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Research Article
Influence of KCl Fertilizer and Trichoderma on the Growth and Yield of Upland Rice

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Abstract

Background and Objective: The rate of population growth is not balanced with the rate of increase in national rice production. The attention of the government and researchers in Southeast Sulawesi on upland rice is still very low, even though the potential for increased upland rice production is quite promising. The research aimed to study the influence of KCl fertilizer and *Trichoderma* spp. on the growth and yield of upland rice. **Materials and Methods:** The study was conducted in a Randomized Block Design (RBD) consisting of 6 treatments i.e.: without KCl fertilizer and *T. asperellum* (K_0), KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1), KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2), KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3), KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4) and KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5) with 4 replication for each treatment. The data obtained were analyzed by analysis of variance (ANOVA) and conducted further tests with the Duncan Multiple Range Test (DMRT) at a 95% confidence level. **Results:** The results of the research revealed KCl fertilizer combination with *T. asperellum* in general, can increase the growth and yield of upland local aromatic red rice. Application of KCl fertilizers as 0.45 g/polybag equivalent to 90 kg ha^{-1} (K_3) can provide optimal potassium nutrients for vegetative growth of upland rice. **Conclusion:** The treatment of KCl fertilizer as 0.45 g/polybag with *T. asperellum* 30 g/polybag (K_3) provides growth and yield of upland rice with an average production of4.95 t ha^{-1}.

Key words: Upland rice, KCl fertilizer, *Trichoderma asperellum*, local aromatic red rice, yield, potassium, nutrient

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice import activities are always carried out by the government to maintain national rice stocks because there are still many regions that have difficulty achieving production targets. The rate of population growth which is not balanced with the rate of increase in national rice production has caused the national rice needs to be unable to be met from national rice production so imports must still be carried out. The attention of the government and researchers in Southeast Sulawesi on upland rice is still very low, even though the potential for increased upland rice production is quite promising because it has a fairly large amount of dry land, which is around 10.620 ha spread across the districts of South Konawe, Bombana, Buton, Muna, North Buton and BauBau. According to Kikuta *et al.*[1], that's upland rice production in Southeast Sulawesi has different among the traditional varieties 1.6 t ha^{-1}, with the highest yield in Undolia variety as 3.6 t ha^{-1} and the lowest yield in Uso as 2.0 t ha^{-1}. The availability of large tracts of land and the community's interest in growing upland rice, especially the aromatic brown rice of the Ungoronu cultivar, is good capital in the future development of upland rice.

The aromatic upland rice is liked by farmers for planting because it has a higher economic value compared to other types of upland rice. The nutritional content is quite high, especially the B and A vitamin content and low glutamic value making it suitable for diabetics is one of the causes of the expensive aromatic brown rice[2]. Some areas in Southeast Sulawesi already have communities that grow upland rice, but traditionally based on their respective local wisdom. Some local upland rice varieties have been planted by the community, but they have not carried out good cultivation, especially fertilizing both odorant and organic fertilizers let alone biological fertilizers. Farmers plant upland rice on land that has been cleared by relying solely on the natural fertility of each land so that productivity is still relatively low[3]. Besides, the cultivation system used by farmers has the potential for the occurrence of shifting farming systems because crop productivity only relies on the natural fertility of the land. If the agricultural land is not fertile then they tend to open new land so that it can cause environmental damage, especially forests.

However, these cultivars still have weaknesses such as the percentage of panicle filled which is still low, i.e. only 50-60% of panicle contains. The problem is thought to be caused by soil nutrient content, especially potassium which is very low. The results of soil analysis at the study site obtained a pH of 5.69 so that the land is classified as acidic land with a relatively low Potassium content. Therefore, the application of KCl fertilizer is considered very important to overcome the number of empty grains in upland rice plants. Another effort that can be done in dealing with the number of empty grains is the use of *Trichoderma* fungus. The specific fungi in the genus *Trichoderma* colonize and penetrate plant root tissues and initiate a series of morphological and biochemical changes in the plant, considered to be part of plant defense response, which in the end lead to induced systemic resistance in the entire plant[4]. According to Khan *et al.*[5], that's *Trichoderma* is well recognized as a biological weapon against different plant pathogens and used as a growth regulator for roots, yield increase, flexibility towards stress and nutrients uptake from soil. According to Sukriming *et al.*[6], inoculation of the fungus accelerates the composting process, improves the physical and chemical properties as well as contributes to the nutrient contents of the compost with indicating are ready for use as organic fertilizer[6].

Based on the problems mentioned above, is the study considered necessary to research by combining KCl fertilizer and *Trichoderma* sp. to overcome the obstacles of upland local rice productivity which is still low due to the high percentage of empty seeds.

MATERIALS AND METHODS

Time and location: The research was conducted in the Experimental Garden of the Faculty of Agriculture, Halu Oleo University, Kendari from March-October, 2018.

Experimental setup: The study was conducted in Randomized Block Design (RBD) consisting of 6 treatments i.e.: without of KCl fertilizer and *T. asperellum* (K_0), KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1), KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2), KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3), KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4) and KCl 0.75 g/polybag+*T. asperellum*10 g/polybag (K_5) with 4 replication for each treatment.

Preparation for planting and seeding media: Topsoil that is used as a planting medium is soil that comes from the district of Anduonohu, the City of Kendari with marginal characteristics. The topsoil is sterilized with hot steam for 3 hrs. After the soil has cooled down, it is put into 10 kg/polybags which are then watered to reach field capacity. The seeds are planted in a plastic tray container with sand media. Before being sown in the container, the seeds are soaked in water for 3 hrs. After the 7 days-old seedlings are transferred to the polybag of 3 plants per polybag and after 2-week-old plants are thinned to only 2 plants that are allowed to grow for good.

Application of *Trichoderma* spp. and KCl fertilizers: The *T. asperellum* was stored at low temperatures in the refrigerator. Before it is used, it must first be refreshed by growing it on the media of Potato Dextrose Agar (PDA). Furthermore, 7 days-old *T. asperellum* fungi isolates were propagated in glutinous rice media. Application of *T. asperellum* was done when the plants are 2 weeks after planting by sowing evenly on the soil surface in a polybag. The application of KCl fertilizer was carried out twice times, namely one week before planting and after the plant and after the plant entered the generative phase.

Maintenance: Plant maintenance includes watering, weeding, controlling pests and diseases. Watering is done twice a day in the morning and evening when there is no rain, weeding is done at any time when there are weeds and controlling pests and diseases are all done manually in a polybag.

Variable observation: The observed variables include; plant height, number of leaves and number of tillers were observed at the age of 60 Days After Planting (DAP), the total number of unhusked rice, number of filled grains and production was calculated at harvest time.

Data analysis: The data obtained were analyzed by analysis of variance (ANOVA) and conducted further tests with the Duncan Multiple Range Test (DMRT) at a 95% confidence level.

RESULTS

Plant height, number of leaves and number of tiller: Plant height, number of leaves and number of tillers are components that can represent the growth of upland rice plants, especially vegetative growth. Based on the results of the analysis of variance, it was found that the treatment of KCl fertilizer combination with *T. asperellum* had a significantly different effect on plant height, the number of leaves and some tillers (Table 1).

The data in Table 1 can be seen that the treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) gives the highest growth in plant height, some leaves and tillers are significantly different from with treatment KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1), KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4) and K_5 in plant height and significantly different from without treatment of KCl fertilizer and *T. asperellum* (K_0), KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1) and KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5) for the number of leaves. The treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) is significantly different from without treatment of KCl fertilizer and *T. asperellum* (K_0) and KCl 0.15 g/polybag+*T. Asperellum* 50 g/polybag (K_1) for the number of tillers. In the plant height parameters, the treatment without treatment of KCl fertilizer and *T. asperellum* (K_0) gave the lowest effect and was significantly different from the other treatments except for KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1) and KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5). In the leaf number parameter, it was seen that the treatment without treatment of KCl fertilizer and *T. asperellum* (K_0) gave the least number of leaves and was significantly different from the other treatments, except for the treatment of KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5). The same thing happened to the number of tillers, where treatment without treatment of KCl fertilizer and *T. asperellum* (K_0) gave the least number of tillers and different from other treatments except KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1), KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2) and KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3).

Number of seed, number of filled seed and yield (t ha^{-1}): The amount of paddy seed, the amount of filled seed and the production of harvested unhusked rice are components of upland rice production which are the production parameters. Based on the ANOVA results, it was found that the treatment of KCl fertilizer and *T. asperellum* combination had a significant influence on the production which included the

Table 1: Effect of *Trichoderma* combination KCl fertilizer on plant height, number of leaves and number of local upland rice tiller

Treatment	Plant height (cm)	Number of leaves	Number of tiller
Without KCl fertilizer and *T. asperellum* (K_0)	98.44^{b}	8.00^{c}	8.00^{c}
KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1)	102.50^{ab}	9.13^{b}	9.13^{b}
KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2)	106.94^{a}	9.60^{ab}	9.60^{ab}
KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3)	108.25^{a}	10.75^{a}	10.75^{a}
KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4)	89.38^{c}	9.61^{ab}	9.61^{ab}
KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5)	97.88^{b}	9.08b^{c}	9.08^{bc}
DRMT 95%	2 = 7.17	2 = 2.14	2 = 21.86
	3 = 7.51	3 = 1.19	3 = 22.91
	4 = 7.73	4 = 1.23	4 = 23.57
	5 = 7.88	5 = 1.25	5 = 24.01
	6 = 7.98	6 = 1.27	6 = 24.34

Numbers followed by unequal letters in the same column differ significantly with the Duncan Multiple Range Test (DMRT) at a 95% confidence level

Table 2: Effect of KCl fertilizer and *Trichoderma* combination on the total number of seed, number of filled seed and yield (t ha^{-1})

Treatment	Total number of seed	Number of filled seed	Yield (t ha^{-1})
Without KCl fertilizer and without *T. asperellum* (K_0)	138.50^{b}	104.50^{c}	3.92^{c}
KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1)	148.75^{ab}	117.63^{b}	4.16^{c}
KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2)	153.13^{ab}	119.00^{b}	4.74^{ab}
KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3)	167.25^{a}	137.50^{a}	4.95^{a}
KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4)	149.38^{ab}	126.25^{ab}	4.81^{ab}
KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5)	145.75^{ab}	128.50^{ab}	4.55^{b}
DMRT 95%	2 = 22.66	2 = 16.95	2 = 0.32
	3 = 23.75	3 = 17.77	3 = 0.34
	4 = 24.43	4 = 18.28	4 = 0.35
	5 = 24.49	5 = 18.62	5 = 0.36
	6 = 25.22	6 = 18.87	6 = 0.36

Numbers followed by unequal letters in the same column differ significantly with the Duncan Multiple Range Test (DMRT) at a 95% confidence level

amount of unhusked rice and the production of unhulled rice. The effect of KCl fertilizer and *T. asperellum* combination can be seen in Table 2.

The data of Table 2, can be seen that the treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) has the highest effect on the amount of seed, but only significantly different from without of KCl fertilizer and without *T. asperellum* (K_0) and not significantly different from KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1), KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2), KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4) and KCl 0.75 g/polybag+*T. asperellum*10 g/polybag (K_5). In the amount of filled seed, it was found that the treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) gave the highest number of filled seed and was significantly different from the without of KCl fertilizer and without *T. asperellum* (K_0), KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1) and KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2), but not significantly different from KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4) and KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5). Likewise, the treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) had the highest effect on the production of dry seed and was significantly different from with the treatment of KCl fertilizer and without *T. asperellum* (K_0), KCl 0.15 g/polybag+*T. asperellum* 50 g/polybag (K_1) and but not significantly different from with the treatment of KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4) and KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5).

The treatment without of KCl fertilizer and without *T. asperellum* (K_0) had the lowest effect on the total number of unhusked rice but it was only significantly different from with treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) and not significantly different from other treatments. The treatment of KCl fertilizer and without *T. asperellum* (K_0) on the amount of grain was obtained the lowest filled seed and significantly different from other treatments. Likewise, it was found that the treatment of KCl fertilizer and without *T. asperellum* (K_0) gave the lowest production and was significantly different from the other treatments except for the treatment of KCl 0.30 g/polybag+*T. asperellum* 40 g/polybag (K_2) and treatment of KCl 0.60 g/polybag+*T. asperellum* 20 g/polybag (K_4).

DISCUSSION

The research conducted on local upland rice plants that were given KCl fertilizer combination with *Trichoderma* showed different responses to each treatment given. The treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) showed an increase in plant response, although the increase in plant response was not always significant (Table 1). Plant growth refers to the irreversible change in the size of a cell, organ, or whole plant. The plant growth can be visualized in terms of increase in length or plant height, stem diameter, the volume of tissue, increase in cell numbers, increase in fresh weight and dry weight, increase in leaf area, leaf weight etc[7]. According to Shoresh *et al.*[8], that host roots colonized by Trichoderma strains enhanced whole-plant tolerance to biotic and abiotic stresses. The enhancement was indicated by increased plant root growth and nutritional status[9] and induced systemic resistance to diseases[10].

The results of observations on the parameters of plant height, number of leaves and number of upland rice tillers showed that the treatment of KCl 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) gave the highest effect compared to other treatments was seems to provide adequate and balanced nutrients. According to Talbott and Zeiger[11], that's plants need nutrients of KCl for regulating stomata opening and closing, osmosis and ionic balance and it also plays a role in photosynthesis. Application of KCl fertilizers as 0.45 g/polybag equivalent to 90 kg ha^{-1} (K_3) can provide optimal potassium nutrients for vegetative growth of upland rice, moreover there is an additional *Trichoderma* as

30 g/polybag capable of increasing other nutrients so that treatment of KCl fertilizers as 0.45 g/polybag equivalent to 90 kg ha^{-1} (K_3) is the best combination of all the treatments that were tried. The *Trichoderma* spp. can colonize plant roots[12], establish symbiotic relationships with a wide range of host plants and promote plant growth and development[8,13]. Several isolates of *Trichoderma* spp. able to produce factors that can encourage plant growth or produce phytohormones such as Indole Acetic Acid (IAA) and similar hormones[14]. Besides, *Trichoderma* sp. able to accelerate the process of decomposition of organic matter and subsequently provide nutrients for pepper plants[15].

The results of observations of the variable number of leaves and leaf area showed that the treatment of KCl fertilizers as 0.45 g/polybag equivalent to 90 kg ha^{-1} (K_3) produced more leaf counts than other treatments. This is because the provision of high KCl can overcome the shortage of Kalim in the study area, where the K_2O content in the research area is classified as very low. The role of K is very important in plant growth because potassium acts as a cofactor for several metabolic enzymes, especially carbohydrate metabolism. It is also known that Kalim's role also can affect the opening and closing of stomata in plants[14]. According to Dobermann and Fairhust[16], when Potassium fertilizer is available, it causes rice plants to grow healthy (wide, long and hard stems), does not fall easily, leaves do not easily roll, carbohydrate translocation becomes good, the root system becomes healthy which causes an increase in absorption nutrient.

Giving *Trichoderma* a less significant response compared to giving KCl to leaf formation. According to Febri *et al.*[17] that's better nutrient uptake will enhance the physiological processes within the rice plants treated with *Trichoderma* spp. leading to good growth performance. Potassium is needed in large quantities, especially during vegetative growth. This is because potassium is needed in division and enlargement which ultimately affects the formation of tillers in rice plants. Potassium is very influential on osmotic potential, water use in plants and is closely related to the formation of organic compounds. Giving high K in plants can reduce the rate of transpiration in plants by controlling the opening and closing of stomata[18].

Observation of rice panicle length showed that the treatment of KCl fertilizer as 0.45 g/polybag with *T. asperellum* 30 g/polybag (K_3) gave the growth in the amount of seed and the number of filled seed was better than the other treatments. The panicle length of plants is usually related to the yield of rice plants where the longer the panicle, the more the total number of unhusked rice. If there is enough photosynthate, the formation of plant organs both vegetative and generative will take place normally. Conversely, if photosynthate availability is limited, then both vegetative and generative growth is relatively late and even limited[18].

The results of observation of the number of rice grain permalai showed that in the treatment of KCl fertilizer 0.45 g/polybag KCl+*T. asperellum* 30 g/polybag (K_3) produced a response to the number of seed per panicles better than other treatments. Zhang *et al.*[19] reported that higher grain yield in the rice plants is because of the improvement in the root growth and shoot growth, which contributes to the remobilization of carbon reserves from vegetative tissues to grains. The role of potassium from KCl is increasingly apparent with the additional contribution of some *Trichoderma rhizosphere*-competent strains that have been shown to have direct effects on plants, increasing their growth potential and nutrient uptake, fertilizer use efficiency, percentage and rate of seed germination and stimulation of plant defenses against biotic and abiotic damage[8].

The availability of adequate nutrients in rice plants, especially the element Potassium can stimulate flower formation and increase the percentage of finished flowers. This happens because, in addition to improving soil structure, plants easily absorb nutrients in the soil and increase nutrient content in the soil. Totok *et al.*[20] state that *Trichoderma* sp. can increase growth and yield due to secondary metabolic production, in the form of phytohormone which can maximize plant growth. Besides, *Trichoderma* spp. is in addition to being able to control pathogenic fungi in the soil, it also can encourage the revitalization phase of plants.

The observations of the weight of 1000 grains of rice showed that the treatment of KCl fertilizer as 0.45 g/polybag with *T. asperellum* 30 g/polybag (K_5), produced an average response of 1000 grains of plant weight which was higher than other treatments. Oosterhuis *et al.*[21] stated that's the element Potassium (K) plays an important role in the formation of yield and quality improvement. According to Lewis and Paparizas[22], that's the weight of 1000 grains is characteristic of varieties. The results of observations on crop production showed that the treatment of KCl 0.75 g/polybag+*T. asperellum* 10 g/polybag (K_5) produced better tonnes per ha crop production compared to other treatments. The expression of genes affecting transport processes in uence plant adaptation to soils with extreme phytoavailabilities of mineral elements[23].

In general, the application of KCl fertilizer and *T. asperellum* can improve the growth and yield of rice plants. The treatment of KCL fertilizer as 0.45 g/polybag with *T. asperellum* 30 g/polybag (K_3) gave the best growth component and amount of seed and the number of filled seed.

CONCLUSION

Application of KCl fertilizers as 0.45 g/polybag equivalent to 90 kg ha^{-1} (K_3) can provide optimal potassium nutrients for vegetative growth of upland rice. Additional *T. asperellum* as 30 g/polybag and KCl fertilizers as 0.45 g/polybag equivalent to 90 kg ha^{-1} (K_3) capable of increasing other nutrients. The result provision of KCl fertilizer and *T. asperellum* can increase the growth and yield of local upland rice. The treatment of KCl fertilizer as 0.45 g/polybag+*T. asperellum* 30 g/polybag (K_3) provides growth and yield of upland rice with an average production of 4.95 t ha^{-1}.

SIGNIFICANCE STATEMENT

This research discovers that's using KCl fertilizer combined with *T. asperellum* increases plant growth and production of local upland red rice. This study will help the researcher to understand the role of KCl fertilizer and *T. asperellum* in the growth and production of local upland red rice. Thus, a new theory that' s the positive and significant effect of the KCl fertilizer and *T. asperellum* combination on the growth and production of local upland red rice.

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