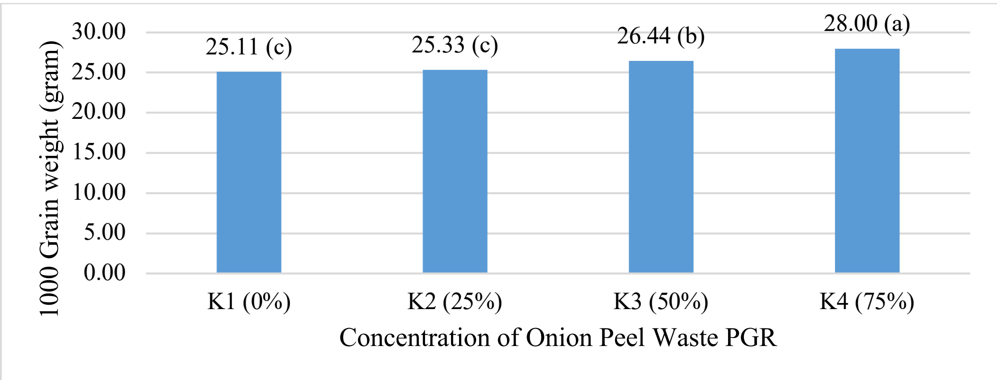

Fig. 1. Effect concentration of onion peel waste PGR on 1000 grain weight

The auxin and gibberellin content in onion peel not only contributes to seed germination but also enhances rice yields (Fig. 1 and Fig. 2). Auxin plays a crucial role in plant biosynthesis, promoting cell proliferation and increasing nutrient reserves in seeds [35]. It influences various physiological processes throughout plant growth and development. Auxin application stimulates cell division and expansion, leading to a higher number of rice grains and larger husks. Since husk size directly affects grain weight, an increase in husk size results in larger grains [36].

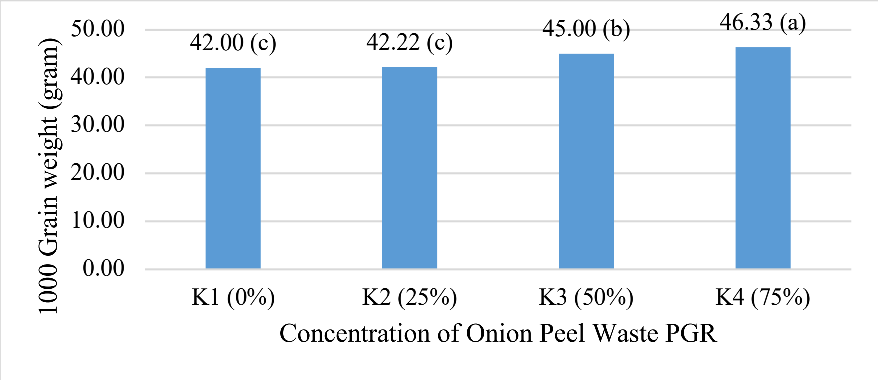

Fig. 2. Effect concentration of onion peel waste PGR on crop grain weight

In addition, the gibberellin hormone in onion peel enhances photosynthetic activity, resulting in increased photosynthate production, which plays a role in grain filling. Gibberellin contributes to plant photosynthesis by stimulating leaf and stem growth. Since photosynthesis primarily occurs in the leaves, an increase in the number of leaves promoted by giberillin enhances photosynthesis activity. The stage begins with gibberellin stimulating cell division before the G1 phase. Furthermore, gibberellin enhances the conversion of starch, fluctame, and sucrose into glucose and fluctose to stimulate leaf growth [37]. Photosynthesis plays an important role in grain filling by capturing light energy and converting it into chemical energy. The resulting photosynthates are then translocated through the phloem to various plant parts, including seeds. A delay in photosynthesis during the grain filling phase reduces photosynthate production, leading to an increase in empty grain. During this phase, not only the roots, stems, and leaves contribute to photosynthesis, but the seeds do as well. As a result, most of the photosyntetic products generated and stored are utilized during grain filling [38]. Insufficient nutrients availability during this stage can further increase the formation of empty grain [39]. The application of PGR containing gibberellin at an appropriate dose can increase the quality and weight of grain.

The best response in terms of 1000-grain and crop grain weights was observed with 75% (K_4) concentration of onion peel waste. Higher concentration resulted in heavier crop grains and increased 1000-grain weight. The increase in grain weight corresponds with the overall rise in crop grain weight. Auxin in shallot skin promotes cell enlargement by increasing the size of the rice husks, thereby increasing the weight of the grain [36]. Additionally, enhanced photosynthetic activity, stimulated by gibberellin, further supports grain weight accumulation. The addition of an appropriate gibberellin concentration can increase chlorophyll content in plants, enhancing photosynthesis and ultimately improving rice yield [40]. Grain weight is strongly influenced by the translocation of photosynthetic products to the developing grains, leading to increased grain mass. A higher photosynthesis rate results in greater photosynthate accumulation in rice grains, thereby increasing their weight [41].

The lack of significant treatment effect on other variables is due to timing of onion peel PGR application. Applying onion peel PGR during seek soaking does not effectively promote plant growth in the vegetative phase. This is because the auxin and gibberellin in onion peel PGR are primarily utilized to support germination and growth of rice sprouts, leaving insufficient amounts to encourage vegetative growth in rice plants [42].

4. Conclusions

The combination of *matriconditioning* planting media treatment and onion peel PGR improved seed viability. The best results were achieved using matriconditioning media composed of soil and husk charcoal, along with a 25% concentration of onion peel PGR (M_2K_2). In addition, applying a 75% (K_4) significantly increased both 1000-grain weight and crop grain weight.

Abbreviations

PGR	plant growth regulators
CDR	completely randomized design
DMRT	duncan multiple range test

Data availability statement

Data will be made available on request.

Credit authorship contribution statement

Alfiyyah Nur Amany: Conceptualization, Formal analysis, Data curation, Funding acquisition, Methodology, Writing – original draft. **Setiyono**: Methodology, Formal analysis, Data curation, Supervision. **Ummi Sholikhah**: Supervision, Investigation, Validation. **Tri Ratnasari**: Supervision, Investigation, Validation, Visualization. **Susan Barbara Patricia Sembiring Meliala**: Investigation, Validation, Writing – review and editing. **Ayu Puspita Arum**: Investigation, Validation. **Dyah Ayu Savitri**: Investigation, Validation.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest or competing interest.

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