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Nutrient uptake and yield of paddy cultivated under intensification with fish amino acid as liquid organic fertilizer

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Abstract

Rice production in South Kalimantan, Indonesia, is still not optimal and needs to be increased. Increasing rice production can be done with the SRI (System of Rice Intensification) method. One of the needs for rice plant nutrients using the SRI method is by using Fish Amino Acid (FAA). The use of FAA as liquid organic fertilizer in organic rice cultivation has not been widely studied and needs to be developed. Therefore, this study was designed to determine the effect of FAA applications on P, K uptake, and rice productivity. The study was conducted in a greenhouse using a one-factor completely randomized design (CRD) consisting of five treatments, namely 0 (f_0), 1 (f_1), 3 (f_2), 5 (f_3), and 7 (f_4) mL FAA L^{-1}. FAA applications have a significant effect on phosphorus uptake, plant wet weight, dry grain weight, and rice productivity of the SRI method, while the FAA application did not significantly affect potassium uptake, plant dry weight, and weight of 100 grains of rice using the SRI method. The best dose of FAA application on P, K uptake and rice productivity in the SRI method are found in the f_1 treatment (1 mL FAA L^{-1}) which can increase up to 30% dry weight and rice productivity compared to f_0 treatment (control) and able to increase up to 20% phosphorus absorption of rice plants compared to f_0 treatment (control).

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Introduction

Rice is one of the food plants widely cultivated to meet the need for rice as a staple food for most people in Indonesia. Statistics Indonesia (2019) reported that rice production in Indonesia in 2018 was 32.4 million tons, while rice consumption in 2018 reached 29.6 million tons, as the difference reached 2.85 million tons. However, this number will not meet the demand for rice as not all farmers sell their rice to the market. Rice production in Indonesia, especially in South Kalimantan, is still not optimal and needs to be increased. Organic farming systems can be an alternative in the development of rice cultivation; besides being environmentally friendly, they can also support sustainable agriculture. Organic rice agriculture can be applied using the System of Rice Intensification (SRI) method. Using this method is expected to increase rice productivity in South Kalimantan.

The system of rice intensification is a pattern of rice cultivation by changing the management of plants, soil, water, and nutrients. This technique has been proven to increase rice productivity by 50%; even in some places, it can increase rice productivity by more than 100% (Uphoff, 2003). The need for organic fertilizer as a source of nutrients in the SRI method, one of which can use liquid organic fertilizer from fish waste or commonly known as Fish Amino Acid (FAA). Fish amino acid is a liquid organic fertilizer that uses fish waste as its basic ingredients, both inside and outside, leftover from fish processing. In general, the fish waste contains many nutrients, namely nitrogen (N), phosphorus (P), and potassium (K), which are components of organic fertilizers (Hapsari and Welasih, 2011).

Research on the use of fish waste as liquid organic fertilizer is still rarely being conducted. Therefore in this study, fish waste is processed into FAA which is then applied to rice plants using the SRI method. This study is expected to be able to provide information to the public regarding the use of fish waste can be an alternative to liquid organic fertilizer, which contains various important nutrients for plants, such as phosphorus and potassium. According to Kuncoro (2008), phosphorus and potassium are very important for increasing rice production. Phosphorus plays an important role in the formation of starch in rice grains, while potassium strengthens the stems so that the plant does not topple easily. The use of fish waste as liquid organic fertilizer with the application of the SRI method in rice cultivation is expected to be one of the efforts to increase rice production in South Kalimantan in terms of quality and quantity. The purpose of this study is to determine the best dose of FAA application to increase P and K uptake, as well as the yield of rice using the SRI method.

Materials and methods

This research was conducted from January to May 2020 at the Greenhouse of the Agroecotechnology Department, the Soil Laboratory of the Soil Department, and the Integrated Laboratory of the Agroecotechnology Department, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia. This research uses a single factor completely randomized design (CRD). The factor being studied is the dose of FAA (F) which consists of five treatments with five repetitions in order to obtain 25 experimental units. The treatment levels are as follows:

f_0 = 0 mL FAA L^{-1} (control)
f_1 = 1 mL FAA L^{-1}
f_2 = 3 mL FAA L^{-1}
f_3 = 5 mL FAA L^{-1}
f_4 = 7 mL FAA L^{-1}

Fish waste used is as much as 2 kg in the form of all parts of the fish. Fish waste is obtained from fishermen located in Aluh-Aluh Village, Banjar Regency, South Kalimantan, Indonesia.

The soil used is rainfed rice field located in Telok Selong Martapura, Banjar Regency, South Kalimantan, Indonesia. Hoe is used to collect the soil at a depth of 20 cm. The taken soil is as much as 300 kg. Then the soil is dried and then weighed as much as 10 kg.

The materials used are fish waste and brown sugar. Brown sugar serves as a food source for the development of the reforming microorganisms during the fermentation process. The ratio of fish waste and brown sugar is 1:1 without being mixed with water. The way to make the FAA is by mashing and mixing the fish waste and brown sugar evenly, then putting it in a jar, covering it with a cloth, and tying it with a rope. The fish waste that has been put in a jar is fermented for one month in a shady place so that an aerobe fermentation process occurs. After the fermentation process is complete, filtering is carried out to separate solids and liquids so that the FAA is ready to use.

The planting media used is rainfed rice soil as much as 10 kg bucket^{-1}, added with manure as basic fertilizer with a dose of 10 ton ha^{-1} or 45 g bucket^{-1}. The provision of manure is carried out at the beginning as the basic fertilizer by mixing the fertilizer with the soil evenly, then put into a bucket, then mixing with water until the state of the media becomes muddy.

Start with testing the seeds by selecting them using saltwater and one chicken egg, where the salt water will make the egg float on the water. This will make selecting the rice seeds easier. The floating seeds indicate poor seed quality, so they need to be separated, and the seeds that sink are of good quality or pithy. Then the seeds of good quality or pithy are washed using plain water until clean. The seeds are soaked in plain water for 24 hours; this soaking aims to soften the grain husks in order to accelerate germination. The soaked seeds are drained and then ripened for two days to stimulate the seeds to germinate. Preparing the seedling media material with a composition of soil and organic fertilizer in a ratio of 1:1; then putting it in a tray lined with banana leaves at the bottom; afterward, the media is given water until its condition becomes moist. Later, the rice seeds are sown by sprinkling them on the prepared planting media. During sowing, it is important to maintain the dampness of the media to keep the plants fresh.

The seeds used are young seedlings, which are less than 12 days age after sowing when the seedlings, which still have two leaves, are planted solely or one seed per bucket. The planting must be shallow and the roots must be shaped like the letter L with the media condition is not being flooded. SRI flow pattern according to Suswadi and Suharto (2011), where water is in muddy condition during 0-7 days age of the rice after planting; then when the tiller is active until it reaches its maximum age that is 7-41 days after planting; intermittent water supply, five days muddy, five days flooded with a maximum of 3 cm height. Primordia, flowering, and grain filling periods are at the age of 41-90 days after planting. Paddy is flooded with water with a maximum of 3 cm height; then, 10 days before harvest, the field is drained.

The maintenance includes replanting dead plants, and controlling the water and the pests seen on plants. FAA liquid organic fertilizer is used as the main fertilizer which is sprayed through the leaves. The application of FAA is carried out in the vegetative phase, which is done 8 times; that is on days 7th, 14th, 21st, 28th, 35th, 42nd, 49th, and 56th after planting. The spray volume for one application of FAA is 125 mL, which is the result of a calculation from 1 L of FAA that is applied eight times with five repetitions for each treatment, so the spray volume is 25 mL plant^{-1}. Harvesting is carried out at the optimal rice harvest age; it is achieved when 90-95% of the grain in the rice panicles is yellow or golden yellow. Harvesting the rice is done when the plants are at 30-35 days of age after flowering evenly.

Preliminary analysis is carried out in the laboratory to determine the levels of P, K, pH, and organic C in the planting media and FAA used in the research. The observation of nutrient uptake was carried out during the harvest phase. Digestion in plant tissue of P contents used ascorbic acid (Raun *et al.*, 1987), while K contents were determined using the flame photometry method (Juo, 1978). Observation of plant wet weight by weighing all parts of the paddy at harvest, the unit used is g plant^{-1}.

The dry weight of the plant was obtained by drying all parts of the paddy in an oven at 65°C for 48 hours and then weighing (g plant^{-1}). The weight of the dry grain of rice was obtained by drying all of the grain in each experiment using an oven at 65°C for 48 hours and then weighing (g plant^{-1}).

The weight of 100 grains of rice is obtained by selecting 100 grains of rice and then weighing it (g 100 grains^{-1}). To obtain data on rice productivity, the dry grain weight of rice was converted into ton ha^{-1}.

Data were analyzed using GenStat 12th edition to determine the effect of FAA on P and K uptake and yield of paddy. Furthermore, they were tested for homogeneity before being analyzed for variance with the F test at 5% significance levels. When the analysis of variance results showed an effect on the treatment given, it is continued with the Duncan's Multiple Range Test at a 5% significance level (Duncan, 1955).

Results and discussion

Chemical characteristics of FAA and planting media

The pH reaction on FAA is acid. However, the pH value is classified as still according to quality standards (pH 4-9), while the organic C, total N, P, and K in FAA are low (Regulation of The Minister of Agriculture, 2011).

Table 1. Chemical characteristics of FAA and planting media.

No.	Parameter	Fish amino acid (FAA)	Soil + chicken manure (planting media)
1.	Organic C	0.06% (low)	1.43% (low)
2.	Total N	0.02% (low)	0.13% (low)
3.	P_2O_5	0.13% (low)	0.19% (low)
4.	K_2O	0.07% (low)	0.21% (low)
5.	pH (H_2O)	4.91 (acid)	6.11 (neutral)

The paddy fields used in this research were rainfed rice fields. According to Saputra (2016), rainfed rice fields have a low level of soil fertility, with soil pH classified as acid, high Al exchange and high soluble Fe, low cation exchange capacity, organic C, total N, available P, exchangeable Na, and Ca. exchange, which is classified as very low. The explanation above is proven from the results of this research that the content of essential macronutrients (N, P, K) and organic C is relatively low even though it has been mixed with chicken manure. However, the pH of the planting media is categorized as neutral.

The chemical characteristics of FAA and planting media used in this research can be seen in Table 1.

Nutrient uptake

The result of the ANOVA shows that the application of FAA has a significant effect on the phosphorus uptake in plant tissue with the SRI method (Fig. 1a) and has no significant effect on potassium uptake in plant tissue with the SRI method (Fig. 1b). Fig. 1a shows that the treatment that has the best value for phosphorus uptake in plant tissue, the f_1 (1 mL FAA L^{-1}) treatment with a value of 0.41% significantly different from the control and the f_3 (5 mL FAA L^{-1}) treatments, and not significantly different from the f_2 (3 mL FAA L^{-1}) and f_4 (7 mL FAA L^{-1}) treatments. Fig. 1b shows that the treatment that has the best value for potassium uptake in plant tissue is the f_3 (5 mL FAA L^{-1}) treatment with a value of 1.76%, but this treatment is not significantly effective as other treatments. Based on the results of ANOVA test, it is known that the application of FAA with different doses has a significant effect on phosphorus uptake in paddy.

The f_1 treatment is significantly different from the control and the f_3 treatments but not significantly different from the f_2 and the f_4 treatment. The highest phosphorus uptake is found in the f_1 (1 mL FAA L^{-1}) treatment with an uptake average of 0.41% and the lowest nutrient uptake is found in the f_0 (0 mL FAA L^{-1}) treatment with an uptake average of 0.34%.

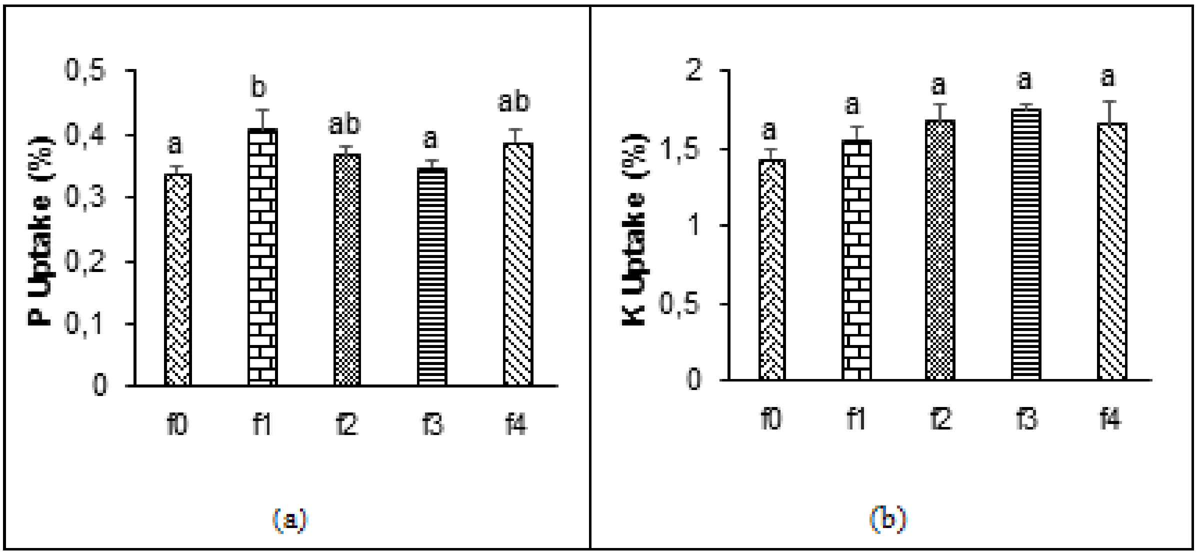

Fig. 1. (a) Phosphorus uptake and (b) potassium uptake under the SRI method applied by FAA.
Note: f_0 = 0 mL FAA L-1, f_1 = 1 mL FAA L-1, f_2 = 3 mL FAA L-1, f_3 = 5 mL FAA L-1, f_4 = 7 mL FAA L-1. The same letter shows no significant difference according to DMRT test at 5% level.

Phosphorus is one of the essential macronutrients for plant growth; phosphorus is needed to produce the energy and the speed of plant growth (Nuryani *et al.,* 2010). The result of the analysis of the chemical properties of phosphorus in FAA is 0.13% and the result of the analysis of the chemical properties of phosphorus in the planting media is 0.19% before being given FAA treatment. The result of the analysis of nutrient uptake in the leaf part of plant tissue in all treatments is classified as high. According to Lukman (2010), the phosphorus status based on the result of the analysis of the phosphorus concentration in the leaves are grouped as follows: <0.05% = very low, 0.05%-<0.10% = low, 0.10%-<0.19% = medium, and >0.19% = high. Based on Lukman (2010), it can be concluded that the application of 1 mL FAA L-1 is able to provide phosphorus for plant tissue.

The increase in phosphorus on paddy with the SRI method is thought to be due to the repeated application of FAA every week during the vegetative process of the plant. Soil pH reactions also affect the availability of phosphorus nutrients in the soil. The result of the pH preliminary analysis on planting media is 6.11 (neutral); the condition of this neutral pH is thought to make the phosphorus nutrient available. According to Erisa *et al.* (2018), phosphorus levels are affected by soil pH. The low soil pH reaction causes Al levels to become high and makes the phosphorus nutrient hard to be absorbed by the plant due to being bound by Al, while the phosphorus nutrient on high pH is not available due to being bound by Ca ions. Another thought is that leaf sampling for the phosphorus analysis of plant tissue is carried out at the maximum vegetative period. It is suspected that during this period, the phosphorus content is increased. This causes the phosphorus content in plant tissue to be relatively high. Delin and Zhu (1996) mentioned that rice plants, in general, have the largest phosphorus nutrient uptake from the tillering stage to the extending stage (plant vegetative period).

According to Hairuddin and Edial (2019), plants will grow if the nutrients needed by the plants are available in sufficient condition. The application of more than 1 mL FAA L-1 has an effect that is not as good as that applied with 1 mL FAA L-1. This is suspected due to the dose of FAA in high or excessive concentrations will inhibit and be toxic to the plants. FAA that undergoes evaporation before being successfully absorbed by the plants also causes the produced phosphorus nutrient uptake to be different. Hairuddin and Edial (2019) said that liquid organic fertilizer application at the optimum amount would stimulate the activity and the division of cells in merismatic tissue, thus affecting plant growth. The high phosphorus uptake in the treatment is caused by the contribution of phosphorus to the content of FAA and planting media, as well as direct uptake through the stomata due to spraying FAA on the leaves.

Based on the results of the ANOVA test, it is known that the application of FAA with different doses does not have a significant effect on potassium uptake in paddy. The highest potassium uptake is found in the f_3 (5 mL FAA L^{-1}) treatment with an uptake average of 1.76% and the lowest nutrient uptake is found in the f_0 (0 mL FAA L^{-1}) treatment with an uptake average of 1.44%. It is suspected that the potassium requirement of rice plants is the same at the time of leaf sampling for plant tissue analysis; one of the functions of potassium is to increase the photosynthesis process.

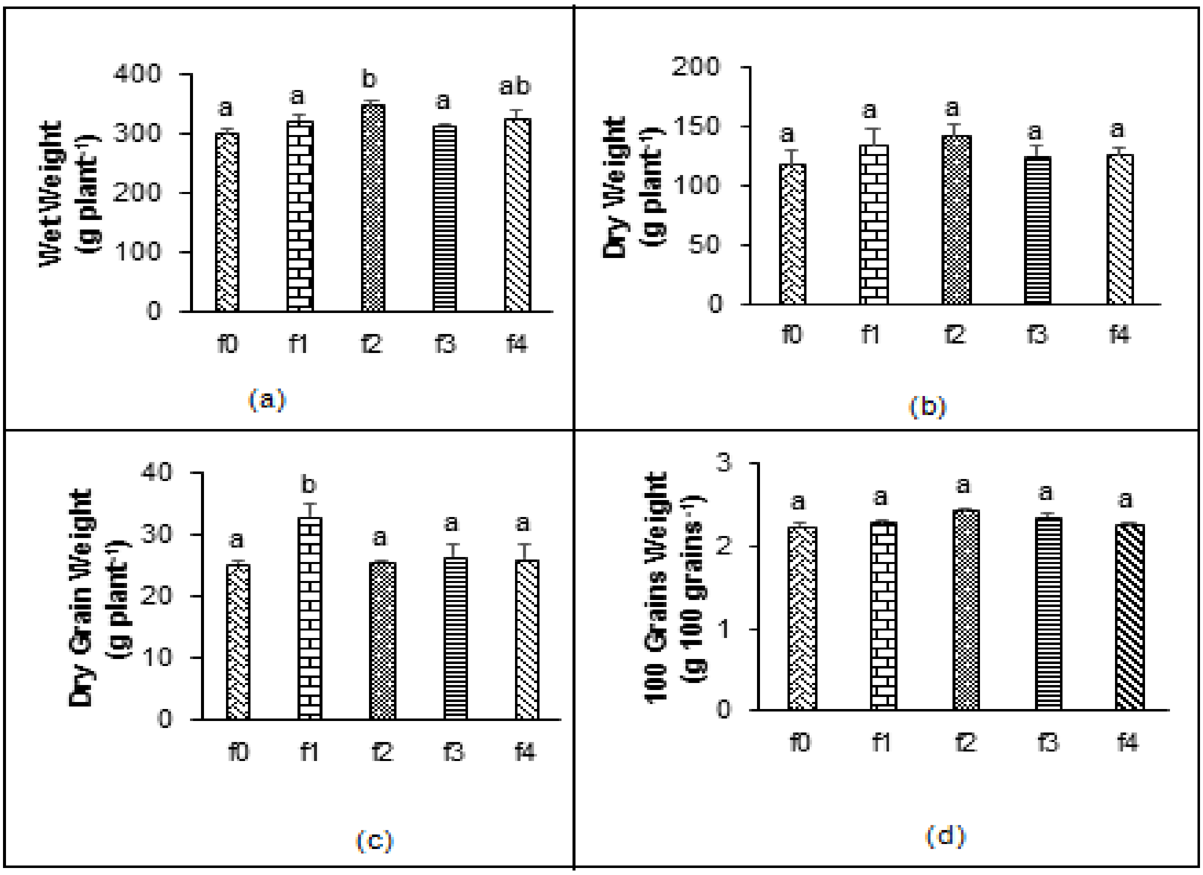

Fig. 2. (a) Wet weight, (b) dry weight, (c) dry grain weight, and (d) 100 grains of rice weight under the SRI method applied by FAA.

Note: f_0 = 0 mL FAA L^{-1}, f_1 = 1 mL FAA L^{-1}, f_2 = 3 mL FAA L^{-1}, f_3 = 5 mL FAA L^{-1}, f_4 = 7 mL FAA L^{-1}. The same letter shows no significant difference according to DMRT test at 5% level.

According to Apriliani *et al.* (2016), the leaf is a crop organ where the photosynthesis process takes place and the leaves produced by the crop that are fertilized with potassium will increase the crop's capacity to produce photosynthates. Potassium is an essential nutrient that crops need in large amounts. Potassium plays an important role in determining the quality of agricultural products in terms of composition and physical appearance (Subandi, 2013). The main function of potassium is to strengthen crop bodies such as leaves, flowers, and fruits so they will not fall off easily (Lepongbulan *et al.*, 2017). The result of the analysis in the FAA is 0.07% and in planting media before giving the treatment is 0.21%. The potassium nutrient that is absorbed by paddy is a contribution from the FAA and the media, where all treatments show that potassium uptake is not significantly different.

This is presumably because the dose of FAA given is not much difference between treatments. According to Hidayati *et al.* (2018), the roots of paddy in SRI cultivation are significantly longer and heavier than conventional methods. This is because the moisture and the well-aerated soil in the SRI method have a major impact on root growth and root viability and eventually also affect plant growth. The SRI method also increases the number of root hairs by 60% and makes it healthier and stronger compared to conventional methods. Soil moisture and wide spacing in rice cultivation with the SRI method make the roots thrive and develop optimally. According to Omwenga *et al.* (2014), the SRI method uses a wider spacing than conventional planting methods. This implies that there is no competition for nutrients between seedlings, for each crop has a larger area in which the crop will absorb nutrients from all directions.

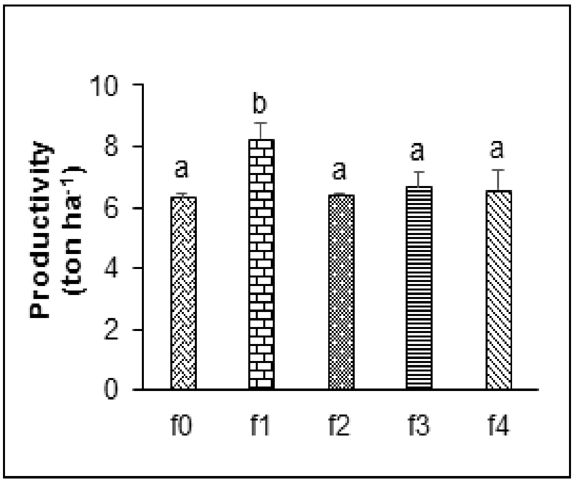

Fig. 3. Rice productivity under the SRI method applied by FAA.

Yield of paddy

The result of the ANOVA shows that the application of FAA has an effect on wet weight in paddy (Fig. 2a), does not affect the dry weight of paddy (Fig. 2b), has an effect on dry grain weight (Fig. 2c), and does not affect the weight of 100 grains of rice with SRI method (Fig. 2d).

Fig. 2a shows that the f_2 (3 mL FAA L^{-1}) treatment has the highest wet weight of paddy that is 349.92 g $plant^{-1}$, different from the control, the f_1 (1 mL FAA L^{-1}) and the f_3 (5 mL FAA L^{-1}) treatments, but not different from f_4 (7 mL FAA L^{-1}) treatment. Fig. 2b shows that the f_2 (3 mL FAA L^{-1}) treatment has the highest dry weight of paddy which is 142.88 g $plant^{-1}$, but not different from other treatments. Fig. 2c shows that the f_1 (1 mL FAA L^{-1}) treatment has the highest dry grain weight that, is 33.08 g $plant^{-1}$ different from the control, the f_2 (3 mL FAA L^{-1}), the f_3 (5 mL FAA L^{-1}), and the f_4 (7 mL FAA L^{-1}) treatments. Fig. 2d shows that the f_2 (3 mL FAA L^{-1}) treatment has the highest 100 grains of rice weight which is 2.44 g $plant^{-1}$, but not different from other treatments.

Based on the results of the ANOVA test, it is known that the application of FAA with different doses has a significant effect on wet weight in paddy. The f_2 treatment is significantly different from the control, the f_1, and the f_3 treatments but not significantly different from the f_4 treatment. The highest wet weight is found in the f_2 (3 mL FAA L^{-1}) treatment with a weighted average of 349.92 g $plant^{-1}$ and the lowest wet weight is in the f_0 (0 mL FAA L^{-1}) treatment with a weighted average of 302.05 g $plant^{-1}$. The control treatment shows the lowest wet weight of paddy, although it was not significantly different from several treatments.

The wet weight of the paddy is obtained from the total weight of the paddy that is still fresh after being harvested and weighed immediately before it wilts due to water loss. The response of paddy to the application of FAA resulted in the highest wet weight at the f_2 (3 mL FAA L^{-1}) treatment. This is because the application of FAA can stimulate the metabolism of paddy. In addition to other nutrients that play an important role, especially phosphorus and potassium which play a role in stimulating the meristem tissue division, root growth, and leaf development. The level of absorption of nutrients and water is up to its optimum limit which is useful for cell division, extension, and differentiation. Potassium plays a role in regulating, closing, and opening stomata which control the plant transpiration and increase the reduction of carbon dioxide, which is then converted into carbohydrates. Phosphorus and potassium elements and other nutrient elements in FAA will increase the photosynthesis activity of plants so than increasing the carbohydrate production as alternative food (Parman, 2007). According to Priyanka *et al.* (2019), the assimilation and the uptake of nitrogen, potassium, phosphorus, and micronutrients which consist of the fish amino acid (FAA), through spraying on the leaves will increase the process of metabolism and cell division, so to produce a higher plant, the more amount of leaves, the more chlorophyll content for increasing the photosynthesis process.

Dry weight shows the biomass produced by the paddy from the photosynthesis process during plant growth. Based on the results of the ANOVA test, it is known that the application of FAA with different doses does not have a significant effect on the dry weight of the paddy. The highest dry weight is found in the f_2 (3 mL FAA L^{-1}) treatment with a weighted average of 142.88 g $plant^{-1}$ and the lowest dry weight is in the f_0 (0 mL FAA L^{-1}) treatment with a weighted average of 119.29 g $plant^{-1}$.

The nutrient uptake in the 3 mL of FAA treatment is thought to be more optimal for paddy so that the plant growth can develop well due to an increase in plant weight. This is in accordance with Hidayah *et al.* (2016) that the increase in the stem weight, the number of leaves and stems, and the stem length is caused by the response of the paddy given fertilizer, making the absorption of the nutrient given goes faster.

Fish amino acid contributes phosphorus nutrient which is responded well by paddy, seen from the response of paddy without the (control) treatment has the lowest crop dry weight compared to the treatment given FAA although not significantly different in all treatments. According to Hidayah *et al.* (2016), the application of phosphorus fertilizer can affect the biomass of plants. If phosphorus nutrient is sufficient, then the root growth will develop better. Phosphorus also functions in respiration, photosynthesis, metabolism, stimulates growth rate, and can increase the number of tillers of paddy, resulting in an increase in the plant weight.

Based on the result of the ANOVA test, there is a significant effect on the wet weight of paddy but does not have a significant effect on the crop dry weight. The wet and dry weight of a plant is affected by the availability of sufficient N nutrients to help increase plant growth like height growth and leaf formation (Wijiyanti *et al.*, 2019). The wet and dry weight are all parts of the paddy; if the plant is getting denser, accordingly, the crop's wet and dry weight will also increase. The dry weight which is not significantly different is indicating that the accumulation of organic compounds that are successfully synthesized by the plant is the same between treatments. According to Kusumaningrum *et al.* (2007), the small number of leaves and size causes the product of photosynthesis that is produced as the component of the plant to below. In accordance with Wijiyanti *et al.* (2019), who said that the result of dry weight is the balance between photosynthesis and respiration. If the respiration is bigger than the photosynthesis of the crop, then the dry weight will be decreased.

Based on the results of the ANOVA test, it is known that the application of FAA with different doses has a significant effect on dry grain weight in paddy. The f_1 treatment is significantly different from the control and other treatments. The highest dry weight is found in the f_1 (1 mL FAA L^{-1}) treatment with a weighted average of 33.08 g $plant^{-1}$ and the lowest dry weight is in the f_0 (0 mL FAA L^{-1}) treatment with a weighted average of 25.34 g $plant^{-1}$.

The treatment without the application of FAA (control) shows the lowest dry, although it was not significantly different from other treatments. This is because the application of FAA contributes nutrients and is responded well by the crop so that it can increase the yield of paddy. According to Bustami *et al.* (2012), plant growth and production will reach optimum if the growth-supporting factors are in optimal condition, such as nutrients needed by the plant, especially phosphorus and potassium, which are in optimum condition and available for the plant as well as other additional macronutrients. Besides that, one of the successes of the SRI method is the addition of organic matter which can improve the physical, chemical, and biological properties of the soil. According to Weinert *et al.* (2014), fish amino acid increases nutrient availability and increases the yield of plants while maintaining the water quality, maximizing the nutrient uptake by leaves and roots, and minimizing the nutrient loss due to leaching.

One of the applications of SRI rice cultivation is the use of young seeds which aims to avoid the competition between the crop roots that can inhibit crop growth so that grain production can become optimal. In accordance with Usman *et al.* (2014), a younger age of transplanting will avoid seedling stagnation in the field due to the transfer of seed (transplanting) and is also an effort to optimize paddy to achieve exponential or doubled tiller growth. The more productive tillers of paddy, the more panicles, and dry grain will be produced. According to Omwenga *et al.* (2014), the synergistic effect of young seedlings is seen in tiller formation, panicle length, and percentage of grain filling. This leads to higher yields. The transplantation of young seedlings induces higher tiller production at an early stage; with the increasing age of the planting rice seedlings, the emergence will be inhibited.

Based on the results of the ANOVA test, it is known that the application of FAA in rice cultivation with the SRI method on different doses does not have a significant effect on 100 grains of rice. The highest weight is found in the f_2 (3 mL FAA L^{-1}) treatment with a weighted average of 2.44 g and the lowest weight is in the f_0 (0 mL FAA L^{-1}) treatment with a weighted average of 2.26 g. 100 grains weight is determined by the size of the grain which can increase its weight.

According to Setyowati *et al.* (2018), the weight of 100 grains is usually a stable feature of an accession; the skin size determines the grain size, and the weight is determined by the grain size. However, the grain size itself has been determined during the emergence of the panicle, so that the development of grain filling is in accordance with the predetermined grain size, and the weight of 100 grains of pithy also describes the quality of the rice crop itself. In accordance with Usman *et al.* (2014), the ongoing development of crops such as grain filling is determined by the netto photosynthates after the needs for growth are met and the temperature is supported, as well as the presence of the right enzyme system involved during the differentiation.

The application of FAA in paddy with the SRI method does not have a significant effect in all treatments on the weight of 100 grains. This is thought to be caused by genetic factors that affect the shape and size of the seeds, making the weight of 100 grains to be almost the same. According to Dunggulo *et al.* (2017), the weight of the seeds is depended on the number of dry materials contained in the seeds. Those dry materials are obtained from the result of photosynthesis which then can be used for the seed filling.

The result of the ANOVA shows that the application of FAA has a significant effect on rice productivity with the SRI method (Fig. 3). The highest rice productivity is found in the f_1 (1 mL FAA L^{-1}) treatment is 8.27 ton ha^{-1} which significantly different from the control and the f_2, the f_3, dan the f_4 treatments.

Based on the results of the ANOVA test, it is known that the application of FAA with different doses has a significant effect on rice productivity. The f_1 treatment is significantly different from the control and other treatments. The highest productivity is found in the f_1 (1 mL FAA L^{-1}) treatment with a weighted average of 8.27 ton ha^{-1} and the lowest productivity is in the f_0 (0 mL FAA L^{-1}) treatment with a weighted average of 6.33 ton ha^{-1}. The treatment without the application of FAA shows the lowest amount, although it was not significantly different from other treatments. Fish amino acid is a nutrient supplier for rice growth with the SRI method, where the 1 mL FAA treatment alone is able to produce the highest productivity. Jumar *et al.* (2021) strengthened the results of the study above that the application of FAA with a dose of 1 mL of FAA L^{-1} was able to increase the number of rice tillers using the SRI method. According to Hapsari and Welasih (2011), fish waste consists of various nutrients like phosphorus and potassium which are the components of organic fertilizers to meet the nutritional needs of plants.

This research uses Situ Patenggang Variety of rice which has the weight average result of 4.6 ton ha^{-1} and it can potentially reach 6.0 ton ha^{-1}. In the f_1 treatment, the productivity, if converted into ton ha^{-1}, reaches 8.27 ton ha^{-1}. It means that it has exceeded the potential yield in general. This is presumably because the cultivation using the SRI method is more focused on better plant growth conditions, especially in the root zone. In accordance with Kurniadiningsih and Legowo (2012), the application of the SRI method in rice farming provides favorable economic benefits, such as increased farm production per hectare per growing season. The use of chicken manure as base fertilizer also has an effect on increasing the yield of rice. The application of chicken manure can increase the pH value of the soil and can also bind the solubility of Al and Fe in the soil with organic materials, making the availability of P element in the soil increase. In line with Saputra and Sari (2021), the chicken manure treatment with doses of 10 ton ha^{-1} can increase rice productivity in tidal and peatland. The increase in production generally occurs because of the existence of more rice tillers. The plentiful tillers, cause the formed productive tillers to be plentiful too, which then allows for a higher yield of grains as well. In accordance with Lhendup *et al.* (2009), a better root system will result in bigger and healthier crops, more tillers in one seedling, and eventually a big harvest for the farmers. There is nothing magical about SRI, nevertheless more output with less input. Therefore, SRI is a good rice production resource conservation technique for the farmers, the consumers, and the environment.

Conclusion

There is an effect of the fish amino acid application on phosphorus uptake, wet weight, dry grain weight, and rice productivity. The f_1 (1 mL FAA L^{-1}) treatment is the best treatment and is able to increase up to 20% phosphorus uptake of rice crop compared to control, and is able to increase up to 30% dry grain weight and rice productivity compared to control. The f_2 (3 mL FAA L^{-1}) treatment is the best treatment with the 8% increase of 100 grains weight compared to control. The f_3 (5 mL FAA L^{-1}) treatment is able to increase up to 16% of crop wet weight compared to control, while the highest potassium uptake is shown by the f_3 (5 mL FAA L^{-1}) treatment with the higher 20% increase of P uptake compared to control.

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