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Effect of humic acid on growth and yield of Tadong upland rice

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ABSTRACT

Malaysia imports 35% of rice to meet local demand. To meet local demands, rice production must be increased by using sufficient chemical fertilizers. However, the cost of chemical fertilizers rises yearly. Thus, efforts are being made to increase rice productivity while using less chemical fertilizer. The study aimed to investigate the effect of humic acid on Tadong upland rice growth and yield offer the use of chemical fertilizers (nitrogen (N), phosphorus (P), and potassium (K)). The experiment was laid out in a completely randomized design with five replications. The application of different concentrations (2-8 g/mL) of human acid (HA) with half of the recommended NPK (30:15:15) was studied. It is found that using 2 g/mL HA with half of the recommended NPK led to a higher flag leaf length and grain yield per pot. Therefore, HA at 2 g/mL with half of the recommended NPK can produce better vegetative growth and yield of Tadong upland rice. Also, it can reduce chemical fertilizer usage in rice cultivation.

Keywords: upland rice; humic acid; vegetative growth; yield; chemical fertilizer

1. INTRODUCTION

The world's largest food crop, rice, meets millions of people's daily caloric demands. However, the increasing population leads to a growing need for food worldwide. Plant nutrition is one of the most crucial elements influencing agricultural quality and output. Currently, the world population increased from 7.5 billion people in 2019 to approximately 7.9 billion people in 2022.

Because of the low rice self-sufficiency level (SSL) of Malaysia and the ability of local production of rice to meet only 70% of the national domestic requirements, Malaysia relies on imports to fulfill its increasing local demand (Rahim et al., 2017). In 2017, Vietnam and Thailand supplied over 80% of the rice imported into Malaysia with a total volume of 630,000 tons (USDA, 2018). Cambodia, India, and Pakistan are also major rice exporters to Malaysia. Consequently, efforts are needed to increase paddy yields to achieve the SSL target and reduce dependence on paddy imports.

Soil provides water and mineral nutrients to plants. But, poor or problematic soil leads to poor plant growth and performance. Soil amendments, such as compost, can be employed to improve soil fertility. However, the collateral damage of using compost to cure the soil is the release of contaminants or the bioaccumulation of dangerous metals. According to Iwegbue et al. (2007), the repeated application of organic amendments can enhance the yield and soil properties, but may also increase contamination. Although heavy metals are naturally present in the soil, increasing heavy metals is detrimental to plants and soil, and the heavy metals in soil inhibit the soil microorganism abundance and activities.

Therefore, the effect of humic acid was investigated in this study. Humic acid (HA) is an organic compound naturally formed during the decomposition of organic matter by animals and plants. It acts as a chelating agent or chelator possessing excellent binding properties. It can be integrated with other soil amendments in paddy and other plants. HA can chelate the nutrient compounds, especially iron, to their available form suitable for plant nutrient uptake, optimize the nutrient supply for a plant, and increase the yield to 70% while reducing the use of fertilizers and pesticides to 30% (Eshwar et al., 2017; Saha et al., 2013; Sivakumar et al., 2007; Turkmen et al., 2004). Thus, HA is a promising alternative natural resource that can increase crop production, improve soil health, and function as a growth stimulant (Suwardi and Wijaya, 2013). However, there is still a lack of knowledge on using HA for upland rice production in Malaysia. Therefore, this study aimsed to determine the best HA concentration for the vegetative growth of Tadong upland rice on a planting medium consisting of 75% Silabukan soil with 25% dairy farm effluent (DFE) compost.

2. MATERIALS AND METHODS

2.1 Materials

The seed used in the study was the Tadong upland rice variety. HA was purchased from Heilongjiang Jiahe Humic Acid Co., Ltd. (China). Thirty plastic pots with a height of 35 cm and a diameter of 30 cm were used as the planting pots. The planting medium consisted of Silabukan soil mixed with DFE in the ratio of 3:1 obtained from the Universiti Malaysia Sabah Compost House.

2.2 Experimental design, planting, and treatment

There were six treatments and five replications in this study. The treatments were T1 (positive control) with nitrogen: phosphorus: potassium (NPK) ratio of 60:30:30, T6 (negative control) with NPK ratio of 30:15:15, T2 with NPK (30:15:15) and 2 g/mL HA, T3 with NPK (30:15:15) and 4 g/mL HA, T3 with NPK (30:15:15) and 6 g/mL HA, and T4 with NPK (30:15:15) and 8 g/mL HA. The experiment was laid out in a completely randomized design with a planting distance of 30 cm × 30 cm. Each pot was planted with one seedling. For each treatment, 200 mL of HA was applied once a month for four months. The chemical fertilizers (urea, triple superphosphate, and muriate of potash) were applied during the vegetative growth two weeks after transplanting. During five months, the growth data were collected every week after transplanting. The rice was harvested after reaching a physiological stage where about 80 to 90% of the spikelet matured.

2.3 Data collection

The measured growth parameters were plant height, the number of leaves, flag leaf length, panicle length, number of tillers, percentage of productive tillers, and phenology. In addition, the recorded yield component parameters were the number of panicles per hill, number of filled grains, number of empty grains, percentage of filled grains per panicle, 1000-grain weight, and yield per pot.

2.4 Statistical analysis of collected data

The collected data were subjected to a one-way analysis of variance (ANOVA) using the SAS® University Edition software. The least significant difference test at 0.05 level of probability was used to compare the means when ANOVA showed the significant treatment effects of this study.

3. RESULTS AND DISCUSSION

3.1 Effect of HA on the vegetative growth of Tadong upland rice

The growth data were analyzed in week 16. One-way ANOVA was conducted using SAS to analyze the effect of the HA concentration on the vegetative growth of Tadong upland rice (Table 1). Statistical analysis revealed that there was no significant difference ($p>0.05$) between the HA concentrations on the plant height (Table 1). T5 (NPK + 8 g/mL HA) had the highest mean plant height, 140.2 cm. In contrast, T6 (negative control, NPK 30:15:15) had the lowest mean plant height. HA can act as a plant growth promoter, such as auxin and cytokinin, increasing the shoot length (Maulana et al., 2008). The plant height increased due to the greater availability of nutrients (Sivakumar et al., 2007). Therefore, HA improved soil fertility by the increased cation exchange capacity, thereby increasing plant nutrient availability.

Based on the results, there was a significant difference among the different HA concentrations in the mean number of leaves ($p<0.05$) (Table 1). The highest mean number of leaves was 57.0 observed in T5 (8 g/mL HA), while the lowest was 41.8 observed in T3 (4 g/mL HA). Regardless of the HA concentration, the number of leaves was comparable to the control treatment, except for that of T5, which was higher. The number of leaves increased at 6 and 8 g/mL HA application. This result is in good agreement with Sivakumar et al. (2007) that the number of leaves per plant was significantly affected by HA due to the improvement of micro and macronutrient uptake. Therefore, T5 showed the highest mean number of leaves, as it received the highest doses of HA (8 g/mL).

No significant difference in the mean flag leaf length of Tadong upland rice was observed ($p>0.05$). The highest mean flag leaf length was 34.7 cm in T2 (2 g/mL HA). Meanwhile, the lowest flag leaf length was 26.0 cm in T1 (positive control) (Table 1). The weight of a thousand grains, the weight of the grains per panicle, and other yield-related factors are connected to the size of the flag leaf in rice (Wang et al., 2016). The improved flag leaf traits can improve grain yield (Rahman et al., 2018). There was also no significant difference in the panicle length of Tadong upland rice ($p>0.05$). The panicle length increased with applying up to 4 g/mL HA only. However, this result is inconsistent with those obtained by Saha et al. (2013), where a significant difference was observed in panicle length.

No significant difference between the HA concentrations in the mean number of tillers of Tadong upland rice was observed ($p>0.05$). The result showed a marginal increase in the mean number of tillers with the increasing dosage of HA application (Table 1). However, the changes were relatively small. This result is in good agreement with the findings of Saha et al. (2013), where the number of tillers was not significantly affected by the HA application. There was no significant difference between the HA concentrations in the percentage of productive tillers ($p>0.05$). The highest and the lowest percentage of productive tiller was 93.54% and 83.96%, observed in T3 and T5, respectively (Table 1). The tiller indirectly contributes to making the plant adaptable to various environments. While the tillers are young and actively growing, the nutrients from their photosynthesis can be transferred to other plant sections to promote growth. The nutrients, such as N, P, and K, retained in dying tiller tissues are consumed by the living tillers to maximize their potential yield. All the tillers that grow contribute to the grain yield (Saito et al., 2006).

Table 1. Effect of HA on the vegetative growth of Tadong upland rice

Treatment	Plant height (cm)	No. of leaves	Flag leaf length (cm)	Panicle length (cm)	No. of tillers	Productive tillers (%)	Chlorophyll content (SPAD)
T1	137.3	43.8^{a}	26.0	29.5	17.0	93.10	26.60^{ab}
T2	134.5	50.00^{ab}	34.7	29.9	15.0	86.13	23.46^{c}
T3	137.0	41.80^{b}	26.5	31.2	14.5	93.54	27.32^{a}
T4	139.5	51.80^{ab}	34.4	29.2	15.2	92.77	27.26^{a}
T5	140.2	57.00^{a}	26.2	26.5	15.6	83.96	23.40^{c}
T6	130.3	45.60^{b}	27.7	31.8	15.7	87.47	25.78^{ab}

Note: Means with the same letter are not significantly different ($p<0.05$).

The statistical analysis showed a significant difference between the HA concentrations in the chlorophyll content of Tadong upland rice ($p<0.05$) (Table 1). The highest mean chlorophyll content was 27.32 in T3, whereas the lowest mean chlorophyll content was 23.4 in T5. The lowest and the highest HA concentrations used in this trial, 2 and 8 g/mL, significantly lower chlorophyll contents, compared to the positive and negative controls. Thus, HA application, regardless of concentration, does not influence the chlorophyll content.

As the plant reaches maturity, leaf senescence increases. The capacity and efficiency of photosynthetic energy conversion are diminished due to the loss of chlorophyll and the disintegration of the photosynthetic apparatus during leaf senescence (Weng et al., 2005; Zhang et al., 2006). The chlorophyll depletion and yellowing of the leaves are distinctive indices of the senescence of the leaves. In addition, a common parameter for assessing the deterioration of the photosynthetic system in leaves during senescence is the chlorophyll content. The low chlorophyll content in T2 may be due to the low irradiance due to shading by the leaves. From the observations, T2 had a higher number of leaves, compared to that of T3, which resulted in a dense plant canopy. This caused shading and reduced light interception. The low chlorophyll content in T5 may be due to the HA inhibition effect on chlorophyll biosynthesis. The inhibition of chlorophyll biosynthesis stimulates the chlorophyll degradation pathway, reducing chlorophyll accumulation and photosynthesis, thus decreasing the total plant growth (Yang et al., 2002).

Regarding phenology, the tillers started to appear 11 days after transplanting (DAT) when 3 to 4 leaves formed. The tiller formation began at the base of the plant and appeared as the secondary shoots. Tillers emerged from within the seedling leaves on the main shoot. The 50% booting occurred at 71 DAT and the panicle emergence began at 73 DAT. The booting is characterized by the bulging of the stem concealing the developing panicle. The 50% heading occurred at 76 DAT when 50% panicle was exerted from the rice stem. At the same time, anthesis was observed on the same day. At 83 DAT, the panicle was 100% exerted.

3.2 Effect of HA on yield and yield components of Tadong upland rice

The statistical analysis revealed no significant difference between the HA concentrations in the number of panicles in Tadong upland rice ($p>0.05$). The highest number of panicles was 16.6, observed in T1 (positive control), whereas the lowest number of panicles was 13.8, observed in both T2 and T5. The results showed no significant effect of HA on the number of panicles (Table 2). The rice plants transition from vegetative to reproductive growth at a critical developmental stage, known as panicle differentiation. This is connected to the yield (Ikeda et al., 2010). The higher number of panicles contributes to a better crop yield.

No significant difference between the HA concentrations in the percentage of unfilled grains was observed ($p>0.05$) (Table 2). The highest percentage of unfilled grain was 12.91%, observed in the treatment applied with 2 g/mL HA. The lowest percentage of unfilled grain was 6.74%, followed by the treatment applied with 4 g/mL HA. The grain filling is theoretically the final stage of rice growth when fertilized ovaries turn into caryopses. The unfilled grains can be due to the late tillering, initiation, and flowering or cold temperature.

Table 2. Effect of HA on the yield and the yield components of Tadong upland rice

Treatment	Unfilled grains (%)	Filled grains (%)	Number of panicles	1000-grain weight (g)	Yield per pot (g/m^2)
T1	9.38	90.67	16.6	38.60	51.00
T2	12.91	87.09	13.8	36.05	65.75
T3	6.74	93.26	14.6	34.64	58.82
T4	8.88	91.12	15.0	37.87	54.31
T5	7.25	92.75	13.8	38.41	62.15
T6	7.04	92.95	16.0	37.19	54.49

Note: Means with the same letter are not significantly different ($p<0.05$).

When a plant produces many tillers, the maturity of the panicles is inconsistent, which declines the quality of the harvested grain. Because of the shade caused by the dense stands, the tillers may not even grow or die before they can generate a panicle. The plants shading themselves inside a thick canopy tend to have longer leaves and less tillering. Besides, the shading results in less effective panicles and filled grains by reducing the tiller number and increasing the percentage of degenerated spikelets (Yao et al., 2000).

The metabolic processes of rice plants, especially photosynthesis and respiration, are impaired by copper deficiency. It can contribute to a decrease in pollen viability and an increase in the sterility of spikelets, thereby producing more unfilled grains. HA has a high affinity and capacity to form a stable chelate with metal ions, thereby reducing metals bioavailability. The major binding groups in HA are carboxylic groups and phenolic-OH (Gondar et al., 2006; Garcia, 2006); therefore, applying HA in the soil can retain the availability of Cd, Pb, Cu, and Zn, minimizing plant uptake (Rong et al., 2020).

Table 2 also showed no significant difference between the HA concentrations in the percentage of filled grains ($p>0.05$). T3 showed the highest percentage of filled grains, but it was not significantly different from the other treatments. The percentage of the filled grains observed in T3 was 93.26%, while the lowest obtained value was 87.09% in T2. The percentage of filled grains was highly affected by the number of empty or unfilled grains, where T2 had a higher number of unfilled grains than T3.

Starch builds up during filling the grains. Almost 80-90% of the final dry weight of an unpolished grain of rice is made up of starch. The grain filling is affected by water stress (Olaetxea et al*.,* 2016). HA may improve nutrient and water uptake, reduce plant water stress, and increase grain filling yield. Additionally, the number of empty grains or a cold environment during pollen generation can impact the percentage of filled grains per panicle. High temperatures during flowering can dry out the pollen tube that is germination, resulting in blanking.

The statistical analysis showed no significant difference between the HA concentrations in the 1000-grain weight. The highest grain weight was 38.60 g recorded in T1. The lowest grain weight was 34.64 g recorded in T3 (Table 2). The number of filled grains, the number of spikelets, the density, and the length of the panicle were the other major yield factors, along with the 1000-grain weight. The factor affecting 1000-grain weight is the size of rice plant seeds. The grain size (length and width) and the grain filling are positively correlated with 1000-grain weight (Kato, 2010). The grain-filling can be affected by the flag leaf, providing a source of photosynthates to grains during the grain-filling process. This result is supported by Rahman et al. (2018), where non-significant variation has been observed in the 1000-grain weight of rice. However, Saha et al. (2013) reported that the application of HA influences 1000-grain weight. Interestingly, the results of this experiment showed a higher grain weight than those of the previous study. The highest 1000-grain weight produced in the previous study was 20.16 g obtained by applying 6 L/ha HA (Saha et al., 2013), which is lower than 34.64 g obtained by 4 g/mL HA in this study.

No significant difference between HA concentrations in the yield per pot was observed ($p>0.05$). T2 produced the highest grain yield per pot, which was 65.75 g/m^2, whereas, the lowest grain yield per pot was 51 g/m^2 produced in T1 (positive control). Increasing the concentration of HA application to 6 g/mL resulted in decreasing the grain yield per pot (Table 2). The grain yield is affected by 1000-grain weight. Kato (2010) reported that the grain length, width, and filling affect 1000-grain weight. In addition, the large panicles reduce the number of panicles, poor grain filling percentage, and taller plants. Plants with larger panicles have superior canopy structures for light absorption and produce fewer tillers. The grain yield is also affected by the flag leaf since it is closer to the panicle and acts as the main source of photosynthates supply. Li et al. (1998) found that the size of the flag leaf contributed to the number of grains and yield. Rahman et al*.* (2018) excised the flag leaf at the base from the heading stage until maturity, resulting in late maturation, decaying, shrunken, reduced grain size, increased sterility, and reduced panicle length. Furthermore, the number of tillers per plant, number of filled grains per panicle, and 1000-grain weight also influenced the grain yield (Osman et al*.,* 2012).

4. CONCLUSION

The results presented in this study indicated that HA at different concentrations had a mixed effect on the Tadong upland rice growth and yield. HA application at the concentration of 4 g/mL increased the chlorophyll content. The application of 8 g/mL HA produced the highest number of leaves. Applying 2 g/mL HA produced the highest flag leaf length. For the yield component, 4 g/mL HA resulted in the highest percentage of filled grain, percentage of productive tillers, and reduced percentage of unfilled grains. The highest yield per pot was obtained with 2 g/mL HA. Based on the grain yield, the best treatment was 2 g/mL HA, because it produced the highest yield per pot (65.75 g/m^2) and the flag leaf length (34.7 cm). Therefore, HA at the concentration of 2 g/mL with half of the recommended NPK can be used to obtain a higher rice yield. Increasing the concentration beyond 2 g/mL HA reduces the yield.

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