JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 7 NO. 2 May 2025

DOI :https://doi.org/10.36378/juatika.v7i2.4229
eissn 2656-1727
pissn 2684-785X
pages : 398 – 407

RESEARCH ARTICLE Open Access

Increasing the Growth of Upland Rice (*Oryza sativa* L.) on Ultisol Soil with the Provision of Solid Compost and Boiler Ash

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Abstract

Rice (*Oryza sativa* L.) is the primary food commodity for 98.86% of the Indonesian population. To meet national demand, rice production can be enhanced through the extensification and intensification of podzolic land using soil conditioners such as solid compost and oil palm boiler ash. This study aims to determine the interaction between solid compost and oil palm boiler ash, assess the effect of each treatment, and identify the optimal doses of solid compost and oil palm boiler ash for the growth and yield of upland rice cultivated in podzolic soil. The research was conducted using a factorial, completely randomized design (CRD). Factor I, solid compost, included the following treatments: 0 g per polybag (0 $t.ha^{-1}$), 12.5 g per polybag (2.5 $t.ha^{-1}$), 25 g per polybag (5 $t.ha^{-1}$), and 37.5 g per polybag (7.5 $t.ha^{-1}$). Factor II, boiler ash, comprised the following treatments: 0 g per polybag (0 $t.ha^{-1}$), 5 g per polybag (1 $t.ha^{-1}$), 10 g per polybag (2 $t.ha^{-1}$), and 15 g per polybag (3 $t.ha^{-1}$). The results indicated that a solid compost dose of 7.5 $t.ha^{-1}$ produced the best growth across all observed parameters. Additionally, a boiler ash dose of 2 $t.ha^{-1}$ was optimal for increasing the number of productive tillers, the number of whole grains per panicle, and the weight of dry milled grain per polybag. Conversely, a boiler ash dose of 3 $t.ha^{-1}$ was most effective in enhancing plant height, the maximum number of tillers, panicle emergence age, harvest age, the percentage of full grains, and the weight of 100 full grains.

Keywords: Oil Palm Boiler Ash, Podsolic Soil, Soil Fertility, Solid Compost, Upland Rice

1. Introduction

Rice (*Oryza sativa* L.) is a plant that produces a primary food ingredient: rice. According to the Center for Agricultural Data & Information Systems (2023), 98.86% of the Indonesian population consumes rice as a staple food. This statistic highlights the growing demand for rice in Indonesia, driven by the increasing population.

The total national rice requirement for 2024 is projected to reach 31.21 million tons (Agricultural Data & Information System Center, 2024), while national rice production is expected to be only 30.62 million tons (Central Statistics Agency, 2025). To address this shortfall, the Government plans to import rice; however, such import activities may lead to economic losses for the country. According to Jiuhardi (2023), importing rice will diminish foreign exchange reserves as the country incurs higher import expenses, negatively impacting local rice prices. The solution that can be done to meet national rice needs is to increase rice production through extensification and intensification. Extensification in increasing rice production can be done by utilizing sub-optimal land. Podzolic soil is included in sub-optimal land, and its existence is widespread in various regions of Indonesia. According to Aditya & Wijayanti (2023), podzolic soil has an area of 45,794,000 ha, 25% of Indonesia's total land area. Regarding area, podzolic soil has high potential and can be utilized in developing food crop cultivation systems. Still, the utilization of podzolic soil as a plant growth medium is less than optimal. According to Hasibuan & Syafriadiman (2020), in general, podzolic soil has low permeability, poor aggregate stability, low organic matter content, low base saturation, and a pH that is classified as very acidic to acidic (4.2 - 4.8) with limited nutrient content.

The quality of podzolic soil can be improved by intensification, namely by enhancing cultivation techniques

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through soil conditioners. Using soil conditioners can improve the fertility of podzolic soil by utilizing oil palm agricultural waste such as solids and boiler ash. It reported that composted solids had a pH of 6.66 with a C-organic content of 9.25% and nutrients N 1.43%, P 0.45%, and K 0.24%. Solids also have the potential to be used as organic fertilizers that can fertilize the soil because they contain microbes such as Aspergillus niger, Aspergillus fimigatus, Cellvibrio sp, Pseudomonas sp, and Micrococcus sp.

Using boiler ash also can potentially increase the fertility of low podzolic soil. Boiler ash has a nutrient content of N 0.84%, P 4.12%, K 2.94%, Ca 4.33%, and Mg 3.41%, with a basic pH of 10.10, which can reduce the acidity of podzolic soil.

Previous studies have shown that solid and oil palm boiler ash can potentially increase plant growth. Sholeha et al. (2023) reported that solid organic fertilizer from oil palm waste significantly increased the weight of 1000 grains of rainfed rice plants compared to no treatment. The dose that gave the best results was 22% ash plus 124 g of solid organic fertilizer per plot. Furthermore, the results of research by Hutauruk & Zega (2023) showed that boiler ash at a dose of 90 g per polybag increased plant height and number of leaves 8 weeks after planting (MST), leaf area, stem diameter, cob length, cob diameter, cob weight with husks, cob weight without husks and air-dried straw weight of corn plants significantly compared to no treatment on podzolic soil. Although the two studies above show that both solid and boiler ash have the potential to increase plant growth and yield, there have not been many studies that combine the two as a joint treatment, especially in upland rice plants planted on podzolic soil.

The Riau Agricultural Technology Assessment Center (2019) issued a recommendation for upland rice fertilization technology on dry land by providing soil conditioners in the form of dolomite as much as 2 tons/ha, organic fertilizer 2.5 tons/ha and inorganic fertilizers N (Urea) 250 kg/ha, P (TSP) 200 kg/ha and K (KCl) 150 kg/ha. These fertilization recommendations can increase productivity from 2.8 - 3.2 tons/ha to 4.2 - 5.2 tons/ha. Based on the description above, the utilization of solid palm oil waste and boiler ash is expected to increase the growth and yield of upland rice plants on podzolic soil, so this study aims to determine the interaction between solid compost and palm oil boiler ash and the effect of each treatment, as well as to obtain the best dose of solid compost and palm oil boiler ash on the growth and yield of upland rice (*Oryza sativa* L.) on podzolic medium.

2. Material and Methods

This research was conducted at the Screen House of the Faculty of Agriculture, University of Riau, Bina Widya Campus KM 12.5, Simpang Baru Village, Tampan District, Pekanbaru City with coordinates 0°28'51.8 "N 101°22'43.7"E, and was conducted at the Soil Science Laboratory, Faculty of Agriculture, University of Riau with coordinates 0°28'46.9"N 101°22'40.3"E. The research was conducted at an altitude of ± 15-16 meters above sea level (asl) for five months from July 2024 to November 2024.

The materials used in this study were upland rice seeds of Inpago 12 Agritan variety, podzolic subsoil from Batu Belah Village, Kampar Regency, Riau Province, solid compost, oil palm boiler ash from the Palm Oil Mill (PKS) of PT. Perkebunan Nusantara V Sei Pagar, Urea, TSP, and KCl fertilizers, 40 x 50 cm polybags, an insecticide with active ingredient dimehipo and fungicide with propineb 70%.

The tools used in this study were tarpaulin, insect net, shovel, meter, measuring cup, soil sieve, scissors, analytical scales, digital scales, cutter, raffia rope, watering can, rice envelopes, trellis, sprayer, documentation tools, and stationery.

This research was conducted experimentally using a factorial completely randomized design (CRD) consisting of two factors, namely factor I solid compost consisting of 4 levels, namely 0 g per polybag (0 tons/ha), 12.5 g per polybag (2.5 tons/ha), 25 g per polybag (5 tons/ha), 37.5 g per polybag (7.5 tons/ha) and factor II boiler ash consisting of 4 levels, namely: 0 g per polybag (0 tons/ha), 5 g per polybag (1 tons/ha), 10 g per polybag (2 tons/ha), 15 g per polybag (3 tons/ha). There were 16 treatment combinations, each consisting of two plants, and repeated three times to obtain 96 experimental units.

Observation parameters consist of plant height (cm) measured weekly until the plant is nine weeks after planting (MST), the maximum number of tillers (stems) is calculated weekly until the plant is nine weeks after planting (MST), the age of panicle emergence (days) is observed daily until the plant produces 75% of the total maximum tillers, the number of productive tillers (stems) is calculated before the rice plant is harvested, the harvest age (days) is observed daily until the plant has entered the harvest criteria of up to 80% of the total tillers, the number of full grains per panicle (grains), the percentage of full grains (%), the weight of 100 grains of full grains (g) and the weight of dry milled grain per polybag (g) are calculated after the rice is harvested and dried and has been separated from full and empty grains. The data obtained were analyzed statistically using analysis of variance (Analysis of Variance). The results showing significant and insignificant effects of the treatment were further tested using the Duncan Multiple Range Test (DMRT) at the 5% level. Variance and DMRT data were analyzed using the SPSS version 27 application.

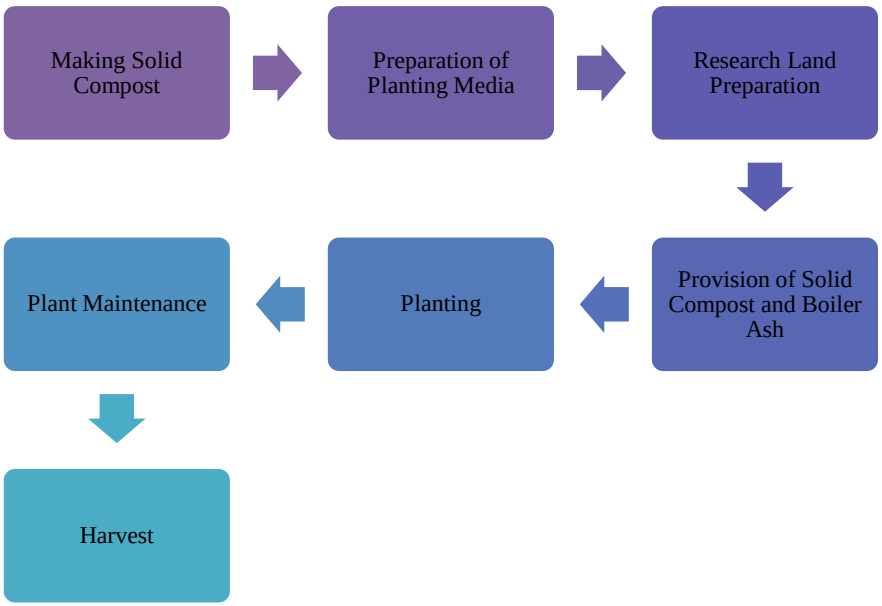

Figure 1. Research flow diagram

3. Results and Discussion

3.1. Plant Height

The results of the variance analysis indicated that the interaction between solid compost and oil palm boiler ash did not significantly affect the height of upland rice plants. However, the main effects of both solid compost and oil palm boiler ash were found to be significant. The average height of the upland rice plants is presented in Table 1.

Table 1. Height of dryland rice plants (cm) 9 MST given various doses of solid compost and boiler ash

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	107.17±6.94 a	107.82±4.74 a	108.75±0.95 a	111.78±1.99 abc	108.88 a
2.5	107.78±1.54 a	112.73±6.55 abc	114.43±5.60 abc	114.52±4.59 abc	112.37 a
5	110.65±2.78 ab	117.50±1.95 bc	118.13±5.67 bc	118.40±3.23 bc	116.17 b
7.5	111.93±5.57 abc	118.02±1.93 bc	118.30±3.46 bc	119.18±3.65 c	116.86 b
Average	109.38 a	114.02 b	114.90 b	115.97 b	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of solid compost at a dose of 5 tons/ha with boiler ash at a dose of 1 tons/ha significantly increased plant height compared to no treatment, a dose of 2.5 tons/ha without boiler ash, and a combination of boiler ash at a dose of 1 tons/ha or 2 tons/ha without solid compost, but not significantly compared to other combinations. This is because solid compost and boiler ash improve the soil's physical, chemical, and biological properties. Solid compost has a high C-organic content, so organic matter as a source of energy for the activities of macro and microorganisms in the soil is available in large quantities. According to Simarmata (2012), soil organisms obtain energy by consuming organic matter. The energy produced is used to improve the physical properties of the soil through the formation of aggregates by the activity of bacteria with organic matter and colloids, as well as earthworms and arthropods, which directly increase soil porosity and infiltration.

The increasing physical quality of the soil and the decomposition process of solid compost and boiler ash produce sufficient nutrients to increase the photosynthesis process so that the photosynthate produced supports optimal plant vegetative growth and development. Bayfurqon's research (2016) reported that the availability of nutrients influences rice plant height. The more deficient the nutrients available in the soil, the more it inhibits the growth and development of rice plants.

The treatment of solid compost at a dose of 5 tons/ha significantly increased plant height compared to a dose of 2.5 tons/ha and without solid compost, but not significantly compared to a dose of 7.5 tons/ha. This is related to the organic matter in solid compost that contributes to soil colloids, thereby increasing the soil cation exchange capacity (CEC). High cation exchange capacity supports the soil in absorbing more nutrient cations that are important for plant growth. Supported by research, which shows a correlation between exchangeable potassium (K-dd) and organic C content. The higher the organic C

content, the higher the CEC, which increases the absorption and exchange of K nutrients. Thus, the nutrients contained in the soil become available for plant use.

Boiler ash treatment at 1 tons/ha significantly increased plant height compared to without boiler ash but not significantly compared to a dose of 2 tons/ha or 3 tons/ha. This is because the N and P nutrients in boiler ash play a role in optimizing the photosynthesis process of plants. The research results by Jiaying et al. (2022) showed that rice plants that were not given N and P nutrients had lower plant heights than other treatments. This is because the photosynthesis and respiration processes of plants are inhibited.

3.2. Maximum number of offspring

The results of the analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the maximum number of tillers of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average maximum number of tillers of upland rice plants is presented in Table 2.

Table 2. Maximum number of tillers of upland rice plants (stems) 9 MST given various doses of solid compost and boiler ash.

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	3.67±1.26 a	4.67±0.58 a b c d e	4.83±0.76 a b c d e	4.33±1.44 abc	4.38 a
2.5	4.17±0.58 ab	4.83±1.04 abcde	5.67±0.76 bcde	6.00±0.87 cde	5.17 b
5	4.50±0.00 a b c d	6.17±0.76 de	5.83±1.04 bcde	6.00±0.87 cde	5.63 b
7.5	5.00±0.87 abcde	6.00±1.32 cde	5.83±0.29 bcde	6.33±0.76 e	5.79 b
Average	4.33 a	5.42 b	5.54 b	5.67 b	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of solid compost at a dose of 2.5 tons/ha with boiler ash at a dose of 2 tons/ha significantly increased the maximum number of tillers compared to no treatment but not significantly compared to other combinations. This is because the combination can provide suitable soil conditions for forming the number of tillers. According to the indicators that characterize soil that can support plant growth well, soil with a high organic matter content can provide sufficient water and nutrients for plants and carry out nutrient cycles in the soil.

The treatment of solid compost at a dose of 2.5 tons/ha significantly increased the maximum number of tillers compared to without solid compost, but not significantly compared to a dose of 5 tons/ha or 7.5 tons/ha. This is because the organic matter in the solid compost makes the podzolic soil loose, so plant roots develop more and absorb nutrients more optimally. Wiryono (2018) stated that plant roots tend to grow and develop faster in soil with a loose structure than in dense soil. Loose soil has larger pores, allowing the root interception to run well.

Boiler ash treatment at a dose of 1 tons/ha significantly increased the maximum number of tillers compared to without boiler ash but not significantly compared to a dose of 2 tons/ha or 3 tons/ha. This is closely related to the ability of boiler ash to reduce acidity and increase the availability of nutrients in the soil. The plant photosynthesis process occurs well, and the photosynthate produced to form rice tillers is greater. This is supported by, which states that significantly increased plant growth is influenced by increased photosynthesis efficiency.

3.3. Age of panicle emergence

The analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the panicle emergence age of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average panicle emergence age of upland rice plants is presented in Table 3.

Table 3. Age of emergence of panicles of upland rice plants (days) given various doses of solid compost and boiler ash

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	77.67±1.04 e	76.00±0.50 cd	75.33±0.58 bcd	75.33±1.26 bcd	76.08 c
2.5	76.67±0.58 de	75.00±1.32 abcd	74.83±1.15 abc	74.50±0.87 abc	75.25 b
5	76.00±1.00 cd	74.83±0.76 abc	74.50±1.00 abc	74.33±0.58 abc	74.92 ab
7.5	75.17±1.04 a b c d	74.83±0.58 abc	73.67±0.58 ab	73.50±1.00 a	74.29 a
Average	76.38 b	75.17 a	74.58 a	74.42 a	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of boiler ash at a dose of 1 tons/ha without solid compost and solid compost at a dose of 5 tons/ha without boiler ash significantly accelerated the age of panicle emergence compared to no treatment. The

increasing dose of solid compost, followed by the increasing boiler ash, results in a faster age of panicle emergence. The fastest age of panicle emergence, 73.50 days after planting (DAP), was obtained at a dose of 7.5 tons/ha solid compost and 3 tons/ha boiler ash. This is related to the role of solid compost and boiler ash, which increase soil pH and free P nutrients from Al and Fe absorption to be available in the soil and absorbed by plants. Research shows that decreasing Al-dd can increase pH and P-available in the soil. Meanwhile, the P nutrients available in the soil play an important role in accelerating the age of rice panicle emergence. (2020) stated that nutrient P plays an important role in the energy transfer process in plants and accelerates plant growth from the vegetative phase to the generative phase.

Solid compost treatment at a dose of 2.5 tons/ha significantly accelerated the age of panicle emergence compared to no solid compost but not significantly compared to a dose of 5 tons/ha. This is because solid compost can improve physical properties, one of which is soil porosity so that plant roots can more easily enter the soil to absorb water and nutrients needed for photosynthesis. Yulina et al. (2023) reported that organic matter can increase soil aggregation so that the soil structure becomes looser, soil porosity increases, and aeration increases. In addition, Gea (2022) stated that nutrients that are available in sufficient quantities will facilitate the physiological and metabolic processes of plants, especially photosynthate translocation. Plants use photosynthate to increase vegetative growth; when vegetative growth has reached optimal conditions, the plants will enter the generative phase, which is marked by the appearance of panicles in rice plants.

Treatment of boiler ash at a dose of 1 tons/ha significantly accelerated the age of panicle emergence compared to without boiler ash but not significantly compared to a dose of 2 tons/ha or 3 tons/ha. This is because the pH of boiler ash, which is classified as alkaline, can reduce acidity and increase the availability of P nutrients in the soil. Munawar (2011) stated that P nutrients play a role as a regulator of the distribution of photosynthesis results, which are distributed to the formation of plant organs, one of which is flowers.

3.4. Number of productive offspring

The analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the number of productive tillers of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average number of productive tillers of upland rice plants is presented in Table 4.

Table 4. Number of productive tillers of dryland rice plants (stems) given various doses of solid compost and boiler ash.

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	3.50±1.00 a	4.50±0.50 a b c d e	4.67±0.58 a b c d e	4.17±1.15 abc	4.21 a
2.5	4.00±0.00 ab	4.33±1.04 abcd	5.50±0.87 bcde	5.33±0.58 bcde	4.79 ab
5	4.33±0.58 a b c d	5.33±0.58 bcde	5.50±1.00 bcde	5.50±0.87 bcde	5.17 bc
7.5	4.83±0.76 a b c d e	5.83±1.15 de	5.67±1.04 cde	6.00±0.50 e	5.58 c
Average	4.17 a	5.00 b	5.33 b	5.25 b	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of solid compost at a dose of 2.5 tons/ha with boiler ash at a dose of 2 tons/ha significantly increased the number of productive tillers compared to no treatment but not significantly compared to other combinations. This is because improving soil quality by applying solid compost and boiler ash increases the availability of nutrients, affecting the increase in productive tillers. The study's results by Ezward et al. (2019) showed that the increase in productive rice tillers was influenced by good soil fertility and sufficient and balanced nutrients.

The treatment of solid compost at a dose of 5 tons/ha significantly increased the number of productive tillers compared to those without solid compost, but not significantly compared to a dose of 2.5 tons/ha or 7.5 tons/ha. This is because the high organic matter content in solid compost can increase the availability of water and air needed for root development in the soil, so that the roots absorb more nutrients and encourage the formation of productive tillers of rice plants, in line with the research of, which reported that organic matter in the form of 100% cow dung (500 g) significantly increased the permeability of ultisol soil compared to without treatment.

Boiler ash treatment at a dose of 1 tons/ha significantly increased the number of productive tillers compared to without boiler ash but not significantly compared to a dose of 2 tons/ha or 3 tons/ha. This is closely related to the ability of boiler ash to reduce Al-dd and H-dd, thereby increasing soil pH. Increasing soil pH will provide nutrients that plants can optimally absorb, conversely, if the soil is acidic, nutrient absorption by plants will be disrupted. Supported by Effendi's research et al. (2024) showed that the combination of organic fertilizer and NPK Phonska fertilizer did not differ significantly in increasing the number of productive tillers of dryland rice plants, because the soil used was acidic, causing nutrient ion bonds to occur through chemical reactions, as a result of which

plants had difficulty absorbing nutrients so that the increase in productive tillers did not occur optimally.

3.5. Harvest age

The analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the harvest age of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average harvest age of upland rice plants is presented in Table 5.

Table 5. Harvest age of upland rice plants (days) given various doses of solid compost and boiler ash

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	107.33±0.29 i	105.83±0.76 gh	104.67±0.29 efg	104.33±0.58 def	105.54 d
2.5	106.17±0.29 h	104.50±0.50 def	104.00±1.32 cdef	103.67±0.29 cde	104.58 c
5	105.17±0.76 fgh	103.50±0.87 bcde	103.33±0.76 a b c d	102.83±0.76 abc	103.71 b
7.5	104.50±0.87 def	103.33±0.29 a b c d	102.33±0.58 ab	102.17±0.76 a	103.08 a
Average	105.79 c	104.29 b	103.58 a	103.25 a	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of boiler ash at a dose of 1 tons/ha without solid compost significantly accelerates the harvest age compared to no treatment. The increasing dose of solid compost followed by the increasing dose of boiler ash, the faster the harvest age. The fastest harvest age, 102.17 days after planting (DAP), was obtained at a solid compost dose of 7.5 tons/ha and a boiler ash dose of 3 tons/ha. This is closely related to nutrient P, which is a component of adenosine triphosphate (ATP) and plays a role in the energy transfer process. The energy that is translocated will increase plant root growth through cell division and formation so that more nutrients are absorbed. Munawar (2011) stated that P nutrients play a role in various biosynthesis reactions, such as photosynthesis, protein synthesis, and plant metabolism.

The treatment of solid compost at a dose of 2.5 tons/ha significantly accelerated the harvest age compared to those without solid compost. This is related to the role of solid compost as an organic fertilizer that can improve the soil's physical, chemical, and biological properties. According to the article, organic fertilizers increase the structure, water absorption capacity, availability of nutrients, and activity of soil microorganisms. In addition, the solid compost used also contributes macro and micro nutrients needed for rice ripening, accelerating the harvest age of rice plants.

Boiler ash treatment at 1 tons/ha significantly accelerates the harvest age compared to without boiler ash. This is because the P nutrient in boiler ash matches the nutrient rice plants require. Rajiman (2020) stated that P nutrient plays a role in accelerating flowering and ripening of seeds or grain.

3.6. Number of grains per panicle

The analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the number of full grains per panicle of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average number of full grains per panicle of upland rice plants is presented in Table 6.

Table 6. Number of full grains per panicle of dryland rice plants (grains) given various doses of solid compost and boiler ash.

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	139.82±12.83 a	146.20±6.06 abc	152.37±8.96 a b c d	145.19±5.22 abc	145.90 a
2.5	143.43±7.71 ab	151.53±8.60 a b c d	159.46±7.22 bcd	157.15± 20.91 a b c d	152.89 ab
5	151.87±9.80 a b c d	160.14±5.56 bcd	162.63±13.88 bcd	163.21±5.52 cd	159.46 bc
7.5	153.44±12.49 a b c d	165.65±4.36 d	167.49±7.74 d	168.51±7.56 d	163.77 c
Average	147.14 a	155.88 b	160.49 b	158.52 b	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of solid compost at a dose of 2.5 tons/ha with boiler ash at a dose of 2 tons/ha significantly increased the number of full grains per panicle compared to no treatment but not significantly compared to other combinations. Solid compost and boiler ash increased the availability of N, P, and K nutrients absorbed by plants in filling rice grains by increasing soil pH and CEC. Puspitorini & Iqbal (2024) state that organic matter has the ability to attract positively charged ions to its surface. This causes the cations to remain in the plant root zone so that they are not easily lost due to the washing process by water. In addition, Utomo (2016) added that the increase in CEC is influenced by soil pH. The higher the pH, the more it increases the soil CEC. The nutrients N, P, and K play a

role in plant photosynthesis. Increased photosynthesis will result in optimal grain filling, increasing the number of full grains per panicle produced.

Solid compost treatment at a dose of 5 tons/ha significantly increased the number of full grains per panicle compared to no solid compost but not significantly compared to a dose of 2.5 tons/ha or 7.5 tons/ha. Solid compost can provide the nutrients needed for grain filling by increasing the soil's ability to store water. The higher the soil's ability to store water, the more water and nutrients plants can absorb for photosynthesis. Supported by research that reported that organic fertilizers had a significant effect on maintaining water in the soil.

Boiler ash treatment at a dose of 1 tons/ha significantly increased the number of full grains per panicle compared to without boiler ash but not significantly compared to a dose of 2 tons/ha or 3 tons/ha. This is closely related to the K nutrient content in boiler ash, which supports the soil in providing sufficient K nutrients for filling rice grains. The study by Kurnia et al. (2021) showed that K nutrients play a role in filling rice grains, thus affecting the increase in rice yields.

3.7. Percentage of grain content

The analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the percentage of full grain of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average percentage of full-grain upland rice plants is presented in Table 7.

Table 7. Percentage of full grain of upland rice plants (%) given various doses of solid compost and boiler ash

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	74.04±5.65 a	77.89±2.80 a b c d	76.50±2.03 abc	75.24±4.05 ab	75.92 a
2.5	75.29±1.58 ab	78.62±5.48 a b c d	79.70±4.09 a b c d e	79.62±1.79 a b c d e	78.31 ab
5	75.55±4.11 abc	80.87±2.51 bcde	81.80±1.23 cde	83.15±2.56 de	80.34 bc
7.5	78.17±4.96 a b c d	83.41±1.60 de	83.57±1.77 de	85.84±0.97 e	82.75 c
Average	75.76 a	80.20 b	80.39 b	80.96 b	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of solid compost at a dose of 5 tons/ha with boiler ash at a dose of 1 tons/ha significantly increased the percentage of full grain compared to no treatment but not significantly compared to other combinations. Solid compost and boiler ash have relatively high K nutrients, so they fill rice grains. Sufficiently available K nutrients will improve grain filling because more photosynthate results are distributed. According to K nutrients play a role in transporting photosynthesis results from leaves to reproductive organs and storage such as fruits, tubers, and seeds.

Solid compost treatment at a dose of 5 tons/ha significantly increased the percentage of full grain compared to no solid compost but not significantly compared to a dose of 2.5 tons/ha or 7.5 tons/ha. The decomposition process of solid compost produces nutrients needed by plants for photosynthesis, and the photosynthee produced will be channeled to form productive tillers and grain filling. stated that the decomposition of organic matter produces nutrients needed by rice plants to increase the formation of the number of effective panicles and the number of grains per panicle.

Boiler ash treatment at a dose of 1 tons/ha significantly increased the percentage of full grain compared to without boiler ash but not significantly compared to a dose of 2 tons/ha or 3 tons/ha. The available K nutrient at a dose of 1 tons/ha stimulates longer root growth, so plants for photosynthesis absorb more water and nutrients. This is supported by research, which shows that K fertilization affects root growth and rice plant yields.

3.8. Weight of 100 grains of grain

The analysis of variance showed that the interaction between solid compost and oil palm boiler ash had no significant effect on the weight of 100 grains of full grain upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average weight of 100 grains of full grain of upland rice plants is presented in Table 8.

The interaction of boiler ash dose of 2 tons/ha without solid compost significantly increased the weight of 100 grains of full grain compared to no treatment. The increasing dose of solid compost followed by the increasing dose of boiler ash, the more it increased the weight of 100 grains of full grain. The heaviest weight of 100 grains of full grain, namely 2.32 g, was obtained at a solid compost dose of 7.5 tons/ha and a boiler ash dose of 3 tons/ha. This is because the K nutrient content in boiler ash plays a role in starch formation, so its availability is sufficient to increase the weight of full grain. Lakitan's statement (2018) supports that in C-3 plants, the results of photosynthate from photosynthesis are accumulated in the form of sucrose or starch. The starch formation reaction is driven by the synthetase enzyme activated by K + ions.

The treatment of solid compost at a dose of 2.5 tons/ha significantly increased the weight of 100 grains of full grain compared to without solid compost. This is closely

related to solid compost, which increases the availability of water and nutrients by improving the physical and chemical properties of the soil, thus affecting the process of opening and closing stomata in the leaves. stated that the opening and closing of stomata affect the process of photosynthesis, because stomata are the entry pathway for carbon dioxide (CO_2) needed in the process. When water availability is insufficient, stomata function is disrupted, inhibiting the entry of CO_2 and reducing the efficiency of photosynthesis. Thus, sufficient water and nutrients will support the growth of rice plants in filling seeds, thus determining the weight of the seeds. The results of his study showed that a decrease in the level of water provision would reduce the weight of seeds per panicle of sorghum plants.

Table 8. Weight of 100 grains of dryland rice grain (g) given various doses of solid compost and boiler ash

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	2.15 ± 0.04 a	2.20 ±0.04 ab	2.20 ±0.03 bc	2.22 ±0.03 bcde	2.19 a
2.5	2.19 ±0.02 ab	2.22 ±0.02 bcde	2.24 ±0.04 bcdef	2.27 ±0.01 efg	2.23 b
5	2.21 ±0.04 bcd	2.25 ±0.03 cdef	2.28 ±0.03 fg	2.29 ±0.03 fg	2.26 c
7.5	2.25 ±0.04 cdef	2.26 ±0.01 def	2.28 ±0.02 fg	2.32 ±0.01 g	2.28 c
Average	2.20 a	2.23 b	2.25 bc	2.27 c	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%

The treatment of solid compost at a dose of 2.5 tons/ha significantly increased the weight of 100 grains of full grain compared to without solid compost. This is closely related to solid compost, which increases the availability of water and nutrients by improving the physical and chemical properties of the soil, thus affecting the process of opening and closing stomata in the leaves. stated that the opening and closing of stomata affect the process of photosynthesis, because stomata are the entry pathway for carbon dioxide (CO_2) needed in the process. When water availability is insufficient, stomata function is disrupted, inhibiting the entry of CO_2 and reducing the efficiency of photosynthesis. Thus, sufficient water and nutrients will support the growth of rice plants in filling seeds, thus determining the weight of the seeds. The results of his study showed that a decrease in the level of water provision would reduce the weight of seeds per panicle of sorghum plants.

Boiler ash treatment at a dose of 1 tons/ha significantly increased the weight of 100 grains of full grain compared to without boiler ash, but not significantly compared to a dose of 2 tons/ha. This is because the nutrient P plays a role in the plant's metabolic process. Kusumawati (2021) explains that P plays a role in the energy transfer process, stimulating cell growth and division and the formation of fruits and seeds.

3.9. Weight of dry milled grain per polybag

The results of the analysis of variance showed that the combination of solid compost and oil palm boiler ash had no significant effect on the weight of dry milled grain per polybag of upland rice plants, while the main effect of solid compost and oil palm boiler ash had a significant effect. The average weight of dry milled grain per polybag of upland rice plants is presented in Table 9.

Table 9. Weight of dry milled grain per polybag of upland rice plants (g) given various doses of solid compost and boiler ash

Solid compost (tons/ha)	Boiler Ash (tons/ha)				Average
	0	1	2	3	
0	11.25 ±3.75 a	15.54 ±2.30 abcde	17.06 ±1.45 bcdef	14.57 ±4.36 abc	14.60 a
2.5	13.74 ±0.77 ab	15.20 ±3.23 abcd	20.33 ±2.68 defg	19.75 ±2.19 cdefg	17.25 b
5	15.75 ±2.53 abcde	19.83 ±2.55 cdefg	20.94 ±3.01 efg	21.36 ±2.75 fg	19.47 bc
7.5	17.45 ±2.83 bcdef	22.65 ±4.45 fg	22.14 ±3.54 fg	23.80 ±1.53 g	21.51 c
Average	14.55 a	18.30 b	20.12 b	19.86 b	

Description: Numbers followed by different letters in the same column and row indicate a significantly different effect according to Duncan's further test at the level 5%.

The interaction of boiler ash at a dose of 2 tons/ha without solid compost significantly increased the weight of dry milled grain per polybag compared to no treatment. This increase in yield is because boiler ash supports grain filling by increasing the efficiency of nutrient absorption, while untreated soil has nutrients that cannot support good rice plant growth. This is supported by research by Sasongko & Zulkifli (2023), which states that untreated soil will reduce the weight of dry seeds produced because there is no change in soil conditions, so nutrients are unavailable and cannot be absorbed by plant roots. Conversely, if the need for macro and micronutrients is met, plant generative growth will increase, affecting seeds' dry weight.

Solid compost treatment at a dose of 2.5 tons/ha

significantly increased the weight of dry milled grain per polybag compared to no solid compost, but not significantly compared to a dose of 5 tons/ha. Solid compost organic matter improves the quality of podzolic soil by improving the biological and physical properties of the soil so that water and nutrients needed for the formation and filling of rice grains are sufficiently available. According to Munawar (2011), organic matter increases soil porosity by increasing the activity of soil fauna that create holes with secretions from their bodies. In this case, the decomposition of solid compost will produce P and K nutrients, which are used to fill grain and transloc photosynthate into seeds.

Boiler ash treatment at a dose of 1 tons/ha significantly increased the weight of dry milled grain per polybag compared to without boiler ash but not significantly compared to doses of 2 tons/ha or 3 tons/ha. This is because boiler ash increases the availability of P and K nutrients, which play an important role in the formation and filling of grain. The results of the study by Sopa et al. (2022) showed that boiler ash at a dose of 3 tons/ha significantly increased the weight of dry pods per peanut plant plot compared to without boiler ash administration.

Figure 2. Results of full grain per experimental polybag for each treatment combination.

4. Conclusion

Based on the results of the research conducted, it can be concluded that:

1. The interaction between solid compost and oil palm boiler ash did not significantly affect the observed parameters.
2. Solid compost significantly enhances the growth and yield of upland rice plants across all observed parameters. A 7.5 tons/ha dosage demonstrated the most favorable growth and yield outcomes in all measured aspects.
3. The application of oil palm boiler ash significantly enhances the growth and yield of upland rice plants across all observed parameters. A dosage of 2 tons/ha of boiler ash is optimal for increasing the number of productive tillers, the number of fully developed grains per panicle, and the weight of dry milled grain per polybag. In contrast, a dosage of 3 tons/ha of boiler ash is most effective for promoting plant height, maximizing the number of tillers, advancing panicle emergence age, reducing harvest age, increasing the percentage of full grains, and enhancing the weight of 100 full grains.

Acknowledgment

The authors would like to thank the Directorate General of Higher Education and the Directorate of Learning and Student Affairs of the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for funding this research activity through the student creativity program in the field of exact research (PKM-RE).

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