CHAPTER 7

APPLICATION OF LEONARDITE TO IMPROVE SOIL QUALITY AND RICE YIELD II. FIELD EXPERIMENT

7.1 Introduction

Inorganic fertilizers are the main source of nutrients in modern rice cultivation. This has led to overuse of inorganic fertilizers thus damages soil structure, increases soil acidity, causes nutrient imbalance, and decreases crop sustainability, yield, and quality (Khan *et al.*,2008). Therefore, considerable interest has been generated regarding the use of compost and/or other organic materials on cultivated lands for restoring soil fertility, yield quality and for preventing potential environmental problems such as soil, water and air pollution (Edwards and Daniel, 1992; Chadwick *et al.*, 2000; Barton and Schipper, 2001; Phongpan and Mosier, 2003; Sharpe *et al.*, 2004). In general, organic materials can provide the macro- and microelements required by plants in different quantities, and thereby can generate a positive residual effect that should be taken into account when planning the next crop. (Edwards and Daniel, 1992; Eghball *et al.*, 2004; Hirzel and Walter, 2008). Leonardite is natural material with high humic acid contents. Therefore, leonardite may be considered as organic materials which have great agronomic potential (Carman *et al.*, 2010; Madanoglu, 2011). Plant nutrients elements contained in leonardite samples were quite high (N, K, S, Ca, Mg, Fe, Zn and Mn). Chemical analysis by XRD and XRF indicated that leonardite samples mainly consist of silica (Si) thus a good source of Si for plant growth (Ratanaprommanee *et al.,* 2016). However, there are few literatures on the effects of leonardite on soil properties and plant growth.

Increasing demand and elevating cost for used materials as soil conditioners in agriculture have led to investigate leonardite use on a field- scale. The aim of this study was to investigate the effects of ground leonardite alone and in combination with compost on rice growth and yield. Chemical fertilizer was also applied for comparison. Soil properties as affected by leonardite application were also evaluated.

7.2 Materials and Methods

7.2.1 Experimental conditions and design

The results of pot experiment indicated that the application of leonardite in combination with compost, particularly IL + compost at the ratio of ratio 3:1 (w/w), gave similar rice growth and yield as chemical fertilizer. To ensure the effects of leonardite, this study was performed under field experiment conditions. Original leonerdite (OL: 100% leonardite), improved leonerdite (IL: leonardite containing 5% dolomite and 10% rock phosphate), compost and chemical fertilizer were applied. Thai jasmine rice cultivar KDML105 was also used in this study. Chemical properties of the soils before and after planting rice were also analyzed (Department of Agriculture, 2005).

A field experiment was conducted at a farmer paddy field. The field experiment was arranged in randomized complete block design (RCBD) with 6 treatments and three replications. The following 6 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: IL + compost (ratio 3:1 w/w, 2000 kg/rai)

7.2.2 Preparation and management of field experiment

Soil preparations were done two weeks before the beginning of the experiment. When ploughed, organic materials and chemical fertilizer were applied and incorporated into the soil in the respective treatments. Two equal splits of each treatment were applied before ploughing and at booting stage of rice. Each block contained eighteen plots of size 24 x 3.5 m. One 30-day old rice seedlings were transplanted into each pot. The distance between the plots was 5 meters, and the blocks were separated by double mud bunds to minimize lateral movement of plant nutrients from one subplot to another. Rice seedlings were transplanted at a spacing of 25 cm between rows and 25 cm between hills.

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), dry weight of the grain and straw dry weight (g per plant).

Figure 7.1 Soil preparation and incorporation of before rice

Figure 7.2 Data collection in the rice field at 1 (A) and 2 month (B) after transplanting.

7.2.4 Growth measurement and chemical analysis.

The soil samples before and after planting rice were analyzed for nutrient content i.e. nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg). The soil samples were also analyzed for other characteristics; the acidity-alkalinity (pH) and organic matter content (%OM) (Department of Agriculture, 2005).

At 30, 60 and 90 days after transplanting, plant height, number of tillers and number of leaves were recorded. At harvesting time (120 days after transplanting) number dry weight of the grain and straw dry weight, were measured. After harvesting,

the rice shoots was oven dried at 60 °C until constant dry weights were recorded. Dried shoots and grains were analyzed for total nitrogen (N) (Bremner, 1965), total phosphorus (P), calcium (Ca), and magnesium (Mg) (Walinga *et al.*,1989) and total potassium (K) (Kalra, 1998).

7.2.5 Statistical analysis and calculation

Analysis of variance for shoot dry weight (straw yield), grain yield and also nutrients uptake (N, P, K, Ca, and Mg) was performed. 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)

7.3 Results and discussion

7.3.1 Chemical properties of the soil after planting rice

7.3.2 Effects of leonardite on growth and yield of rice

The incorporation of compost or leonardite alone and the combination of these two organic materials, into soil exhibited higher plant height (at 1 and 2 months after transplanting) than the control and chemical fertilizer treatments. The highest plant height was obtained with T4 (OL, 2,000 kg/rai) with the height of 54.06 and 133.19 at 1 and 2 months after transplanting, respectively (Table 7.1). The high numbers of tillers were obtained when organic materials were applied to the soils. At 1 month after transplanting, T4 gave the highest number of tillers (27.57) however at 2 month after transplanting, T6 (IL + compost (ratio 3:1) : 2000 kg/rai) gave the highest number of tilles (38.0) followed by T4. The similar trend of differences among the treatments was observed with the width of tillers and number of leaves. The maximum number of leaves were obtained by T3 (compost: 2,000 kg/rai) (139.55) followed by T4 (132.28) and these values were significantly higher than the control and chemical fertilizer treatment

Table 7.1 Growth parameters of rice variety jasmine rice 105 at 1 and 2 months after Transplanting

Tr	Treatments	Plant height (cm)		Number of Tillers/ plant		Width tillers (cm.)		Number of leaves/plant	
	Month	1	2	1	2	1	2	1	2
T1	Control	46.41^{c}	126.10^{b}	26.07^{ab}	31.90^{bc}	5.84^{bc}	31.90^{bc}	50.70^{ab}	95.71^{e}
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	48.01^{bc}	126.75^{b}	21.87^{cd}	29.27^{c}	6.28^{abc}	29.27^{c}	47.20^{ab}	106.51^{de}
T3	Compost: 2,000 kg/rai	50.38^{b}	129.14^{b}	21.87^{cd}	33.63^{bc}	5.72^{bc}	33.63^{bc}	44.37^{b}	139.55^{a}
T4	OL: 2,000 kg/rai	54.06^{a}	133. 19^{a}	27.57^{a}	33.70^{bc}	6.83^{a}	33.70^{bc}	56.80^{a}	120.85^{bcd}
T5	IL: 2,000 kg/rai	51.97^{ab}	130.27^{b}	26.87^{ab}	32.97^{bc}	6.57^{ab}	32.97^{bc}	48.60^{ab}	117.75^{cd}
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	50.43^{b}	128.70^{b}	25.13^{bc}	38.00^{a}	6.42^{ab}	38.00^{a}	52.87^{ab}	132.28^{bc}
	Mean	50.20	129.02	24.89	33.24	6.27	33.24	50.39	118.77
	F-test	*	*	*	*	*	*	*	*
	% CV	3.81	10.79	3.81	4.67	3.81	0.89	3.81	17.28

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

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

Grain yield was significantly influenced by chemical fertilizers and organic materials application treatments (Table 7.2), as compare to the control treatment. Chemical fertilizer provided the highest grain yield followed by T6 with values of 47.77 and 45.03 g per plant, with the highest grain yield increase over control of 35.85 and 28.05 %, respectively (Table 7.2). Among organic inputs, T5 and T6 gave rather high values of grain and straw yield as compare to chemical fertilizer treatment. As compare to all the treatments including chemical fertilizer, the straw yields of rice were significantly increased in T5 and T6 with the value of 225.8 and 223.41 g/plant, respectively. These values were 121.76 and 119.46% higher than the control (101.80 g/plant), respectively. Straw yield followed the same results as found in pot experiment that chemical fertilizer gave only about half of the straw yield, as compared to treatments 5 and 6. The results from pot and field experiment suggested the important of organic input (high carbon content materials) in biomass production.

Table 7.2 Effect of different treatments on growth parameters.

Tr	Treatments	Grain yield (kg)	Grain yield (g/plant)	Grain yield (kg/rai)	Grain yield increase over control (%)	Straw yield (g/plants)	Straw yield increase over control (%)
T1	Control	41.00[c]	35.16[c]	827.2[c]	0.00	101.80[d]	0.00
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	55.70[a]	47.77[a]	1123.7[a]	35.85	124.81[c]	22.60
T3	Compost: 2,000 kg/rai	45.50[b]	39.02[b]	918.0[b]	10.98	107.76[d]	5.85
T4	OL: 2,000 kg/rai	48.00[bc]	41.17[bc]	968.4[bc]	17.07	181.66[b]	78.45
T5	IL: 2,000 kg/rai	51.00[b]	43.74[b]	1028.9[b]	24.39	225.75[a]	121.76
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	52.50[b]	45.03[b]	1059.2[b]	28.05	223.41[ab]	119.46
	Mean	48.95	41.98	987.56		160.86	
	F-test	*	*	*		*	
	% CV	2.98	2.98	2.98		7.43	

[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 leonerdite) ; IL (improved leonerdite)

7.3.3 Effects of leonardite on nutrients in rice shoot and grain

The nutrients (N, P, K, Ca and Mg) concentration of rice at 1 month of all the treatments is shown in Table 7.3. On the average the highest nutrients concentration was obtained in the control treatment at all sampling time. The application of IL + compost gave rather high N concentration, 3.23 and 1.03 at 1st and 3rd month of rice cultivation. However the values among the treatments seemed not much different (except for the control). The P concentration did not show significant different among treatments except for T3 and T5 which exhibited the lowest P concentration at the 1st and 2nd month, respectively. After 3 months of transplanting, the application of leonardite in T4 to T6 provided higher P concentration than chemical fertilizer and compost application. The concentrations of K, Ca and Mg in the rice shoot of all the treatments seemed to be similar when compare in the same sampling stage, although the control showed the highest values of K and Ca.

Table 7.3 Nutrients concentrations in rice shoots at 1, 2 and 3 month after transplanting

Tr	Nutrients concentration in rice shoot (%)														
	N			P			K			Ca			Mg		
month	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
T1	3.22^{ab}	2.66^{a}	1.22^{a}	0.39^{abc}	0.34^{ab}	0.21^{a}	0.28^{ab}	0.25^{a}	0.25	0.16	0.10^{a}	0.07	0.13	0.15^{a}	0.16^{ab}
T2	3.32^{a}	1.68^{b}	0.89^{b}	0.39^{abc}	0.32^{ab}	0.12^{d}	0.29^{ab}	0.23^{ab}	0.21	0.15	0.07^{b}	0.08	0.13	0.15^{ab}	0.17^{a}
T3	2.74^{b}	1.45^{b}	0.82^{bc}	0.36^{c}	0.31^{ab}	0.12^{cd}	0.27^{b}	0.24^{a}	0.23	0.14	0.05^{c}	0.08	0.13	0.12^{b}	0.16^{ab}
T4	3.36^{a}	1.31^{b}	0.92^{b}	0.41^{ab}	0.28^{ab}	0.15^{bcd}	0.31^{a}	0.23^{ab}	0.22	0.13	0.05^{cd}	0.08	0.13	0.14^{ab}	0.15^{ab}
T5	3.35^{a}	1.27^{b}	0.57^{c}	0.43^{a}	0.27^{b}	0.13^{bcd}	0.30^{ab}	0.23^{ab}	0.23	0.13	0.04^{cd}	0.08	0.13	0.13^{ab}	0.15^{b}
T6	3.23^{a}	1.59^{b}	1.03^{ab}	0.39^{abc}	0.32^{ab}	0.16^{b}	0.30^{a}	0.23^{ab}	0.21	0.14	0.02^{e}	0.08	0.12	0.14^{ab}	0.16^{ab}
Mean	3.22	0.17	0.92	0.40	0.31	0.15	0.29	0.23	0.22	0.14	0.04	0.08	0.13	0.14	0.15
F-test	*	*	*	*	*	*	*	*	ns	ns	*	ns	ns	*	*
% CV	8.42	27.34	18.65	6.55	12.99	13.12	6.97	6.84	15.14	2.145	11.3	17.15	10.05	12.33	6.90

[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 leonerdite) ; IL (improved leonerdite

T1: Control, T2: Chemical fertilizer (16-16-8) rate of 20 kg/rai, T3: Compost (2,000 kg/rai), T4: OL (2,000 kg/rai), T5: IL (2,000 kg/rai) and T6 : IL + Compost (ratio 3:1 2000 kg/rai)

Nitrogen concentration obtained by the control and chemical fertilizer treatment (1.05 and 1.04%, respectively) was significantly lower than those obtained by T5 and T6 (1.14 and 1.10%, respectively). The highest P concentration was found in T6 (0.57%) however no significant difference was found among the treatments. The average values of K, Ca and Mg were 0.04, 0.27 and 0.18, respectively. There were no significant differences between the treatments.

Table 7.4 Nutrients concentrations in rice grains at harvesting

Tr	Treatments	Nutrient in rice (%)				
		N	P	K	Ca	Mg
T1	Control	1.05^{bc}	0.51^{ab}	0.04	0.03	0.17
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	1.04^{bc}	0.51^{ab}	0.04	0.02	0.17
T3	Compost: 2,000 kg/rai.	1.08^{abc}	0.54^{a}	0.05	0.03	0.18
T4	OL rate 2,000 kg/rai.	1.04^{bc}	0.54^{a}	0.05	0.03	0.18
T5	IL rate 2,000 kg/rai.	1.14^{a}	0.54^{a}	0.05	0.03	0.18
T6	IL + Compost (ratio 3:1) rate 2000 kg/rai.	1.10^{a}	0.57^{a}	0.04	0.02	0.18
	Mean	1.06	0.53	0.04	0.27	0.18
	F-test	*	*	ns	ns	ns
	% CV	4.69	7.43	11.01	22.22	5.74

[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 leonerdite) ; IL (improved leonerdite)

Nitrogen uptakes of rice shoot for all of the treatments are shown in Table 7.5. At 1 month after transplanting, T5 and T6 gave significantly higher N uptake (7.45 and 7.27 g N/plant, respectively) than the rest of the treatments and the values increase 106.37 and 101.39% over the control. However, at 2 and 3 months after transplanting, T6 provided the highest values of N uptake (3.60 and 2.29 g N/plant, respectively) with the percentage increase of 48.76 and 68.38%, respectively. Nitrogen uptakes of dry weight of the grain for the T2 and T5 gave significantly higher N uptake (0.5 g N/plant) than the rest of the treatments and the values increase 35.14% over the control. Chemical application gave lower N uptake than T6 at all stage of sampling indicating

Table 7.5 Nitrogen uptake in rice shoots at 1, 2 and 3 month after transplanting

Tr	Treatments	1 month (shoot)		2 month (shoot)		3 month (shoot)		Harvest (grain)	
		N uptake gN/plant	increase over control (%)	N uptake gN/plant	increase over control (%)	N uptake gN/plant	increase over control (%)	N uptake gN/plant	increase over control (%)
T1	Control	3.61^{d}	0.00	2.42^{b}	0.00	1.36^{b}	0.00	0.37^{c}	0.00
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	6.15^{bc}	70.36	3.09^{ab}	27.69	1.64^{ab}	20.59	0.50^{a}	35.14
T3	Compost: 2,000 kg/rai	4.81^{cd}	33.24	2.85^{ab}	17.77	1.44^{b}	5.88	0.42^{b}	13.51
T4	OL: 2,000 kg/rai	6.22^{bc}	72.30	2.55^{ab}	5.37	1.71^{ab}	25.74	0.43^{b}	16.22
T5	IL: 2,000 kg/rai	7.45^{ab}	106.37	2.84^{ab}	17.36	1.42^{b}	4.41	0.50^{a}	35.14
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	7.27^{ab}	101.39	3.60^{ab}	48.76	2.29^{a}	68.38	0.44^{b}	18.92
	Mean	6.21		3.13		1.72		0.44	
	F-test	*		*		*		*	
	% CV	14.18		26.35		22.59		5.61	

* indicates the effect is significant at P< 0.01

/1 Values within each column followed by same letter are not significantly different at P < 0.05

P uptake followed similar trend like N uptake. At 1 month after transplanting, T5 and T6 gave significantly higher P uptake (0.96 and 0.88 g P/plant, respectively) improved leonerdite and the control treatment, the values increase 118.18 and 100.0% over the control (Table 7.6). The application of IL plus compost in T6 provide the highest P uptake after 2 and 3 months after transplanting, T6 provided the highest values of P uptake (0.73 and 0.35 g P/plant, respectively) with the percentage increase of 92.11 and 75.0%, respectively. Phosphorus uptakes of dry weight of the grain for the T6 gave significantly higher P uptake

(0.26 g P/plant) than the rest of the treatments and the values increase 44.44% over the control. The results showed that the application of IL provide high P uptake this might due to rock phosphate in IL.

Table 7.6 Phosphorus uptake in rice shoots at 1, 2 and 3 month after transplanting

Tr	Treatments	1 month (shoot)		2 month (shoot)		3 month (shoot)		Harvest (grain)	
		P uptake gP/plant	increase over control (%)	P uptake gP/plant	increase over control (%)	P uptake gP/plant	increase over control (%)	P uptake gP/plant	increase over control (%)
T1	Control	0.44^{d}	0.00	0.38^{d}	0.00	0.20^{b}	0.00	0.18^{e}	0.00
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	0.73^{bc}	65.91	0.58^{abc}	52.63	0.22^{b}	10.00	0.25^{ab}	38.89
T3	Compost: 2,000 kg/rai	0.63^{c}	43.18	0.54^{bcd}	42.11	0.21^{b}	5.00	0.21^{d}	16.67
T4	OL: 2,000 kg/rai	0.76^{bc}	72.73	0.52^{cd}	36.84	0.28^{ab}	40.00	0.22^{cd}	22.22
T5	IL: 2,000 kg/rai	0.96^{a}	118.18	0.61^{abc}	60.53	0.29^{ab}	45.00	0.24^{bc}	33.33
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	0.88^{ab}	100.00	0.73^{ab}	92.11	0.35^{a}	75.00	0.26^{a}	44.44
	Mean	0.77		0.60		0.28		0.23	
	F-test	*		*		*		*	
	% CV	12.29		26.35		21.71		4.90	

* indicates the effect is significant at P< 0.01

/1 Values within each column followed by same letter are not significantly different at P < 0.05

K uptake followed similar trend like N uptake. At 1 month after transplanting, T5 and T6 gave significantly higher K uptake (0.67 and 0.68 g K /plant, respectively) improved leonerdite and the control treatment, the values increase 118.18 and 100.0% over the control (Table 7.7). The application of IL plus compost in T6 provide the highest K uptake after 2 and 3 months after transplanting, T6 provided the highest values of K uptake (0.73 and 0.35 g P/plant, respectively) with the percentage increase of 92.11 and 75.0%, respectively. Potassium uptakes of dry weight of the grain for the T4, T5 and T6 gave significantly higher K uptake (0.019, 0.020 and 0.019 g K/plant) than the rest of the treatments and the values increase 26.67, 33.33 and 26.27 % over the control.

Table 7.7 Potassium uptake in rice shoots at 1, 2 and 3 month after transplanting

Tr	Treatments	1 month (shoot)		2 month (shoot)		3 month (shoot)		Harvest (grain)	
		K uptake gK/plant	increase over control (%)	K uptake gK/plant	increase over control (%)	K uptake gK/plant	increase over control (%)	K uptake gK/plant	increase over control (%)
T1	Control	0.32[e]	0.00	0.28[b]	0.00	0.28[b]	0.00	0.015[b]	0.00
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	0.53[cd]	65.69	0.42[a]	50.00	0.39[ab]	39.29	0.019[ab]	26.67
T3	Compost: 2,000 kg/rai	0.47[d]	46.27	0.42[a]	50.00	0.40[ab]	42.86	0.018[ab]	20.00
T4	OL: 2,000 kg/rai	0.57[abcd]	79.07	0.43[a]	53.57	0.40[ab]	42.86	0.019[a]	26.67
T5	IL: 2,000 kg/rai	0.67[abc]	109.00	0.51[a]	82.14	0.52[a]	85.71	0.020[a]	33.33
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	0.68[ab]	112.29	0.52[a]	85.71	0.47[a]	67.86	0.019[a]	26.67
	Mean	0.56		0.44		0.42		0.19	
	F-test	*		*		*		*	
	% CV	14.75		17.08		23.26		11.79	

[*] indicates the effect is significant at P< 0.01

[/1] Values within each column followed by same letter are not significantly different at P < 0.05

Ca uptake followed similar trend like N uptake. At 1 month after transplanting, T6 gave significantly higher Ca uptake (0.31 g Ca/plant, respectively) improved leonerdite and the control treatment, the values increase 82.35 % over the control (Table 7.8). The application of IL plus compost and Chemical fertilizer provide the highest Ca uptake after 2 months after transplanting, T2 and T6 provided the highest values of Ca uptake (0.12 and 0.10 g Ca/plant, respectively) with the percentage increase of 140.00 and 100.00%, respectively. and 3 months after transplanting, T5 and T6 provided the highest values of Ca uptake (0.17 g Ca/plant, respectively) with the percentage increase of 112.50 %, respectively. Calcium uptakes of dry weight of the grain for the T5 gave significantly higher Ca uptake (0.012 g Ca/plant) than the rest of the treatments and the values increase 33.33 % over the control. The results showed that the application of IL provide high Ca uptake this might due to 5% dolomite in IL.

Table 7.8 Calcium uptake in rice shoots at 1, 2 and 3 month after transplanting

Tr	Treatments	1 month (shoot)		2 month (shoot)		3 month (shoot)		Harvest (grain)	
		Ca uptake gCa/plant	increase over control (%)	Ca uptake gCa/plant	increase over control (%)	Ca uptake gCa /plant	increase over control (%)	Ca uptake gCa /plant	increase over control (%)
T1	Control	0.17[c]	0.00	0.05 [e]	0.00	0.08 [c]	0.00	0.009	0.00
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	0.27[abc]	58.82	0.12 [a]	140.00	0.14 [b]	75.00	0.009	0.00
T3	Compost: 2,000 kg/rai	0.24[bc]	41.18	0.09[bc]	80.00	0.13 [b]	62.50	0.010	11.11
T4	OL: 2,000 kg/rai	0.23[bc]	35.29	0.09[bc]	80.00	0.15 [b]	87.50	0.011	22.22
T5	IL: 2,000 kg/rai	0.28[abc]	64.71	0.10 [ab]	100.00	0.17 [ab]	112.50	0.012	33.33
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	0.31[ab]	82.35	0.07[e]	40.00	0.17 [ab]	112.50	0.010	11.11
	Mean	0.26		0.09		0.15		0.10	
	F-test	*		*		*		ns	
	% CV	24.68		16.41		19.38		23.43	

[*] indicates the effect is significant at P< 0.01

[/1] Values within each column followed by same letter are not significantly different at P < 0.05

Mg uptake followed similar trend like N uptake. At 1 month after transplanting, T5 gave significantly higher Mg uptake (0.29 g Ca/plant, respectively) improved leonerdite and the control treatment, the values increase 93.33 % over the control (Table 7.9). The application of IL plus compost provide the highest Mg uptake after 2 and 3 months after transplanting, T6 provided the highest values of Mg uptake (0.31 and 0.35 g Mg/plant, respectively) with the percentage increase of 82.35 and 94.44 %, respectively. Magnesium uptakes of dry weight of the grain for the T6 gave significantly higher Mg uptake (0.083 g Mg/plant) than the rest of the treatments and the values increase 40.68 % over the control. The results showed that the application of IL provide high Mg uptake this might due to 5% dolomite in IL.

Table 7.9 Magnesium uptake in rice shoots at 1, 2 and 3 month after transplanting

Tr	Treatments	1 month (shoot)		2 month (shoot)		3 month (shoot)		Harvest (grain)	
		Mg uptake gMg/plant	increase over control (%)	Mg uptake gMg/plant	increase over control (%)	Mg uptake gMg/plant	increase over control (%)	Mg uptake gMg/plant	increase over control (%)
T1	Control	0.15[d]	0.00	0.17[c]	0.00	0.18[d]	0.00	0.059[d]	0.00
T2	Chemical fertilizer (16-16-8) rate of 20 kg/rai	0.24[bc]	60.00	0.27[ab]	58.82	0.31[bc]	72.22	0.081[ab]	37.29
T3	Compost: 2,000 kg/rai	0.22[c]	46.67	0.21[bc]	23.53	0.28[c]	55.56	0.071[c]	20.34
T4	OL: 2,000 kg/rai	0.24[bc]	60.00	0.26[ab]	52.94	0.28[c]	55.56	0.074[bc]	25.42
T5	IL: 2,000 kg/rai	0.29[ab]	93.33	0.28[ab]	64.71	0.33[abc]	83.33	0.080[ab]	35.59
T6	IL + Compost (ratio 3:1) : 2000 kg/rai.	0.26[abc]	73.33	0.31[a]	82.35	0.35[ab]	94.44	0.083[a]	40.68
	Mean	0.25		0.26		0.29		0.07	
	F-test	*		*		*		*	
	% CV	14.44		18.47		12.70		5.25	

[*] indicates the effect is significant at P< 0.01

[/1] Values within each column followed by same letter are not significantly different at P < 0.05

Conclusion

Results of the field experiment confirm those of the pot experiment. On the average, the application of improve leonardite exhibit better rice growth and yield improvement than the original leonardite. The combination of improve leonardite and compost (3:1 w/w) at the rate of 2,000 kg/rai could further enhance the rice growth, grain yield and nutrients uptake. The pot and field experimental results ensure the benefits of leonardite in soil and rice yield improvement. On the average, rice growth parameters and grain yield obtained by IL alone and/or IL plus compost were as high as those obtained by chemical fertilizer. In addition, leonardite not only provided nutrients necessary for rice growth but also provide organic matter for soil quality improvement.