

Comparative Evaluation of Four Indigenous Rice Cultivars as Influenced by Ethylene Gas in Jammiri Village in Bali Local Government Bali, Taraba State Nigeria

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Abstract

Rice (Oryza sativa) is a fundamental food that provides the essential food requirements for more than 60% of the global population. Increasing food production becomes not only necessary but compulsory to be able to feed the geometric increase of human population. One of the models to do that is to improve the nitrogen use efficiency. This will enable nitrogen fertilizer to remain as ammonium which is positively charged and stays bonded to soil surface. This will prevent it from leaching out rhizosphere, polluting the underground water and the atmosphere. However, rice production is associated with low nitrogen use efficiency as a result of leaching and denitrification. Ethylene plays important roles in root elongation, partial disease resistance, and inhibition of nitrification, grain filling, regulating root structure, increasing water use efficiency and triggering growth in rice. Ethylene gas plays an important role in most stages of plant growth the objective of the study was to compare the concentration of ethylene gas produced by each of the variety under investigation. Three experiments were set up in Nayinawa Group Farm. The first experiment was to find out if rice varieties differ in their ethylene production. The second experiment was to find out if among the varieties, one would produce ethylene gas that would inhibit the conversion of ammonium into nitrate. The third was to find out if ethylene produced would vary with soil type. The result showed that rice cultivars varied in ethylene production ($P > 0.01$). The result showed the ethylene production by different rice cultivars varied with soil type ($P < 0.01$).

Key words: ethylene gas, rhizosphere, oxidation ammonium, rice.

Introduction

Rice is an indispensable food being consumed by more than half of the world population. Its production is more than 323. 6 million tons (Faggeia, 2018). It also provides B-vitamin (Manful *et al.*, 2010). Worldwide, human population gets its calorie exceeding 20% protein exceeding 15% from rice (Redman, *et al.*, 2012). It is also predicted scientifically that rice provides more than 30% of energy out of the 100% of the over-all energy provided by all the

food crops (De Datta, 2016). Its farming serves as source of employment to many people that would have been jobless in the rural areas (De Datta, S.K, 2016). The cultivation and consumption of rice is always in increasing rate and it is regarded as one of the most consumed cereals (Foo and Hameed, 2015). Rice husk is now used to generate energy more especially to those countries that import oil to provide energy (Wang *et al.*, 2015). Ganvir (2011), reported that, health problems may result when the fluoride concentration in drinking water exceeds 1.5 mg/L. This may include failure of the human body to metabolize calcium and phosphorus. To remove this, aluminium hydroxide is coated with rice husk ash (Gavril *et al.*, 2011). Industrial activities are origin of heavy metal that contaminate soil and they can be injected into human body through food consumption (Pain *et al.*, 2013). For the purpose of reducing the cost of their remediation, rice straw can be used to remove them. The lignin content of rice straw will react with the heavy metals to form chelate and detoxify them (Richard *et al.*, 2014).

Rice bran contains high amount of oil that can be related to palm kernel and cotton seed oil (Levinch, 2017). But the growing of rice since it is hydrophyte crop, it requires flooded areas and it is known as another way of increasing the concentration of greenhouse gasses in the atmosphere. Rice is mostly grown in flooded lands or semi flooded lands, only some varieties of rice are cultivated in a well-drained land. Upon all the advantages of rice farming, it leads to the generation of greenhouse gases, such as nitrogen oxides and their derivatives, methane and carbon dioxide (de Miranda *et al.*, 2015) Ethylene also known as ethane is a simple colourless and combustible gas made up of two carbons linked together by dual bonds. The gas has a molecular formula as C_2H_4 . According to Bleeker (2014), it is plant hormone that plays major roles in plant life cycle stating from germination to the final ripening. The biological role of this gas was known before its discovery; it is known to control the growth and development of plants and that is why it is called a plant hormone. It is considered to play an important role in seed germination, fruit ripening, response to pathogenic infection and environmental stress and petal and leave abscission. But upon all these roles, nothing was known about ethylene until in the late nineteen centuries, a young researcher Dimitri Nikolayevich was able to identify the gas. Later in twentieth century, a gas chromatograph was used to detect the gas and classify it as a plant hormone. (Gowda *et al.*, 2015).

Nitrogen use efficiency (NUE) in rice

Nitrogen is considered to be one of the growth limiting factors for many years, an agricultural researchers have been paying their attention on how to supply enough nitrogen to crops in order to get best yield. The efficacy of this can only be achieved by maximizing the amount of nitrogen returning to the soil and minimising its amount leaching out of the plant root zone (De Willigen, P., 1991) Rice is one of the crops that can consume high amount of nitrogen, but its utilization efficiency is small, which is not more than 35% (Dobermann *et al.*, 2002). According to Subba Rao (1999), apart from denitrification, leaching is another way by which nitrogen is lost ranging to loss of 20 to 50% of the applied nitrogen. It is considered as the most prominent way by which nitrogen is lost in the rice farm in which more than 50% of the applied nitrogenous fertilizer is lost by leaching. It is estimated that more than 80 million tons of nitrogen fertilizer is applied to the soil world-wide (Frink *et al.*, 1999), but plant can efficiently utilize only 30% of it, the larger percent is either leached down the soil which contaminates the ground water or denitrified and into the atmosphere to cause global warming (Glass, 2003). The loss of nitrogen through leaching and denitrification when fertilizer is applied to the soil can be mitigated if ammonia oxidation is inhibited. This will make rice to have efficient fertilizer utilization (Hauck, 1983). Rice is a plant that can tolerate high concentration of ammonia (Wang *et al.*, 1993a, b) ...Research has shown that the ability of the rice to withstand the high degree of ammonia concentration is related to the enzyme called glutamine synthetase

it has and lack of more build-up of free ammonia in its tissues (Magahals and Hubber, 1991; Balkos *et al.*, 2010).

Impact of ethylene gas on soil microbes and impact of soil microbe on ethylene in the rice rhizosphere.

Rhizosphere is the portion of the soil within the influence of root. This area has numerous microorganisms due to root exudates. But the presence of these microorganisms depends on the physical and chemical properties of the soil (Peiffer, *et al.*, 2013). The amount of organic matter and percentage of soil fungi and bacteria are higher in the rhizosphere, but still the concentration of ethylene is lower than non-rhizosphere soil due to the decomposition and consumption of ethylene by microbes, transfer of ethylene to the leaves and adsorption process (Otani, T and Ade, N., 1993). Microbes play a role in determining the concentration of ethylene in the rhizosphere by the decomposition of organic matter to produce ethylene and then consume it (Abeles, 1992). Microbes are the key basis of ethylene in the soil both in aerobic and flooded condition, but it is oxidized in aerobic condition (Zecmeister-Boltenstern & Smith, 1998). The microbial activities are said to be affected when there is a small change in ethylene concentration (Abeles *et al.*, 1992). Increase in organic matter increases the ethylene concentration. (Arshad & Franken Berger, 1990). This organic matter is decomposed by microbes.

Biological nitrification inhibition (BNI) and its importance

The ability of plant root to release substances that can inhibit the conversion of ammonia to nitrate is what is called biological nitrification inhibition (BNI) (Subbarao *et al.*, 2013). A biological nitrification is an aerobic process that developed many years ago (Berner, 2006). The process is the function of ammonia-oxidizing bacteria (AOB) and ammonia-oxidizing archaea (AOA). The key examples of ammonia-oxidizing bacteria are *Nitrobacter spp* and *Nitrosomonas spp* (Linninger *et al.*, 2006; Taylor *et al.*, 2010). These oxidizers are mostly accountable for ammonia oxidation large agricultural soil, however, bacterial *spp* like *Nitrosospira* and *Nitrosocystus* and fungus *Aspergillus flavus* also have a significant impact on ammonia oxidation more especially in forested ecosystem (Summer *et al.*, 1976). The nitrification has an agricultural and environmental implication. Agriculturally, it encourages leaching, causes low nitrogen use efficiency and increases the cost of production. Environmentally, the leached nitrate contaminates the ground water and nitrous and nitric oxide are greenhouse gases that cause global warming (IPCC, 1996). Biological nitrification inhibition will maximize nitrogen use efficiency (NUE) through improvement of nitrogen that will be lost by leaching and denitrification (Subbarao *et al.*, 2012a). Ethylene produce by rice inhibits nitrification (Hommes *et al.*, 1998). According to Tanaka (2010) conducted an experiment to investigate the biological nitrification inhibition using two cultivars of rice which were upland rice cultivar (IAC25) and lowland rice cultivar (IR64 or Nippon bare). The result showed that the upland rice cultivar had higher biological nitrogen inhibition in the rhizosphere than the lowland cultivar (IR64 or Nippon bare). The higher inhibition was as a result of higher release of the exudates. This was endorsed by noticing higher concentration of nitrate in the lowland cultivar IR64 than the upland cultivar IAC25. A part from ethylene inhibition of ammonium oxidation, compounds like dicyandiamide (DCD) and (3, 4-Dimethylpyrazole phosphate (DMPP) inhibit it by deactivating ammonia monooxygenase (AMO) which is an enzyme of ammonium oxidation bacteria. For instance, *Nitrosospira and nitrobacteria* (Di and Cameron, 2011).

Objective of the study

To compare the concentration of ethylene gas production by four rice varieties

To find out which among the four varieties can stop nitrification

To find out if soil types have a difference influence on the production of ethylene gas

materials and methods

The seeds of rice cultivars (*Oryza sativa*), were, chika buhu, Bare, Cd and Pol biya and were bred by the Department of Agricultural Technology, Federal Polytechnic, Bali, Taraba State, Nigeria. A pot experiment was set up in the Department of Agricultural Technology, Federal Polytechnic Bali Research Farm. Four (4) different cultivars of rice (Chika buhu, Bare, Cd and Pol biya) were planted in white and black pots and were irrigated every day until they were ready for transplanting.

Transplanting

After the filling of all the pots with the soil, twelve seedlings of the planted rice were gently and randomly uprooted and transplanted in to the prepared pots. This transplanting was carried out in the evening to avoid any stress to the plants due to transpiration. After the plants were fully recovered from the transplanting stress, the prepared metal tubes were inserted in to the pot and very close to the rice root. If the tubes were to be far away from the root, this would have a negative effect on the accumulated concentration of the ethylene gas. The closer the tube is to the root, the more the accumulation of the ethylene gas that may be predicted (Yamauchi et al., 1995). The distance between the soil in the pot and the head of the tube was 2 cm. This had given space for regular watering and the application of nutrient solution.



Figure 1: Rice cultivars under flooded Soil Management



Figure 2: Rice cultivars under Alternate Wetting and Drying

Method of measuring the concentration of ethylene gas

According to Bulens (2011), ethylene can be measured by a gas chromatograph after the samples have been collected directly from the head space inserted in to the samples. But the concentration of the ethylene is quantified by a gas chromatograph when a straight lined relation between the peak and the computed concentration is known. The calibration graph should be at least three to cover the whole range of the detector range. For the accuracy of measurement, the calibration curve has to be repeated before separate measurement is done.

Method of sampling and analysis of ethylene gas

According to Yamauchi (1995), the ethylene sample was collected by placing the rice in a test tube which was plugged with a head stopper. Then 1 ml of ethylene gas was withdrawn and injected into a gas chromatograph for the determination of its concentration. The chromatograph will only show the area, but the calibration graph was used to determine the concentration. In this experiment, 5- ml samples were withdrawn by syringe and needle from the prepared metal probes or tubes that was inserted very close to the rice root of each pot and injected into the evacuated collection bottle. After the samples were collected, then, they were taken to the laboratory for analysis and the machine used for the analysis was gas chromatograph. After the analysis, the data collected were subjected to one way analysis of variance (ANOVA) together with a turkey test using a statistical package for social science (SPSS) as the soft wire used.



Figure 3.A metal tube for the accumulation and collection of ethylene gas

Results and Discussion

Three experiments were conducted with four indigenous varieties of rice (Chika Buhu, Bare, Cd, and Pol biya) in Federal Polytechnic Bali School of Agricultural Technology Department of Agricultural Technology. The first was to compare the concentration of ethylene gas produced between the four varieties of rice. The second research was to find out which among the four varieties can stop nitrification. The third experiment was to find out if soil types have a difference influence on the production of ethylene gas. The rice varieties were cultivated under one management condition which was flooding and drying (AWD). The results obtained were displayed and discussed below. On the experiment to compare the concentration of ethylene gas production by four rice varieties, the original hypothesis was there was no statistically significant difference among the four rice varieties in the production of ethylene gas. But this result showed that there was a statistically significant difference in ethylene gas produced by the four varieties of rice ($P < 0.01$). See figure 1, 2 and 3 below.

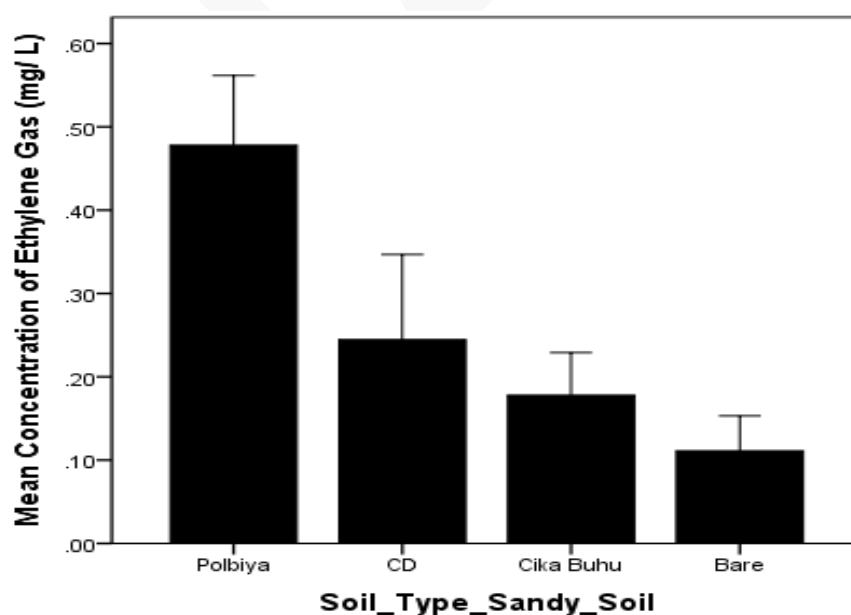


Figure 1: Mean Concentration of Ethylene Gas for the four indigenous rice cultivar. The values 0.48 ± 0.03 , 0.24 ± 0.04 , 0.18 ± 0.02 and 0.11 ± 0.01 are means and standard deviation for Polbiya, CD, Chika Buhu and Bare, respectively

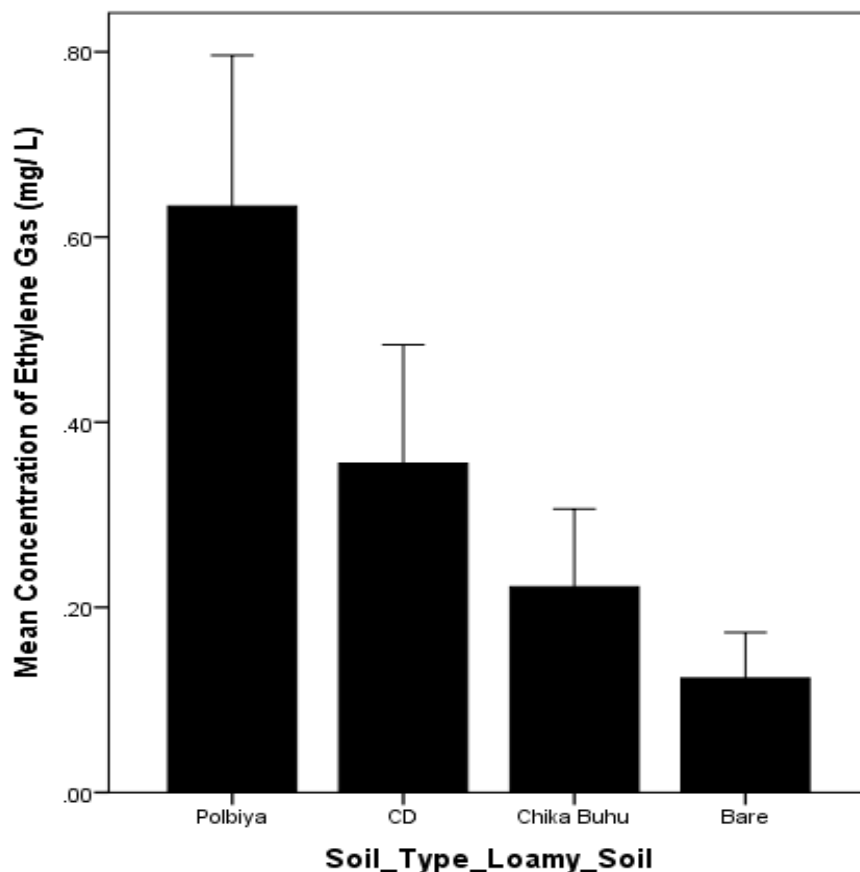
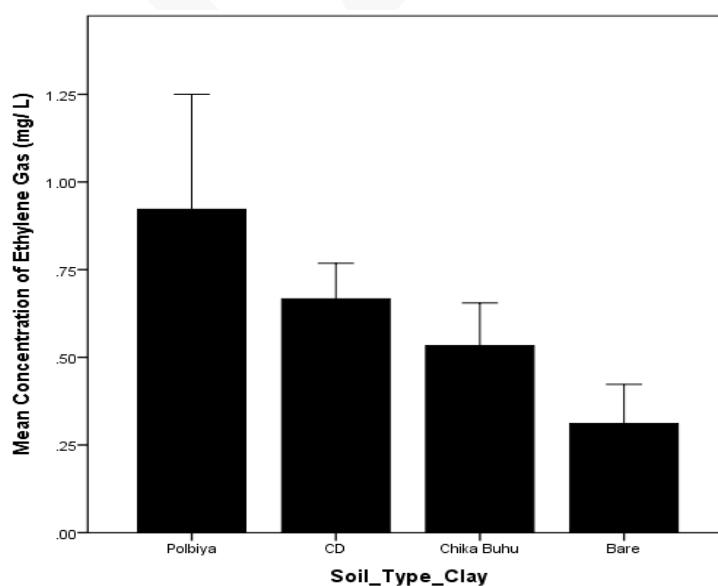


Figure 2: Mean Concentration of Ethylene Gas for the four indigenous rice cultivar. The values 0.63 ± 0.07 , 0.36 ± 0.06 , 0.22 ± 0.03 and 0.12 ± 0.02 are means and standard deviation for Polbiya, CD, Chika Buhu and Bare, respectively



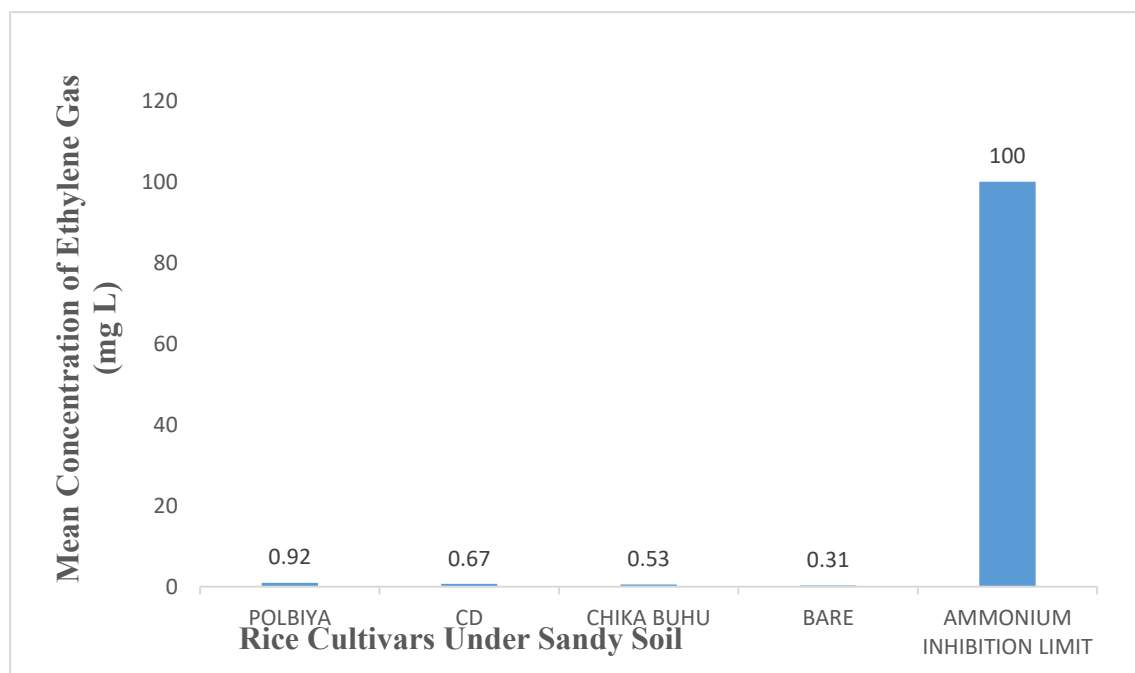


Figure 3: Mean Concentration of Ethylene Gas for the four indigenous rice cultivars. The values 0.92 ± 0.14 , 0.67 ± 0.04 , 0.53 ± 0.09 and 0.31 ± 0.04 are means and standard deviation for Polbiya, CD, Chika Buhu and Bare, respectively.

Comparison of ethylene gas production

On the comparison of ethylene gas production, the original hypothesis was there was no statistically significant difference in the concentration of ethylene gas produced by the indigenous rice cultivars (Polbiya, CD, Chikabuhu and Bare). But this research reported that there was a statistically significant difference in the concentration of ethylene gas produced by them. See figure 1, 2 and 3 above ($P < 0.05$). There are few reports on ethylene emission from rice plant. But the result of (Imakawa et al., 2002), where they conducted an experiment on 16 rice cultivars and 10 soya beans cultivars to find out if there is variation in the rate of ethylene production and growth between them. The result of their experiment reported that there was variation in the rate of ethylene production between them, but the difference existing in rice cultivars in relation to ethylene production was much lower than the soybeans. Larsen & Vangdal (2013), also conducted a research on 9 plum cultivars to investigate whether there is variation in the rate they produce ethylene and respire in relation to parking. At the end, they concluded that there was a difference in the rate of ethylene production among the 9 plum cultivars. Both the two results contradict my own result, but these contradictions may be as a result of difference in cultivars, time taken, number of cultivars used, method of production and the soil and environment in which they were grown. On the second experiment to find out which of the rice variety could inhibit the oxidation of ammonium, none of them was able to inhibit the oxidation of ammonium. See figure 4, 5 and six below.

Figure 4: Mean Concentration of Ethylene Gas for the four indigenous rice cultivars. The values 0.48, 0.24, 0.18 and 0.11 are means of Polbiya, CD, Chika Buhu and Bare grown in loamy soil, respectively.

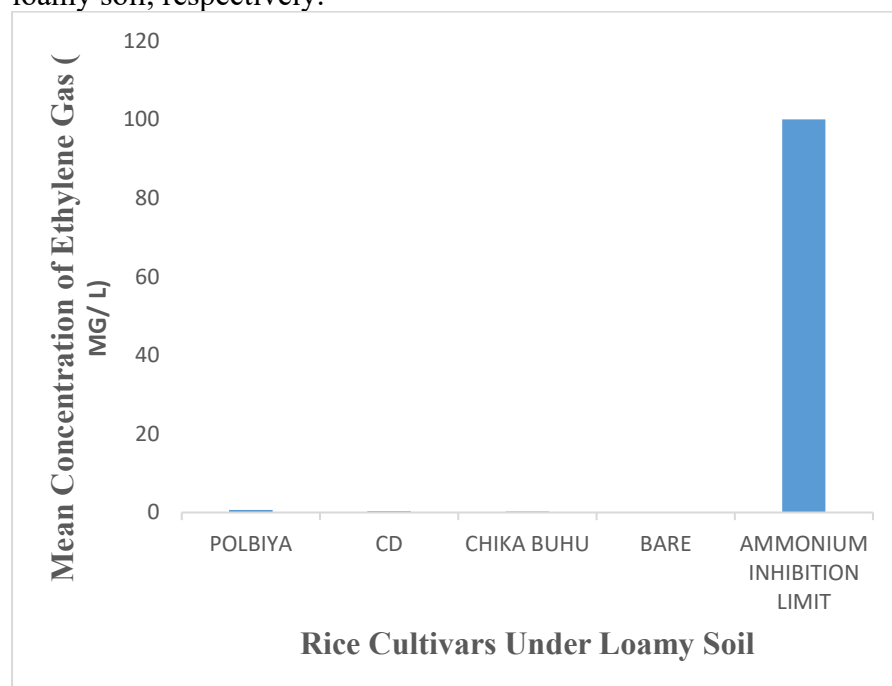


Figure 5: Mean Concentration of Ethylene Gas for the four indigenous rice cultivar. The values 0.92, 0.67, 0.53 and 0.31 are means Polbiya, CD, Chika Buhu and Bare grown in loamy soil, respectively.

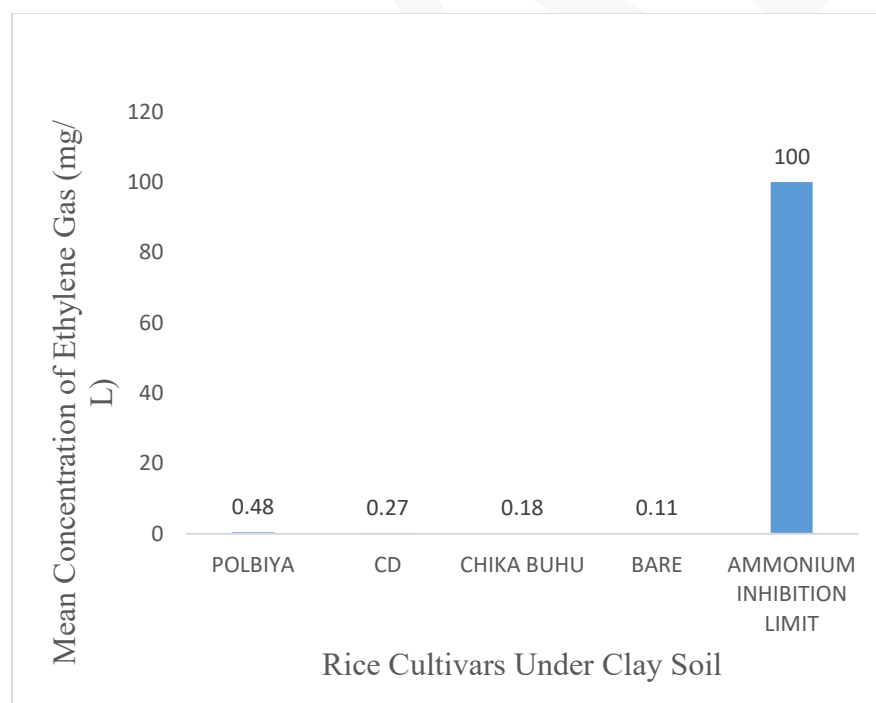


Figure 6: Mean Concentration of Ethylene Gas for the four indigenous rice cultivars. The values 0.92, 0.67, 0.53 and 0.31 are means and standard deviation of Polbiya, CD, Chika Buhu and Bare grown in clay soil, respectively.

Biological Nitrification inhibition (BNI).

The overall objective of this study was to investigate the possibility of the ethylene gas being produced by the varieties of rice to have impact on nitrification via the inhibitory effect of ethylene on ammonia oxidase. According to this research, the obtained concentration of ethylene gas could not inhibit biological nitrification even if they are summed together. According to McCarty & Bremner (2012), for ethylene to inhibit biological nitrification, it seems 100 ppm of ethylene is required to have an impact. None of measurements observed in this study was even half of the ethylene concentration needed to inhibit either 1-7% or complete nitrification. Porter (1990) conducted an experiment to see the effect of ethylene on nitrification. He treated a clay loamy soil with ammonium sulphates under different ethylene partial pressure. He later analysed the soil to see the concentration of ammonia (NH_4), nitrate (NO_3) and nitrite (NO_2). He found that at the ethylene concentration of 0.17 ppm, the nitrification was the same as untreated soil, at the ethylene concentration of 1.7 ppm, there was a partial inhibition of nitrification and at the ethylene concentration of 45.5 ppm, there was a complete inhibition of ammonia oxidation. Based on the result of McCarty & Bremner (2012) and Porter (2013). This research had logically concluded that the mean concentrations of ethylene gas produced by Polbiya, CD, Chikabuhu and Bare could not inhibit biological nitrification. On the experiment to see if the production of ethylene gas by the indigenous rice cultivars varies with soil type, the original hypothesis was it did not vary with soil varieties, but the result of this finding showed it varied with soil type. See figure 7, 8 and 9 below.

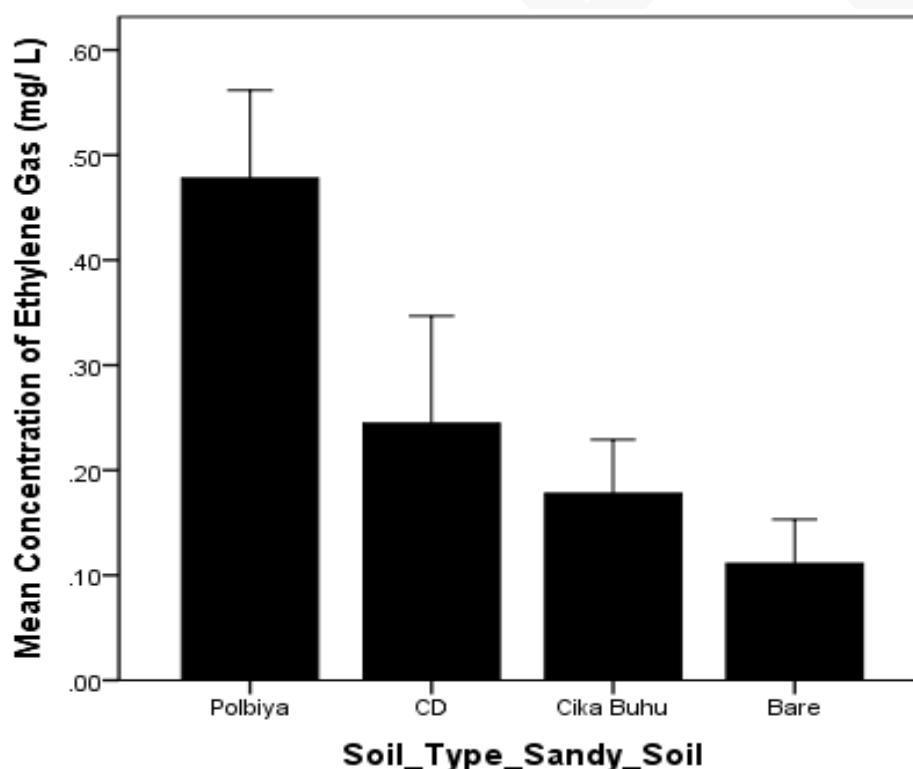


Figure 7: Mean Concentration of Ethylene Gas for the four indigenous rice cultivar. The values 0.48 ± 0.03 , 0.24 ± 0.04 , 0.18 ± 0.02 and 0.11 ± 0.01 are means and standard deviation for Polbiya, CD, Chika Buhu and Bare, respectively.

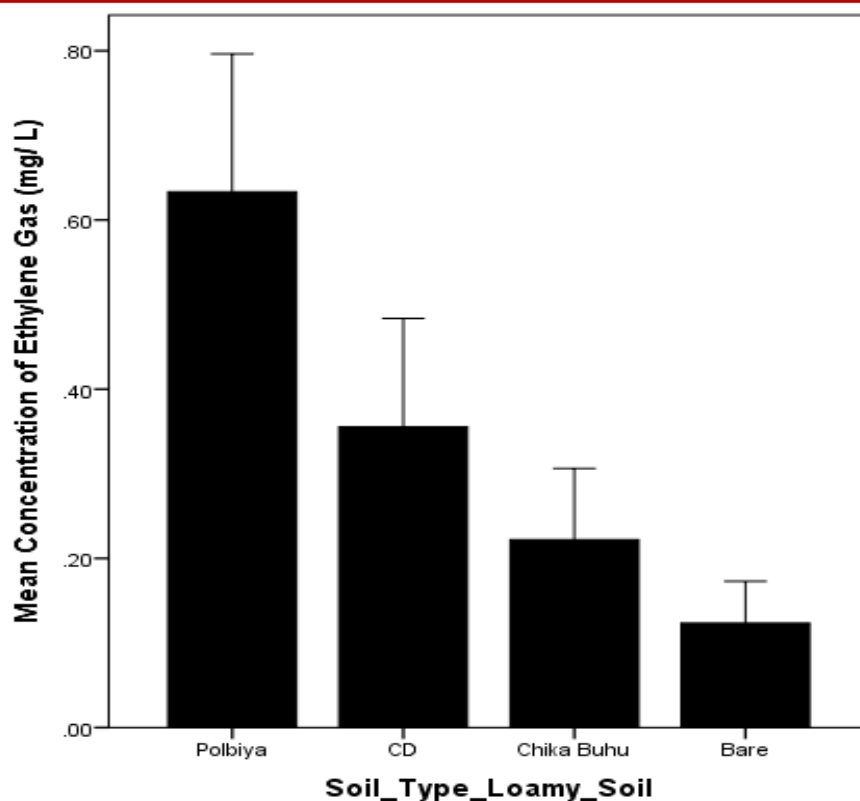


Figure 8: Mean Concentration of Ethylene Gas for the four indigenous rice cultivar. The values 0.63 ± 0.07 , 0.36 ± 0.06 , 0.22 ± 0.03 and 0.12 ± 0.02 are means and standard deviation for Polbiya, CD, Chika Buhu and Bare, respectively

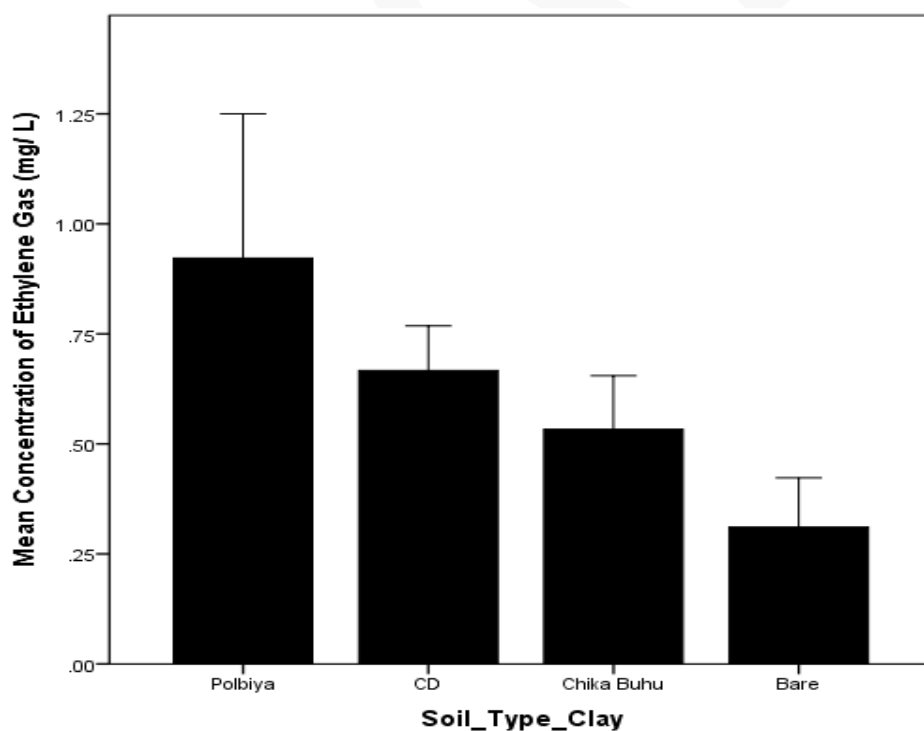


Figure 9: Mean Concentration of Ethylene Gas for the four indigenous rice cultivars. The values 0.92 ± 0.14 , 0.67 ± 0.04 , 0.53 ± 0.09 and 0.31 ± 0.04 are means and standard deviation for Polbiya, CD, Chika Buhu and Bare, respectively.

On the experiment to investigate if ethylene gas production varies with soil type, the original hypothesis was the production of ethylene gas did not vary with soil type. But the result of this finding showed that there was statistically significant difference in the ethylene gas produced by the indigenous rice cultivars, see figure 7, 8 and 9 above ($P < 0.01$). These figures showed there was highest production of ethylene gas in clay soil, higher in loamy soil and lowest in sandy soil. On the aspect of clay soil, it retained more water and had poor aeration, rice root experience low- oxygen condition. This stress stimulated the rice to produce most ethylene gas (Frank et, al 1992). On the aspect of a sandy soil, it drained quickly and contained more air spaces. Rice root received more oxygen and experienced less stress, so the plants produced less ethylene gas (Lincoln et, al 2015). On the aspect of loamy soil, it had moderate water retention and aeration that was why it produced less ethylene gas (Michael B, Jackson. (2008).

Conclusion & further Research

The role of ethylene in rice cannot be over emphasised, it plays a functional role in all stages of rice growth and development. Concentration of nitrogen oxide and its derivatives being sent to the atmosphere to cause a global warming and in the other hand, reduce the nitrogen use by rice and other crops. This research reported that rice cultivars differ in their production of ethylene gas. The production of ethylene gas vary with rice variety. The produced ethylene gas could not inhibit the oxidation of ammonium. There is a need to further a research on how to enhance more production of ethylene in rice and other crops so as to increase their nitrogen use efficiency and reduce the loss of nitrogen through leaching and denitrification as well as looking at its negative effect on rice if the concentration is high. The enhancement of ethylene production will maintain the quality of ground water by minimising NO_3 leaching and eutrophication and maintain the air quality by reducing N_2O emission from nitrification and denitrification, and this helps to convert climate change.

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