

Effects of Leonardite on Soil Quality and Rice Yield Improvements

ผลของลีโอนาร์ไดท์ต่อการปรับปรุงคุณภาพดินและผลผลิตข้าว

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บทคัดย่อ: ลีโอนาร์ไดท์เป็นวัสดุธรรมชาติที่อุดมด้วยฮิวมัสจึงมีศักยภาพสูงในการนำมาใช้ทางการเกษตร อย่างไรก็ตามข้อมูลเกี่ยวกับการใช้ ลีโอนาร์ไดท์ในข้าวนาดำมีน้อยมาก จึงได้ทำการทดลองในกระถางเพื่อวัดผลของลีโอนาร์ไดท์ต่อคุณภาพของดินและผลผลิตของข้าว พันธุ์ขาวดอกมะลิ 105 โดยใช้ปุ๋ยเคมีและปุ๋ยหมักในการเปรียบเทียบ ผลการทดลองพบว่า โดยเฉลี่ยแล้วการใส่ปุ๋ยหมักเพียงอย่างเดียวหรือใส่ร่วมกับ ลีโอนาร์ไดท์สามารถเพิ่มระดับอินทรีย์วัตถุ ไนโตรเจน ฟอสฟอรัส และ โพแทสเซียม ได้ประมาณสองเท่าเมื่อเปรียบเทียบกับกรรมวิธีควบคุม การใช้ลีโอนาร์ไดท์ที่ปรับปรุงร่วมกับปุ๋ยหมักในกรรมวิธีที่ 8 และ 9 (ลีโอนาร์ไดท์ปรับปรุง + ปุ๋ยหมัก (1:1) และ ลีโอนาร์ไดท์ปรับปรุง + ปุ๋ยหมัก (3:1), ตามลำดับ) ให้ค่า จำนวนกอ (30.3 และ 32.0 กอ/ต้น, ตามลำดับ), จำนวนรวง (19.33 และ 18.67 รวง/ต้น, ตามลำดับ) และผลผลิตเมล็ด (50.58 และ 50.29, กรัม/ต้น, ตามลำดับ) สูงกว่ากรรมวิธีควบคุมอย่างมีนัยสำคัญทางสถิติ ค่าที่เพิ่มสูงขึ้นทั้งหมดนี้ไม่แตกต่างอย่างมีนัยสำคัญจากการใช้ปุ๋ยเคมี ผลการทดลองนี้แสดงให้เห็นว่าการใช้ลีโอนาร์ไดท์ร่วมกับปุ๋ยหมักให้ผลดีกว่าการใช้ลีโอนาร์ไดท์ หรือปุ๋ยหมักเพียงอย่างเดียว ดังนั้นจึงสรุปได้ว่าการผสมดินด้วยลีโอนาร์ไดท์ร่วมกับปุ๋ยหมักสามารถใช้เป็นทางเลือกทดแทนปุ๋ยเคมีเพื่อให้ผลผลิตข้าวที่สูงได้

คำสำคัญ: ปุ๋ยหมัก กรดฮิวมิก ลีโอนาร์ไดท์ ข้าว คุณภาพดิน ธาตุอาหารพืช

Abstract: Leonardite is a natural humus-rich material thus a high potential to use in agriculture. However, there is very little information available regarding the use of leonardite for lowland rice. To determine the effects of leonardite on soil quality and rice yield, a pot experiment was conducted using Thai jasmine rice cultivar KDML105. Chemical fertilizer and compost were used for comparison. On the average, the application of compost alone or with leonardite increased soil organic matter, N, P, and K levels about twice as compared to the control. The combination of improved leonardite and compost in treatment 8 and 9 (IL + compost (1:1) and IL + compost (3:1), respectively) gave significantly higher number of tillers (30.3 and 32.0 tillers/plant, respectively), number of panicle (19.33 and 18.67 panicle/plant, respectively) and grain yield (50.58 and 50.29 g/plant, respectively) than the control. All the increased parameters did not show significant different from those obtained using chemical fertilizer. The results indicated that the use of leonardite plus compost showed better performance than leonardite or compost alone. It is therefore concluded that the incorporation of leonardite plus compost into the soil could be used as an alternative to chemical fertilizer for obtaining high yield of rice.

Keywords: Compost, humic acid, leonardite, rice, soil quality, plant nutrients

Introduction

The continuous use of chemical fertilizers accelerates the depletion of soil organic matter and impairs physical and chemical properties of soil in addition to causing micronutrient deficiencies. In Thailand, most of the cultivated soils have less than 1.5% soil organic matter (SOM) that could be considered to be low. This important component of soil is declining with time due to intensive cropping and use of high doses of chemical fertilizers with little or no addition of organic matter. Soil organic matter serves as a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, retains moisture, reduces compaction, reduces surface crusting, and increases water infiltration into soil. Therefore, loss of SOM is often considered as one of the main causes of soil fertility and productivity decline. For these reasons, it is essential to apply good quality organic materials that can be used to improve soil properties and productivity. Organic inputs such as finished compost and leonardite are efficient and effective in replenishing

the soil with organic matter or humus being depleted with continued cropping. Leonardite is rich in organic matter (50 to 75%) and its humic acid content could range between 30 to 80% therefore this natural humus-rich materials offers a good choice as soil and crop yield improvement (Ratanaprommanee and Shutsrirung, 2014). Humic acid improves the physical, chemical and biological properties of the soil and accelerates plant growth by influencing the growth of roots. Initiation of root enhancement and increased root growth may be observed by the application of humic acids and fulvic acids to the soil (Pettit, 2004). Significant impacts of humic substances on soil structure and plant growth are extensively reported in the literatures. (Fong *et al.*, 2007; El-Razek *et al.*, 2012; Ihsanullah and Bakhshwain, 2013). The benefits of compost and organic manures on rice and wheat yield improvement are well documented (Singh and Yadav, 1986; Hussain *et al.*, 1998) Wattanaphayapkul (2014) applied cattle dung, chicken dung and wood vinegar to improve growth, yield and seed quality of Hom Mali rice. Application

of diluted wood vinegar and cow dung resulted in significantly higher plant height, number of tillers and grain yield of KDML 105. Application of diluted wood vinegar and chicken dung promoted the highest grain yield of 224.5 g/pot of KDML 105. However reports on the utilization of leonardite in cereals crops are rare. Application of compost plus 10% leonardite (w/w) at the rate of 5,000 kg/rai gave the highest shoot and root dry weights of Chinese kale. The highest P, K, Ca, and Mg uptake were also obtained with compost plus leonardite (Inthajak, 2012). High plant nutrients and humic acid content in leonardite samples indicated its high possible use to improve organic matter, humic acid and some plant nutrient levels in the soils. However the very low pH values and low P content of most leonardite samples should be raised before soil application (Ratanaprommanee and Shutsrirung, 2014). Somchan and Shutsrirung (2014) suggested that leonardite should be mixed with 5% dolomite and 10% rock phosphate to get an improved quality (improved leonardite) before soil application. Increasing demand and elevating cost of used materials as soil conditioners in agriculture have led to investigate the potential use of leonardite on a field scale.

Several leonardite mines have been discovered and started to the production of this natural high-humus material in Thailand. The aim of the present study was to investigate the effects of ground leonardite alone and in combination with compost as organic amendments on rice yield and some soil properties.

Materials and Methods

This study was performed under pot experiment conditions. The aim of this experiment was to evaluate the effect of original leonardite (OL: 100% leonardite), improved leonardite (IL: leonardite containing 5% dolomite and 10% rock phosphate), compost and chemical fertilizer on growth and yield of rice. Chemical properties of the soils before and after planting rice were also analyzed (Department of Agriculture, 2005). The experiment was arranged in completely randomized design with three replications. The following 9 treatments were conducted, T1: control, T2: chemical fertilizer (16-16-8; 20 kg/rai), T3: compost, according to the recommended rate of Department of Agriculture (2,000 kg/rai), T4: OL (2,000 kg/rai), T5: IL (2,000 kg/rai), T6: OL + compost (ratio 1:1 w/w; 2000 kg/rai), T7: OL + compost (ratio 3:1 w/w: 2000 kg/rai), T8: IL + compost (ratio 1:1 w/w: 2000 kg/rai) and T9: IL + compost (ratio 3:1 w/w) 2000 kg/rai. Thai jasmine rice cultivar KDML105 was used in this study. Two equal splits of each treatment were applied at 5 days before the rice planting and 30 days after the initial input. During the trial, the water level was maintained in the range of 5 to 10 cm above the soil surface, including the prevention and control of pests and weeds. Data were collected on plant height (cm), number of tillers (per plant), number of leaves (per plant), number of panicle (per plant), dry weight of the grain and straw dry weight (g per plant). The data obtained were subjected to analysis of variance by using MSTATC computer software and means were separated by LSD test (Steel *et al.*, 1997)

Results and Discussion

1. Soil chemical properties

Chemical properties of the soil before planting rice

Soil analysis was done before sowing and after harvesting of rice (Table 1). The observed data showed that the soils used in the pot experiment were slightly acidic, with an average of 6.09 and low organic matter content (1.45%). The initial concentration (before planting rice) of total nitrogen (N) was 0.11%, available phosphorus (P) and exchangeable potassium (K) were 17.33 and 122 mg/kg, respectively. The optimum values of available P in soil is 26 - 42 mg P/kg (Office of Agricultural Research and Development Region 1, 2016). The results showed that the quantity of phosphorus in the

soil was inadequate for plant growth. Inadequate P levels in the soil can impact the plant, especially under stressful conditions. Adequate P levels are required to enhance shoot and root growth and promote early maturity. Therefore, the soil phosphorus should be raised to improve crop yield.

Chemical properties of the soil after planting rice

The analysis results of the soil after planting rice under submerged conditions are shown in Table 1. The pH values of all the soil samples were increased and ranged from 6.91 - 7.34 which was higher than that of the pre-planting soil (pH 6.09). Submergence caused a small initial decline followed by a gradual increase in pH values of soil solution (Islam and Islam, 1973). The soil pH in all the treatments applied with compost, leonardite (OL and

Table 1. The analysis results of the soil after planting rice

Tr	Treatments	pH	OM (%)	Total Nitrogen (%)	Available P (mg/kg)	Exchangeable (mg/kg)		
						K	Ca	Mg
-	Pre-planting soil	6.09	1.65	0.09	17.33	122	1025	95
T1	Control	7.11	1.50 ^c	0.07 ^b	15.97 ^f	154 ^e	1414 ^e	95 ^d
T2	Chemical fertilizer (16-16-8): 20 kg/rai	7.02	1.48 ^c	0.07 ^b	42.88 ^a	273 ^{cd}	2248 ^{cd}	83 ^{de}
T3	Compost: 2,000 kg/rai	7.13	2.71 ^b	0.14 ^a	33.51 ^d	278 ^{cd}	2282 ^c	93 ^{de}
T4	OL: 2,000 kg/rai	7.25	2.51 ^b	0.13 ^a	33.22 ^d	326 ^b	2197 ^d	80 ^e
T5	IL: 2,000 kg/rai	6.91	3.13 ^a	0.16 ^a	28.12 ^e	256 ^d	2400 ^b	92 ^{de}
T6	OL + Compost (ratio 1:1):2000 kg/rai	7.26	3.16 ^a	0.16 ^a	41.12 ^{ab}	174 ^e	2607 ^a	111 ^{bc}
T7	OL + Compost (ratio 3:1): 2000 kg/rai	7.24	2.97 ^a	0.15 ^a	39.45 ^{bc}	294 ^c	2466 ^b	111 ^c
T8	IL + Compost (ratio 1:1): 2000 kg/rai	7.27	2.67 ^b	0.14 ^a	37.50 ^c	411 ^a	2416 ^b	127 ^b
T9	IL + Compost (ratio 3:1): 2000 kg/rai	7.34	2.61 ^b	0.13 ^a	33.69 ^d	171 ^e	2563 ^a	144 ^a
	Mean	7.17	2.52	0.13	33.96	260	2287	104
	F-test	ns	*	*	*	*	*	*
	% CV	5.00	5.97	15.85	3.63	5.72	1.9	8.08
	Soil properties suitable for growing crops ¹	6 - 7	2.5 - 3	-	26 - 42	130	1040	135

^{a-f} Within rows not sharing a common superscripts are not significantly different ($P < 0.05$)

* Not significantly different at $P < 0.05$

¹ Office of Agricultural Research and Development Region 1 (2016)

IL) and the combination of compost plus leonardite resulted in higher soil pH (more alkali) than the control soil under submerged condition. However, chemical fertilizer and improved leonardite (IL) decreased the soil pH (pH 7.02 and 6.91, respectively) compared with the control (pH 7.11) (Table 1). The lower pH value of fertilizer treated soil and higher pH value in compost manure treated soil explains the acidifying effects of the NPK fertilizer and the neutralizing effects of compost and leonardite plus compost. The compost manure has been found to be capable of improving soil pH because of the relative exchangeable Ca, Mg and K it contained (Olayinka and Adebayo, 1985). Soils with added organic matter can help adjust soil pH to the neutral range (6.5 - 7.5), which is of benefit to the rice crop, because this pH range appears to favor nutrient uptake by wetland rice (Sahrawat, 2005). Soil organic matter (SOM) in the control soil (1.65%) showed little decreased after planting (1.50%) this might due to the decomposition of added organic matter is relatively low under submerged conditions. The soils in the treatments with compost and/or leonardite application (T3 to T9) led to significant increase in SOM (2.51 to 3.16%), as compare to the control and chemical fertilizer application. The increased values obtained in this experiment could be attributed to the levels of compost and/or leonardite application.

Significant differences were found in N, P, K and Ca levels among the treatments with organic application (T3 to T9) however these nutrients levels in the soils after planting rice could be considered adequate for the next crop (Table 1). The addition of organic materials into the soil resulted in increases in the soil nitrogen levels (0.13 - 0.16%). The levels of available phosphorus (mg P/kg) in all the treatments with organic amendment were increased about twice

(28.12 - 42.88 mg P /kg) and reach the optimum values (26 - 42 mg P/kg) (Office of Agricultural Research and Development Region 1, 2016) for plant growth while the P level of the control soil was quite low (15.97 mg/kg). The levels of exchangeable K and Ca showed similar trend as the P level, the values obtained from organic application showed much higher values than those of the control (Table 1). In general, the application of compost plus leonardite led to a certain increase in Mg level with the value ranged from 111 -144 mg/kg. Plant nutrient elements contained in all the leonardite samples were quite high (N, K, S, Ca, Mg, Fe, Zn and Mn) except for phosphorus. (Shutsrirung *et al.*, 2016). However, in the present study, the application of 2,000 kg/rai of original leonardite (OL) seemed to be sufficient to reach the optimum P level for crop demand. Our results indicated that leonardite and improved leonardite could provide a rich source of nutrients with high organic matter content and the use of this high humus material can be beneficial to improve soil nutrients level for the next crop, which may ultimately increase crop yields.

2. Effects of compost and leonardite on growth and yield of rice

Plant height, number of tiller and number of leaves

Plant height was not significantly different ($P < 0.05$) between the treatments except T5 that gave significant lower height (85.33 cm) than the rest of the treatments (Table 2). The application of original leonardite (OL: 100% leonardite) resulted in the lowest number of tillers and leaves per plant. Ratanaprommanee and Shutsrirung (2014) suggested that the pH and phosphorus level of OL should be raised before soil application due to the low pH values (1.84 to 2.55) and low P content (28.6 to 211.2 mg/kg) of

Table 2. Growth parameters of rice variety jasmine rice 105 at 2 months after transplanting

Tr	Treatments	Plant height (cm)	Number of tillers/ plant	Number of leaves/plant
T1	Control	93.13 ^{ab}	22.00 ^b	77.00 ^b
T2	Chemical fertilizer (16-16-8): 20 kg/rai	92.00 ^{ab}	36.67 ^a	123.00 ^a
T3	Compost: 2,000 kg/rai	91.13 ^{ab}	27.00 ^{ab}	92.00 ^b
T4	OL: 2,000 kg/rai	90.63 ^{ab}	20.00 ^b	78.00 ^b
T5	IL : 2,000 kg/rai	85.33 ^b	25.33 ^{ab}	94.67 ^b
T6	OL + Compost (ratio 1:1):2000 kg/rai	92.67 ^{ab}	29.00 ^{ab}	91.33 ^b
T7	OL + Compost (ratio 3:1): 2000 kg/rai	94.33 ^a	27.00 ^{ab}	91.33 ^b
T8	IL + Compost (ratio 1:1): 2000 kg/rai	94.50 ^a	30.33 ^{ab}	94.67 ^b
T9	IL + Compost (ratio 3:1): 2000 kg/rai	91.93 ^{ab}	32.00 ^{ab}	98.33 ^b
	Mean	91.74	27.70	93.37
	F-test	*	*	*
	% CV	5.60	28.90	14.76

^{a-n} Within rows not sharing a common superscripts are not significantly different ($P < 0.05$)

* Not significantly different at $P < 0.05$; OL (original leonardite); IL (improved leonardite)

most leonardite samples. In our study, the improved leonardite (IL: leonardite containing 5% dolomite and 10% rock phosphate) was used in T5, T8 and T9. The IL applied in these three treatments increased both the tillers and leaves per plant compared with the OL treatments (T4, T6 and T7). The increased values of the tillers per plant obtained in T5, T8 and T9 (25.3, 30.3 and 32.0 tillers/plant, respectively) exhibited large differences from those obtained from T4 (20.0 tillers/plant). In addition, the increased values did not show significant difference from that obtained using chemical fertilizer (36.7 tillers/plant). The similar trend of differences among the treatments was observed with the number of leaves. Among organic materials application treatments, the IL, OL plus compost and IL plus compost showed obvious increase in the number of leaves compare with OL application alone and the control. Compost application (T3) gave an increase of both tillers/plant and number of leaves/plant moreover the increase was further improved by the mixture of compost and

improved leonardite (T8 and T9). The growth enhancement by these combined effects in the T8 and T9 might be due to high humic acid and micronutrients in leonardite. Tillers of the rice plant during the early stages of development are crucial stage to the production of effective ears (Nguyen *et al.*, 2004; Sivakumar *et al.*, 2007). Leonardite which contains high amount of humic substances, particularly humic acid, induced stimulation of plant growth as reported by Chen and Aviad (1990); and Arancon *et al.* (2002). Our results suggested that higher soil P level obtained in IL treatments might play an important role increasing number of tillers per plant. It was reported that the application of humic acid increased the synthesis and activity of IAA which played a significant role in promoting the plant growth. Mohammadipour *et al.* (2012) showed that the application of humic acid improved the plant growth parameters. In the present study, high humic acid content in leonardite might affect rice growth improvement.

Yield and yield components of rice

The number of panicles produced was the highest under T2 followed by T3, T9 and T8 (22.67, 20.33, 19.33 and 18.67, respectively). It was observed that high grain yields were also obtained with these 4 treatments, the highest grain yield was obtained by T2 followed by T8, T9 and T3 (52.13, 50.58, 50.29 and 49.22 g/plant, respectively) (Table 3). The grain yield increment under the T2, T8, T9 and T3 was 56.8, 52.2, 51.3 and 49.2%, respectively as compared to the control treatment. No significant differences of the number of panicle and grain yield were found among T2, T8, T9 and T3 treatments. However, the grain yield of these four treatments was significantly higher than those of the control and the rest of the treatments except T5. Our results suggested that total tillers and panicle per plant showed a very important parameter because of its association with other important yield components,

particularly grains yield (Table 2 and 3). On the average, the higher tiller number and panicle number had led to higher grain yield (Figure 1). Gravois and Helms (1992) reported that among different yield components of rice, panicle density had the largest positive direct effect on rice yield. It seemed that there has been no report on the application of leonardite for soil and crop yield improvement. However, there are several reports on pure humic acid application on crop yield. Saha *et al.* (2014) concluded that the combine application of humic acid and manure considerably influenced rice grain yield. The highest grain yield was obtained with the application of humic acid (1 L/rai) plus poultry manure (480 kg/rai). Foliar application of lignite humic acid markedly increased grain yield of rice. The application of 1.5% humic acid gave the highest grain yield (682 kg/rai) (Bama, 2009). In the present study, the results also suggested that

Table 3. Effect of different treatments on growth parameters

Tr	Treatments	Panicle per plant	Grain yield (g/plant)	Grain yield	Straw yield (g/plants)	Straw yield
				increase over control (%)		increase over control (%)
T1	Control	14.33 ^b	33.24 ^d	-	105.80 ^e	-
T2	Chemical fertilizer (16-16-8): 20 kg/rai	22.67 ^a	52.13 ^a	56.80	124.81 ^{cde}	17.96
T3	Compost: 2,000 kg/rai	20.33 ^{ab}	49.22 ^{ab}	48.06	108.76 ^{de}	2.79
T4	OL: 2,000 kg/rai	16.33 ^b	38.61 ^{cd}	16.15	208.66 ^a	97.22
T5	IL : 2,000 kg/rai	15.33 ^b	39.75 ^{cd}	19.59	229.58 ^a	117.00
T6	OL + Compost (ratio 1:1):2000 kg/rai	16.67 ^b	42.78 ^{bc}	28.68	195.31 ^{ab}	84.60
T7	OL + Compost (ratio 3:1): 2000 kg/rai	15.67 ^b	39.36 ^{cd}	18.41	168.31 ^{abcd}	59.08
T8	IL + Compost (ratio 1:1): 2000 kg/rai	18.67 ^{ab}	50.58 ^{ab}	52.16	139.85 ^{bcde}	32.18
T9	IL + Compost (ratio 3:1): 2000 kg/rai	19.33 ^{ab}	50.29 ^{ab}	51.27	181.68 ^{abc}	71.72
	Mean	17.70	43.99		162.53	
	F-test	*	*		*	
	% CV	19.84	12.01		22.00	

^{a-n} Within rows not sharing a common superscripts are not significantly different ($P < 0.05$)

* Not significantly different at $P < 0.05$; OL (original leonardite); IL (improved leonardite)

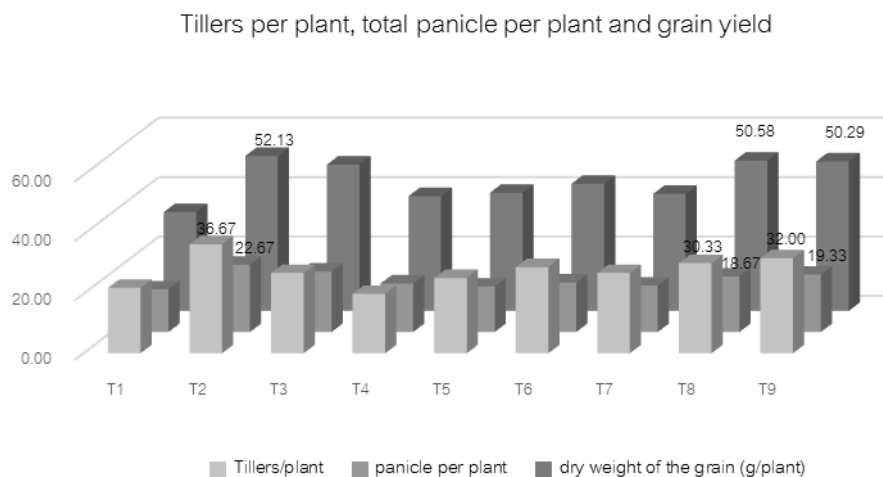


Figure 1. Tillers, panicle and grain yield as affected by chemical fertilizers and organic amendments

T1 = Control; T2 = Chemical fertilizer (16-16-8): 20 kg/rai; T3 = Compost: 2,000 kg/rai; T4 = OL: 2,000 kg/rai; T5 = IL : 2,000 kg/rai; T6 = OL + Compost (ratio 1:1):2000 kg/rai; T7 = OL + Compost (ratio 3:1): 2000 kg/rai T8 = IL + Compost (ratio 1:1): 2000 kg/rai; T9 = IL + Compost (ratio 3:1): 2000 kg/rai

leonardite which contains high amount of humic substances, particularly humic acid, influenced rice plant in a direct and indirect manner. Leonardite influences the plant growth directly either through its effects on ion uptake or by more direct effects on the growth regulation of the plant (Vaughan and Linehan, 1976). Straw yield did not follow the same order as found for panicles and grain yield. The highest straw yield was obtained under T4 and T5 while chemical fertilizer (T2) gave only about half of the straw yield, as compared to these two treatments (Table 3). This result indicated that the high straw yield in T4 and T5 did not seem to lead to higher yields.

Conclusion

It can be concluded that, among organic fertilizers, the combined effects of improved leonardite and compost at the rate of 2,000 kg/rai exhibited the highest increase in soil organic matter, plant nutrients and had led to the highest yield components and grain yield of Thai jasmine rice cultivar KDML105. From the above discussion it is

clear that leonardite have a significant influence on growth and productivity in rice when applying in combination with compost. Organic fertilizers can be a better supplement of inorganic fertilizer to produce better growth and yield without harmful to the environment. From an environmental and economic viewpoint as well as for sustainable soil management, application of IL + compost, 2,000 kg/rai could be recommended for use with lowland rice. The use of improved leonardite as alternative to commercial chemical fertilizers not only results in soil and crop yield improvement but also reduces pollution due to reduced nutrient run-off and N leaching. However, to confirm the effects of leonardite on soil and rice yield improvement, field experiment should be conducted.

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