CHAPTER 6

APPLICATION OF LEONARDITE TO IMPROVE SOIL QUALITY AND RICE YIELD I. POT EXPERIMENT

6.1 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) which is considered low. This important component of soil is declining with time due to intensive cropping and use of higher 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 of 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 high humus materials offers a good choice as soil and crop yield improvement. 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 impact of humic substances (HS) on soil structure and plant growth was reported (Fong *et al.,*2007; El-Razek *et al.,* 2012; Ihsanullah and Bakhashwain, 2013).

The benefits of compost on rice and wheat yield improvement are well documented (Singh and Yadav, 1986; Hussain *et al.,* 1998) however reports on the utilization of leonardite in cereals crops are rare. 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 *et al.,* 2016). To improve such properties of leonardite, Somchan and Shutsrirung (2015) suggested that leonardite should be mixed with 5% dolomite and 10% rock phosphate. The use of improved leonardite as alternative to commercial chemical fertilizers not only results in soil and crop yield improvement but it also reduces pollution due to reduced nutrient run-off and N leaching.

6.2 Materials and Methods

6.2.1 Experimental conditions and design

This study was performed under pot experiment conditions. The aim of this experiment was to evaluate the effect of original leonerdite (OL: 100% leonardite), improved leonerdite (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). Cultivation took place in the screen house of the Faculty of Agriculture, Chiang Mai University, Thailand.

The experiment was arranged in completely randomized design with 9 treatments and 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)

T9: IL + compost (ratio 3:1 w/w; 2000 kg/rai)

Twenty-seven plastic pots having a diameter of 25 cm and a height of 30 cm were used. Thai jasmine rice cultivar KDML105 was used in this study. Each pot soil was crushed then each material was applied and mixed well with the respective treatment. The holes at the bottom of each pot were carefully sealed before filling with 4 kg of soil. One 30-day old rice seedlings were transplanted into each pot.

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).

6.2.2 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 days after transplanting, plant height, number of tillers and number of leaves were recorded. At harvesting time (120 days after transplanting) number of panicle, dry weight of the grain and straw dry weight, were measured. Rice plant was carefully removed from each pot and the roots and stem were washed thoroughly with tap water. The rice shoots were oven dried at 60 °C until constant dry weights were recorded. Dried shoots 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).

6.2.3 Statistical analysis

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)

6.3 Results and discussion

6.3.1 Chemical properties of the soil after planting rice

The analysis results of the soil for nutrient contents after planting rice under submerged conditions is shown in Table 6.1 The pH values of all the soil samples were increased and ranged from 6.91-7.34 which was higher than those 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 IL) and the combination of compost plus leonardite resulted in higher soil pH (more alkali) 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). 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 moderate to high content of organic matter or 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 favour nutrient uptake by wetland rice (Sahrawat, 2005). 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 high SOM increased (2.51 to 3.16). This increase could be attributed to the levels of compost and/or leonardite application.

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 (P; mg/kg) in all the treatments with organic amendment were increased about twice (28.12 – 42.88 mg/kg) and reach the optimum values (26 -42 mg P/kg) 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 6.1). In general, the application of compost plus leonardite led to a certain increase in Mg level with the value ranged from 111.43 - 143.60 mg/kg. Compost is rich source of nutrients with high organic matter content and use of compost can be beneficial to improve organic matter status. Physical and chemical properties of soil can be improved by using compost, which may ultimately increase crop yields. In addition to humic acid, leonardite can also be used to improve plant nutrients level in soils particularly micronutrients. Plant nutrient elements contained in all the leonardite samples were quite high (N, K, S, Ca, Mg, Fe, Zn and Mn) except for phosphorus. (Ratanaprommanee *et. al.,*2017).

Table 6.1 The analysis results of the soil after planting rice.

Tr	Treatments	pH	OM (%)	Total Nitrogen (%)	Available P (mg/kg)
-	Pre-planting soil	6.09	1.65	0.09	17.33
T1	Control	7.11	1.50^{c}	0.07^{b}	15.97^{f}
T2	Chemical fertilizer (16-16-8): 20 kg/rai	7.02	1.48^{c}	0.07^{b}	42.88^{a}
T3	Compost: 2,000 kg/rai	7.13	2.71^{b}	0.14^{a}	33.51^{d}
T4	OL: 2,000 kg/rai	7.25	2.51^{b}	0.13^{a}	33.22^{d}
T5	IL: 2,000 kg/rai	6.91	3.13^{a}	0.16^{a}	28.12^{e}
T6	OL + Compost (ratio 1:1):2000 kg/rai	7.26	3.16^{a}	0.16^{a}	41.12^{ab}
T7	OL + Compost (ratio 3:1): 2000 kg/rai.	7.24	2.97^{a}	0.15^{a}	39.45^{bc}
T8	IL + Compost (ratio 1:1): 2000 kg/rai.	7.27	2.67^{b}	0.14^{a}	37.50^{c}
T9	IL + Compost (ratio 3:1): 2000 kg/rai.	7.34	2.61^{b}	0.13^{a}	33.69^{d}
	Mean	7.17	2.52	0.13	33.96
	F-test	ns	*	*	*
	% CV	5.00	5.97	15.85	3.63

$^{a-n}$ 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)

Table 6.1 (Continued)

Tr	Treatments	Exchangeable (mg/kg)		
		K	Ca	Mg
-	Pre-planting soil	122.0	1025.00	95.10
T1	Control	153.45^{e}	1414.00^{e}	95.10^{d}
T2	Chemical fertilizer (16-16-8): 20 kg/rai	273.10^{cd}	2247.75^{cd}	83.05^{de}
T3	Compost: 2,000 kg/rai	278.48^{cd}	2282.25^{c}	92.88^{de}
T4	OL: 2,000 kg/rai	326.33^{b}	2196.75^{d}	80.08^{e}
T5	IL: 2,000 kg/rai	256.43^{d}	2399.75^{b}	91.78^{de}
T6	OL + Compost (ratio 1:1):2000 kg/rai	173.58^{e}	2607.00^{a}	111.43^{bc}
T7	OL + Compost (ratio 3:1): 2000 kg/rai.	293.98^{c}	2466.00^{b}	110.98^{c}
T8	IL + Compost (ratio 1:1): 2000 kg/rai.	410.63^{a}	2415.75^{b}	126.95^{b}
T9	IL + Compost (ratio 3:1): 2000 kg/rai.	171.13^{e}	2562.50^{a}	143.60^{a}
	Mean	259.68	2287.3	103.92
	F-test	*	*	*
	% CV	5.72	1.9	8.08

$^{a-n}$ 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)

6.3.2 Effects of 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 6.2). The application of original leonardite (OL: 100% leonardite) resulted in the lowest number of tillers and leaves per plant. Ratanaprommanee *et. al.* (2017) 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-1) of 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 that 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 however the increase was further enhanced 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 (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.

Table 6.2 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

$^{a\text{-}n}$ 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)

Yield and Yield components of Rice

The number of panicles produced was highest under the T2 followed by T3, T9 and T8 (22.67, 20.33, 19.33 and 18.67, respectively). It was observed that the highest 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, respectively). The grain yield increment under the T2, T8, T9 and T3 was 56.8, 52.2, 51.3 and 49.2, as compared to the control treatment (Table 6.3). 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 for Tr. 5. Straw yield did not followed the same order as found for panicles and grain yield and the highest straw yield was obtained under Tr. 4 and 5 while chemical fertilizer gave only about half of the straw yield, as compared to these two treatments. 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 (Figure 6.1). Gravois and Helms (1992) reported that, among different yield components of rice, panicle density had the largest positive direct effect on rice yield. The results also suggested that leonardite which contains high amount of humic substances, particularly humic acid, influenced the nutrition and growth of plants in an indirect manner. It might also influence 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).

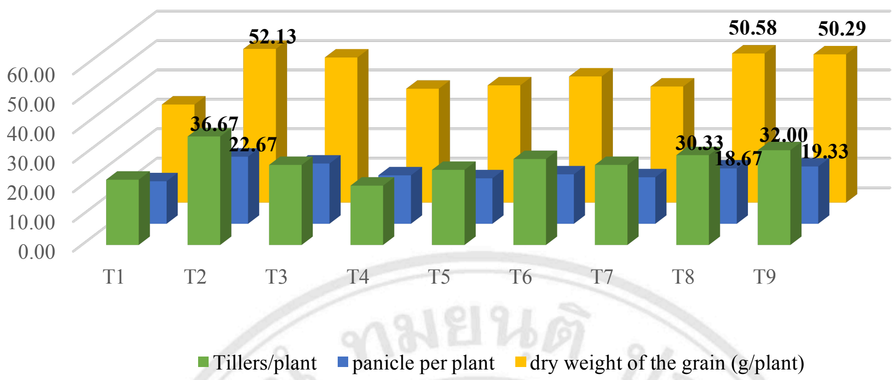
Table 6.3 Effect of different treatments on number of panicle, grain yield and straw yield

Tr	Treatments	panicle per plant	Grain yield (g/plant)	Grain yield increase over control (%)	Straw yield (g/plants)	Straw yield 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 leonerdite) ; IL (improved leonerdite)

Tillers per plant, total panice per plant and grain yield



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

Figure 6.1 Tillers and panicle per plant and grain yield as affected by chemical fertilizers and organic amendments

Nutrients concentration in the straw of rice

On the average, the N, P, K concentration in rice straw did not show much difference among the treatments. The value of N, P and K concentration ranged from 0.35 to 0.47, 0.09 to 0.14, 0.20 to 0.26%, respectively (Table 6.4). The highest N and P concentration was obtained by T7 (OL + compost, ratio 3:1) with the value of 0.47 and 0.14%, respectively. The application of chemical fertilizer gave the highest K concentration (0.26%) while T8 (IL + compost, ratio 1:1) gave the lowest K concentration (0.20%). As compare to the control (0.10%), the application of IL alone (T5) and compost plus leonardite (T6 – T9) seemed to raise the Ca concentration in the rice straw (0.17 – 0.31%) more than other treatments (T2 – T4) (0.12 – 0.15%). However, Mg concentration did not showed any difference among the treatments.

Table 6.4 Nutrient concentration in rice straw at harvesting time

Tr	Treatments	Nutrients concentration (%)				
		N	P	K	Ca	Mg
T1	Control	0.41^{ab}	0.11^{b}	0.24^{b}	0.10	0.15
T2	Chemical fertilizer (16-16-8): 20 kg/rai	0.34^{b}	0.11^{b}	0.26^{a}	0.15	0.15
T3	Compost: 2,000 kg/rai	0.35^{b}	0.13^{b}	0.25^{b}	0.13	0.15
T4	OL: 2,000 kg/rai	0.35^{b}	0.11^{b}	0.25^{b}	0.12	0.16
T5	IL: 2,000 kg/rai	0.40^{ab}	0.12^{b}	0.24^{b}	0.31^{a}	0.15
T6	OL + Compost (ratio 1:1):2000 kg/rai	0.38^{ab}	0.09^{bc}	0.24^{b}	0.22	0.14
T7	OL + Compost (ratio 3:1): 2000 kg/rai	0.47^{a}	0.14^{a}	0.23^{b}	0.21	0.15
T8	IL + Compost (ratio 1:1): 2000 kg/rai	0.35^{b}	0.09^{bc}	0.20^{bc}	0.20	0.13
T9	IL + Compost (ratio 3:1): 2000 kg/rai	0.36^{ab}	0.10^{b}	0.25^{b}	0.17	0.13
	Mean	0.38	0.11	024	0.19	0.14
	F-test	*	*	*	*	ns
	% CV	18.6	9.12	6.13	15.30	15.31

* indicates the effect is significant at P< 0.05; [ns] indicates the effect is not significant at P< 0.05

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

Nutrients uptake in rice

The nutrients uptake of rice for all of the treatments are shown in Table 6.10 and all of the nutrients studied were significantly increased compared to control (p<0.05). A high nutrients uptake (N, P, K, Ca and Mg uptake) was obtained in treatment 5 with the IL rate of 2,000 kg/rai with a value of 0.91 gN/plant, 0.28 gP/plant, 0.56 gK/plant, 0.72 gCa/plant and 0.35 gMg/plant which increased by 111.63, 133.33, 124.00, 554.55 and 118.75 percent compared to the control treatment of 0.43 gN/plant., 0.12 gP/plant, 0.25 gK/plant, 0.11 gCa/plant and 0.16 gMg/plant (Figure 6.2).

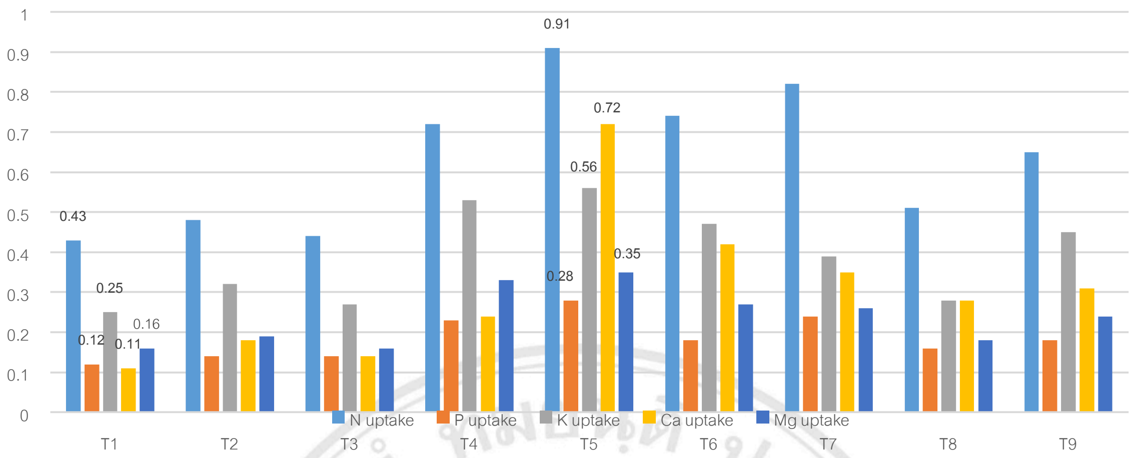
Table 6.5 Nutrients uptake in rice straw at harvesting time

Tr	Treatments	Nutrients uptake (g/plant)				
		N	P	K	Ca	Mg
T1	Control	0.43^{c}	0.12^{b}	0.25^{d}	0.11^{f}	0.16^{c}
T2	Chemical fertilizer (16-16-8): 20 kg/rai	0.48^{c}	0.14^{bc}	0.32^{cd}	0.18^{def}	0.19^{bc}
T3	Compost: 2,000 kg/rai	0.44^{c}	0.14^{bc}	0.27^{d}	0.14^{ef}	0.16^{c}
T4	OL: 2,000 kg/rai	0.72^{abc}	0.23^{ab}	0.53^{ab}	0.24^{cde}	0.33^{ab}
T5	IL: 2,000 kg/rai	0.91^{a}	0.28^{a}	0.56^{a}	0.72^{a}	0.35^{a}
T6	OL + Compost (ratio 1:1):2000 kg/rai	0.74^{abc}	0.18^{abc}	0.47^{abc}	0.42^{b}	0.27^{abc}
T7	OL + Compost (ratio 3:1): 2000 kg/rai	0.82^{ab}	0.24^{ab}	0.39^{bcd}	0.35^{bc}	0.26^{abc}
T8	IL + Compost (ratio 1:1): 2000 kg/rai	0.51^{bc}	0.16^{bc}	0.28^{d}	0.28^{cd}	0.18^{c}
T9	IL + Compost (ratio 3:1): 2000 kg/rai	0.65^{abc}	0.18^{abc}	0.45^{abc}	0.31^{bc}	0.24^{abc}
	Mean	0.62	0.18	0.39	0.31	0.24
	F-test	*	*	*	*	*
	% CV	34.48	36.71	24.28	24.66	32.62

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

Table 6.5 (Continued)

Tr	Treatments	Increase over control (%)				
		N	P	K	Ca	Mg
T1	Control	-	-	-	-	-
T2	Chemical fertilizer (16-16-8): 20 kg/rai	11.63	16.67	28.00	63.64	18.75
T3	Compost: 2,000 kg/rai	2.33	16.67	8.00	27.27	0.00
T4	OL: 2,000 kg/rai	67.44	91.67	112.00	118.18	106.25
T5	IL: 2,000 kg/rai	111.63	133.33	124.00	554.55	118.75
T6	OL + Compost (ratio 1:1):2000 kg/rai	72.09	50.00	88.00	281.82	68.75
T7	OL + Compost (ratio 3:1): 2000 kg/rai	90.70	100.00	56.00	218.18	62.50
T8	IL + Compost (ratio 1:1): 2000 kg/rai	18.60	33.33	12.00	154.55	12.50
T9	IL + Compost (ratio 3:1): 2000 kg/rai	51.16	50.00	80.00	181.82	50.00
	Mean					
	F-test					
	% CV					



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

Figure 6.2 Nutrients uptake in rice straw at harvesting time as affected by chemical fertilizers and organic amendments

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 it 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.