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EFFECT OF CROP ROTATION ON SOIL PROPERTIES AND RICE YIELD

CHUONG, V.N*
Department of Crop Science, Agricultural Faculty of An Giang University – VNU, HCM City, Viet Nam.
*Corresponding Author Email: nvchuong@agu.edu.vn

Abstract

The field experiments were carried out to evaluate the impacts of rice rotation on rice productivity and soil properties. The study was conducted with the aim of evaluating the impact of rice rotation with upland crops in improving soil quality as well as the growth and yield of rice crop 2022-2023 on the alluvial soil cultivation in Tri Ton district, An Giang province. The field experiment was arranged in a completely randomized block design (RCBD) with 3 treatments and 4 replications. Three plant types of rotations were evaluated: rice-rice-rice (control-RRR), rice-soybean-rice (RSOR), rice-sesame-rice (RSER). The collected data for evaluation include soil physical properties such as bulk density, porosity, and available water holding capacity. Soil chemical properties such as pH, EC, available nitrogen, available phosphorus, exchangeable K, soil organic matter (SOM); biomass and rice yield. For the soil chemical parameters, the RSOR treatment showed an effective improvement in the available N, available P, exchangeable K and OM in the soil. Rice yield and rice biomass in the end crop tended to increase in the rotation treatments with soybean and sesame compared to the 3-crop intensive rice cultivation. Long-term experiments need to be continued to better see the effect of crop rotation on soil fertility (especially soil physical fertility), as well as crop growth and yield.

Keywords: Rotation, Rice, Soybean, Sesame, Yield, Soil Property

1. INTRODUCTION

Rice has been the main crop In the Mekong Delta of Vietnam. The area planted for summer-autumn rice nationwide in 2022 reached 1,914.7 thousand hectares, down 38.1 thousand hectares compared to the summer-autumn crop in 2021; yield reached 56.6 quintals/ha, down 0.5 quintals/ha; production reached 10.8 million tons, down 304.3 thousand tons (General statistics office of Vietnam, 2022). In Vietnam, continuous rice planting has leaded a negative effect on soil properties, such as reduced soil nitrogen supply and organic carbon content (Cassman et al., 1995; Dobermann and Witt, 2000) rice-upland crop rotations have been studied and used to raise soil fertility and decrease input (Yanagisawa and Muramatsu, 1995; Witt et al., 2000; Chang et al., 2006; Nishimura et al., 2008; Huang et al., 2009; Yamaguchi et al., 2009). In rice-upland rotation systems, local tillers drain their rice fields after harvesting rice and then planting an upland plant, such as soybean, maize or sesame (Li, 1992; Xie and Chen, 2002; Qunhua et al., 2004). However, the growth needs asked by rice are quite different from those required by upland crops. Rice will develop best under wet soils, reduced, and anaerobic soil conditions, conversely upland plants need unpuddled, aerobic and a lot of oxygen in soils. Rice soils are a large difference from upland soils in physical, chemical properties (Kirchhof et al., 2000). Furthermore, because of long-term submergence and mineral fertilizer application, rice soils experience degradation of soil quality, such as breakdown of stable aggregation and deterioration of soil organic matter (SOM), which negatively affects agricultural sustainability (Bopara et al., 1992; Mohanty and Painuli, 2004). Soil nutrient is a standard

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used to assess the health of agricultural soils. It has been an indicator for assessing quality of soil and crop management practices (Gregorich et al., 1994; Hussain et al., 1999; Doran and Zeiss, 2000). Many soil properties have been considered to assess the soil quality, but evaluation of pH, OM, and total N of soil have been considered essential for appraising the chemical properties of soil quality (Gregorich et al., 1994; Doran and Zeiss, 2000). Nowadays, many kinds of new plants including rice- baby maize and rice - edamame beans are widely used. However, prior studies have been designed to determine the impacts of these rice-upland crop rotations on physical-chemical properties of agricultural soils. This study was carried out to assess the impacts of long-term cropping system on (i) rice yield and (ii) soil quality properties.

2. MATERIALS AND METHODS

2.1. Location

The field study was conducted over a period of one years at the local farm of the Tri Ton district, An Giang, Vietnam. The field experiment has been designed in an irrigation rice starting in 2022. The experimental field was monoculture rice cropping before this time. The area is characterized by a tropical monsoon climate with an annual mean temperature of 20–40^{o}C, ranging from 2^{o}C in January to 35^{o}C in May and mean precipitation of 1200– 1400 mm/year, with about 90% falling between April and September.

2.2. Plant Cultivation and experimental Design

The field experiment consisted of three differently cropping kinds of rotation: rice-rice-rice, rice-soybean-rice, and rice-sesame-rice. Then preliminarily ground with a stubble mill to the 0–20 cm depth about three days before transplanting the rice. In the rice crop, the rice variety used OM 18, which has widely grown in Vietnam. Rice was directly sowed with a rate of 90 kg/ha. Fertilizers were completely applied according to local tillers. It is noteworthy that there has been a significant reduction in nitrogen input starting in precious years due to severe rice shedding in some crop rotation formulas. The rate and time of fertilizer application are regulated as follows: priming, including total phosphorus, 50% nitrogen and 50% potassium, is carried out one week before transplanting as a mixed fertilizer; 25% nitrogen is applied at mid tillering in the form of urea, and 25% nitrogen and 50% potassium are applied at the beginning of flowering in the form of urea and potassium chloride, respectively. Total fertilizer: 100N-45P_2O_5-30K_2O kg/ha. The whole experimental area was 363 m^2, which consisted of 3 treatments x 4 replicates = 12 experimental plots, with an area of each plot of 5.5 x 5.5 = 30.25 m^2. Weeds, insects and diseases were controlled as required to avoid yield loss. The field experiment was designed with three treatments and four replications. Between the experimental plots, the embankment was 25-30cm high and blocked by agricultural mulch to ensure that the water does not seep or overflow between the experimental plots. Each experimental lot was placed plastic pipes under the embankment to bring water in as well as drain water out. The irrigation canal system is reasonably designed to ensure that the water and the

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field can be easily transported and drained out of the field without affecting the growth and development of rice plants.

Soil properties before and after the experiment were analyzed by the method of Tian et al., (2008). All soil properties such as pH, N, P, and K were analyzed by Carter and Gregorich, (2007). The soil texture was assessed by the relative distribution of sand, silt, and clay in the sample by the Hydrometer method (Bouyoucos, 1927). The textural classification was analyzed by USDA textural triangle. The bulk density of soil was measured by the core sampler method (Amusan et al., 2006). The core sampler was put into the soil to 0-20 cm depth. Weight of core sampler keep in moisture box and that moisture box keep in the oven at 105 ℃ for 24hrs till constant Wight. Bulk density (g cm-3) was calculated by following formula. Bulk density ($g.cm^{-3}$) = Oven dry weight of soil (g)/ Volume of soil (cm^3). Particle density was calculated by using the method given by (Baver, 1949). 20 g of oven-dried soil was added in 100 mL of the graduated cylinder and that cylinder water fill before the soil adds at the 50 ml mark. Soil and content keep for 10 minutes. The difference between the initial volume of water and the volume of soil plus water mixture was recorded which represents the volume of water displaced or volume occupied by the soil particles. Particle density ($g.cm^{-3}$) = Oven dry weight of soil (g)/Volume of soil solids (cm^3). Porosity in the soil was determined by the (Baver, 1949) method by using the following formula. Total porosity (%) = (1 − Bulk density of soil/Particle density of soil) × 100. Water holding capacity: Hilgard apparatus used for determining water holding capacity of soil that procedure was given by (Piper, 1950). The air-dry soil was transferred by spatula in the Hilgard apparatus. The Hilgard apparatus was placed in a water-filled petri-dish and the level of water maintain half-length of Hilgard apparatus submerged in it. Hilgard apparatus keep for overnight for saturation. The next day the apparatus was removed from the pertri-dish, take weight Hilgard apparatus and soil. Dry weight of soil also was recorded. Water holding capacity (%) = (Gain in weight at saturation point/Dry weight of the soil) × 100.

Biomass and actual yield: When harvesting, use a frame with an area of $5m^2$ randomly placed in the experimental plots, then cut close to the base of all rice in the frame. The rice in the frame was separated from seeds and straw to determine the fresh weight. And then, representative samples of rice and straw were taken and dried at 60°C for 72h. Rice was reduced to 14% moisture content to determine actual yield, straw was weighed and moisture determined at dry weight. Actual yield (t/ha) = ($W_{14\%}$/1000) x ($10000m^2/5m^2$)

Statistical analysis the experiment was conducted according to the complete randomized block design (CRBD). The data of this experimental data were statistically analyzed using analysis of variance of the technique (Panse, 1954).The difference between treatments was measured by applying the “F” test at a 5 percent level of significance (0.05 LSD)

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3. RESULTS AND DISCUSSION

3.1 Soil Physical properties

Bulk density

The analysis results of soil bulk density between the experimental treatments (Figure 1) showed that values of soil density ranged from 1.02-1.13 g/cm^3 in the depth of 0-15cm. The higher value of soil bulk density was 1.13 g/cm^3 in the RSOR treatment than those of 1.02 g/cm^3 (RSER), 1.03 g/cm^3 (control –RRR) and significant differences at level 1%. These values are within the suitable range for the growth of plant roots in the crop layer. The density value of the surface layer is usually low, because the surface layer is affected by the process of soil preparation. Therefore, the organic matter of the surface layer is quite high because the organic residue from the previous crop, so the top soil is usually porous. In the lower layer (15-30cm), the bulk density values ranged from 1.46-1.47 g/cm3 and insignificant differences at 5%. This soil layer is always compacted, which causes to reduce the growth of plant roots and take the water and nutrients of plant from roots. According to previous studies of Singh et al., (2009), If the clay density exceeds 1.4 g/cm^3, the plant roots of plant prevent the crop growth in this layer. The soil bulk density of different rice-upland plant rotations was significantly greater than the rice intensive cultivation, and rice -soybean and rice – sesame had relatively greater values of MWD compared with other rotations (Qunhua et al., 2004).

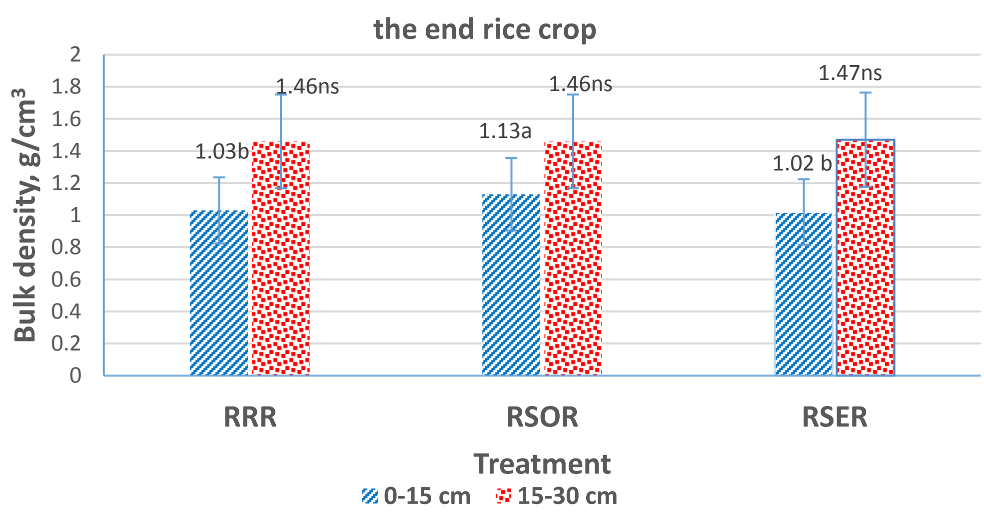

Figure 1: Soil bulk density in the soil depth of 0-15 cm and 15-30 cm

Porosity

The analytic results of soil porosity in the treatments presented in Figure 2 showed that the porosity values of three treatments in the soil layer (0-15cm) and the soil layer (15-30cm) were statistically significant differences (p>0.01). The maximum soil porosity of 0-15cm in the depth was 58.9% in the RSOR treatment, the minimum porosity value was

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53.7%, while in RRR treatment, the following height porosity was 58.5% in RSER. In the lower soil layer (15-30 in the depth), the porosity values ranged from 40.9 to 48.9%. RSOR treatment had the greatest average porosity values of 48.9%, followed by RSER (47.4%), and observed the minimum value of RRR (40.9%). The research results of showed that the porosity value is inversely related to the density of the soil layers because the percentage of soil porosity was calculated from the density value with the density of the soil (Ekka et al., 2017). The long –term rotation of rice –upland was significantly greater than the soil physical – chemical properties when comparing with the rice intensive cultivation (Gupta et al., 2010).

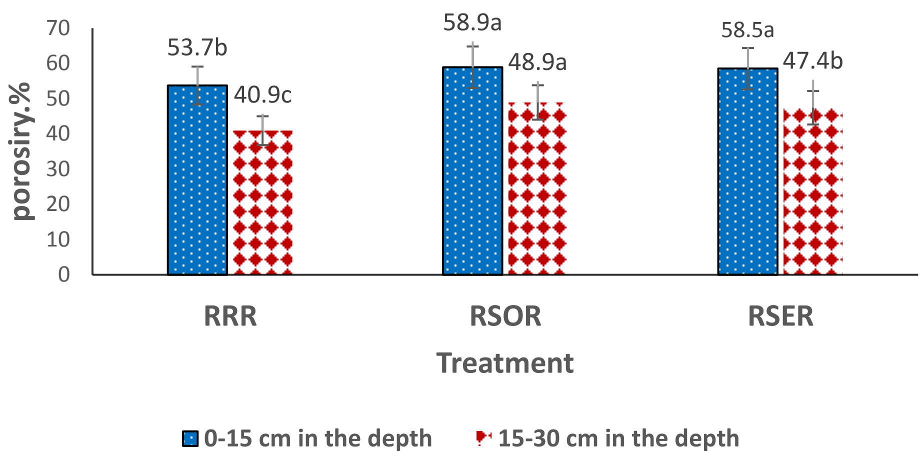

Figure 2: Porosity in the soil depth of 0-15 cm and 15-30 cm

Available water holding capacity

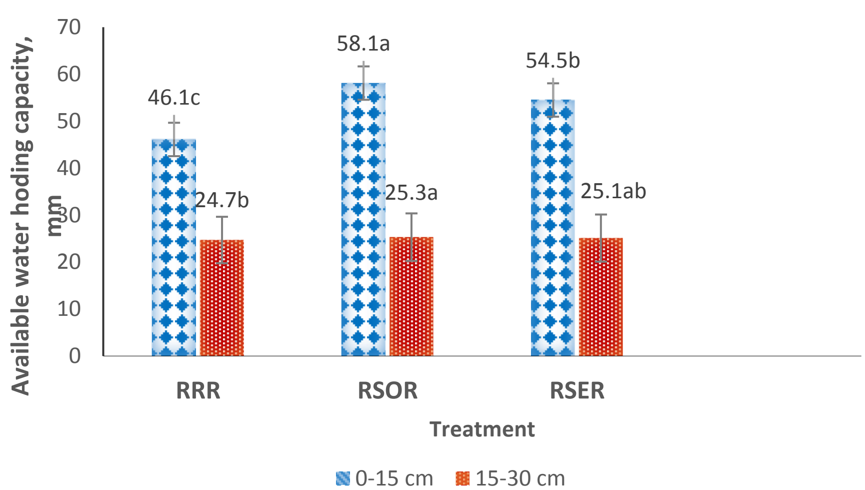

Figure 3: Available water holding capacity (AWHC)

3.2 Soil chemical properties

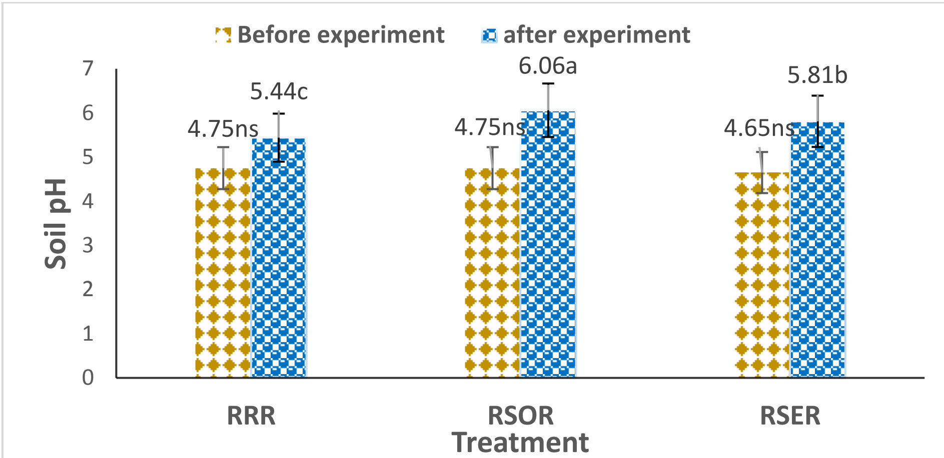

Figure 4: Soil pH

Soil pH of three treatments increased compared to before the experiment. pH values ranged from 5.44-6.06 and statistically significant differences ($p>0.05$). There was a strong dependency of soil pH value in rice -upland rotation. Soil was acid before the experiment, which valued from 4.65 to 4.75 and insignificant differences in the depth of 0–15 cm. However, the average pH values significantly increased greater than at harvest. The pH was significantly affected under three treatments. The highest pH was reported with RSOR (6.06) treatment, followed by RSER treatments (5.81). The lowest pH was recorded with RRR (5.44) treatments.

Table 1: Chemical properties of Soil affected by rice rotation

Treatment	EC (mS/cm)	Available N (mg/kg)	Available P (mg/kg)	Exchangeable K (meq /100g)	SOM (%)
RRR	0.70	21.6^{a}	35.9^{c}	0.23^{b}	3.67^{c}
RSOR	0.71	19.7^{b}	51.3^{a}	0.26^{b}	3.78^{b}
RSER	0.62	21.3^{a}	41.9^{b}	0.36^{a}	3.88^{a}
F test	**ns**	**	**	**	**
CV (%)	**14.1**	**14.3**	**15.3**	**24.5**	**11.1**

The results in Table 1 showed that the technique of crop rotation between rice and upland crops showed a wide variation in soil chemical quality. Most of the chemical properties such as available N, available P, exchangeable K and SOM remarkably increased in two rotation treatments to compare with intensive farming (except EC). RSER rotation mainly had the highest value, followed by RSOR and the lowest value of RRR. Significant differences in soil chemical (such as soil pH, Available N, Available P, exchangeable K and soil SOM) and physical properties (soil bulk density, porosity and available water holding capacity) were found among cropping seasons (rice and upland rotation. Rice-upland rotations promoted the soil quality to some extent, which might result in the best yield in rice-upland rotations among the studied rotations (Song et al., 2012)

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3.3 Rice biomass and yield

Table 2. Rice biomass and yield affected by rice rotation

Treatment	YIELD (t/ha)	Biomass (t/ha)
RRR	6.65[c]	3.64[c]
RSOR	6.77[b]	4.25[b]
RSER	6.86[a]	4.57[a]
F	**	**
CV (%)	11.4	10.0

(**): significantly different at level 1%

Rice productivity remarkably raised when upland crop rotations were applied during the field experiment (Table 2). The rice yields were slightly increased but positive, which presented the yield benefit of long-term application of rice upland crop rotations. Similar results were reported by previous studies of Ghoshal and Singh, (1995) and Kim et al., (2008). However, in different kinds of upland plants and the amount of organic and inorganic fertilizer application, effects of these positive increases were different. RSER raised the maximum average yield of 6.86 t/ha, which was 3.06% higher than RRR. The increased yield may be attributed to the high N fix capacity and high biomass in upland crops (Lee et al., 2000; Fageria, 2007). Light raises were found in RSER, RSOR compared with RRR and the differences were statistically significant. The rotation of rice-sesame-rice obtained the maximum biomass, followed by RSOR, and RRR had the minimum biomass (Table 2)

4. CONCLUSION

Rice-soybean-rice (RSOR) and rice-sesame-rice (RSER) significantly raised the physical-chemical properties of RSOR and RSER compared with those of rice-rice-rice (RRR). Among three rotation treatments, RSER treatment was an optimum method of rice – upland rotation for local application with the highest physical-chemical properties, especially in the depth of 0–15 cm. These studied results may provide some information for the higher yield promotion of rice in Mekong Delta. The soil surface nutrients of available N, available P, exchangeable K and SOM were positively increased to enhance the soil fertility. Therefore, the next studies need to focus on many different rice-upland rotations in order to enhance soil fertility and rice yield.

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