THE ROLE OF ALLIUM EXTRACTS IN STIMULATING RICE GROWTH

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Abstract. In Indonesia, the demand for rice always increases from year to year. However, the rice production in 2021 decreased by 0.45% more than in 2020. Therefore, production needs to be improved again to meet national food self-sufficiency. One of the innovations to increase growth is utilizing natural plant growth regulators (PGRs) derived from Allium extracts. This study aimed to find one of the best types of Allium extract that can stimulate rice growth. The study area was conducted in the greenhouse, Faculty of Agriculture, Universitas PGRI Yogyakarta, Bantul Regency, Yogyakarta Special Region, Indonesia. The research was a single factor arranged in a complete randomized design (CRD) and three replications. The treatments involved four allium species i.e., control (without treatment), shallot (*Allium ascalonicum* L.), garlic (*Allium sativum* L.), and onion (*Allium cepa* L.). Each type of Allium extract was used at a concentration of 20%. The research results showed that the Allium extract types significantly affected seedling growth, especially seedling height for the first time. The shallot and garlic extracts decreased seedling dry weight. The Allium extract types can stimulate shoot dry weight clump^{-1}. Application of shallot extract could cause the highest grain dry weight clump^{-1}. The study findings show that shallot and garlic extracts harm seed germination and seedling growth, but the onion extract does not. However, shallot is a type of Allium whose extract can stimulate rice growth. Therefore, we recommend the shallot extract type for stimulating growth in rice cultivation.
Keywords: *Allium extract, rice, shallot, garlic, onion, phytohormone*

Introduction

Rice is a staple food in the Indonesian population. Optimal rice growth can support maximum yields. Therefore, an attempt has been made to stimulate plant growth regulators (PGRs) through growth hormones. PGRs in their natural form can modify or control through physiological action, growth, and maturation of plants. The PGR produced in the plant is called plant hormone or phytohormone.

However, synthetic hormones are very expensive; alternatively, natural PGR from Allium extracts is used. Allium bulbs contain auxins (IAA), gibberellic acid (GA), and cytokinins. IAA and GA hormones can play a role in stimulating rice growth. However, it is not yet known what type of Allium extracts can be used to stimulate rice growth.

In Indonesia, the demand for rice has increased from year to year. However, rice production in 2021 decreased by 0.45% more than in 2020 (BPS, 2021). Within the last 10 years (2010-2019), the area dan production of rice has been declining as much as 1.8% and 1.6%, respectively (Pudjiastuti et al., 2021). Rice production can be increased again to maintain national food security. Therefore, it is necessary to have a solution. Using Allium extract at certain concentrations can increase rice production.

During this time, a rice intensification system has been implemented to obtain higher production, optimal use of labor and capital, input costs, and the need for less water

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(Toungos, 2018). In addition, rice production in Indonesia has been carried out through five farming programs, i.e., superior seed selection, good tillage, proper fertilization, pest and plant disease control, and good irrigation.

PGRs are natural and synthetic compound forms that can modify or control plants through the action of physiological growth and maturation. Phytohormones are produced in the plant (Ogunyale et al., 2014) in small amounts but can majorly affect growth and production. For example, IAA, GA, and zeatin (cytokinin) are growth-promoting hormones, while abscisic acid (ABA), ethylene, and phenolic compounds are growth-inhibiting hormones (Agustina et al., 2010). These phytohormones are capable of being produced by plants. One of these plant families is from the Alliaceae (Wen et al., 2021). The following literature review will discuss three types of Allium extract, i.e., shallot, garlic, and onion. These three types are most likely to contain phytohormones.

Shallot bulbs (*Allium ascalonicum* L.) contain PGR, i.e., IAA and cytokinins. However, an excessive concentration of shallot extract will inhibit plant growth. The IAA is a hormone that can affect plant growth: height growth, leaves number, chlorophyll content, root gain, and stem diameter of *Arenga pinnata* (Patma et al., 2013). In addition, shallot contains IAA and GA hormones, so shallot extract can help seed germination and growth of roots and shoots of *Ixora coccinea* (Salsabila et al., 2021).

The highest concentration of IAA in shallots was found in bulbs (5.376 mg kg^{-1}), decreased in roots (3.314 mg kg^{-1}), and the lowest was in leaves (1.006 mg kg^{-1}). The results showed that the IAA content was the highest in shallot var. Bima (6.014 mg kg^{-1}) compared to var. Maja, Mentes, Pancasona, and Trisula (Sopha and Hartanto, 2021). A concentration of 20% shallot extract most effectively increased the live cuttings percentage, but a concentration of 10% significantly affected the leaves number in *Mucuna bracteata* D.C (Prameswari and Pratomo, 2021). Shallots contain GA_3, IAA, ABA, and zeatin (Dahab et al., 2018), and are effective for increasing germination, fresh weight, and dry weight of melon plants. In addition, shallot extract has the potential to be a source of organic hormones (Yunindanova et al., 2018).

The phytohormone content in garlic (*Allium sativum* L.) was higher than that in shallot, i.e., GA_3 (2.719 mg 100 g^{-1}), IAA (0.0312 mg 100 g^{-1}), ABA (0.3138 mg 100 g^{-1}), and zeatin (0.0149 mg 100 g^{-1}) (Dahab et al., 2018). Garlic extract contained enzymes and more than 200 other chemical compounds. The garlic extract contained thiosulfinate (307.66 ± 0.043 µM/g), flavonoids (64.33 ± 7.69 µg QE/g), and polyphenols (0.95 ± 0.011 mg GAE/g) as major compounds (Corbu et al., 2021). Garlic contained vitamins, minerals, flavonoids, ascorbic acid, sulfur, iodine, and some amino acids. Sulfur had an important role in the fruiting process of various fruit crops (Al-hadethi et al., 2016).

Garlic contains a high level of phenolic compounds (Griffiths et al., 2002), out of which flavonoids are the main in garlic bulbs. Flavonoids can be classified into various sub-classes, i.e. flavones, flavanones, flavonols, isoflavones, flavanonols, flavonols, flavanols, chalcones, and anthocyanins (Perez-Gregorio et al., 2010). The application of garlic extract could result in a marked reduction in nodulation in the roots, plant height, leaf area, and root development of arrears (*Vigna unguiculata*) and peanuts (*Arachis hypogea*) compared to control (Adeleke, 2019).

Many organosulfur compounds are found in onions (*Allium cepa* L.). Diallyl sulfide, diallyl monosulfide, disulfide, trisulfide, and tetrasulfide are the main sulfur compounds

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in onion. Onions are considered an excellent source of flavonoids of the polyphenol family. Flavonols are a sub-class of flavonoids (Pareek et al., 2017). Red and yellow cultivar onions contain polyphenols in the form of gallic acid, ferulic acid, and quercetin. The research results showed that red-cultivar onions had better antioxidant activity than yellow cultivars. Higher polyphenol and flavonoid content were also associated with higher antioxidant activity (Cheng et al., 2013).

Onions contain vitamins (A, B_1, B_2, C, nicotinic acid, and pantothenic acid) and also essential substances, such as protein, calcium, phosphorus, potassium, Fe, Al, Cu, Zn, Mn, and I. In addition, onions contain phenolic compounds, namely, phenolic acids and flavonoids that can act as natural antioxidants, anti-carcinogens, and anti-microbial agents (Akbudak et al., 2018). The research results showed that yellow cultivars accumulated N, P, K, Mg, Fe, Mn, Zn, Cu, and reducing sugars in much larger quantities than red cultivars. Red cultivars contained sugar and vitamin C in much more significant amounts than yellow cultivars (Jurgiel-Malecka et al., 2015). Therefore, a concentration of 20% onion extract can be recommended to stimulate early flowering in a higher percentage. There was an improvement in the quality of higher yields by regulating the metabolism of amino acids, including proline and indole, and the activity of catalase and hydrogen peroxide in apple flower buds (El-yazal and Rady, 2014).

Based on the literature review previous studies have shown that shallot and garlic extract contained growth-promoting hormones (IAA, GA, and cytokinin) and inhibitors (ABA) of plants, as well as phenolic compounds. The application of shallot and garlic extract at a concentration of 20% positively affected the seed germination of melon, the flower cuttings, and the buds of apples and legumes. However, there was not enough information about the effect of Allium extract on the growth and yield of rice. No study was carried out on the application of shallot, garlic, and onion extracts to examine seed germination, growth, and yield of rice. No type of Allium extract was known that can increase the growth and yield of rice. Therefore, this study aimed to research the application of Allium extract in rice cultivation and to find one of the best types of Allium extract that can stimulate rice growth.

Materials and methods

Study area

The study was conducted from December 2021 to April 2022. The study area was in the greenhouse of the Faculty of Agriculture, Universitas PGRI Yogyakarta, Bantul Regency, Yogyakarta Special Region, Indonesia. The height of the study area was 118 m above sea level (m ASL) and located at the 8°30’-7°20’ South latitude and 109°40’-111°0’ East longitude. During the study period the average air temperature and humidity were 33°C and 60%, respectively.

Materials and tools

The materials used were wooden germination boxes of 50 cm (width) × 80 cm (length) × 20 cm (height), latosol soil, cow manure, urea, and NPK Phonska, polybags in size of 40 cm (width) × 35 cm (height), paper, mica plastic labels, bamboo sticks of 50 cm (height), rice seed variety of Padjajaran Agritan, plastic germination tub with a size of 30 cm (length) × 25 cm (width) × 5 cm (height), water, shallot, garlic, and onion. The equipment used were a hoe, sickle, ruler, Philips Blender HR2115/01, filter paper,

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soil sieve of 2 × 2 cm, pipette volume of 10 mL, plastic bottle volume of 1 L, Erlenmeyer pyrex volume of 500 mL, oven Binder drying oven ED series, ACIS AD-i Series digital analytical balance, manual scales capacity of 30 kg, and grain moisture tester JV-001S.

Experimental design

This study was carried out in two stages of experiments. The first was about seed germination and seedling growth of rice, and the second was about rice growth and yield. The study was a single factor arranged in a complete randomized design (CRD) and three replications. The treatments consisted of four types, i.e., control (without treatment), shallot (*Allium ascalonicum* L.), garlic (*Allium sativum* L.), and onion (*Allium cepa* L.). Each type of Allium extract used a concentration of 20%. In the first experiment, only one sample was used for each repetition so a total of 12 plastic germination baths were needed. While in the second experiment, each test consisted of six samples so in total 72 polybags were needed.

Research procedures

Processing steps of Allium extract at 20% concentration were followed. First, the bulbs with a fresh weight of 100 g was put in a blender, and 200 mL of water was added for extraction. Next, the shallot extract was fed into the Erlenmeyer tube for a centrifuge for 10 min at a speed of 500 rpm. The resulting shallot extract was poured into a measuring cup and added the water up to a volume of 500 mL. After that, the extract was filtered with filter paper. The liquid that escaped from the sieve was used as a phytohormone. Next, the liquid of the solution was fermented for seven days in plastic bottles.

Latosol soil as a planting medium was taken from the top-soil layer at a depth of 0-20 cm. The soil was dredged, then crushed with a hoe to a uniform grain, and filtered with a soil sieve. In the first experiment, the seed germination test required 36 plastic tubs. Each germination plastic tub was filled with 1 kg of soil, and the soil surface was flat. For the second experiment, 90 polybags were needed, each filled with 10 kg of soil. Polybags were placed on a table located inside the greenhouse building. In this study, the Padjajaran Agritan variety was used.

The first experiment was done by randomizing all germination plastic tubs filled with soil. Randomization was carried out at once against all of the treatments. Next, the treatment was labelled by a paper affixed to the outer wall of the germination plastic tub. Randomization was carried out in the second experiment on all polybags with the same method. Next, the treatment was labelled by mica plastic with the help of bamboo sticks. Bamboo sticks were plugged into the center planting medium in the plastic germination tub.

The first experiment was carried out by scattering as many as 20 rice seeds per plastic germination tubs above the soil surface in water-saturated conditions. In total, 240 rice seeds were needed. However, the preparation of the second experiment was carried out in wooden germination boxes filled with a mixture of soil and manure in a ratio of 1:1. As many as 216 rice seeds were stocked over the soil medium in water-saturated conditions. Seedlings ready were planted into polybags at the age of 18 days after sowing (DAS). Rice seedlings that showed uniform growth were selected as planting materials. For the first experiment, the application of Allium extract was as

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much as 2 mL per plastic germination tub applied evenly above the soil surface suitable for the treatment. Each treatment was given simultaneously when stocking seeds. For the second experiment, Allium extract treatment was given twice with a dose of 2 mL polybag^{-1}, namely at planting time and 15 days after planting (DAP). The plant spacing between seedlings in polybags was 25 × 25 cm. A rice seedling was planted in the middle of the soil surface inside the polybag. Seedlings were planted at a depth of 2 cm. Only one seedling was planted in each polybag, so the overall need was as many as 72 rice seedlings.

The water availability in the first experiment was kept in field capacity until 10 DAP. However, in the second experiment, water was always maintained at 2 cm from the soil surface daily at 1-105 DAP. The recommended dose of fertilizer was 225 kg ha^{-1} (or 0.08 g for one-kg soil) urea and 225 kg ha^{-1} (or 0.08 g for one-kg soil) NPK Phonska 15-15-15 for rice cultivation. Fertilization was carried out in two stages. The first application was 40% of the recommended dose at 14 DAP. The second application was as much as 60% of the recommended dose at the age of 35 DAP. Weed control was carried out twice during the study. Pest control was carried out twice during flowering using Dursban pesticides. Rice harvesting was carried out at 105 DAP when the grains matured physiologically (95% turned yellow).

The experiment culture of rice crops with Allium extract application at 105 DAP can be seen in *Figure 1*.

Figure 1. *Photo of rice crops with Allium extract application at 105 DAP*

Measurement and parameter

For the first experiment, the rate and power of germination were observed from the 1st to the 10th day, while the seedling height and dry weight were observed at 10 DAS. Germinated seeds were counted and measured if shoots appeared 2 cm above ground level in a germination plastic tub. The seedling height was calculated from the average of all seedlings that have grown, while the seedlings' dry weight is calculated from all seedlings that have grown per germination plastic tub. For the second experiment, plant growth was observed at 80 DAP, including the tiller number and plant height, while shoot and grain dry weight was observed at 105 DAP. Measurement of rice growth and yield

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was carried out on all samples in each repeat, then the average per clump was calculated. The seedlings and shoots were dried in an oven for 48 h at 80°C or until the dry weight was constant. The grain dry weight was measured using a digital analytical balance after drying under sunlight until it reached a seed moisture content of 14%.

Statistical analysis

Observational data were analyzed by analysis of variance at 5% significance level. To determine the difference between treatments, Duncan's new multiple range test (DMRT) was used at 5% significance level (Gomez and Gomez, 1984).

Results

Effect of Allium extract types on the seed germination and seedling growth

The research results in the first experiment showed that Allium extract types did not significantly affect the rate and power of germination. Still, the treatments affected the seedling height and dry weight. The results of multiple comparisons with DMRT at 5% significance level on seed germination and seedling growth are presented in *Table 1*.

Table 1. *Effect of Allium extracts types on the seed germination and seedling growth at 10 DAS*

Allium extract type	Germination rate	Germination power (%)	Seedling height (cm)	Seedling dry weight (g per germination plastic tub)
Control	3.19 a	98.33 a	4.00 b	0.54 a
Shallot	2.96 a	91.67 a	4.00 b	0.44 b
Garlic	2.93 a	90.00 a	4.33 b	0.47 b
Onion	3.32 a	98.33 a	5.00 a	0.56 a

The number followed by the same character in a column is not significantly different based on DMRT at 5% significant level

Table 1 explains that the Allium extract types did not significantly affect the rate and power of germination. However, the onion extract application could increase the seedling height and greatly differ from shallot and garlic extracts or control. The treatment of shallot and garlic extracts caused the seedling dry weight to be lower than the control and onion. Shallot and garlic extracts application inhibited the rice seedlings growth. For more details, the effect of Allium extract types on the height and dry weight of seedlings are presented in *Figure 2*.

Figure 2a shows that the application of onion extract was effectively stimulating the rice seedlings height. *Figure 2b* shows that applying shallot, garlic, and onion extract were not effectively stimulating the rice seedlings dry weight.

Effect of Allium extract types on the growth and yield of rice

The research results in the second experiment showed that the type of Allium extract did not significantly affect the tiller number and plant height, but it affected the shoot and grain dry weight. The results of multiple comparisons with DMRT at 5% significance level on the growth and yield of rice are presented in *Table 2*.

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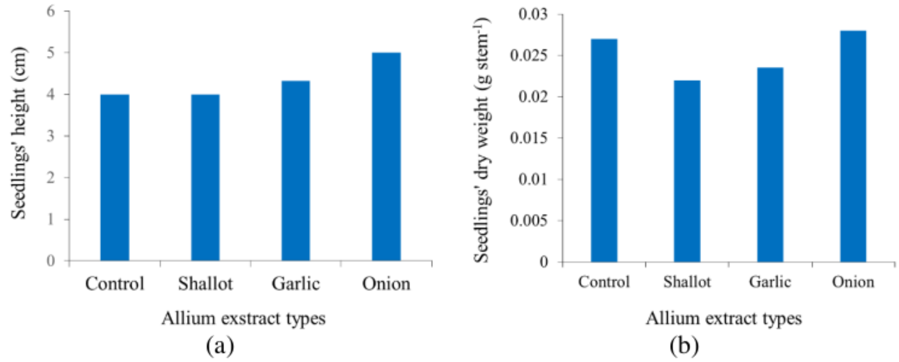

Figure 2. *Application of Allium extract on the seedling height (a) and seedling dry weight (b)*

Table 2. *Effect of Allium extracts types on the growth and yield of rice*

Allium extract type	Tillers number (stem clump^{-1})	Plant height (cm)	Shoot dry weight (g clump^{-1})	Grain dry weight (g clump^{-1})
Control	8.44 a	75.67 a	24.28 b	20.64 b
Shallot	9.78 a	84.22 a	42.89 a	31.10 a
Garlic	10.11 a	75.44 a	27.00 b	22.35 b
Onion	9.11 a	77.67 a	35.61 ab	16.83 b

The number followed by the same character in a column is not significantly different based on DMRT at 5% significant level

Table 2 explains that the Allium extract types could increase the shoot dry weight and be significantly different from the garlic extract, but was not significantly different from the onion extract. On the other hand, the shallot extract application could increase the grain dry weight clump^{-1} and be significantly different from the garlic and onion extract. The effect of Allium extract types on shoot and grain dry weight can be seen in *Figure 3*.

Figure 3a and *b* show that the application of shallot extract gave higher shoot and grain dry weight than other treatments.

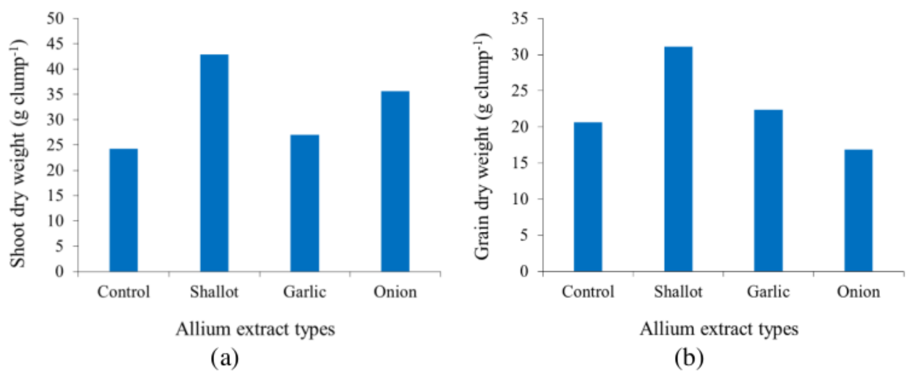

Figure 3. *Application of Allium extract on shoot dry weight (a) and grain dry weight (b)*

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Discussion

Allium extracts have a bad effect on rice seed germination. The application of shallot and garlic extract actually inhibits the rice seedlings dry weight. Shallot and garlic extract contained high phenolic compounds so can interfere with the initiation of seedlings growth. Seed germination was sufficiently stimulated by the PGRs contained in itself. Thus, seed germination did not require additional PGRs from organic material.

The rate germination, power germination, and seedlings height did not require the additional external phytohormones from shallot and garlic extract, but required onion extract. The addition of shallot extract and garlic did not increase the rice seedlings height of rice. Conversely, onion extract can increase the vertical growth of rice seedlings. The application of Allium extract will increase the concentration of IAA in the rice seed and will inhibit it because the content becomes excessive. According to Lee et al. (2022), poor seed germination and inhibition of seedling growth is due to excessive accumulation of IAA.

Shallot and garlic extract contained phytohormones, especially GA. The GA compounds were considered negative regulators of innate immunity in rice crops (Yang et al., 2013). The GA content in rice seeds was enough to support their seed germination. The GA could diffuse into the aleurone layer and initiate signaling synthesizing amylase and other hydrolytic enzymes. Then, hydrolytic enzymes secreted into the endosperm and hydrolyzed food reserves. Next, the hydrolytic enzymes will hydrolyze starch, lipids, hemicellulose proteins, polyphosphates, and other stored materials into simpler forms that are available to the embryo (Ali and Elozeiri, 2017).

Not all types of Allium extracts have a significant effect on rice growth and yield. Garlic and onion extracts were not effective for increasing the dry weight of shoot and grain, while shallot was effective. Adding external phytohormones to the soil media effectively optimized the shoots dry weight. Besides, the shallot extract application could significantly increase the grain dry weight. The content of IAA in shallot could stimulate the growth of rice plants. According to Sopha and Hartanto (2021), shallot bulb tissue contained higher IAA concentrations than leaves and roots.

The IAA is a common auxin form that participates in plant growth and development. The sources of IAA can come from organic material. Shallot bulbs can produce natural hormones, namely IAA. The IAA played a role in stimulating plant growth, such as enlargement, elongation, cell division, affected nucleic acid metabolism, and plant metabolism (Pamungkas and Puspitasari, 2018). Auxin affected some aspects of the plant development (Wang et al., 2018). The use of IAA contained in Allium extract, especially in shallot has a good role in increasing plant growth.

The use of exogenous auxin in the right concentration increased the yield of dry matter of plants (Sosnowski et al., 2023). Therefore, the IAA of shallot can be used to stimulate the growth and yield of rice. However, the shallot extract has been shown to increase rice shoot and grain dry weight more than garlic extract.

Based on the discussion above, it can be affirmed that Allium extract is better used to support plant growth of rice than in nurseries. Shallot bulb extract supports rice growth better than garlic and onion.

Conclusion

The research results and discussion above showed that seedling growth, especially seedlings height in the first time was significantly affected. The shallot and garlic

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extracts decreased the seedling dry weight. The shallot extract can increase rice shoots dry weight. The application of shallot and garlic extract harms seed germination and seedlings growth, except for onion extract. Application of shallot extract could cause the highest grain dry weight clump^{-1}. The study findings show that the shallot and garlic extract harms the seed germination and seedlings growth, but the onion extract does not. However, the shallot is a type of Allium that extract can stimulate rice growth. Therefore, we recommend the shallot extract type for stimulating growth in rice cultivation.

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