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COMBINED EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH OF RICE PLANTS

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ABSTRACT

Rice is one of the most important staple cereal foods in human nutrition and a major food grain for about 75% of the world’s population. Rice has become a major staple food in Ghana, being the second most important cereal crop after corn. Inorganic, organic and bio fertilizers are the main plant nutrient sources for replenishing agricultural soils. In this study the effect of compost as an organic fertilizer and NPK inorganic fertilizer was evaluated on the growth of rice plants. The experiment was conducted in pots in a greenhouse environment at Gunnarsholt, Iceland, during the 2019 growing season. The major objective was to evaluate the effect of compost as an organic fertilizer and NPK as an inorganic fertilizer used in the growing of rice varieties. The experiment was laid out in a 3 × 4 factorial design with the levels of fertilizers at the full rate of inorganic fertilizer (NPK 90 60 60 kg/ha), compost 12 t/ha, ½ (compost 12 t/ha) + ½ (inorganic fertilizer) and control. The three rice varieties were APO, IR 55419 and UPL R1 7. The full rate of inorganic fertilizer NPK 90 60 60 kg/ha was used as a check for comparison. Results collected at 7 and 9 weeks after planting showed that varieties and fertilizer levels had a positive influence on plant height. The leaf chlorophyll at 9 weeks after planting also responded positively to fertilizer level and varieties, whereas root length was influenced only by varieties. Plant dry biomass did not respond to the fertilizer treatments. A significant difference was obtained between the control, inorganic and organic fertilizers as well as between the APO and IR 55419 varieties. It can be concluded from the findings that use of a quality rice variety and the application of compost, sole or as a complement to chemical fertilizer, has the potential of producing a high yield compared to a full rate of inorganic fertilizer.

Keywords: low soil fertility, soil fertility management, compost, NPK fertilizer, rice variety

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1. INTRODUCTION

1.1 Use of inorganic fertilizers, organic fertilizer and compost for rice cultivation

Rice is one of the most important staple cereal foods in human nutrition and a major food grain for about 75% of the world's population (Chaudhary & Tran 2001). Rice is an excellent source of carbohydrates providing up to 50-60% of the daily calories ingested by more than 2.5 billion people across the world (Belder et al. 2004; Metwally et al. 2011). It is also a main source of zinc intake, providing up to 49% and 69% of dietary zinc for children and women, respectively (Arsenault et al. 2010).

Rice has become a major staple food in Ghana, being the second most important cereal crop after corn. Rice consumption was estimated at 35 kg/year per person with the population at 28.2 million and was expected to hit 40 kg per person by 2020. Total consumption of rice was as high as 1.0 million metric tons, with the domestic rice production of 450,000 MT, which was less than 50% of the country's rice requirement (GAIN 2018). The average yield level of rice in Ghana is very low, 2.43 t ha^{-1} (GAIN 2018) compared to other rice-growing countries like South Korea and Japan where the average yield is 7.00 and 6.22 t ha^{-1}, respectively (FAO 1999).

One of the major factors contributing to the low rice yield in Ghana is degraded soil fertility. It has become one of the most pressing constraints among smallholder farmers in Sub-Saharan Africa (SSA). Research has shown that more than 50% of the world's 1.5 billion hectares of agricultural land is severely degraded, resulting in low crop yield (Martey 2018). Over 8 million tons of nutrients are consistently extracted from soils in Sub-Saharan Africa. In Ghana, around 5 kg of soil supplements per hectare are taken out by crops annually and in return inorganic fertilizer of around 8 kg per hectare is applied (Mahama et al. 2018). The declining soil fertility in Ghana is due to the high cost of inorganic fertilizer, low fertilizer use efficiency, imbalance in fertilizer use, and the continuous use of inorganic fertilizers. Furthermore, lack of high yielding, drought- and disease-resistant varieties is also a major factor in the low rice yields (Rouf et al. 2017). Increase in rice yields and soil productivity must be achieved by using limited available resources in a sustainable manner (Somasundaram & Coats 1991). In order to reach higher yield targets in rice production, balanced soil nutrition is necessary, which implies adoption of appropriate soil fertility management practices, supply of nutrients in adequate quantities, and the introduction of high-yielding and fertilizer-responsive varieties (Sahoo et al. 2018).

Inorganic, organic and bio fertilizers are the main plant nutrient sources used for replenishing agricultural soils (Masarirambi et al. 2012). Several research findings have indicated that neither inorganic fertilizer nor organic sources alone can sustainably improve productivity (Satyanarayana et al. 2002). Continuous application of inorganic fertilizer such as nitrogen not only degrades the soil but can also lead to pest problems by increasing the increase, longevity and overall fitness of certain pests (Siavoshi et al. 2011). However, the use of organic fertilizer alone might not meet the plant requirements because of the relatively low nutrient content. Application of organic fertilizer with chemical fertilizer stimulates microbial activity, promotes efficiency in the use of nutrients (Moharana et al. 2012) and increases accessibility of the surrounding nutrients, resulting in adequate nutrient uptake by plants. Therefore, in order to increase the soil productivity by supplying all the plant nutrients in readily available form and to maintain good soil health, it is necessary to use organic fertilizer in combination with inorganic fertilizers to obtain optimum yields (Rama et al. 2012). Organic fertilizers such as cow dung, poultry manure, organic waste, crop residues and compost will not only increase grain yields but also increase the efficiency of applied nutrients due to their favourable effect on the physical, chemical and biological properties of soil (Hussainy 2019). However, extensive application of nitrogen fertilizer, whether in the form of organic matter or chemicals, can negatively affect the soil because excess nitrogen is converted to nitrates which are detrimental to the soil and human health (Mukherjee 2013).

1.2 Problem statement

The increasing demand for food leads to intensive mining and depletion of the soil fertility and subsequently causing adverse environmental issues (Martey 2018). The use of inorganic fertilizer can increase rice grain yield by 25% (Barker & Herdt 1985). However, there is a serious concern in the long-term adverse effect of continuous use of inorganic fertilizers on the deterioration of soil structure and soil health (Ghosh & Bhat 1998). Heavy applications of chemical fertilizers alone slowly cause a decline in soil productivity. This decline seriously affects rice paddy fields and decreases yield with time. Increased usage of organic fertilizers is an important factor in increasing the sustainability of food production (FFTC 1994).

1.3 Project purpose

It is from this point of view that I wanted to study the effect of organic and inorganic fertilizers on the growth and yield components of rice. The present research work was undertaken with the following objectives:

- To ascertain the effects of compost on growth and yield of rice varieties.
- To evaluate the combined effect of compost and inorganic fertilizer on rice genotypes.
- To evaluate for high yielding rice genotypes among the varieties.

The following hypotheses were tested in this research:

1. Application of compost does not influence the growth of rice.
2. Combination of compost and inorganic fertilizer does not affect the growth of rice.
3. Rice genotypes are not different in terms of growth.

2. LITERATURE REVIEW

2.1 The use of organic fertilizers in agricultural production

In the past few decades, inorganic fertilizers have become incorporated in traditional agricultural practices throughout the world. This strong focus on chemical fertilizers has been based on a perception of the soil as being an inert medium for plant roots instead of seeing crops as a fraction of the interacting species (FFTC, 1994). Inappropriate use of chemical fertilizers has degraded the soil to an alarming level, leading to an imbalance in the productivity of the soil (Mirza et al. 2010)

The attention in agronomy is shifting towards global environmental issues, with the utilization of organic wastes such as farmyard manure, compost, vermicompost and poultry manure as some of the effective measures considered. Organic materials supply essential plant nutrients without any detrimental effect to crops and soil (Mirza et al. 2010) because they are carbon-based compounds that promote growth and productivity of plants and also improve soil fertility by minimizing or reducing leaching of nutrients from the soil (Martey 2018). Organic sources release nutrients more gradually compared to inorganic fertilizers, thus reducing the boom-and-bust pattern of plant growth. Organic fertilizers also improve soil structure, reduce soil erosion and are relatively cheaper compared to chemical fertilizer (Siavoshi et al. 2011).

Compost can be a rich source of available nitrogen, phosphorus, potassium and micronutrients, coupled with high microbial and enzymatic activities (Chaoui et al. 2003). Continuous application of compost improves soil organic carbon, soil water retention and transmission which positively affect the physical properties of soils (Das et al. 2016). According to Amanullah (2016) organic fertilizers have been shown to improve soil structure, nutrient exchange and maintain soil health, thus attracting more people to organic farming. Poultry manure is also an excellent source of organic fertilizer because it contains high levels of nitrogen, phosphorus, potassium and other essential nutrients. It has been reported that poultry manure supplies phosphorus for plants more readily than other organic fertilizer sources do (Saeed et al. 2016).

2.2 Effect of organic and inorganic fertilizers on plant height

Traditionally plant height is considered as one of the components in grain yield of rice. In addition, it also provides insight into the effects of the metabolism of several nutrients in plants. Research showed that exclusive application of chemical fertilizers significantly increased plant height compared with organic fertilizer, but maximum plant height was acquired with the application of organic and inorganic fertilizers together. The experiment consisted of application of equal amounts of mineral and organic fertilizer. Inorganic sources of nutrients gave an average plant height when applied separately, while control (non-application of fertilizer) eventually recorded the lowest plant height. Plant height responds positively to the combined application of organic and inorganic fertilizers due to the presence of macro and micro nutrients in the organic matter (Muhammad et al. 2003).

According to Siavoshi et al. (2011) plant height, number of tillers per hill, spikelet number per panicle, grain yield and 1000-grain weight increased with the application of organic and chemical fertilizers and this could be due to the increase in the absorption of available nutrients. They also stated that the difference in plant height was due to the variation of major nutrients in fertilizer sources. A similar result was observed by Ibrahim et al. (2008) in ascertaining the combined effect of organic manure with compost on rice. Differences in growth and yield observed in rice plants could also be due to the variation in absorption of essential nutrients by the plants (Amanullah 2016). However, incorporation of compost into the soil at different rates influenced plant growth, especially plant height. Compost application at the rate of 4 t h^{-1} increased plant height by 4 cm compared to plants under control treatment.

According to Mahmud et al. (2016) chemical fertilizers applied at different levels also had a significant effect on plant height. Their study revealed that plant height was as high as 94.5 cm from mineral fertilizer application at the rate of 150-24-99-18 kg NPKS ha^{-1} compared to 89.0 cm in plants under control treatment. The height of the rice plants from the application of inorganic fertilizer alone was not significantly different from that of organic fertilizer alone, but maximum plant height was attained from 100% NPK plus organic manures (Moe et al. 2017). The increase in height of plants obtained by the use of chemical fertilizer (nitrogen) could have been due to the high stimulating effect of nitrogen on various physiological phases in cell division and cell elongation (Alim 2012).

Combined application of compost and chemical fertilizer at different levels on rice plants greatly influenced plant height in a study by Alim (2012). This could have been due to the availability of major nutrient sources for plant growth. While chemical fertilizers render nutrients which are readily accessible in soil solution and thereby making them instantaneously available, organic fertilizers provide nutrients through microbial activities (Mahmud et al. 2016). Alim (2012) reported that plant height varies significantly among varieties, and the varietal differences could be the result of the differing genetic makeup of the cultivars, since plant height depends on the number of internodes which represent the genotypic traits of the variety.

2.3 Effect of organic and inorganic fertilizers on tiller number

Tillering is an essential parameter for panicle number and thereby an important factor in grain yield production (Siavoshi et al. 2011). Hasanuzzaman et al. (2010) reported an increase in tiller number per unit area under combined application of organic and inorganic fertilizer treatment. This could have been due to the availability of a high level of nitrogen which plays a vital role in cell division and elongation. Organic fertilizer sources offer more balanced nutrition, especially micronutrients which positively affect the number of tillers in rice plants (Belefant 2007). According to Belefant (2007) the application of manure or chemical fertilizer alone to soil increases the tiller number but combined application of manure and chemical fertilizer resulted in higher number of tillers. Tiller induction by manure was observed in several rice varieties, including varieties with high and low tillering potential.

Tiller number is one of the most significant components of grain yield, especially the effective tillers, because more highly effective tillers per hill give more grain yield per hectare. Combined application of organic and mineral fertilizers produced a higher number of tillers per hill as compare to all other treatments. This could be attributed to the accessibility of available nitrogen in the soil by the plants, which plays a key role in cell division and enlargement (Muhammad et al. 2003). According to Alim (2012), varieties also differ significantly in the number of tillers produced per hill or unit area and this could be due to the variation in their genetic make-up which might be highly affected by genetic factors.

2.4 Effect of organic and inorganic fertilizers on chlorophyll content

Leaf chlorophyll content is among the most significant indicators of photosynthetic activities because it is the vital pigment in photosynthesis (Niinemets & Tenhunen 1997). Leaf chlorophyll concentration is an essential variable which is regularly measured to ascertain the level of chloroplast as well as the metabolism of the plant. Chlorophyll is an antioxidant compound found and preserved within the chloroplast and mostly available in the green area of leaves, stems, flowers and roots (Hasanuzzaman et al. 2013).

Nitrogen is an important macronutrient which is taken up by plants in the form of nitrate or ammonium ions for the formation of all amino acids, enzymes and proteins. There is a positive relationship between chlorophyll and nitrogen due to the role nitrogen plays in plants. Nitrogen forms the structural element of both chlorophyll and protein molecules which in turn influence the formation of chloroplasts and the chlorophyll content in plants (Bojović & Marković 2009). Low nitrogen content in plants leads to yellowing of leaves, a decrease in leaf area, and delayed photosynthetic activities. It is necessary to understand not only the uptake of nitrogen but also its distribution in plants since it affects both the quality of crop produced and the environment. Uptake and accumulation of nitrogen in crops are the two main factors of the nitrogen cycle in agro systems (Lemaire & Gastal 2002).

Total chlorophyll content is an indicator of nitrogen accumulation in plants, which in turn explains root system activities and the movement of both organic and inorganic nutrients from the root zone to the top of the plants. Physiological nitrogen efficiency in plants shows the activities in the top of the plant which involve absorption of nitrogen, processes and synthesis. However, a leaf shows the structural and functional mechanisms of the photosynthetic apparatus based on the intensity of the light received during the growth period (Prioul et al. 1980). Leaf chlorophyll content is approximately proportional to leaf nitrogen content (Evans 2008).

2.5 Effect of organic and inorganic fertilizers on biomass

Dry matter accumulation in plants is an essential factor of crop growth, which is significantly influenced by Integrated Nutrient Management (INM) practices (Hussainy 2019). According to Mahmud et al. (2016), application of compost at different levels affects the growth and straw yield of rice plants significantly. Their study revealed that a maximum straw yield of 8.04 t ha^{-1} was recorded from compost application at 4 t ha^{-1} while the control treatment gave the lowest value of 6.12 t ha^{-1}. However, different levels of mineral fertilizer application also had a significant effect on straw yield. The application of NKPS fertilizer at 150-24-99-18 kg ha^{-1} gave the highest straw yield of 8.11 t ha^{-1} while the lowest straw yield (6.48 t ha^{-1}) was observed in the control treatment. Alim (2012) also reported that the straw yield of rice plants varied significantly with application of different sources and levels of nitrogen fertilizer. According to Moe et al. (2017) total dry matter accumulation of plants varied significantly under different levels of inorganic fertilizer. Mineral fertilizer gave higher dry matter accumulation than organic fertilizer at the vegetative stage, but organic manure combined with inorganic fertilizer treatments produced higher dry matter content compared with organic manure treatments alone.

In any case, combined application of compost and NPKS fertilizer also influenced plant biomass significantly. The combination of compost at 4 t ha^{-1} and N, P, K, S chemical fertilizer at 100-16-66- 12 kg ha^{-1} produced the highest biomass of 8.73 t ha^{-1} compared to the 5.42 t ha^{-1} of biomass obtained from the control treatment. This might have been due to the increased vegetative growth of the plants (Mahmud et al. 2016). It was observed that organic fertilizer alone or combined with chemical fertilizers significantly increased the length, number and size of leaves as the nutrient absorption capacity of the plant promoted better root development and translocation of carbohydrates from source to growing points caused by the use of organic fertilizer (Singh & Agarwal 2001). The available nutrients might have helped in enhancing leaf area, which resulted in higher photo-assimilates and more dry matter accumulation (Singh 2008).

The straw yield of rice plants varied significantly depending on the varieties. This could be due to the ability of a variety to grow tall and give a high tiller number per hill or per unit area, as these two parameters greatly influence plant biomass (Alim 2012).

3. MATERIALS AND METHODS

3.1 Study site

A pot experiment was conducted at Gunnarsholt, located in South Iceland (63°51'N, 20°18'W), in a greenhouse during the 2019 cropping season. Gunnarsholt is situated at 50–60 meters above sea level.

3.2 Treatments and experimental layout

The experimental treatments consisted of: 1) exclusive application of compost, 2) exclusive application of inorganic fertilizer, 3) combination of compost and inorganic fertilizer, and 4) no fertilizer added (control). Each fertilizer treatment was tested on three rice varieties: APO, IR 55419-04 and UPL RI 7. The experiment was set out in a completely randomized design with five replications using the plant spacing of 20 cm x 20 cm (see Appendix I). The four levels of fertilizers (i.e. treatments) are designated as follows: (1) control, (2) inorganic fertilizer (NPK: 90 60 60 kg ha^{-1}), (3) compost 12 t ha^{-1} and (4) combination of ½ (compost 12 t ha^{-1}) + ½ (inorganic fertilizer: NPK: 90 60 60 kg ha^{-1}). The full rate of inorganic fertilizer (NPK 90 60 60 kg ha^{-1}) was used since it is the recommended rate for rice cultivation in northern Ghana.

The quantity of fertilizer applied per pot was calculated based on the fertilizer requirement of rice per hectare in the following manner: 2000 g of soil was used in a 2 L capacity of 13 cm width x 18 cm length.
The mass of compost added to each pot was calculated as follows:

- Mass of soil per hectare =Area of the field × soil depth × bulk density of the soil
  10,000 cm × 10,000 cm × 20 cm × 1.00 g/cm^3 = 2,000,000,000 g of soil.
- For 2,000 g of soil, ratio and proportion were applied in the calculation of the compost at 12,000 kg compost / 2,000,000,000 g of soil (1 hectare).
  (12,000,000 g of compost × 2,000 g of soil) / 2,000,000,000g of soil = 120 g of compost.
  The amount of compost required was therefore calculated to be 120 g per pot.

3.3 Compost and soil quality assessment

The compost and soil were analyzed for total organic carbon, soil texture, pH, C, N, C/N ratio, P, K, S, Ca, Mg, Na, Mn, Zn, Cu and Fe. The analysis of carbon and nitrogen was done using a carbon analyzer (vario MAX CN). The percentages of nitrogen as N_2 and carbon as CO_2 were obtained by this method. Measurements of P, K, Ca, Mg, S, Na, Zn, Cu, Mn, Zn and Fe were carried out by Efnagreining ehf. in Hvanneyri, Iceland. Samples were dried to a constant weight at 60°C and then ground before analysis. Soil and compost samples were oven-dried at 60°C to a constant weight.

Samples were then ground and sieved through 2 mm mesh prior to analysis. 60% nitric acid was used to digest each sample unit at 125-128°C for 24 hours. Samples were cooled down at room temperature and measurements of mineral elements were done in an ICP Mass Spectrometer (Sequential Inductively Coupled Plasma Spectrometer, Jobin Yvon Ultima 2).

3.4 Procedure and process of experiment

A mass of 2,000 g of potting soil was used for each pot. Rice seeds of three varieties were obtained from the United States Department of Agriculture (USDA) National Germplasm: APO, IR 55419 and UPL RI 7. Seeds were planted in a plastic nursery tray on 5th June 2019. Three weeks later seedlings were transplanted to individual pots. Compost was added and mixed thoroughly with the soil one week before transplanting of the rice seedlings. Soil was moistened a day before transplanting and application of chemical fertilizer was done just after transplanting. Irrigation of plants was done at regular intervals using a calibrated automatic sprinkler. Soil moisture was maintained throughout the experiment at field capacity. The temperature was regulated at an average 25°C throughout the experiment to mimic the temperature of Ghana, which ranges between 20°C and 35°C throughout the rice growing season.

3.5 Growth data collection

3.5.1 Plant height

Plant height was measured three times during the growth of the plants: 5, 7 and 9 weeks after planting (WAP). The length from the ground level to the tip of the longest leaf was measured.

3.5.2 Chlorophyll content

Chlorophyll levels were measured 7, 8 and 9 weeks after planting with the use of a chlorophyll meter (OPTI SCIENCES CCM 200 plus, which is a portable Soil Plant Analysis Development [SPAD] chlorophyll meter). The SPAD meter was used to acquire a rapid estimation of *in situ* leaf chlorophyll content. The measurements were taken on the upper-most collared leaf halfway from the leaf base to the tip and halfway from the midrib to the leaf margin, as recommended by Yuan et al. (2016). Fifteen units were measured from each pot and the average was taken.

3.5.3 Total dry matter (TDM)

At the end of the experiment, above- and below-ground biomass was collected and weighed. Plants were oven-dried at 80°C for 72 hours and then weighed. Root weight, stem weight, leaf weight and panicle weight (when applicable) were obtained. The total dry matter was calculated using the following formula: Total dry matter (TDM) = Root dry weight + dry stem weight + leaves dry weight.

3.6 Data Analysis

Data collected from this experiment were analyzed using Statistical Package for Social Science (SPSS). The treatment effects on plant height, chlorophyll content, root length and plant biomass were all analyzed using two-way ANOVA. Tukey's HSD at 95% confidence level was applied to compare the means difference at 5% level of significance.

4. RESULTS

Chemical composition of the potting soil and the organic fertilizer (compost) were analyzed in order to determine the availability of major and minor plant nutrients (see Table 1). The compost had a higher carbon rate of 15.1% than the soil, which had 7.6%. Lower nitrogen content of 0.46% was obtained from the soil compared to 1.16% found in the compost. The compost had a C:N ratio of 13:1 while the soil had a higher ratio of 16:1. The soil pH of 7.2 was above 6 but below 8.5, which makes high biological activity possible (Table 1).

Table 1. Results of the texture and chemical properties of the soil and compost used for the experiment carried out in Gunnarsholt as analyzed at the laboratories at Keldnaholt and Hvanneyri.

Properties	Soil sample	Compost
Soil texture	Potting soil	
pH	7.15	
C	7.61%	15.14%
N	0.46%	1.16%
C/N ratio	16:1	13:1
P	0.0113 g/kg	0.7 g/kg
K	1.094 g/kg	11.0 g/kg
S		3.9 g/kg
Ca	17.897 g/kg	24.2 g/kg
Mg	1.128 g/kg	13.3 g/kg
Na	0.500 g/kg	4.0 g/kg
Mn	0.097 g/kg	0.600 g/kg
Zn	0.00068 g/kg	0.112 g/kg
Cu	0.0032 g/kg	0.070 g/kg
Fe		43.480 g/kg

4.1 Plant height

The fertilizer treatments did not have a significant effect on plant height in the first seven weeks of growth after planting. However, at week nine after planting (9 WAP) a significant difference emerged. The rice varieties differed in plant height and were significantly different in all weeks measured. There was no interaction between fertilizer treatments and varieties (see table 2).

At 9 WAP, fertilizer had a positive influence on the plant height in addition to variation between the varieties. The tallest plant (20.2 cm) on average was observed in the application of ½ (compost) + ½ (inorganic fertilizer) and the shortest (16.77 cm) was found in the control treatment (see Table 3 and Figure 1). Compost improves the moisture level, aeration and temperature of the soil and therefore facilitates plant growth, which in turn increases plant height (Agrawal et al. 2003). Plant height at 5 WAP was not significantly affected by fertilizer application while significant differences were observed between the ½ (compost) + ½ (inorganic) treatment and the control (Table 3).

Table 2. Two-way ANOVA result showing F values of plant height at 5, 7 and 9 weeks after planting (WAP) as affected by fertilizer levels and varieties at Gunnarsholt in the 2019 cropping season. Significant levels are presented by: ***: p<0.001, **: p<0.01, *: p<0.05, and NS: not significant.

Sources of Variation	Degrees of freedom	F values		
		5 WAP	**7 WAP**	**9 WAP**
Fertilizer	3	1.607^{NS}	2.510^{NS}	3.382*
Varieties	2	15.125***	8.147*	7.832**
Fertilizer x Varieties	6	0.534^{NS}	0.588^{NS}	0.656^{NS}

Table 3. Means of rice plant height at 5, 7 and 9 weeks after planting (WAP) as affected by fertilizer levels in the experiment carried out in the 2019 cropping season. Average values with the same superscript(s) are statistically similar and those having different superscript(s) differ significantly at 0.05 level of probability (p<0.05).

Fertilizers	Rice plant height (cm)		
	5 WAP	**7 WAP**	**9 WAP**
Control	12.39^{a}	14.35^{a}	16.77^{b}
NPK 90 60 60 kg/ha	12.03^{a}	15.70^{a}	18.29^{ab}
Compost 12/ha	13.11^{a}	15.73^{a}	19.01^{ab}
½ (compost) + ½ (inorganic)	12.81^{a}	16.39^{a}	20.23^{a}
p value	0.200	0.070	0.026

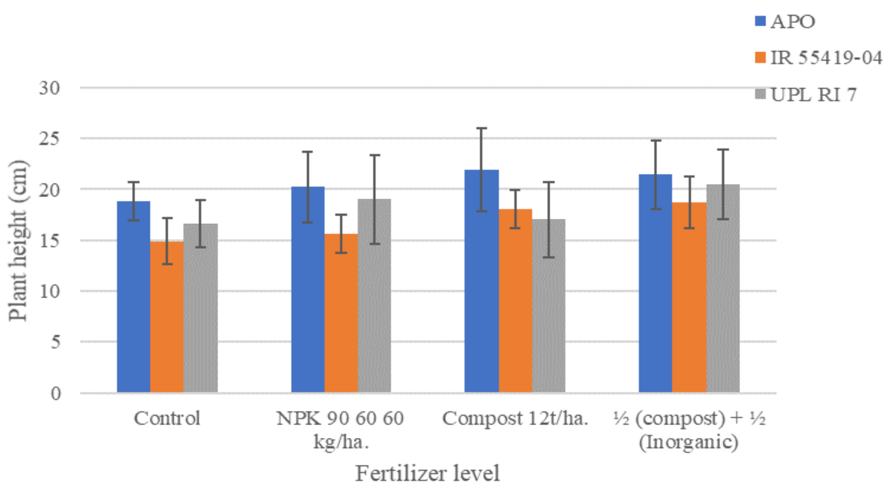

Figure 1. Plant height at 9 weeks after planting (WAP). Column heights represent mean heights and are grouped by fertilizer treatments. They are patterned according to rice varieties. The vertical bars indicate standard deviation.

The differences in plant height among varieties was investigated further. At 9 WAP significant differences were observed between APO (the tallest variety), and IR 55419 and UPL R1 (shorter varieties). At 5 and 7 WAP, the APO was significantly different from the IR 55419 but statistically like UPL R1 7 (Table 4).

Table 4. Average height of the three rice varieties at 5, 7 and 9 weeks after planting (WAP). Average values with the same superscript(s) are statistically similar and those having different superscript(s) differ significantly at the 0.05 level of probability ($p<0.05$).

Varieties	Rice plant height (cm)		
	5 WAP	**7 WAP**	**9 WAP**
APO	12.95^{a}	16.35^{a}	20.62^{a}
IR 55419	11.18^{b}	14.00^{b}	16.84^{b}
UPL R1 7	13.63^{a}	16.28^{a}	18.28^{b}
p value	0.000	0.001	0.001

4.2 Leaf chlorophyll content

The effects of fertilizer treatments were assessed on leaf chlorophyll at 7, 8 and 9 WAP. At 7 WAP, the leaf chlorophyll content was not significantly affected by fertilizer level nor variety. No significant interaction was detected (Table 5 and Figure 2). In the 8th and 9th WAP the fertilizer started to significantly affect the levels of leaf chlorophyll (see Table 5 and Table 6).

Table 5. ANOVA results showing F values for rice leaf chlorophyll content at 7, 8 and 9 weeks after planting (WAP). Significant levels are presented by: **: $p<0.01$, *: $p<0.05$, and NS: not significant.

Sources of Variation	Degrees of freedom	F values		
		7 WAP	**8 WAP**	**9 WAP**
Fertilizer	3	0.93^{NS}	3.85*	4.37**
Varieties	2	0.93^{NS}	4.72*	6.67**
Fertilizer x Varieties	6	0.95^{NS}	1.35^{NS}	1.47^{NS}

Fertilizer clearly had a positive effect on leaf chlorophyll content at 8 and 9 WAP. The highest value (1.76) at 8 WAP was found in ½ compost + ½ inorganic fertilization, while the lowest value (1.39) was recorded for the control. On average, leaf chlorophyll content was higher in the application of compost at 12 t h^{-1} than any other treatment at 9 WAP (Table 6). The significant impact of compost on leaf chlorophyll content is usually evident by the dark green coloration of the crop due to higher chlorophyll "a" and "b" supplied by organic fertilizer (Das et al. 2016)

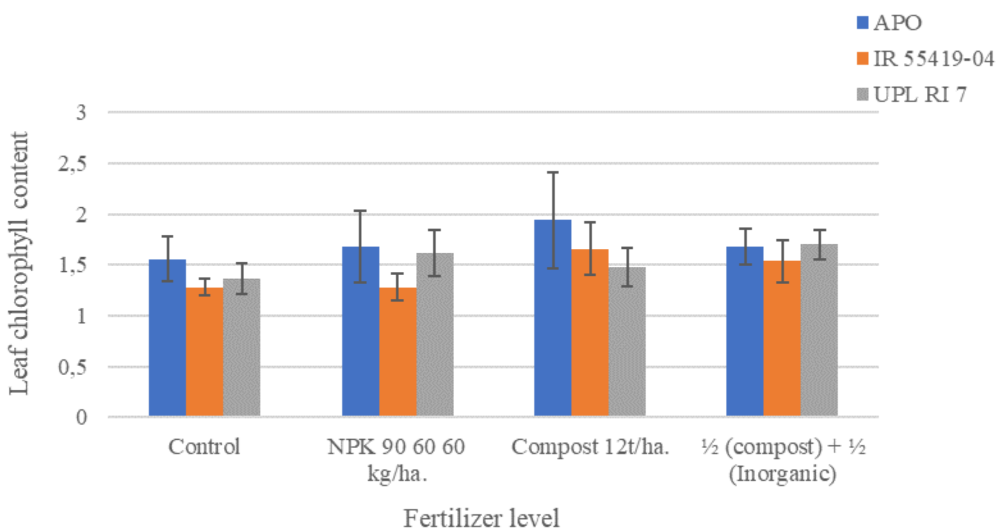

Figure 2. Leaf chlorophyll content at 9 weeks after planting (WAP). Column height represents average leaf chlorophyll content and are grouped by fertilizer treatments. They are patterned according to rice varieties. The vertical bars indicate standard deviation.

At 8 and 9 weeks after planting (WAP), leaf chlorophyll content was influenced significantly by fertilizer source and differed among varieties. At 8 WAP, application of ½ (compost) + ½ (inorganic) had the highest value (1.76) for leaf chlorophyll content which was statistically like the application of only compost 12 t ha^{-1} (1.76) and NPK 90 60 60 kg ha^{-1} (1.55). The lowest value (1.39) of chlorophyll content was observed for the control treatment (non-application of fertilizer). For the 9 WAP, the highest leaf chlorophyll content (1.69) was obtained in compost 12 t ha^{-1} under different fertilizer levels, which did not vary significantly from the combined application of compost and inorganic, while the lowest height was observed in the control (Table 7). This experiment also revealed that fertilizer had a positive effect on leaf chlorophyll content in rice plants.

Table 6. Mean of rice leaf chlorophyll content at 7, 8 and 9 weeks after planting (WAP) as affected by fertilizer levels in the experiment carried out in the 2019 cropping season. Average values with the same superscript(s) are statistically similar and those having different superscript(s) differ significantly at the 0.05 level of probability ($p<0.05$).

Fertilizers	**Leaf chlorophyll content**		
	7 WAP	**8 WAP**	**9 WAP**
Control	1.11^{a}	1.39^{b}	1.40^{b}
NPK 90 60 60 kg/ha	1.25^{a}	1.55^{ab}	1.53^{ab}
Compost 12/ha	1.25^{a}	1.70^{ab}	1.69^{a}
½ (compost) + ½ (inorganic)	1.22^{a}	1.76^{a}	1.64^{a}
p value	0.434	0.015	0.008

The chlorophyll content furthermore varied significantly by rice variety (see table 8). The fertilizer level had a positive effect on leaf chlorophyll content in the rice plants. On average the rice plants that received the equivalent of 12t/ha of compost had the highest chlorophyll content (see table 7). IR 55419 differed significantly from APO and in both 8 and 9 weeks after planting (see table 8).

The interaction effect of the three different rice varieties and the four levels of fertilizer on leaf chlorophyll content at 9 weeks after planting (WAP).

Table 7. Means of rice leaf chlorophyll content at 7, 8 and 9 weeks after planting (WAP) across the three different varieties tested. Average values with the same superscript(s) are statistically similar and those having different superscript(s) differ significantly at the 0.05 level of probability ($p<0.05$).

Varieties	**Leaf chlorophyll content**		
	7 WAP	**8 WAP**	**9 WAP**
APO	1.27^{a}	1.77^{a}	1.72^{a}
IR 55419	1.15^{a}	1.45^{b}	1.44^{b}
UPL R1 7	1.22^{a}	1.59^{ab}	1.54^{ab}
p value	0.402	0.013	0.003

4.3 Root length

The root length of the rice plants was not affected by fertilizer level, but a significant difference was observed between varieties at 9 WAP. The interaction of fertilizer and variety of rice plant root length was not significant (Table 8 and Figure 3).

Table 8. ANOVA results showing F values for rice plant root length at 9 weeks after planting (WAP). Significant levels are presented by: ***: $p<0.001$, **: $p<0.01$, *: $p<0.05$, and NS: not significant.

Sources of Variation	**Degrees of freedom**	**F values**
Fertilizer	3	0.724^{NS}
Varieties	2	6.356**
Fertilizer x Varieties	6	0.603^{NS}

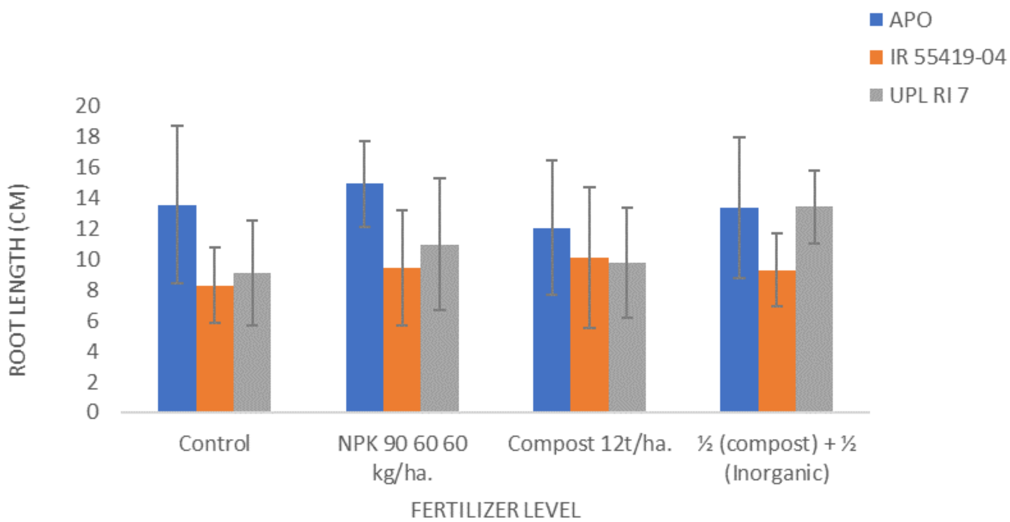

Figure 3. Root length at 9 weeks after planting (WAP). Columns represent averages and are grouped by fertilizer treatments. They are patterned according to rice varieties. The vertical bars indicate standard deviation.

Varieties tested showed significant variations in root length at 9 WAP. The longest root (13.46 cm) was found in APO and the shortest root (9.26 cm) was observed in IR 55419. On average, the root length of UPL R1 7 (10.80 cm) was statistically similar to APO and IR 55419 (Table 9).

Table 9. Means of rice plant root lengths at 9 weeks after planting (WAP) Average values with the same superscript(s) are statistically similar and those having different superscript(s) differ significantly at the 0.05 level of probability ($p<0.05$).

Varieties	Rice plant root length (cm)
APO	13.46^{a}
IR 55419	9.26^{b}
UPL R1 7	10.80^{ab}
p value	0.004

5. DISCUSSION

The results of this study demonstrate the beneficial effects of compost application for the growth of rice plants. Furthermore, they show the positive effects of combining organic and inorganic fertilizer (see Figure 1). The reason for the observed results could be the lower carbon to nitrogen ration (C:N) of the compost, as this has a positive relationship in decomposition of organic matter which leads to release of essential nutrients needed by plants. One of the factors that affects decomposition of organic material is the C:N (Emmanuel et al. 2018). The compost used in this study had a low C:N ratio of 13:1 (Table 1). This finding agrees with the work of Toma and Hatano (2007) who reported that organic matter with a lower C:N ratio was easily mineralized, and the chances of nitrification and denitrification were high, so N_2O was easily produced. Similar results were observed by Danga et al. (2010) who reported that organic materials with a C:N ratio higher than 30:1 were incorporated into the soil, and soil nitrogen was immobilized at the early phase decomposition processes. When the C:N ratio falls within 20:1 and 25:1, neither release of mineral nitrogen nor immobilization was observed. They added that organic materials with a C:N ratio lower than 20:1 usually releases mineral nitrogen in the processes of decomposition. This is likely to explain the observed results as the compost used in this study had a C:N ratio of 13:1 and therefore the material was readily decomposable and released nutrients readily.

One of the important factors in organic matter decomposition is the soil pH. The soil used in this study had a pH of 7.2 (Table 1). This soil pH is favourable for the microbial activity in the soil and contributes to the decomposition of the compost. These results harmonize with the work of Maida (2005) who found that highly acid or alkaline soils retard biological oxidation of organic matter due to the unfavorable condition it poses on the microorganisms, i.e. when the soil pH drops below 6 or rises above 8.5. The lack of interaction between the compost and the rice variety is a clear sign that organic fertilizer, in this case compost, alone can provide enough nutrient elements needed by the plants (see Tables 2, 5, 8 and 10). It also indicates that most rice varieties respond similarly to compost application. These are important findings, since it shows that organic fertilizers can be readily incorporated into current rice cultivation without the need of planting specialized varieties. The lack of a significant effect of the compost and variety at the early stage of the study could have been due to the high nutrient reserve in either the soil or the seed at the early stages of the plant growth (Maida 2005).

Plant height is not traditionally considered as one of the yield components in the grain yield of rice, but it gives insight into the mechanisms of several nutrients in plant metabolism (Muhammad et al. 2003). As for the fertilizer level, no significant variation was recorded for rice plant height at 5 and 7 weeks after planting but in 9 WAP a significant difference was observed (Table 3). At 9 WAP ½ (compost) + ½ (inorganic) had the tallest plant height (20.2 cm), which was statistically similar to compost 12 t ha^{-1}. (19.0 cm) and NPK 90 60 60 kg ha^{-1} (18.3 cm), and the shortest plant height (16.8 cm) was obtained in the control. However, the tallest plant height (13.1 cm) at 5 WAP was obtained by application of compost 12 t ha^{-1} and was not statistically different from ½ (compost) + ½ (inorganic). The shortest plant height (12.3 cm) was observed in application of inorganic fertilizer alone, NPK 90 60 60 kg/ha, which did not differ significantly from the control treatment (non-fertilizer application). The study revealed that application of compost alone at 12 t ha^{-1} or combining compost and chemical fertilizer positively influenced plant height. This observation agrees with the findings of Amanullah (2016) who reported an increase in rice plant height from application of organic manure and compost alone. A similar result was also reported by Mahmud et al. (2016), stating that incorporation of vermicompost to the soil influenced plant growth, especially plant height compared to control treatment (non-fertilizer application). This could have been due to the potential of compost in improving soil moisture retention, soil porosity and plant growth characters. At 7 WAP, the tallest plant height (16.9 cm) was observed in the ½ (compost) + ½ (inorganic) treatment which was statistically similar to application of compost 12 t ha^{-1} and NPK 90 60 60 kg ha^{-1}, while the shortest plant height (14.4 cm) was obtained in the control treatment (Table 3). The significant increase in plant height under ½ (compost) + ½ (inorganic) could have been due to the integrated effect of nutrients released by organic and inorganic fertilizers. This study supports the work of Mahmud et al. (2016) who reported that the combined application of compost and chemical fertilizer on rice plants had a great influence on plant height which might have been due to the presence of major nutrients from the organic fertilizer combined with the instantaneous readily soluble nutrients from the inorganic fertilizers. Moe et al. (2017) also found out that the height of the rice plants from the application of inorganic fertilizer alone was not significantly different from that of organic fertilizer alone, but that maximum plant height was attained from combining application of 100% NPK with organic manures. Significant differences in plant height were observed among rice varieties at 5, 7 and 9 WAP. The highest plant height (13.6 cm) at 5 WAP was recorded in the UPL R1 7, which was statistically like the APO (13.0 cm), and the lowest (11.2 cm) was observed in the IR 55419. However, the APO recorded the highest plant height of 16.35 cm at 7 WAP and IR 55419 had the least height, or 13.50 cm, of all the varieties (Table 5). At 9 WAP, the highest plant height (20.6 cm) was obtained in the APO, which was similar to UPL R1 7 (18.3 cm) while the IR 55419 had the least value of 16.8 cm for plant height. These results demonstrate the genetic influence on plant height and support the work of Alim (2012) who reported that plant height varied significantly among varieties and for different sources of fertilizer. This varietal differences in plant height could thus result from the genetic makeup of the cultivars. He added that plant height is dependent on the number of internodes for their length and this represents the genotypic characteristics of a variety.

The interaction effect between fertilizer and variety was not significant on plant height at 9 WAP. However, the highest plant height (21.5 cm) was recorded in the APO x compost at 12 t/ha which was followed by APO x ½ (compost) + ½ (inorganic) (21.5 cm). Meanwhile, control treatment x IR 55419-04 gave the lowest plant height (14. 9 cm) among the interactions (Figure 1). The highest plant height observed could have been due to the combined effect of the genetic makeup of the variety and appropriate application of compost to the soil. This result agrees with the findings of Mahmud et al. (2016) who reported that incorporation of compost into the soil at different rates influenced plant growth, especially plant height. Compost application at the rate of even 4 h^{-1} increased plant height by 4 cm compared to plants under the control treatment.

The high leaf chlorophyll content observed in the combined application of ½ (compost) + ½ (inorganic) at 8 WAP could have been due to the high nitrogen presence in inorganic fertilizer. Lemaire and Gastal (2002) reported similar results, stating that nitrogen can be found in both organic and inorganic form and that there was a higher nitrogen content in the seeds, leaves, shoots and roots of the plant. The results also support the findings of Das et al. (2016) who postulated that there were significant impacts of the nutrient sources on leaf chlorophyll content and that this is usually evident in the dark green coloration of such crops and a signal of nutrient efficiency. They added that the combined effect of inorganic fertilizer and manure was high chlorophyll a and b components in leaves of maize and this affected the total chlorophyll content. This could be due to the nutrients released by inorganic fertilizer towards the pre- and the post-anthesis stage. Significant differences in leaf chlorophyll content at 8 and 9 WAP among the rice varieties observed in this study revealed that the varieties reacted differently in the absorption of nitrogen given different sources of fertilizer based on their genetic makeup. A similar result was reported by Prioul et al. (1980), i.e. that total chlorophyll content serves as an indicator for accumulation of nitrogen by plants which reveals root system activities and movement of nutrients from the root zone to the top of the plant (leaves). Also, physiological nitrogen efficiency is shown in the activities at the top of the plant which involves absorption, processes and synthesis of nitrogen.

The lack of interaction effect of chlorophyll content between the fertilizer and the variety is an indication that rice varieties respond similarly to fertilizer treatments. Furthermore, careful selection of rice genotype could also help in nutrient absorption for plant growth. The lack of effect for both the fertilizer and variety at 7 WAP could be attributed to slow release of nutrients from the fertilizers, especially the compost, and the ability of the plant roots to absorb enough nutrient reserves from the soil at that tender stage.

Plant dry biomass was not influenced by fertilizer. Furthermore, no genetic effect was detected. However, there were comparative differences with the maximum biomass obtained in the application of ½ (compost) + ½ (inorganic), while the minimum biomass was observed in the control treatment. The high dry biomass observed could be due to the essential nutrient elements supplied by organic and inorganic fertilizer, which promote vegetative growth of the plant. This result seconded the work of Mahmud et al. (2016) who reported that combined application of compost at 4 t ha^{-1} and N, P, K, S fertilizer at 100-16-66-12 kg ha^{-1} gave the highest straw yield of 8.73 t ha^{-1} compared to the control treatment of 5.42 t ha^{-1}. This might be due to the availability of nutrients which substantially increased vegetative growth and thereby increased rice straw yield. Sci et al. (2018) also reported high straw biomass from combined application of organic and inorganic fertilizer compared to other treatments due to the presence of adequate amounts of both nitrogen and soil moisture that increase accessibility and uptake of NH^{4+}. They added that increase in nitrogen absorption goes along with absorption of both phosphorus and potassium, which promotes high tiller numbers and leaves (straw yield). Root length of the rice plants was not influenced by either fertilizer or variety. However, the longest roots were observed in the combined application of organic and inorganic fertilizer and exceeded the control treatment.

6. CONCLUSIONS

The results of this study are quite clear and have important implications for the sustainable development of rice cultivation. The most important conclusions that can be drawn from the study are listed below:

1. Compost can be appropriately used as an organic fertilizer to substitute or complement chemical fertilizer.
2. Using compost as an organic fertilizer at 12 t ha^{-1} has similar beneficial effects on rice plant growth as a full rate of inorganic fertilizer (NPK 90 60 60 kg/ha.).
3. The use of compost as an organic fertilizer provides an attractive source of soil nutrients for rural smallholder farmers and could help reduce the cost of farming, since it is relatively cheaper than chemical fertilizer and can also be prepared by the farmers themselves if trained.
4. This research was carried out in pots in a controlled environment. It is necessary to repeat the experiment in the field under rain-fed conditions to ascertain the actual potential of compost use.
5. When selection of high-quality rice variety is considered, productivity in grain yield can be appreciably improved.

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APPENDICES

APPENDIX I

Schematic presentation of the treatment combinations layout for the pot experiment involving the use of compost and inorganic fertilizer in the Gunnarsholt greenhouse during the 2019 cropping season.

1. FL3RV1R2	**2.** FL0RV2R2	**3.** FL3RV3R2	**4.** FL0RV2R5
5. FL1RV3R3	**6.** FL1RV2R2	**7.** FL0RV1R3	**8.** FL2RV1R2
9. FL1RV1R2	**10.** FL2RV3R4	**11.** FL3RV1R1	**12.** FL0RV1R2
13. FL1RV1R1	**14.** FL3VR3R1	**15.** FL0RV1R4	**16.** FL1RV1R4
17. FL0RV3R5	**18.** FL1RV3R3	**19.** FL2RV1R5	**20.** FL1RV2R5
21. FL0RV3R1	**22.** FL3RV2R3	**23.** FL0RV1R5	**24.** FL2RV3R2
25. FL0RV2R3	**26.** FL2RV1R4	**27.** FL3RV2R1	**28.** FL2RV2R5
29. FL2RV2R2	**30.** FL1RV1R5	**31.** FL2RV3R5	**32.** FL3RV1R4
33. FL0RV2R1	**34.** FL2RV3R1	**35.** FL1RV2R3	**36.** FL1RV3R1
37. FL3RV2R2	**38.** FL0RV3R3	**39.** FL3RV1R3	**40.** FL2RV2R3
41. FL2RV1R1	**42.** FL2RV3R3	**43.** FL1RV2R4	**44.** FL1RV3R2
45. FL2RV1R3	**46.** FL3RV2R5	**47.** FL3RV1R5	**48.** FL0RV2R4
49. FL1 RV3R4	**50.** FL3RV3R3	**51.** FL3RV2R4	**52.** FL0RV1R1
53. FL0RV3R2	**54.** FL1RV1R3	**55.** FL2RV2R4	**56.** FL1RV2R1
57. FL2RV2R1	**58.** FL3RV3R4	**59.** FL3RV3R5	**60.** FL0RV3R4

APPENDIX II

Means of rice plant root length at 9 weeks after planting (WAP) as affected by different fertilizer levels for the pot experiment carried out in the Gunnarsholt greenhouse during the 2019 growing season.

Fertilizers	**Rice plant root length (cm)**
Control	10.32[a]
NPK 90 60 60 kg/ha	11.75[a]
Compost 12/ha	10.62[a]
½ (compost) + ½ (inorganic)	12.01[a]
p value	0.543

APPENDIX III

Two-way ANOVA result showing F values for rice plant biomass at 9 Weeks After Planting. Significant levels are presented by: ***: $p<0.001$, **: $p<0.01$, *: $p<0.05$, and NS: not significant.

Sources of Variation	**Degree of freedom**	**F values**
Fertilizer	3	1.027[NS]
Varieties	2	1.402[NS]
Fertilizer x Varieties	6	1.484[NS]

APPENDIX IV

Means of rice plant biomass at 9 weeks after planting (WAP) as affected by different fertilizer levels for the pot experiment carried out in the Gunnarsholt greenhouse during the 2019 growing season.

Fertilizers	**Rice plant dry biomass (g)**
Control	0.71[a]
NPK 90 60 60 kg/ha	0.119[a]
Compost 12/ha	0.137[a]
½ (compost) + ½ (Inorganic)	0.140[a]
p value	0.389

APPENDIX V

Means of rice plant biomass at 9 weeks after planting (WAP) as affected by different varieties for the pot experiment carried out in the Gunnarsholt greenhouse during the 2019 growing season.

Varieties	**Rice plant dry biomass (g)**
APO	0.153[a]
IR 55419	0.091[a]
UPL R1 7	0.106[a]
p value	0.256

APPENDIX VI

The interaction effect of the three different rice varieties and the four levels of fertilizer on rice plant biomass at 9 weeks after planting (WAP).