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Effects of the sludge application at different concentrations on growth and production of rice (*Oryza sativa* L.) using a water channel underneath soil surface

UNIVERSIDAD NACIONAL DE COLOMBIA

Efectos de la aplicación de lodos a diferentes concentraciones sobre el crecimiento y producción de arroz (*Oryza sativa* L.) utilizando un canal de agua establecido por debajo de la superficie del suelo

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ABSTRACT

Keywords:
Aerobic
Anaerobic
Sludge
Rice
Water channel

Indonesia's strategies are focus on improving food production using environmentally-friendly measures in its agricultural development. This research was designed in accordance with the national strategies on increasing the productivity of rice using efficient water while reducing methane emissions from rice fields. A low rice yield is obtained when the conventional anaerobic methods (flooded soil) are used. Additional to the water, sludge from palm oil factories was also applied. This research aimed to establish a proper concentration of sludge to increase the productivity of rice sown in aerobic condition with the water level at 5 cm below soil surface. The study was conducted by making experiments with 5 levels. Waste sludge from palm oil factories was applied on the soils tested with concentrations of 0 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1}, 20 t ha^{-1} and 25 t ha^{-1}. Height of the plant, total number of tillers, number of productive tillers, number of filled grains, percentage of filled grains, weight of 1000 grains and weight of filled grain per plot were studied. Application of 25 t ha^{-1} organic sludge showed a high level of productivity increasing the total number of tillers, the number of productive tillers and weight of filled grain per plot.

RESUMEN

Palabras clave:
Aerobio
Anaerobio
Lodo
Arroz
Canal de agua

Las estrategias de Indonesia para desarrollar su agricultura se centran en mejorar la producción utilizando medidas respetuosas con el medio ambiente. Esta investigación fue diseñada de acuerdo con las estrategias nacionales para incrementar la productividad del arroz y un uso eficiente del agua mientras se reducen las emisiones de metano de los cultivos de arroz. El bajo rendimiento de arroz en los campos que emplean métodos convencionales se debe al suelo inundado (anaerobio). Además del uso eficiente del agua, también se aplicaron lodos residuales de las fábricas de aceite de palma. Esta investigación tiene como objetivo establecer una concentración adecuada de lodos para aumentar la productividad del arroz cultivado en condición aeróbica con el nivel de agua a 5 cm por debajo de la superficie del suelo. Se realizaron experimentos con 5 niveles. Los tratamientos que se probaron involucraron aplicación de lodos residuales de fábricas de aceite de palma con concentraciones de 0 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1}, 20 t ha^{-1} and 25 t ha^{-1}. Parámetros como la altura de la planta, número total de retoños, número de retoños productivos, número de granos llenos, porcentaje de granos llenos, peso de 1000 granos y peso de arroz molido seco fueron estudiados. La aplicación de 25 t ha^{-1} de lodos orgánicos mostró un alto nivel de productividad al incrementar el número total de retoños, el número de retoños productivos y el peso del arroz molido seco.

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Rice is a vital commodity in Indonesia as it is a basic food in the people diet. Food security in this country is highly dependent on the availability of this grain. Indonesia's population is in continuous growth, which implies to improve the rice productivity otherwise, the rice supply will be adversely affected. Currently, Indonesia is importing to meet its own rice supply. As a mandatory action, innovative cultivation techniques of rice must be considered to reduce the dependence on the other countries (Wardani *et al*., 2019).

Indonesia's strategy to improve the national agriculture is to incorporate a cleaner production considering the environmental issues. This strategy adopted by Indonesian government must be accompanied with efficient use of water as well as reduction of methane emission from rice fields (Leimona *et al*., 2015). Other measures include the use of organic fertilizers (Amjad *et al*., 2016).

Sludge is the waste of processes from wastewater treatment, which in this case is from palm oil factories. The process of waste treatment in palm oil factories consists in decomposition by bacterias. The bacterias can break down molecules and transform complex chemical structures into simpler ones and accelerate the absorption of nutrition in plants (Widiastuti *et al*., 2019). The sludge is stored in a waste pool and can be recommended for use as an organic fertilizer (Khairuddin *et al*., 2016).

Sludge derived from wastes of palm oil factories can be used as compost due to its humus and trace element contents. Application of sludge in soils can improve its fertile. Sludge taken from an anaerobic pool contains elements of nitrogen (0.047%), calcium (0.111%), phosphorus (0.004%), carbon (0.016%), magnesium (0.09%), and potassium (0.161%). Meanwhile, an aerobic pool contains elements of nitrogen (0.041%), calcium (0.145%), phosphorus (0.003%), carbon (0.012%), magnesium (0.083%) and potassium (0.131%). Fertilizers that have solidified from the liquid waste can be a supplement of an organic fertilizers and at the same time are environmentally friendly (Dwi *et al*., 2009). Pandapotan *et al*. (2017) evaluated the use of these sludge in an Ultisol. They found that a concentration of 21.25 t ha^{-1} can increase pH level of soil, C-organic, and the presence of phosphorus can improve its absorption in plants and the growth of the corn.

This research aimed to establish a proper concentration of sludge to increase the productivity of rice in aerobic using a water channel at 5 cm below soil surface.

MATERIALS AND METHODS

The research was conducted in rice fields of Parent Seed Center Institution in Padang Marpoyan, Pekanbaru city, Riau province, Indonesia. It has a temperature between 27–34 °C, is wet and has flat topography. This study brings together the previous research that was done in the field from June until October 2019.

The sludge chemical characterization indicated a total nitrogen 750 mg L^{-1}, phosphorus 18 mg L^{-1}, potassium 2,270 mg L^{-1}, magnesium 615 mg L^{-1} , calcium 439 mg L^{-1}, boron 7.6 mg L^{-1}, iron 46.5 mg L^{-1}, manganese 2.0 mg L^{-1} copper 0.89 mg L^{-1} and zinc 2.3 mg L^{-1} (Lang, 2007).

Preparation of experiment field

The experiment field was carried out in a muddy soil by and was prepared by a semi-mechanical method using tractor and manual work. The soil was broken down into smaller particles and was flooded with water about 21 days removing weed completely. The land was set up according to research plan setting the height of water at 5 cm below the soil surface with 2 m interval between channels.

Dosage treatment of organic sludge fertilizer

According to the 5 different levels of organic sludge from waste of palm oil factories, 15 squares (3 m^2 each) were prepared in the fields with 3 replications. G0=0 t ha^{-1}; G1=10 t ha^{-1}; G2=15 t ha^{-1}; G3=20 t ha^{-1}; G4=25 t ha^{-1} were the five levels evaluated.

Preparation of seeds and seed bed

Batang Piaman was the only variety of rice seeds used in the research, which is known for its great adaptability in low altitude areas. Seed bed was set up close to the experiment fields with an area of 5 m^2, 0.5 kg of compost was spread at 1 t ha^{-1}. It was kept in moisture conditions before the seedlings were sown. The seedling were soaked in water for 2 days before planting. The floating seeds indicated bad quality and were discarded while ones that sank were used. The seeds were then cleaned and dried before they were sown and distributed evenly on the seed bed.

Planting seeds

The seedlings were transferred at 12 days after sowing, which were carefully removed to avoid to damage the roots. Then, these were planted in their respective plots about 2 cm deep. They were sown at 25 cm distance resulting 48 seedlings in each square.

Maintenance of rice plants

Weed control was performed twice at 20 days after planting (DAP) and at 40 DAP. Using a single application during planting phase of Curater 3G (17 kg ha^{-1}) pests were prevented.

The irrigation management was planned to keep the depth of the water channels at 5 cm below soil surface with 2 m between channels (Figure 1). The level of water in the channels remained stable under soil surface because the inlet and outlet sluice gate were conditioned.

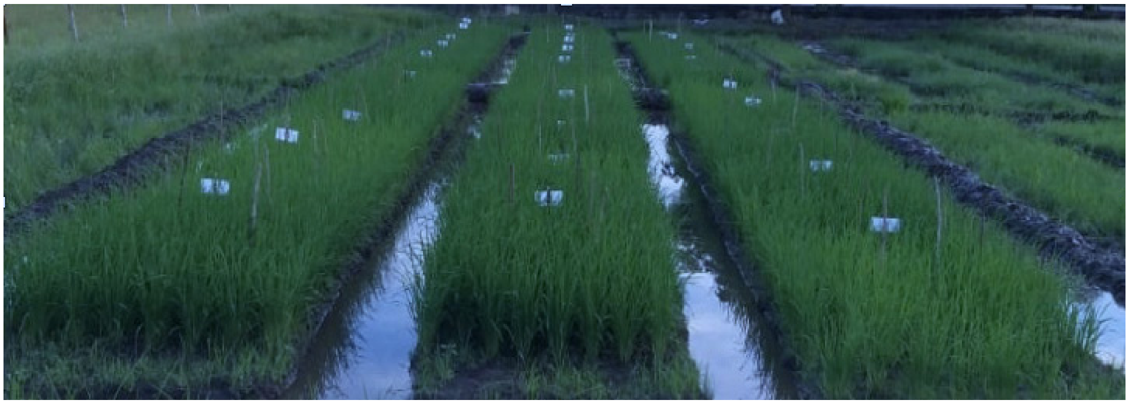

Figure 1. Rice crop in field. Water channels set at 5 cm below ground surface.

The fields were drained upon entering the ripening of seedlings, which was about 2 weeks before harvesting stage.

Harvesting stage

When almost all of the rice turned yellow (80%) was the criteria used to harvest. It was carried out in each plot. Every treatment was done in triplicated i.e, each treatment had 3 plots.

After harvesting was concluded, filled grains were dried for 3 days or until the water content was less than 14%, then were weighed and analyzed.

Parameters of observation

- The height of plant was established by measuring the length of the plant from the surface of soil to the farthest tip of leaf. The measuring was taken once at the end of the vegetative phase.
- Total number of tillers; every stem in each unit of experiment was counted.
- Number of productive tillers: each tiller that produces panicles at harvesting time for each sample.
- The age of plant in each unit of experiment was carried out during harvesting time. It was done by counting the total number of growing days from the planting time to harvesting time.
- Number of filled grains per panicle was counted along with the counting of rice production from the same sample in each plot.
- Weight of 1000 grains (g) was done together with the counting of rice production. The weight of 1000 grains had approximately 14% water content. The sample was taken from every unit in the experiment.
- Weight of filled grain per plot with approximately 14% water content (kg).

Statistical analysis

Results were expressed as mean±standard deviation of three repetitions. The assays were compared by using one-way analysis of variance (ANOVA), followed by Duncans New Multiple Range Test post-hoc test, with statistical significance (P<0.05). All statistical analyses were performed using IBM SPSS software.

RESULTS AND DISCUSSION

Application of organic sludge in different concentrations had an effect on the total number of tiller and productive tiller but it did not affect the height and age of the rice plants (P<0.05) (Table 1).

Application of 25 t ha^{-1} of organic sludge showed the highest plant height (116.45 cm); however, there was not significant differences with the other concentrations of organic sludge. The height of Batang Piaman variety was not affected by different concentrations of sludge fertilizer. This is probably because the fertility level of the soil is the same, causing few changes on the plant development. The characteristics of the lowland rice plant height of the Batang Piaman variety are not influenced by the relatively small differences in soil environment. Plant height could differ if the plant is planted in environments with different properties.The difference in soil environment caused by the treatment of various doses of organic sludge fertilizer can not significantly affect the growth of plant height because the different doses of organic sludge fertilizer applied do not cause significant changes in the soil environment. According to Huang *et al.* (1996) the genetic factor of Batang Piaman rice controls the height when the differences in the soil environment are not wide; the rice plants usually have 4-6 vertical nodes whose height is highly influenced by the qualitative gene and quantitative portrait loci. Also, Sasaki *et al.* (2002) stated that the length of internodes in rice plant is controlled by a gene that is expressed in every node, meaning that the lengthening of rice stem is coordinated in every node.

Table 1. Effects of the few changes on the plant development on height of plant, number of total tillers, number of productive tillers and harvesting age.

Concentration of organic sludge (t ha^{-1})	Height of plant (cm)	Number of total tillers	Number of productive tillers	Harvest age (days after planting)
0	115.84 a	22.76 d	10.93 b	106.66 a
10	115.94 a	23.60 cd	10.86 b	106.33 a
15	115.33 a	24.53 bc	11.66 b	105.66 a
20	116.20 a	25.20 b	13.26 ab	106.00 a
25	116.45 a	27.10 a	15.26 a	106.00 a
CV(%)	15.62	17.25	18.34	15.26

Numbers followed by the same lower case in the same column were not significantly different based on Duncan's New Multiple Range Test at 95% confidence level.

Application of 25 t ha^{-1} of organic sludge produced the highest number of tillers (27.10) and the highest number of productive tillers (15.26), which was different from the other treatments, being 25 t ha^{-1} the highest concentration. Organic sludge contains trace elements of nitrogen, calcium, phosphorus, carbon, magnesium, and potassium, all necessary components to improve the soil fertility. Macro elements found in sludge of palm oil factories can increase the number of productive tillers when these macro-elements are proportionately applied. The rise in the number of tillers after the use of organic sludge at 25 t ha^{-1}, showed that trace elements contribute to metabolism process, especially calcium which activates a number of enzymes in the process (Maryam and Amiri, 2014). The formation of tillers is influenced by the availability of nitrogen element. This substance is important given that stimulates their growth. In addition, nitrogen plays a crucial role in the vegetative growth as well as in the formation of productive tillers. Phosphorus-trace element is essential in rice plant particularly in its initial stage of growth. During this phase, phosphorus stimulates the formation of roots and multiplication of roots and tillers. Element phosphorus is fundamental in the growth of plants. This element supports plants in their flowering stage (De Groot *et al.*, 2003). According to Enstone *et al.* (2003), a plant will grow well when all the necessary elements are available in enough quantities and in a state that can be absorbed by the plant itself.

Applying organic sludge in different concentrations did not affect the harvesting time of rice plant. The harvesting period is influenced more by genetic factors rather than different environments (different concentrations of organic sludge). This also supports that the Batang Piaman rice takes between 105-117 days to harvest (Indonesian Agency for Agricultural Research and Development, 2003). Also, Islam *et al.* (2015) support this statament that heritability value of the harvesting stage of rice plants is 81.81, which is classified as high and indicates that the harvesting age is more determined by genetic rather than environment.

According to Table 2, application of organic sludge in different concentrations impacted the parameter of quantity of filled grains in each tiller and grain yield from each plot but it did not affect the percentage of filled grains and the weight of 1000 grains (P<0.05).

Table 2. Effects of the sludge applications at different concentrations on number of filled grains in each tiller, weight of 1000 grains and grain yield in each plot.

Concentration of organic sludge (t ha^{-1})	Number of filled grains in each panicles	Percentage of filled grains (%)	Weight of 1000 grains per plot (g)	Weight of filled grain per plot (kg)
0	102.62 c	81.29 a	26.82 a	2.40 c
10	103.04 c	84.54 a	27.04 a	2.88 bc
15	113.38 b	84.59 a	26.95 a	3.25 b
20	115.31 b	86.13 a	27.77 a	3.45 ab
25	125.69 a	88.89 a	27.45 a	3.99 a
CV(%)	18.87	15.68	16.05	19.45

Numbers followed by the same lower case in the same column were not significantly different based on Duncan's New Multiple Range Test at 95% confidence level.

The highest number of filled grains from each tiller resulting using 25 t ha^{-1} of organic sludge was 125.69 grains, which was different from other treatments. Filled grains are derived from a compound of assimilates resulting from the photosynthesis process that must be supported by the availability of trace elements in soil. These trace elements such as nitrogen, calcium, phosphorus, carbon, magnesium, and potassium come from organic sludge.

Trace elements contained in organic sludge work simultaneously to form the higher filled grains from each tiller. Nitrogen synthesizes amino acid and protein in the rice plant. Phosphorus transports the results of metabolism process in the plant stimulating the flowering and pollination processes and the formation of roots and seeds. Potassium participates in the process of photosynthesis, transporting the results of assimilation process, enzymes and minerals including water. Calcium plays a role in the arrangement of chlorophyll, which is needed by enzymes in the metabolism of carbohydrate, and strengthen meristem cells. In the meantime, magnesium is a major component in the buildup of chlorophyll, which determines the speed of photosynthesis/ formation of carbohydrate runs as well as transporting Phosphate (Tränkner *et al.*, 2018).

Different concentrations of organic sludge did not impact the percentage of filled grains in each tiller in the rice plants. The content of filled grains is determined by the result of photosynthesis (carbohydrate) in the stem and leaves which is then transferred and deposited inside the grains. It means, the percentage of filled grains did not show a response regard to the environment of the soil but it was heavily influenced by genetic factors. Manalu *et al.* (2017) stated that the score of the percentage filled grains is 70.6 (high) indicating a dominant influence by genetic factors rather than environmental factors.

The different concentrations of organic sludge did not show significant impact on the weight of 1000 grains. It was not influenced by environmental factors but more readily affected by genetic factors. This is in accordance to characteristic of Batang Piaman rice, in which the weight of 1000 grains is less than 27 g (Indonesian Agency for Agricultural Research and Development, 2003). Fan *et al.* (2006) reported that the weight of 1000 grains were mainly controlled by the Quantitative Trait Loci (QTL). Dou *et al.* (2016) further expressed that the weight characteristic of 1000 grains was influenced by each variety.

Application organic sludge at 25 t ha^{-1} resulted heavier in weight of filled grain per plot (3.99 kg) compared to the other treatments. The higher yield in each plot was due to some supporting factors such as the total number of tillers, number of productive tillers and number of grains for each tiller, which showed a high number applying 25 t ha^{-1} of organic sludge. According to Amjad (2016), to find the accurate portion of fertilizer, the concentration should establish based on the amount of trace element available in soil; therefore, the growth of rice plant could be optimal.

CONCLUSIONS

Based on the data, different doses of organic sludge fertilizer affected the total number of productive tillers and the productive ones, number of filled grains and seed weight in each plot. In general, the total number of tillers and the productive ones, number of filled grains and weight of seeds in each plot is proportional to the increase in the various doses of organic sludge fertilizer. The higher doses of the sludge, the higher increase in the total number of tillers and the productive ones, number of filled grains, and seed weight in each plot. The 25 t ha^{-1} of organic sludge fertilizer could increase the seed weight by 66.25% compared to that with no organic sludge fertilizer added.

Based on the result of the research, the researchers suggest that the cultivation of rice plant can develop in fields where the water channel is at 5 cm below soil surface using organic sludge at 25 t ha^{-1}. For future research, it is recommended to increase the doses of organic sludge fertilizer, in order to obtain optimal yields using different rice varieties in dissimilar soil environments.

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