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Rice Cultivation on Reducing Excessive Soil Fertility and Rice Growth in Continuous Vegetable Cropped Greenhouse Soil

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Abstract: The effects of rice cultivation on reducing excessive soil nutrient levels in greenhouse vegetable cropping systems were evaluated. Additionally, rice growth and yield characteristics were evaluated in clay loam and sandy loam soils with three cropping systems including Single Rice (SR), Barley-rice (BR) and red pepper in Greenhouse (GH). Red-pepper cropping was divided by three levels of continuous cropping for 2, 4 and 6 years. Before rice cropping, soil pH and concentrations of P, K and Ca were variable in both soil textures and all parameters increased with increasing cropping years in GH. After rice cropping, the amount of soil P and K that decreased was greater in Clay Loam (CL) than in Sandy Loam (SL), however Ca was higher in SL than CL. Soil pH significantly increased in all treatments. The salt concentration of soil (EC) was higher in sandy loam and it corresponded with the cropping years. Rice growth and grain yield were better in barley pre-cropped plots than other cropping systems and they were negatively related to continuous cropping years.

Key words: Greenhouse, rice, excessive soil nutrient, soil EC

INTRODUCTION

In Korea, greenhouse cultivation of red-pepper is rapidly increasing. From 1990 to 2000 cropping acreage increased by 3,563 ha[1]. Fourty-six percent of the greenhouse cropping area is located in Yeongnam province with Gyeongsangnam-Do, the South-eastern part of Korea, occupying 38%. For greenhouse vegetable cropping, the common soil series are clay loam and sandy loam. Soil pollution is the most serious problem[2] and is caused by the use of high input compost and inorganic fertilizers used for improving productivity and when continuous cropping in the same place. The enlargement of the greenhouse size and the limited area of well adjusted land hamper the ability to move the cropping place, therefore, Korean farmers usually maintain the greenhouse at the same location more than five years if there are no serious problems[3]. Red-pepper can grow in salt concentrations below 0.16% (1,600 mg kg^{-1}, 2.5 dS m^{-1}), however, it will be damaged and uptake of soil nutrients will be restricted if the concentration rises above 0.4% (4,000 mg kg^{-1}, 6.25 dS m^{-1})[1]. A valuable EC is 0.08-0.16% (1.25-2.50 dS m^{-1}) for red-pepper growth in most soil textures. The most valuable practice used to reduce salt damage is rice cropping in summer season. This method can be introduced including corn cultivation to cleaning heavy nutrients in the soil, changing the soil, or using soil dressing and adaptable fertilization to escape soil sickness[3-5].

In Korea, the chemical content of the soil in vinyl housing is higher than in the open field. More than half of the vinyl housing soils have Electric Conductivity (EC) more than 4.0 dS m^{-1} and available phosphate greater than 1,000 ppm[6-8].

The leaching of NO_3-N through the soil profile was expected due to the fact that NO_3-N content was rapidly decreased by removal of the polyethylene film cover from the frame of house after crop harvest[6]. Salt accumulation increased in vinyl house soil because of continuing cultivation. Therefore fertilizer applications should be limited in order to avoid salt toxicity, quality deterioration for crop and salt contamination of ground water[9]. Jung *et al.*[7] introduced the multiple linear regression analysis for estimating the contribution degree of soil chemical properties to the value of EC. It showed that the standardized partial regression coefficient was high in the order of NO_3>Av.SO_4^{2}>Ex.Na>Cl>Av. P>NH_4-N>Ex.Mg>Ex.Ca. Among the soil chemical properties, the contribution of anion was remarkably high. Additionally, the EC value correlated with total content of anions at

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r=0.932** and total content of cations at r=0.452**. Shin[10] studied the status of salt accumulation, its effect on plant growth and salt elimination by watering in plastic film house soils and supported very important informations such as the effect of the salt concentration on growth retard, nutrient absorption and yields and to find the optimum rate of irrigation for salt elimination and for managing soil water were evaluated, however, there was no study about soil texture and cropping systems related study.

In these experiments five cropping systems in two representative Korean soil textures were used to evaluate the reduction of excessive soil nutrients through the use of rice cropping and the effects of three cropping systems and continuous cropping years on rice growth and grain yield were also evaluated

MATERIALS AND METHODS

The data of this study was obtained from two experiments conducted in the field and in pots at the National Yeongnam Agricultural Experiment Station in Milyang, Korea. Milyang is located in a temperate zone with hot, humid summers and heavy rain from June to August and cold, dry winters from November to February.

The field experiment was a Non-randomized Block Design with ten treatments, two soil series and five cropping systems and three psuedo-replications. The treatments were no-fertilized rice cropping after greenhouse vegetable cropping at five sites. Two soil textures, Clay Loam (CL) and Sandy Loam (SL) were selected for these experiment and three cropping systems, rice single, barley-rice, red pepper-rice, were introduced. Soil chemical properties of each experiment are expressed in Table 1. Rice cropping was done after red pepper cropping for 2, 4, 6 years continuous red-pepper cropped field.

The pot experiment was done in a greenhouse with ten treatments, five cropping systems in two soil series and three completely randomized replications. The experimental rice plants were grown at 1/2000 a^{-1} in Wagner pots. The representative greenhouse soils at a depth of 20 cm were moved from the field to the experimental pot site. The pots were submerged in water for five days before transplanting. Gravels, 1.5-2.0 cm diameter, were used to fill the pots at a depth of 5 cm and silicon hoses, one cm diameter with 1.5 mm thickness, were installed to measure of soil Electric Conductivity (EC). Water depth was maintained at about 3-4 cm by filling the glass Beaker everyday. Tap water was used throughout the rice growth duration. Five days after water submergence, three hills with five rice (*Oryza sativa* L. Var. Geomobyeo 1-ho, short season variety) seedlings per hill were transplanted into each pot.

In all pot experiments, no chemical fertilizers were applied for rice growth. Before and after the experiment, field soil was sampled at a depth of 20 cm for analysis of soil nutrient content. Two representative soils, clay loam and sandy loam, were selected for pot experiment and field soils were used to each pot with three cropping systems and three cropping years in the greenhouse pre cropping field. Rice cultivation methods with no-fertilization and rice grain yield and yield components, were followed by RDA[11] standard. Chemical analyses of soil and plant were followed by the analysis standard of NIAST[12]. All nutrient contents were the results of before and after the rice cropping. The expressed chemical characteristics of irrigation water were sampled at the water inlet.

RESULTS AND DISCUSSION

Soil characteristics: Before the experiment, the pH of the soil in a Rice Single cropping system (RS) was higher in the Clay Loam soil (CL: 5.16) than in the Sandy Loam (SL: 4.91) which means the pH depend on soil physicochemical characteristics. However, in Barley-rice cropping system (BR), the pH was a little higher in SL (Table 1). Increasing cropping years in greenhouse, the pH of soil was more rapidly increased in SL than CL but the 2nd cropping year was higher in CL.

Before the rice cropping, the available P_2O_5 (Av. P) content of soil was lower in CL than SL in both cropping systems (Table 1). A significant relationship between cropping systems and average P content was established in CL and SL soil textures. The average P content rapidly increased in the SL soil as red pepper continuous cropping years increased. The largest P content was recorded for the six year greenhouse cropping system at 539 and 722 mg kg^{-1} for CL and SL, respectively. After rice cropping, the Av. P content was further reduced in CL, specifically in the soil cropped continuously for four and seven years, than that in the SL soil (Table 3). The decrease Av. P could be contributed to agricultural practice that reduce soil and water pollution and eliminate the over-production of algae and waterweeds[13]. The K content of the soil was higher in CL than SL in all the treatments and cropping year increasing in greenhouse. Although K content decreased after rice cropping, it was approximately two times higher in CL than SL. Calcium content of soil was a little higher in SL than CL before rice cropping but it was nearly two times greater in SL than CL in continuous greenhouse red pepper cropped field (Table 1). After rice cropping, the decrease in Ca was similar between CL and SL, however it was about two

Table 1: Chemical properties of experimental soil, Clay Loam (CL) and Sandy Loam (SL) before the experiment

	Soil texture									
	Clay loam					Sandy loam				
			Greenhouse					Greenhouse		
Nutrient	Rice single	Barley-rice	2	4	6	Rice single	Barley-rice	2	4	6
pH	5.2c	4.9d	5.2bc	5.4b	6.0a	4.9c	4.9c	5.08c	6.3b	6.9a
Av. P (mg kg^{-1})	189e	208d	255c	517b	539a	261d	223e	476c	516b	722a
K (cmol+kg^{-1})	0.23d	0.31c	0.50bc	0.56b	0.71a	0.13c	0.20bc	0.20bc	0.23b	0.42a
Ca (cmol+kg^{-1})	3.1de	3.5d	4.2c	5.9ab	6.2a	2.7d	4.1c	4.4c	7.8b	13.8a

[a]Within experiments, means followed by the same letter(s) indicate treatment that are not significantly different

Table 2: Chemical properties of irrigated water in the red-pepper cropped field

Area	pH	EC ($dS\ m^{-1}$)	PO_4^-	SO_4^-	NO_3^-	NH_4^+	Ca	Mg	K	Na	Cl^-
			mg L^{-1}								
Bubuk Unjeon	6.70	0.22	0.25	7.8	7.0	1.2	20.5	5.4	6.1	9.7	6.9
Muan	6.66	0.14	0.08	3.0	20.2	1.0	15.3	4.0	2.4	6.8	3.1
Bubuk Cheongun	6.74	0.12	0.49	2.9	23.7	2.1	10.6	3.3	3.4	5.3	2.4
Samrangjin Imcheon	6.79	0.23	0.38	10.6	32.1	1.1	24.5	4.9	4.3	20.9	10.4
Changwon Desan	7.01	0.37	1.07	26.8	34.7	1.1	28.3	5.7	5.1	52.6	12.6
Average	6.78	0.22	0.45	10.2	23.5	1.3	19.8	4.7	4.3	19.1	7.1

Table 3: Soil chemical properties in each cropping systems and continuous cropping year after the cultivation of rice

	Soil texture									
	Clay loam					Sandy loam				
			Greenhouse					Greenhouse		
Nutrient	Rice single	Barley-rice	2	4	6	Rice single	Barley-rice	2	4	6
pH	5.35	5.35	5.84	5.86	6.36	5.36	5.47	5.74	7.39	7.76
AC*-B C**	0.19	0.46	0.41	0.48	0.35	0.45	0.53	0.76	1.06	0.81
Av.P (mg kg^{-1})	165	159	255	298	366	294	237	267	493	699
AC-B C	-24	-49	0	-219	-273	33	14	-209	-23	-23
K(cmol+kg^{-1})	0.09	0.13	0.20	0.27	0.33	0.08	0.13	0.20	0.20	0.28
AC-B C	-0.14	-0.18	-0.30	-0.29	-0.38	-0.05	-0.07	0.00	-0.03	-0.14
Ca(cmol+kg^{-1})	2.15	1.98	3.33	4.27	4.28	1.65	2.59	3.07	5.70	6.65
AC-B C	-0.95	-1.52	0.87	-1.63	-1.92	-1.05	-1.51	-1.33	-2.10	-7.15

*After rice cropping, **Before rice cropping

Table 4: Characteristics of plant height and tiller numbers per hill as affected by soil series and cropping systems in pot experiment

	Classify				
		Tillering stage		Panicle initiation stage	
Soil series	Cropping system	Plant height (cm)	Tiller No. $hill^{-1}$	Plant hei. (cm)	Tiller No. $hill^{-1}$
Clay loam	Rice single	30.8cd	13.1bc	58.7c	16.0bc
	Barley-rice	29.5d	14.8a	59.2bc	18.2a
	GH – 2 year	31.8bc	12.6c	57.8d	12.9d
	GH – 4 year	32.9b	12.6c	59.0b	15.7c
	GH – 6 year	36.2a	14.7a	61.8a	16.5b
	Average	32.2	13.6	59.3	15.9
Sandy loam	Rice single	28.7d	9.1e	51.2c	10.4c
	Barley-rice	30.0c	13.0bc	56.7a	16.2a
	GH – 2 year	31.8ab	12.7c	56.7a	13.2b
	GH – 4 year	30.9bc	14.4a	54.5b	16.2a
	GH – 6 year	29.7cd	10.6d	52.6c	13.2b
	Average	30.2	12.0	54.3	13.8

[a]Within experiments, means followed by the same letter(s) indicate treatment that are not significantly different

times greater in six years continued red pepper cropped field (Table 3).

Chemical properties of irrigation water: In the red-pepper cropped field, chemical properties of irrigated water was variable among the different sites (Table 2). The chemical properties are as followed: soil pH ranged from 6.7 to 7.0; EC ranged between 0.12 to 0.37 ($dS\ m^{-1}$) and other nutrients PO_4^-, 0.08 to 1.07; SO_4^-, 2.9 to 10.6; NO_3^-, 7.0 to 34.7; NH_4^+, 1.0 to 2.1; Ca, 10.6 to 28.3; Mg, 3.3 to 5.7;

Table 5: Grain yield and yield components of rice in pot experiment

Soil series	Cropping system	Culm length (cm)	Panicle No. $hill^{-1}$	Spikelet No. $panicle^{-1}$	Filled grain (%)	1000-grain weight (g)	Grain yield (g $hill^{-1}$)
Clay loam	Rice single	64.3ab	12.0b	83a	81.8b	23.2	17.5b
	Barley-rice	65.3a	15.6a	82a	78.3c	23.3	19.3a
	GH–2 year	62.7bc	7.9d	77b	81.7b	24.4	13.6cd
	GH–4 year	61.2c	8.9c	77b	84.3ab	24.5	14.3c
	GH–6 year	64.6ab	9.1c	85a	84.3ab	24.1	14.2c
	Average	63.6	10.7	81	82.1	23.9	15.8
Sandy loam	Rice single	55.2e	6.1ef	80ab	79.4c	23.8	11.5d
	Barley-rice	61.1c	11.3b	75b	81.2b	23.3	13.5cd
	GH–2 year	59.7cd	8.4d	76b	85.7a	24.1	13.8cd
	GH–4 year	60.3cd	7.8de	73bc	76.6cd	24.5	11.7d
	GH–6 year	56.0e	7.0e	80ab	81.2b	24.0	10.1e
	Average	58.5	8.1	77	80.8	23.9	12.1

[a]Within experiments, means followed by the same letter(s) indicate treatment that are not significantly different

Table 6: Grain yield and yield components of rice in farmer's farm

Soil series	Cropping system	Culm length (cm)	Panicle No. $hill^{-1}$	Spikelet No. $panicle^{-1}$	Filled grain (%)	1000-grain weight (g)	Grain yield (g $hill^{-1}$)
Clay loam	Rice single	81.3ab	19.7a	90.0a	92.2a	25.7a	5.60a
	Barley-rice	82.3a	16.9c	90.9a	87.0c	24.6b	5.45b
	GH–2 year	79.4bc	19.8a	78.7c	92.9a	25.5ab	5.17d
	GH–4 year	80.2b	18.6b	65.5d	90.8b	23.0c	5.14d
	GH–6 year	80.4b	17.0c	83.4b	87.2c	24.0bc	5.28c
	Average	80.7	18.4	81.7	90.0	24.6	5.33
Sandy loam	Rice single	83.0b	17.8b	90.3a	90.4a	25.8a	5.26a
	Barley-rice	89.4a	19.2a	89.3a	80.5c	23.1c	5.04b
	GH–2 year	77.9c	17.4b	81.8c	79.9c	22.9c	4.65c
	GH–4 year	68.2d	11.2d	72.4d	88.2b	24.4b	4.58c
	GH–6 year	74.5c	13.7c	88.1ab	80.7c	24.4b	3.93d
	Average	78.6	15.9	84.4	83.9	24.1	4.69

Above values are the average of all sites in Bubuk Unjeon, Muan, Bubuk Cheongun, Samrangjin Imcheon, Changwon Desan

K, 2.4 to 6.1; Na, 5.3 to 52.6 and Cl^{-}, 2.4 to 12.6 mg L^{-1}. The main sources contributing to fluctuating nutrient contents of irrigation water include different irrigation origins, leaching and chemical fertilizer runoff which can be classified by upstream, down stream or base of village.

The soil EC of SL dramatically decreased in GH6 as time increased. Four weeks after Transplanting (TP), it was reduced from 8.2 to 4.2 at just after rice TP to four weeks after TP. However, other GH2 and GH4 ranged from 3.0 to 3.2 which lowered to 2.0 four weeks after TP (Fig. 1). In RS and BR, EC was similar for initial time after TP and four weeks after resulting in levels lower than 2.0.

In SL, soil EC was 12.0 and 9.7 in GH4 and GH6, respectively and EC decreased as time increased after TP. In RS and BR, EC was maintained or decreased slightly over increasing time.

Soil EC was a problem in SL, especially as cropping years increased in green house. Soil EC decreased in each soil layer with increasing soil depth in all cropping systems and soil textures (Fig. 2). The EC of soil in each layer was higher in GH and it increased over increasing vegetable cropping years. In CL, EC in GH was higher at a soil depth of 0-10 cm. Other soil layers were not harmful because the soil sickness escalates when EC is higher 4.0 which has been established the critical point by Korean researchers. Contrary to CL, soil EC in SL was higher at soil depth of 10-20 and 20-30 cm which were higher than 4.0 in 9 years (this was introduced for introducing of long-term effects without any description in the content) continuous vegetable cropped field. The increasing speed of soil EC was faster in SL than CL in both cropping years and soil depth.

Rice growth and grain yield related characteristics in pot experiment: Plant height and tiller numbers in the pot experiment were higher in CL than SL (Table 4). Plant height was greatest in the 6-year continuous green house red pepper cropping system (GH6) in Clay Loam (CL) at both tillering and Panicle Initiation Stage (PIS), however, very similar plant height were found in each soil textures. Barley-rice (BR) and GH2 was lowest at tillering and PIS, respectively (Table 4). The improvement in plant height for BR at PIS is due to slowly released compost that contributed to the activation of late growth. However, in SL, the greatest improvement occurred in GH2 while small differences were observed among the GH2, GH4 and GH6. In contrast to CL, plant height was lowest in RS for both growth stages.

In CL, tiller numbers per hill were lowest in GH2 and 4 (Table 4). The low number of tillers could be attributed to less accumulation of compost which delayed initial rice

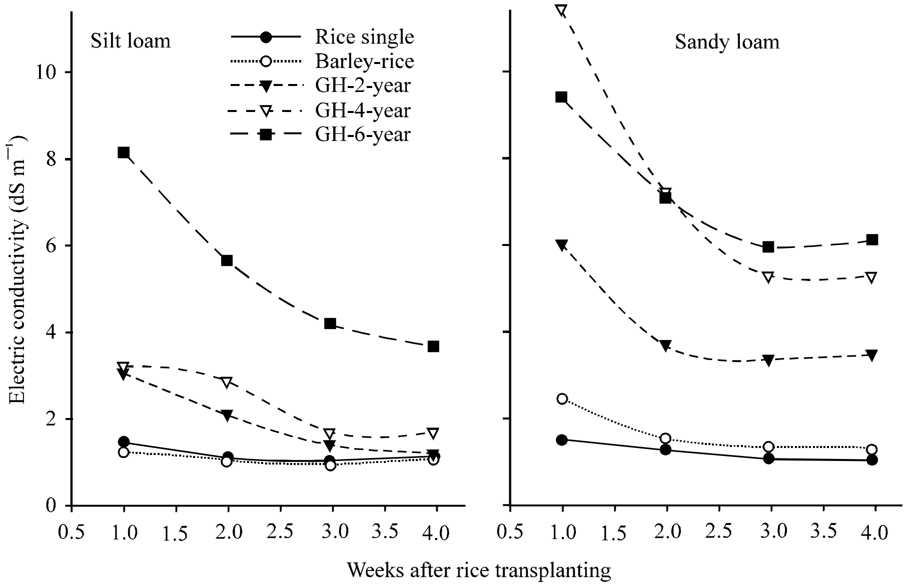

Fig. 1: Electric Conductivity (EC) of penetrated solution was as affected by soil texture, cropping systems and rice cropping duration

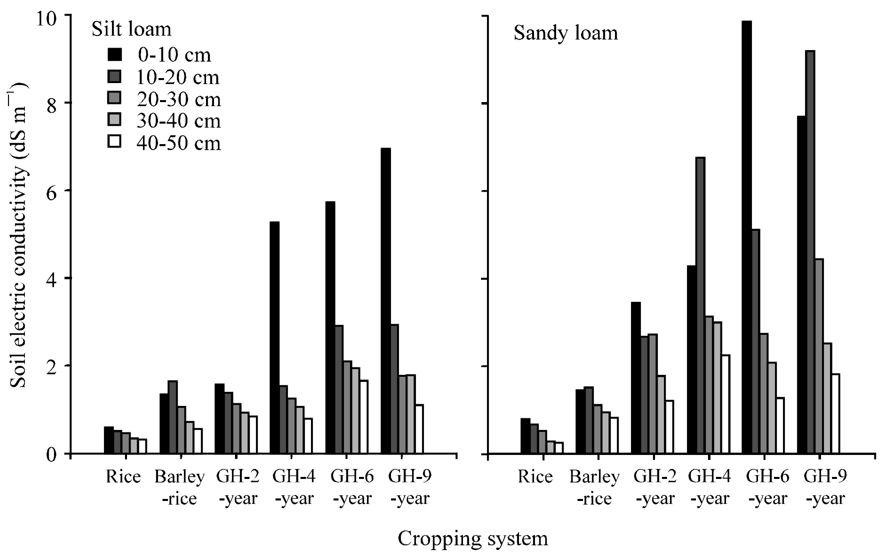

Fig. 2: Soil Electric Conductivity (EC) of penetrated solution was as affected by soil texture, cropping systems and soil depth in red-pepper cropped paddy field

growth as well as the C/N ratio of the selling compost which ranged from 20 to 30. However, in SL, tiller numbers were lowest in RS and GH2 which was due to a lower buffer effect for nutrients caused by a lower soil microorganism population or nutrient holding capacity.

Yield components, except 1000-grain weight and grain yield were higher in CL than SL (Table 5). The average grain yield of all cropping system treatments was 23% higher in CL than SL. In CL, culm length was lowest in GH4 and 2, however RS, BR and GH6 were similar (64.3 to 65.3 cm). However it was lowest in RS and GH6 in SL and it ranged between 55.5 to 56.0 cm. Panicle numbers per hill was greatest in BR(15.6) followed by RS(12.0) and lowest in GH2, 4 and 6 treatments. In SL, it was greatest in BR with other treatments ranging from 6.1 to 8.4. The lowest was in RS. In CL, spikelet numbers per panicle was highest in RS, BR and GH6 but lowest in GH2 and 4, which was similar to SL. In CL, filled grain (%) was greatest in GH4 (84.3) and 6 (84.3) but lowest in BR treatment. However, it was greatest in GH2 (85.7) but lowest in GH4

(76.6) in CL. The 1000-grain weight was similar among GH2, 4, 6 in both soil series and higher than RS and BR. In CL, grain yield per pot was greatest in BR(19.3) followed by RS(17.5) and lowest in GH treatments. In contrast to CL, SL grain yield was highest in BR (13.5) and GH2(13.8) and lowest in RS(11.5), GH4(11.7) and 6(10.1).

Rice growth and grain yield related characteristics in field experiment: In field experiment, yield component except, spikelet numbers per panicle and grain yield, were higher in CL than SL (Table 6). Average grain yield of all cropping systems treatments was 12% higher in CL than SL. In CL, culm length was lowest in GH2, 4 and 6. RS and BR were similar at 81.3 and 82, respectively. In SL, it was highest in BR(89.4) and lowest in GH4(68.2). Panicle numbers per hill in CL was greatest in RS(19.7) and GS2(19.8) followed by GH4 (18.6). However, in SL, it was greatest in BR(19.2) and decreased as GH cropping years increased. Similar to the pot experiment, the spikelet numbers per panicle in CL was highest in RS and BR but lowest in GH2(78.7) and GH4(65.5). This was similar to SL. In CL, filled grain (%) was greatest in RS(90.4) and GH4(88.2) and other treatments ranged from 79.7 to 80.7. The 1000-grain weight was highest in RS (25.8) but lowest in GH2(22.9). Others treatments exhibited a little differences ranging from 23.1 to 24.2.

In CL, grain yield per ha was greatest in RS (5.60 t ha^{-1}) followed by BR (5.45) and lowest in GH treatments. Similar to CL, SL grain yield was highest in RS (5.26) and BR(5.04) and yield decreased as GH cropping years increased (Table 6). The highest grain yield in RS was due to the cropping duration and standard fertilization level recommended by the RDA. However, the primary purpose of rice cropping is to reduce soil sickness and rice yield is secondary.

These results are summarized as grain yield of rice was greater in clay loam soil compared to sandy loam soil due to well organized soil in clay loam that maintains water, nutrients, etc. By rice cropping, Av. P and K_2O contents were reduced in clay loam soil compared to sandy loam. However, soil pH and Ca content were further reduced in sandy loam. Between the soil series, clay loam was better for rice growth and grain yield in continuous greenhouse vegetable cropped field. Additionally rice cropping reduced excessive nutrients and soil EC dramatically. These results indicate that soil sickness can be reduced in vegetable cropping soil by lowering soil EC and balancing soil nutrient conditions. Additionally, submerging the rice disrupted diseases and pests cycles. Even though low rice yield was obtained in continuous greenhouse system, the primary purpose of rice cropping was achieved by reducing soil nutrient levels and reducing soil sickness.

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