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Using of Organic or Inorganic Fertilizers to Grow Thai Jasmine Rice 105 in Soil with Natural Radioactivity (^{226}Ra, ^{232}Th and ^{40}K); Transfer of Radioactivity to Roots

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Abstract- This research study the radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K using organic and inorganic fertilizers were successfully measured as gamma ray spectrometry technique with HPGe detector on Thai Jasmine rice 105 plant (root) and on corresponding soil samples. Soil sample and natural water source of chemical characteristics (pH, OM, K, P and N) were also analyzed for their estimated effects on distribution of radioactivity concentration. The result of chemical characteristics showed that the pH of soil sample of organic and inorganic fertilizers before planting is acids in a range of 3.74-3.77 and the pH of natural water source is weak acids as 5.69±0.02. Result of organic matter found that the OM, N, P and K of soil in all fertilizer is in a range of 1.26±0.02-1.35±0.02%, 0.0895±0.0025%, 3 ppm and 54 ppm, respectively. Result of distribution of radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K found that soil sample before planting is relatively little value in both of fertilizers. The concentrations of ^{226}Ra, ^{232}Th and ^{40}K for Soil of organic fertilizer farm were 26.72±0.66, 11.24±0.51 and 103.26±3.93 Bq/kg, respectively. The concentrations of ^{226}Ra, ^{232}Th and ^{40}K for soil of inorganic fertilizer farm were 18.50±0.56, 8.82±0.41 and 63.30±2.81 Bq/kg, respectively. However, when using the organic fertilizer for planting found that it effects on radioactivity concentration of ^{40}K which has higher value than that inorganic fertilizer for planting. While radioactivity concentration of ^{226}Ra and ^{232}Th is slightly change value in both of fertilizers. Using the organic and inorganic fertilizer planting resulted in uptake of radioactivity concentration from soil to root (TF) showed that the distribution radioactivity concentration of ^{40}K uptake was higher than that of ^{226}Ra and ^{232}Th in all fertilizer planting.

Keywords: radioactivity concentration, Thai jasmine rice 105, organic fertilizers, inorganic fertilizers

1. Introduction

Natural radioactivity is diffuse in the environment, varying considerably in activity concentrations. In the main, the natural radioactivity was found in soil which it arises from ^{238}U, ^{232}Th and ^{40}K. From the human activities and the atmospheric testing of nuclear devices that occurred over the period 1945 to 1980 can be found artificial radioactivity in the environment (Eisenbud, 1973; Ravisankar et al., 2012). Radionuclides can appear in plants, either through direct atmospheric interception onto external plant surfaces, indirectly from resuspended material, or through uptake of radionuclides via the root system (Vandenhove et al., 2009). Nutrients are taken up from the soil throughout the period of plant growth, forming the main source of plant minerals (Verma and Sharma, 1999). Moreover, the soil influence by natural and fallout radionuclides has a nonstop radiological effect because it is freely transferred to human body via food chain like edible crops and drinking waters. For the transfer of the radioactivity from soil-to-human food stuff is plant uptake. If these radionuclides are transferred to the edible portions of the plant which may cause a source of cumulative exposure to the human (Shanthi et al., 2012).

However, the uptake and distribution of radionuclides in plants depend on several factors such as pH of soil, exchangeable Ca and K and organic matter contents, type of plant, physicochemical properties of the radioactivity, fertilizer application, irrigation, ploughing, liming and climate conditions etc. (Shanthi et al., 2012; Pulhani et al., 2005). Rice is the main food for more than half of the world's population (Khush, 2005). The white and brown rice absorbed radionuclides and metals from soil. However, the transfer of other elements, those of Th and U were higher in white rice than in brown rice. The measurement of distributions of ^{137}Cs, ^{133}Cs, and K in rice plant components is cultivated from Aomori, Japan. These the result indicated that the distributions of ^{137}Cs and ^{133}Cs were similar in rice grain, while those between Cs isotopes and K varied (Tsukada et al., 2002). The distributions of ^{137}Cs, ^{210}Pd, and ^{40}K in rice plants grown on the West Coast of India; the concentrations of radionuclide in the grains showed minimum compared with other rice components. The above studies showed the radionuclide accumulation abilities in response to different concentrations of rice plant components (Karunakara et al., 2013).

Thai jasmine rice is also known as Thai Hom Mali rice. Characteristics is the long grain rice which is well known for its fragrance and taste all around the world. Moreover, it is one of the main export products of Thailand. Organic and inorganic fertilizers are vastly used to enhance yield of the crop by supporting nutrient reserves in soil. However, these fertilizers interfere with physical, chemical, and biological properties of the soil. Consequently, these fertilizers affect the production quality of soil. Soil-to-rice plant transfer factors vary according to the characteristics of soil type, agricultural management (fertilization), regional climatic condition and the physical and chemical forms of the radionuclides in the soil. The soil quality that before planting rice must prepare the soil to be suitable for the grown of rice. Soil contains a good amount of available chemicals such as nitrogen (N), potassium (K) and phosphorus (P). These chemicals are essential nutrients to grow plants. However, essential nutrients of soil may not enough for growth of plant which its increased nutrients by using organic and inorganic fertilizers. Main chemical composition of organic and inorganic fertilizer is K, P and N. Phosphate, potassium and nitrogen compounds are the main raw materials used for fertilizers in industrial production. As a matter of fact, phosphorus, potassium and nitrogen are essential elements for plants growth. However, a possible negative effect of fertilizers is the contamination of cultivated lands by some naturally occurring radioactive materials (Lambert et al., 2007).

The rice plants the uptake of radionuclides in the soil through their roots in varying concentrations. In this work was to study mainly aims to investigate and evaluate the distribution of ^{238}U, ^{232}Th and ^{40}K in rice plant using the organic and inorganic fertilizers planting. Moreover, to analyse the effects of the soil chemical characteristics on soil to root of these radionuclides.

2. Materials and methods

2.1 Sample collection

This research was to study the radionuclide activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil and root samples which divided the area into 2 farms as planting using organic and inorganic fertilizers. Each area was divided an approximate 390 m^2. For preparing before planting, it was plough roughly for the first time to turn the soil in ground floor up to the top and to dry the soil which using for 10 days. After that we sow rice in all farms and put water in the rice planting. Then, we kept the soil before planting rice in all farms. Accordingly, we fill the inorganic fertilizer (20-20-0) for inorganic farm planting and organic fertilizer by using manure 97.5 kg for organic farm planting (Nucharee et al., 2015). Then, after rice starts to grow about 10 cm which using for 2 mounts. We kept the soil and root after planting rice. In collecting the soil sample, we used a square frame with an area of 30×30 cm^2 and a layer of 5 cm depth. In collecting the root sample, the roots and the straw was separated by cutting to select only the rice root part which washed with water to remove soil residue. Accordingly, the soil and root samples were collected from random for 6 points and were mixed by one point instead of planting area of 65 m^2. These points random was also used in the present work to collect the soil samples. Then, these samples were divided to analyze the chemical properties and radioactivity with a gamma-ray detector as detail follow.

2.1.1 Sample collection to analysis chemical properties

The soil samples were collected from random points from fields in the study areas that it was kept before admixture fertilizer and after admixture fertilizing. About 500 g of soil were dried in oven below 110 ºC for 12 h. Then, the samples were placed in a polythene bag. The water is used planting from natural water sources. These samples were analyzed the chemical properties. Samples were analyzed for pH of soil samples were measured using the soil about 25 g and 40 mL of pure water to obtain a 2:1 water-to-soil ratio (Hanlon, 2009). Other main distinguishing features, such as organic matter (OM), K, P, N were determined using the walkley & black method, NH_4OAc pH 7 & flame photometry method, bray II & molybdenum-blue method and kjeldahl method, respectively.

2.1.2 Sample collection to analysis radioactivity

About 4 kg of soil sample dried in oven 110 ºC for 12 h to remove moisture and attain constant dry weight. The soil samples were then crushed into fine powder and homogenized by filtering through 1 mm sieve and 3 sets of each soil sample weighing 300 g has been reported as one sample. Thereafter, the samples were placed in a polythene bag, labeled and transported to the radiation laboratory sample processing room for subsequent investigation. The soil sampling taking place from the one month which made to ensure adequate collection of representative samples in the study area. For root sample, about 5 kg of root was cut to length approximate 1 cm and dried to remove moisture and attain constant dry weight and 3 sets of each root sample weighing 1 kg has been reported as one sample. All the samples were stored for a period of one month at room temperature to reach secular equilibrium of ^{226}Ra, ^{232}Th and ^{40}K with their progenies prior to the radiometric analysis with a gamma-ray detector (Ghose et al., 2012; Khan and Khan, 2001).

2.2 Radioactivity measurements

The concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil and rice root samples were determined by using gamma spectrometry techniques by hyper-pure germanium probe (HPGe) model GR 2519 of the Canberra. The standard reference of soil sample which are efficiency calibration curve by using the lower limit of detection (LLD) for ^{226}Ra, ^{40}K and ^{232}Th were 3.61, 22.83 and 2.84 Bq, respectively. For the root sample using the lower limit of detection (LLD) for ^{226}Ra, ^{40}K and ^{232}Th were 1.62, 12.25 and 1.26 Bq, respectively. The energy resolution is 1.9 keV at the energy 1.332 MeV of cobalt-60 (^{60}Co) and relative efficiency of 25%. The detector was contained in a cylindrical lead shield with a thickness of 10 cm in order to prevent the gamma rays from the environment into interference. The detector is connected to the DSA-1000, which is built with an electrical supply and multichannel by using the program Genie-2000 to analyze of gamma radiation. The calibrations of energy and resolution of the detector were performed using multi-nuclide source produced by Eckert and Ziegler Isotope Products. The source was obtained in a 500 mL Marinelli beaker and activity is 1.027 μCi or 38.00 kBq. The radio nuclides used were Cd-109, Co-57, Te-123 m, Cr-51, Sn-113, Sr-85, Y-88, Cs-137 and Co-60. The efficiency corrected intensities of the measured discrete gamma ray at energies 351.92 keV (^{214}Pb) and 609.32 keV (^{214}Bi) were used to determine the activity concentrations of the ^{226}Ra, ^{232}Th activity concentration was determined from the gamma ray 583.19 keV (^{208}Tl) and 911.20 keV (^{228}Ac). The emission line 1460.82 keV was used to estimate the ^{40}K concentration. All samples were counted via gamma detector for 10,800 s.

2.3 Transfer factor (TF) for natural radioactivity

TFs were calculated as the ratio of the radionuclide concentration in plant or plant part (Bq/kg, dry weight of root) to the concentration in the soil (Bq/kg, dry weight of soil). The minimum detectable concentration (MDC) of this measurement for ^{226}Ra, ^{40}K and ^{232}Th in soil sample were 3.02, 19.14 and 2.38

Bq/kg and the root sample were 6.85, 54.94 and 5.92 Bq/kg, respectively which was shown in Equation 1:

$$\boldsymbol{TF = \frac{R}{S}} \quad (1)$$

where

R = the radionuclide concentration in root (Bq/kg, dry weight)

S = the corresponding concentration in soil (Bq/kg, dry weight)

3. Results and discussion

3.1 chemical parameters

The chemical properties in soil for organic fertilizers and inorganic fertilizers and natural water source which were done before planting of rice are presented in (Table 1). The pH of soil sample of organic and inorganic fertilizer cultivation before planting rice is 3.77 and 3.74, respectively. The system pH generally influences adsorption of cationic species such as radium (Ra). The hydrogen ion (H^+) is typically released when a cation is adsorbed onto the soil, which is favored under alkaline conditions and inhibited under acidic conditions. Thus, increasing the mobility of Ra in soil and water if there is the decrease in pH which is caused by the presence of organic acids (Smith and Amonette, 2006). For pH of natural water source is 5.69±0.02, this showed that it is an acidic and base behavior. This may be the rapid desorption of Ra at pH 3.0 is decreasing with pH increase that the soils with higher content of adsorbed bases demonstrated greater ability to fix little amounts of Ra (Rusanova, 1962).

For the organic matter (OM) of soil sample in organic and inorganic fertilizer farms were 1.35±0.02 and 1.26±0.02%, respectively. The OM in natural water source has rather little. These findings indicated that the organic fertilizers through the process of decomposition and excretion from animals, which is a short period of time resulting to be fermented and decomposed by nature. The result study indicated that soil horizons enriched in OM accumulated radium from groundwater (Rusanova, 1962). Moreover, the effect of OM on ^{232}Th in soil mobility found that the ^{232}Th moves under the influence of OM which observed prominent accumulation of ^{232}Th in soil horizons right under the layer with high OM content (Hansen and Huntington, 1969).

The N, P and K of soil sample in organic fertilizer were 0.078%, 3 ppm and 53 ppm, respectively. For the N, P and K of soil of inorganic fertilizer were 0.0895%, 3 ppm and 54 ppm, respectively while the N, P and K of water is rather little varied from 0.052-0.167 ppm. For organic fertilizer of N, P and K value were 0.078%, 3 ppm and 53 ppm, respectively.

Table 1. chemical properties in soil for organic fertilizers and inorganic fertilizers and natural water source before planting.

Characteristics	Soil of organic fertilizer farm	Soil of inorganic fertilizer farm	Natural water source
pH	3.77±0.01	3.74±0.01	5.69±0.02
OM (%)	1.35±0.02	1.26±0.02	0.003±0.001
Total N (%)	0.078±0.004	0.0895±0.0025	0.052±0.001
Extr.P (ppm)	3	3	0.55±0.05
Extr.K (ppm)	53	54	0.167±0.003

Table 2. Comparison of radionuclide activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil sample before planting with literature work

Country	sample	Radionuclide activity concentration (Bq/kg)			reference
		Ra-226	Th-232	K-40	
Thailand	Soil of organic fertilizer farm	26.72±0.66	11.24±0.51	103.26±3.93	Present work
	Soil of inorganic fertilizer farm	18.50±0.56	8.82±0.41	63.30±2.81	
Sungai Besar	Soil	7.5-11.3	17.3-25.2	106.0-124.8	Kh. Asaduzzaman (2015)
Saudi Arabia Taif	Soil	23.8	18.6	162.8	Wassila Boukhenfouf (2011)

3.2 Radionuclide activity concentrations of soil sample before rice planting

(Table 2) shows the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil sample before planting under organic fertilizer and inorganic fertilizer farm. This result found that the concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil for organic fertilizer planting was higher than that the soil for inorganic fertilizer planting. The concentrations of ^{226}Ra, ^{232}Th and ^{40}K for soil of organic fertilizer farm were 26.72±0.66, 11.24±0.51 and 103.26±3.93 Bq/kg, respectively. The concentrations of ^{226}Ra, ^{232}Th and ^{40}K for soil of inorganic fertilizer farm were 18.50±0.56, 8.82±0.41 and 63.30±2.81 Bq/kg, respectively. The distribution of ^{226}Ra, ^{232}Th and ^{40}K in different organic and inorganic fertilizer farm. This was because the uptake of Ra and Th possibly depended mainly on phosphorus and alkaline- earth concentrations in the soil (Rodrı´guez et al., 2002). Moreover, the values of soil to plant transfer factor are a variable parameter apparently independent of the radionuclide concentration in the soil (Nisbet and Woodman, 2000).

3.3 Radionuclide activity concentrations of soil and root after planting

(Table 3) shows the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil and root samples was growth by organic and inorganic fertilizer. When comparing under planting by using the organic fertilizer in soil and rice root samples, it was found that the concentrations of ^{226}Ra, ^{232}Th and ^{40}K in root has higher than that the soil sample. The concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil sample of organic fertilizer farm were 24.90±0.57, 12.20±0.32 and 139.20±4.44 Bq/kg and root sample were 26.84±1.58, 12.87±0.89 and 230.07±14.74 Bq/kg, respectively. The distribution of radioactivity may be due to the widespread use of fertilizers (Bhatti et al., 1994).

When considering using the inorganic fertilizer planting, it can be seen that the concentrations of ^{226}Ra and ^{232}Th from soil to root was decrease but the concentrations of ^{40}K was increase. The concentrations of ^{226}Ra, ^{232}Th and ^{40K} in soil of inorganic fertilizer farm were 26.27±0.64, 12.10±0.34 and 105.22±4.18 Bq/kg and root were 22.16±1.40, 12.02±0.85 and 176.66±13.85 Bq/kg, respectively. This was because the distribution of ^{226}Ra and ^{40}K reflects the mobility and transportation from the roots to rest of the plant. The ^{226}Ra is preferably retained in the roots compared with the aboveground plant parts. Roots generally behave as a natural barrier to radionuclide transport in upper plant parts (Rusanova, 1962). Moreover, the rate of radionuclide translocations from roots to shoots depends on the plant components (Pulhani et al., 2005; Tsukada et al., 2002). Therefore, such parameter may vary among different components, as well as crops.

Considering the radioactivity concentration of ^{226}Ra and ^{232}Th and ^{40}K in soil and root samples during planting by using the organic and inorganic fertilizer, it was found that using the organic fertilizer resulted with higher radioactive residues. The activity concentrations of ^{226}Ra and ^{232}Th were decrease while the ^{40}K was increase. Moreover, the result show that transfer factor (TF) of ^{226}Ra, ^{232}Th and ^{40}K for organic fertilizer were 1.08±0.09, 1.05±0.10 and 1.65±0.16 Bq/kg, respectively. For inorganic fertilizer planting, The TF of ^{226}Ra, ^{232}Th and ^{40}K were 0.84±0.07, 0.99±0.10 and 1.68±0.07, respectively. This finding indicated that the activity concentrations of ^{40}K uptake is greater than that of ^{226}Ra and ^{232}Th in all fertilizer planting. When compare during for organic and inorganic fertilizer, the TF value in ranging was 1.65±0.16-1.68±0.07 which insignificant different. These results indicate the fundamental nutrient status of potassium for the plants. The high TFs of ^{40}K were considered since potassium is important in fertilizing the crop and plays a vital role in the ability of the plant adaptation to environmental pressures. However, potassium relics in homeostatic symmetry in the plant and is easily adapted by the plants (Pulhani et al., 2005).

Table 3. Comparison of radionuclide activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil, root samples and transfer factor (TF) after adding the organic and inorganic fertilizer planting with literature work

Country	Condition	sample	Radionuclide activity concentration (Bq/kg)			Transfer factors (TFs)			Reference
			Ra-226	Th-232	K-40	Ra-226	Th-232	K-40	
Thailand	organic fertilizer farm	Soil	24.90±0.57	12.20±0.32	139.20±4.44	1.08±0.09	1.05±0.10	1.65±0.16	Present work
		Root	26.84±1.58	12.87±0.89	230.07±14.74				
	inorganic fertilizer farm	Soil	26.27±0.64	12.10±0.34	105.22±4.18	0.84±0.07	0.99±0.10	1.68±0.07	
		Root	22.16±1.40	12.02±0.85	176.66±13.85				
Kampung Permatang Tok		Root	6.5-11.6	12.8-19.6	78.5-100.5	0.24-0.43	0.33-0.59	0.83-1.24	Kh. Asaduzzaman (2015)
		Rice	1.9-3.8	5.0-11.4	82.9-97.8				
Egypt		Cowpea				0.51	0.53	1.36	R. Elsaman (2020)
		Sesame				0.42	0.43	1.33	

4. Conclusions

Natural radioactivity was studied in soil and rice root samples from Thai Jasmine rice 105 cultivation plot grown using organic and inorganic fertilizers. Result of chemical properties in soil for organic fertilizers and inorganic fertilizers and natural water source before planting of rice by comparing measurements of 2 farms found that these properties were insignificant different. Using the organic fertilizer for rice planting resulted in distribution radioactivity concentration ^{40}K from soil to root has higher than that planting using the inorganic fertilizer while the distribution radioactivity concentration of ^{226}Ra and ^{232}Th was little increase. Trend of using the inorganic fertilizer planting which were considering of uptake from soil to root (TF) found that the distribution radioactivity concentration of ^{40}K uptake was higher than that of ^{226}Ra and ^{232}Th in all fertilizer planting.

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