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Efficiency of Biogas Effluent from Durian Shells and Seeds Combined with Chicken Manure on Soil Chemical Properties, Growth and Nutrient Concentrations of Chinese Kale (*Brassica oleracea*)

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The objective was to study the effect of biogas effluent from durian shells and seeds combined with chicken manure on soil chemical properties, growth and nutrient concentrations of chinese kale. The experiment was carried out in a Completely Randomized Design (CRD) with 4 replications. Six treatments were control (no fertilizer, T1); four concentrations (25, 50, 75 and 100%, T2-T5) of biogas effluentand chemical fertilizer (formula 16-8-8, T6). Biogas effluent and chemical fertilizer were applied 14, 22, 30 and 38 days after planting (DAP). The experiment was conducted for 46 days at the Agricultural Technology Faculty in Rambhai Barni Rajabhat University. Soil pH, electrical conductivity (EC), nutrient (nitrogen, phosphorus and potassium) concentrations of soil were analyzed at the initiation and end of the experiment. Plant height, leaf number, leaf length, leaf width, branch diameter, stem diameter, chlorophyll content (SPAD value), fresh and dry weights of plants were collected every week. Nitrogen, phosphorus and potassium concentrations in plants were determined at the end of the experiments. Results showed that 25, 50, 75 and 100% biogas effluent results on height, leaf number, leaf length, leaf width, branch diameter, stem diameter, chlorophyll content and dry weight did not differ from results with chemical fertilizer. It was also found that chinese kale treated with 50% biogas effluent had similar fresh weight as that resulting from the chemical fertilizer treatment. All growth parameters of the plant used as control (no-fertilizer) were significantly lower than those plants treated with biogas effluent and chemical fertilizer ($P \leq 0.01.$). From the analysis of nutrient concentrations in whole plants, it was found that chinese kale which received 50% biogas effluent had nitrogen concentration similiar to that of the chemical fertilizer treatment. Nitrogen concentrationas in whole plants affected by the control was significantly lower than that resulting from the biogas effluent and chemical fertilizer treatments ($P \leq 0.01$). Biogas effluent did not effect phosphorus or potassium concentrations in whole plants. Based on the analysis of the chemical soil properties, soil pH in chemical fertilizer treatment showed the lowest in comparison to the remaining treatments. The

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lowest and highest soil EC was found in the control and 100% biogas effluent treatment, respectively. There was no significant difference in soil nitrogen concentration among treatments while phosphorus and potassium concentration were significantly different ($P \leq 0.01$).

Keywords: *Brassica oleracea*, biogas effluent, soil chemical properties, growth, nutrient concentrations

Introduction

Chinese kale is a popular vegetable for consumers. It grows well in Thailand and in all types of soil. The problems with chinese kale production is the increase of production costs. One of the factors of high production cost is the cost of chemical fertilizer. For example in 2014, Thailand imported 5,415,020 tons of chemical fertilizers from abroad, which was 66,103 million Baht (Department of Agriculture, 2015). Finding substitutes for chemical fertilizers may reduce the amount of chemical fertilizer imports and the cost of production.

Durian is a popular fruit in Thailand. In 2015, Chanthaburi province had 31,543 hectare of durian which produced 234,514 tons of fresh durians (Office of Agricultural Economics, 2016). Durian peels and seeds are the reminants from eating and processing durian. The consumption of durian has increased and durian peel and seed have become a waste problem. According to the research of Prathumyot *et al.* (2016) durian shells and seeds are a potential resource for biogas production. After the biogas process, the effluent from degradation of manure, durian peels and seeds remains inside the fermentation tank system.

Numerous researchers showed that the biogas effluent could be used as an organic fertilizer to improve soil and increase crop yield (Ausungnoen *et al.*, 2014; Thonkamdee *et al.*, 2013; Kumpukul and Chantsavang, 1995). The use of biogas effluent that is used as organic fertilizer is one more way to reduce the importation of chemical fertilizer from abroad and reduce production cost.

The results of Prathumyot *et al.* (2016) showed that the effluent from the biogas production process contained nitrogen, phosphorus and potassium which they are the main nutrients for plant growth. For this reason, the objective of this research was to study the effect of biogas effluent fermented from durian peels and seeds on soil chemical properties, growth and nutrient concentration of chinese kale.

Objectives

1. To study the effect of biogas effluent from durian shells and seeds combined with chicken manure on soil chemical properties.
2. To study the effect of biogas effluent from durian shells and seeds combined with chicken manure on growth and nutrient concentration of chinese kale

Materials and methods

The experiment was carried out in a Completely Randomized Design (CRD) with 4 replications. Six treatments were control (no fertilizer, T1); four concentrations (25, 50, 75 and 100%, T2-T5) of biogas effluent and chemical fertilizer (formula 16-8-8, T6). Biogas effluent and chemical fertilizer were applied 14, 22, 30 and 38 days after planting (DAP). The experiment was conducted for 46 days at the Agricultural Technology Faculty in Rambhai Barni Rajabhat University. Soil pH, electrical conductivity (EC), nutrient (nitrogen, phosphorus and potassium) concentrations of soil were analyzed at the initiation and end of the experiment.

Plant height, leaf number, leaf length, leaf width, branch diameter, stem diameter, chlorophyll content using a SPAD meter (SPAD value), fresh and dry weights of plants were collected weekly. Nitrogen, phosphorus and potassium concentrations in plants were determined at the end of the experiments. Statistical comparisons were performed by analysis of variance (ANOVA) followed by Duncan's multiplerange test (DMRT).

Results

Chemical properties of soil and biogas effluent at the beginning of experiment

The chemical propertiesanalysis of soil and biogas effluent are shown in Table 1.

Table1. Chemical properties of soil and biogas effluent at the beginning of experiment

Chemical properties	**Soil**	**Biogaseffluent**
pH	5.60	7.96
Electrical conductivity(ds/m)	0.89	24.55
Nitrogen concentration (ppm)	536.67	2359.03
Phosphorus concentration (ppm)	105.84	163.03
Potassium concentration (ppm)	424.35	5356.18

Growth parameters

There were no differences in plant height of chinese kale at 14, 22 and 30 DAP. At 38 and 46 DAP, the difference in plant height was significantly different (P≤0.01). Plant height of chinese kale that received chemical fertilizer and biogas effluent treatments did not differ. Plant height of chinese kale as influenced by the control treatment was significantly lower compared to the plants treated with biogas effluent and chemical fertilizer treatments (Fig. 1).

The treatments did not effect leaf number 14, 22, and 30, days after planting. However, at 38 and 46 DAP the control resulted in the lowest leaf number (Fig. 2).

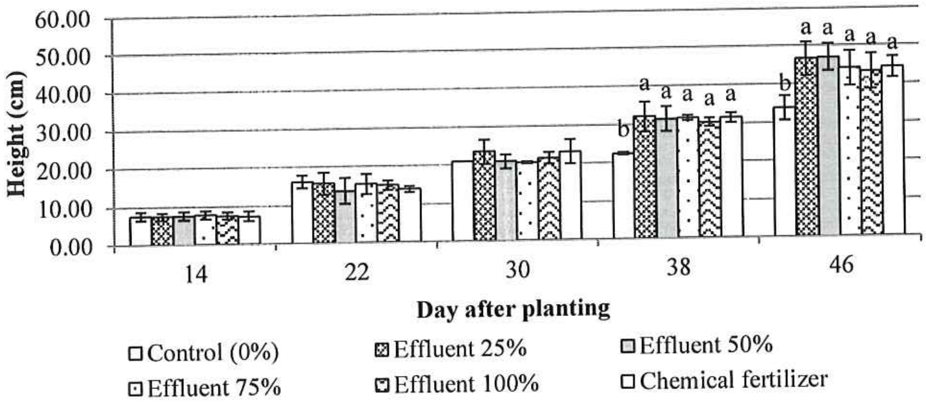

Figure1. Plant height during the experimental period. English alphabets indicate a significant difference between treatments at the 0.01 probability level, according to DMRT.

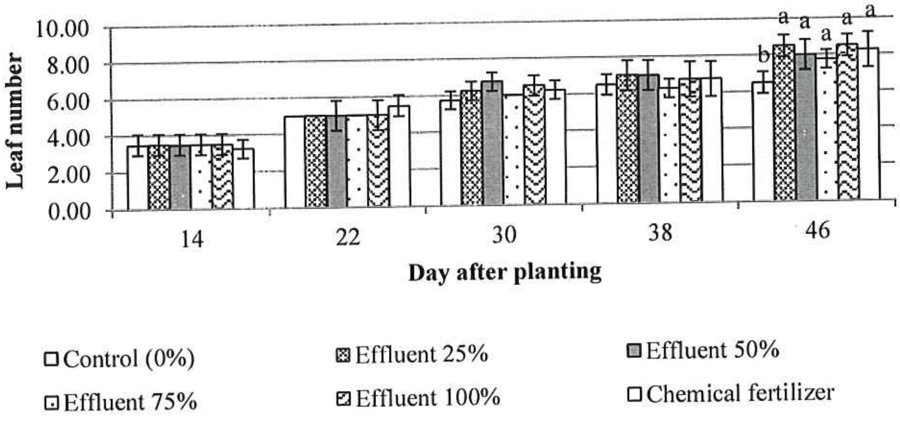

Figure 2. Leaf number of chinese kale during the experimental period. English alphabets indicate a significant difference between treatments at the 0.01 probability level, according to DMRT.

The difference in leaf length among treatments did not differ at 14, 22, and 30 DAP. At 38 and 46 DAP, there was statistically significant difference in leaf length ($P \leq 0.01$). Leaf length was reduced by the control treatment compared to the remaining treatments (Fig. 3).

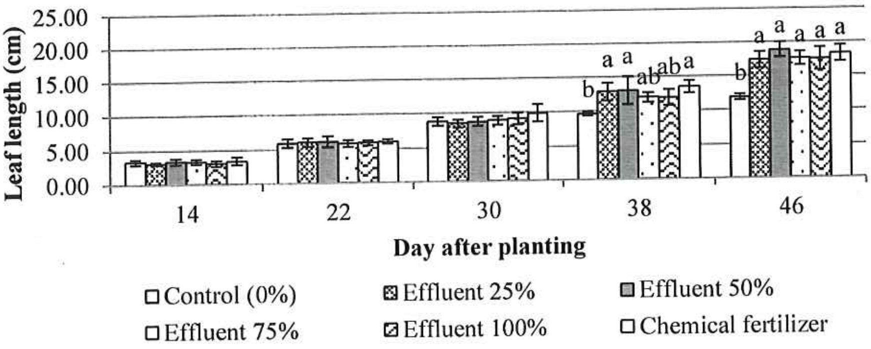

Figure 3. Leaf length of chinese kale during the experimental period. English alphabets indicate a significant difference between treatments at the 0.01 probability level, according to DMRT.

Leaf width did not differ at 14, 22, and 30 DAP. The difference on leaf width occurred 38 DAP ($P \leq 0.01$). Chinese kale treated with 25, 50, 75 and 100 % biogas effluent did not differ from those that received chemical fertilizers. Leaf width of control plants was less, but did not differ from plants treated with 100% biogas effluent. At 46 DAP, leaf width of chinese kale as influenced by the control treatment was significantly lower compared to the plants treated with biogas effluent and chemical fertilizer (Fig. 4).

The results of branch diameter were similar to those of leaf width. Namely, there were no statistically significant differences in branch diameter among treatments at 14, 22, and 30 DAP. The difference in branch diameter among treatments was found at 38 and 46 DAP. Chinese kale treated with 25, 50, 75 and 100 % biogas effluent did not differ in branch diameter from plants treated with chemical fertilizers and branch diameter of control plants was less, but did not differ from plants treated with 100% biogas effluent at 38 DAP. Chinese kale applied with 25, 50, 75 and 100% biogas effluent were not different in branch diameter from plants that received chemical fertilizers and the lowest branch diameter was the result of the control at 46 DAP (Fig. 5A).

The results showed that stem diameter did not differ 14, 22 and 30 DAP. The difference in stem diameter was statistically significant ($P \leq 0.01$) at 38 and 46 DAP. Chinese kale treated with 25, 50, 75, and 100% biogas effluent did not differ in stem diameter compared to the plants that received chemical fertilizer. The least stem diameter resulted from the control (Fig. 5B).

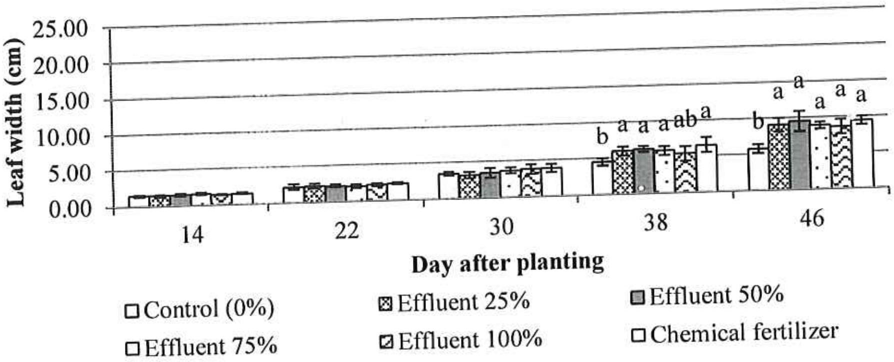

Figure 4. Leaf width of chinese kale during 14, 22, 30, 38 and 46 DAP. English alphabets indicate a significant difference between treatments at the 0.01 probability level, according to DMRT.

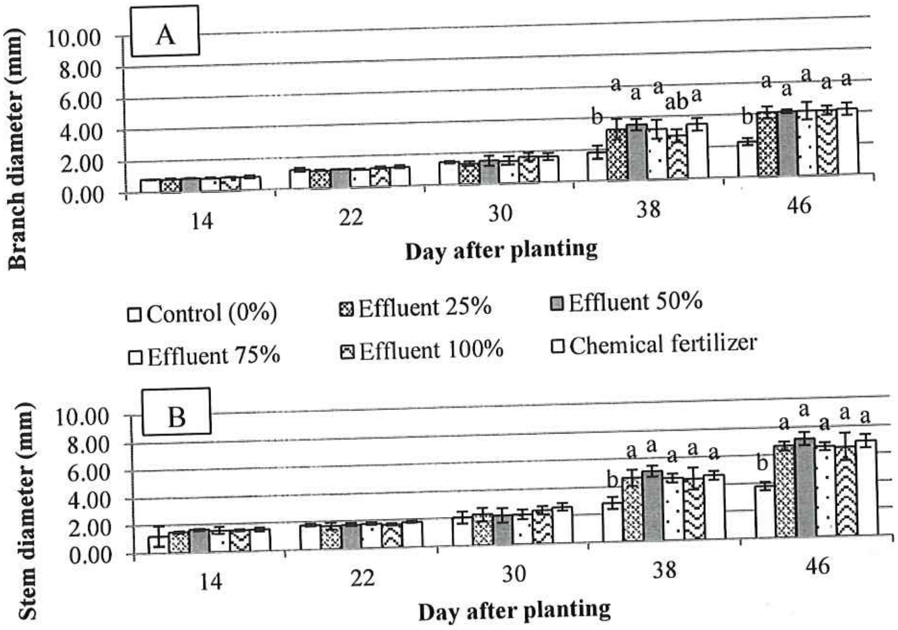

Figure 5. Branch diameter (A) and stem diameter (B) of chinese kaleat 14, 22, 30, 38 and 46 DAP. English alphabets indicate a significant difference between treatments at the 0.01 probability level, according to DMRT.

Table 2. Chlorophyll content of chinese kale expressed by SPAD value at 14, 22, 30, 38 and 46 DAP.

Treatment	SPAD value				
	14 DAP	**22 DAP**	**30 DAP**	**38 DAP**	**46 DAP**
Control0%	34.32±2.04	38.78±1.61	39.25±1.71^{b}	40.78±3.06^{b}	38.91±4.80^{b}
Effluent25%	33.58±3.27	37.93±1.73	43.61±1.64^{ab}	51.18±2.38^{a}	51.75±2.31^{a}
Effluent50%	32.50±2.14	37.59±1.92	43.70±2.20^{ab}	50.41±1.63^{a}	50.69±3.06^{a}
Effluent75%	33.28±1.20	37.69±3.28	43.74±1.00^{ab}	53.22±3.23^{a}	54.99±2.93^{a}
Effluent100%	33.13±1.90	38.31±2.31	44.32±2.78^{ab}	52.56±2.67^{a}	54.99±3.60^{a}
Chemical fertilizers	35.64±1.08	41.98±2.52	47.82±4.36^{a}	54.12±1.41^{a}	52.38±3.87^{a}
F-test	ns	ns	**	**	**
CV (%)	6.14	5.94	5.77	4.95	6.95

Means with different letters in each column are significantly different ($P \leq 0.01$) according to DMRT. *significant at $P \leq 0.01$; ns = not significant at $P \leq 0.01$.

In reference to chlorophyll content, there were no statistically significant difference among treatments at 14 and 22 DAP. The difference in chlorophyll content occurred at 30 DAP where the chemical fertilizer increased chlorophyll content compared to the control. At 38 and 46 DAP, chlorophyll content was reduced by the control treatment compared to the remaining treatments (Table 2).

Results of fresh weight show that there was no significant difference in fresh weight among the treatments at 14, 22 and 30 DAP. At 38 and 46 days, all effluent treatments and the chemical fertilizer treatment increased fresh weight compared to the control treatment (Table 3).

Dry weight of chinese kale at 14, 22, and 30 DAP did not differ among the treatments. However, all treatments increased dry weight compared to the control treatment at 38, and 46 DAP and the control resulted in the lowest dry weight (Table 4).

Table 3. Fresh weight of chinese kale at 14, 22, 30, 38 and 46 DAP

Treatment	Fresh Weight (g)				
	14 DAP	**22 DAP**	**30 DAP**	**38 DAP**	**46 DAP**
Control 0%	0.40±0.08	1.133±0.36	3.87±1.03	5.99±0.26^{b}	8.75±0.37^{c}
Effluent 25%	0.41±0.04	1.425±0.38	3.59±1.04	14.43±5.62^{a}	36.80±3.51^{ab}
Effluent 50%	0.42±0.05	1.163±0.25	4.04±1.74	19.35±2.61^{a}	40.81±0.71^{a}
Effluent 75%	0.49±0.02	1.058±0.12	4.36±0.26	16.56±5.35^{a}	35.23±3.71^{b}
Effluent 100%	0.38±0.06	1.128±0.08	4.01±0.74	12.86±3.93^{ab}	35.06±2.17^{b}
Chemical fertilizers	0.41±0.06	1.500±0.08	4.58±0.50	15.25±2.58^{a}	39.18±1.10^{a}
F-test	ns	ns	ns	**	**
CV (%)	13.12	19.85	24.66	27.39	7.08

Means with different letters in each column are significantly different ($P \leq 0.01$) according to DMRT. *significant at $P \leq 0.01$; ns = not significant at $P \leq 0.01$.

Table 4. Dry weight of chinese kale at 14, 22, 30, 38 and 46 DAP

Treatment	Dry weight				
	14 DAP(mg)	**22 DAP(g)**	**30 DAP(g)**	**38 DAP(g)**	**46 DAP(g)**
Contron 0%	30.53±2.67	0.12±0.03	0.37±0.10	0.68 ± 0.04^{b}	1.04 ± 0.07^{b}
Effluent 25%	30.45±5.46	0.12±0.03	0.31±0.08	1.33 ± 0.49^{ab}	3.29 ± 0.43^{a}
Effluent 50%	31.68±2.74	0.11±0.04	0.33±0.10	1.84 ± 0.22^{a}	3.51 ± 0.49^{a}
Effluent 75%	33.20±3.52	0.10±0.01	0.39±0.01	1.55 ± 0.53^{a}	3.03 ± 0.41^{a}
Effluent 100%	30.00±2.16	0.11±0.01	0.39±0.10	1.25 ± 0.34^{ab}	3.00 ± 0.48^{a}
Chemical fertilizers	31.25±3.01	0.14±0.01	0.38±0.08	1.59 ± 0.37^{a}	3.64 ± 0.20^{a}
F-test	ns	ns	ns	**	**
CV (%)	10.99	27.03	23.15	26.94	13.09

Means with different letters in each column are significantly different ($P \leq 0.01$) according to DMRT. *significant at $P \leq 0.01$; ns = not significant at $P \leq 0.01$.

Table 5. Nutrient concentrations in whole plants at the end of experiment

Treatment	Nutrient concentrations		
	N (%)	**P (%)**	**K (%)**
Control 0%	1.73 ± 0.37^{c}	0.47±0.06	5.04±1.48
Effluent 25%	3.20 ± 0.17^{b}	0.39±0.05	7.23±0.47
Effluent 50%	3.53 ± 0.19^{ab}	0.43±0.04	6.63±0.43
Effluent 75%	3.28 ± 0.73^{b}	0.42±0.08	6.08±1.05
Effluent 100%	2.92 ± 0.21^{b}	0.45±0.02	5.93±0.56
Chemical fertilizers	4.46 ± 0.34^{a}	0.38±0.07	5.10±1.00
F-test	**	ns	ns
CV (%)	12.11	12.95	15.23

Means with different letters in each column are significantly different ($P \leq 0.01$) according to DMRT. *significant at $P \leq 0.01$; ns = not significant at $P \leq 0.01$

Nutrient concentration in whole plants

Chemical fertilizer increased Nitrogen concentration compared to the remaining treatments and effluent treatments increased N concentration compared to the control. Phosphorus, and potassium concentration were not effected by any of the treatments (Table 5).

Soil Chemical Properties

At the end of the experiment soil pH was increased by the 50% effluent treatment compared to the remaining treatments. Soil pH was decreased by the chemical fertilizer treatment compared to the remaing treatments and was 4.44. EC was increased by effluent at 100% compared to the remaing treatments. The control treatment resulted in the lowest EC. Nitrogen concentration was not effected by any of the treatments. All treatments increased phosphorus concentration compared to the control. Potassium concentration was increased by all effluent treatments compared to the control and the chemical fertilizer treatment. The chemical fertilizer treatment resulted in a low potassium concentration (Table 6).

Table 6. Soil chemical properties at the end of experiment

Treatment	**Soil chemical properties**				
	pH	**EC (ds/m)**	**N (ppm)**	**P (ppm)**	**K (ppm)**
Control 0%	5.75 ± 0.01^{b}	0.76 ± 0.15^{c}	603.33 ± 37.86	91.68 ± 5.20^{b}	477.78 ± 14.18^{e}
Effluent25%	5.57 ± 0.05^{c}	2.23 ± 0.14^{bc}	633.33 ± 75.06	128.38 ± 2.92^{a}	1013.65 ± 41.99^{d}
Effluent50%	5.91 ± 0.03^{a}	1.98 ± 1.20^{bc}	610.00 ± 176.92	118.37 ± 1.43^{a}	1302.56 ± 91.52^{c}
Effluent75%	5.61 ± 0.03^{c}	3.81 ± 083^{b}	783.33 ± 60.28	123.35 ± 8.03^{a}	1692.97 ± 60.89^{b}
Effluent100%	5.65 ± 0.02^{bc}	5.98 ± 0.65^{a}	760.00 ± 70.00	117.55 ± 6.62^{a}	2239.16 ± 187.32^{a}
Chemical fertilizers	4.44 ± 0.09^{d}	3.34 ± 0.54^{b}	770.00 ± 60.44	110.85 ± 13.76^{a}	553.38 ± 60.02^{e}
F-test	**	**	ns	**	**
CV (%)	0.81	23.07	13.27	6.50	7.73

Means with different letters in each column are significantly different ($P\leq0.01$) according to DMRT. *significant at $P\leq0.01$; ns = not significant at $P\leq0.01$.

Discussion

The results in this experiment showed that chinese kale treated with 25, 50, 75, and 100% biogas effluent had height, leaf number, leaf length, leaf width, branch diameter, stem diameter, chlorophyll content and dry weight equal to plants treated with chemical fertilizer. In addition, it was also found that chinese kale treated with 50% biogas effluent resulted in the same fresh weight as plants treated with chemical fertilizer. This may due to the height, leaf length, leaf width and stem diameter of chinese kale treated with 50 % biogas effluent was more than those receiving 25, 75 and 100% biogas effluent. Results of plant growth in this experiment agreed with the findings of Panichsakpatana (1995) who reported that the growth of guinea grass treated with biogas effluent was the same as plants treated with chemical fertilizer (ammonium sulfate). Nitrogen is an important nutrient for the growth of stems and leaves. Nitrogen also promotes green color and succulent leaves and root systems that relate to the effective absorption of water and minerals from the soil (Pukpakdee, 1998). In this experiment, results showed that the nitrogen concentration in whole plants treated with 50% biogas effluent was similar to that of plants treated with chemical fertilizer.

Chemical fertilizers accelerated the decay of organic matter and caused soil structure deterioration which affect plant growth. The use of chemical fertilizers containing high nitrogen may cause acidic soils (Panyakul, 2011).The results of soil pH indicated that soil pH as influenced by the chemical fertilizer treatments was lowest when compared to that of the remaining treatments. Results are consistented with Panichsakpatana (1995) who found that the use of chemical fertilizers in growing guinea grass for three consecutive seasons reduced the pH of soil. In conclusion, the biogas effluent was an effective bio-fertilizer and promoted growth of chinese kale equivalent to chemical fertilizer. Moreover, the biogas effluent maintained soil pH as compared to the chemical fertilizer.

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