Effects of Chicken Manure, Perlite and Rate of Chemical Fertilizer on Virgin Cane Grown in a Coarse-textured Soil

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ABSTRACT: Field experiment was conducted to investigate the effect of chicken manure (CM) and perlite (PL) and chemical fertilizer on virgin cane in Korat soil series located in a farmer field, Nakhon Ratchasima province. This soil had coarse texture nature with low fertility status. Split plot design was employed. Main plot consisted of no application (T1), the applications of chicken manure: 6.25 (T2) and 12.5 (T3) t/ha, perlite; 0.625 (T4) and 1.25 (T5) t/ha, the combination between CM and PL: T2 and T4 (T6), and T3 and T4 (T7). Subplot comprised two rates of chemical fertilizer; 1) 18.8:18.8:18.8 kg/ha of $N:P_2O_5:K_2O$ as basal application and 147.5:32.5:52.5 kg/ha of $N:P_2O_5:K_2O$ as topdressing (F1), and 2) 37.5:37.5:37.5 kg/ha of $N:P_2O_5:K_2O$ as basal application and 295:65:105 kg/ha of $N:P_2O_5:K_2O$ as topdressing (F2). Sugarcane, K95-84 after variety was planted at the early rainy season and harvested when the plant was 12-month old. Results revealed that the application of CM at the rate of 12.5 t/ha (T3) highly significantly promoted the highest fresh cane yield of 103 t/ha but was not statistically different from those obtained from T2, T6 and T7. The control (T1) without soil amendment addition gave the lowest fresh cane yield of 55.84 t/ha. Similar effect was also on aboveground biomass and number of cane. Chemical fertilizer had less clear effect on fresh cane yield and plant components despite F1 being the only half amount of F2. Chicken manure significantly promoted higher concentrations of all major plant nutrients, calcium and iron in leaf and tip and in cane while perlite-amended soil giving a very high amount of silicon concentration in both plant parts. Nitrogen, phosphorus, calcium, magnesium, iron, and manganese in leaf and tip, and nitrogen, potassium, calcium, magnesium in cane highly significantly had a positive correlation with fresh cane yield, thus; it is necessary to provide sufficient amounts of these nutrients to the plant to retain a satisfactory yield. Based on the result of this study, the application of CM at the rate of 12.5 t/ha with a recommended rate of chemical fertilizer can be recommended for use in the coarse-textured soil.

Keywords: sugarcane, chicken manure, perlite, coarse-textured soil, chemical fertilizer

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Introduction

Sugarcane (*Saccharum officinarum* L.) is one of the major economic crops in Thailand. The plant is important for sugar industry and currently used to produce ethanol as a renewable energy. Sugarcane planted areas in 2015/2016 and 2016/2017 growing seasons were 1.50 and 1.52 million hectares, respectively (Global Agricultural Network, 2018). The average fresh cane yield of the country was 58.94 t/ha in 2017 (Office of the Cane and Sugar Board, 2018). The most extensive sugarcane growing area is in the northeast, Thailand, with, in the same year, the total planting area of 760,107.36 ha and the average yield of 58.18 t/ha, comparatively lower than the average yield of the country. This is due probably to most soils in this region having low productivity with approximately 80% of the growing areas being medium- to coarse-textured with inherently low fertility status. Major problems of these soils are water and nutrients deficiency, high leaching and weakly structured feature. (Sumitra, 1996). In general, sugarcane grown in this region is under rainfed condition with the cane being harvested during dry season. Severe soil moisture shortage is the major reason of which sugarcane can thrive on only for a virgin cane and/or a single ratoon production (Wongviwatchai et al., 2002).

As moisture and soil fertility is one of the factors affecting the growth and yield of sugarcane. Research on the use of soil amendments for alleviating these problems or in the other word improving sandy soil properties was widely undertaken. The application of chicken manure in a degraded sandy soil at a rate of 10 t/ha reduced bulk density and increased total porosity and available water capacity (Obi and Ebo, 1994). Escobar (2008) noted that chicken manure had beneficial effects on three tropical nutrient poor soils (Andisol, Ultisol, and Oxisol), increasing pH and EC, correcting Al and Mn toxicity and augmenting some nutrient concentrations. In addition, Adeleye (2010) studied the main effect of poultry manure on soil physio-chemical properties and it was found that poultry manure application improved soil physical properties; it reduced soil bulk density, temperature and also increased total porosity and soil moisture retention capacity. It also improved the amounts of soil organic matter, total N, available P, exchangeable Mg, Ca, K and lowered exchange acidity. Using filter cake with fertilizer (13-13-21 grade) also gave high yield of sugarcane (Wongviwatchai et al., 2002). The experiment on Roi-et soil series showed that using ripper prior to the normal land preparation combined with the application of 3.125 t/ha of slaked lime, 6.25 t/ha of chicken manure and 0.31 t/ha of fertilizer 21-7-18 grade gave the highest cane yield of 98.13 t/ha (Khodphuwiang et al., 2006). Combined application between chicken manure at the rate of 3.125 t/ha and chemical fertilizer (0.31 t/ha of 16-16-8 and 21-7-18 grade) also increased virgin cane to 62.06 t/ha and first ratoon cane to 22.31 t/ha when compared to the use of only chemical fertilizer (Prasantree et al., 2006). The application of nitrogen, phosphorus, potassium at different rates showed that 200: 150: 150 kg/ha of $N:P_2O_5:K_2O$ had the effect on sugarcane components such as number of cane, cane length, cane diameter, cane yield and weight of cane, resulting in higher cane yield (Ayub et al. 1999). The application of 13-13-21 grade chemical fertilizer at the rate of 325 kg/ha^{-1} induced a steady increase of cane yield as the rate of duck manure increased when applied together (Ratanarak and Prachuabmoh, 1988). Sugarcane, K95-84 variety, significantly produced the highest virgin cane yield of 97.50 t/ha in Satuk soil series amended with

6.25 t/ha of chicken manure compared to 83.75 t/ha obtained from the control with no manure application (Khumdech et al., 2011). Results showed that the application of rice husk-mixed chicken manure gave the yield of 15.6 ton/rai, which was significantly higher than the one with no application (13.4 ton/rai). Sugarcane also responded to fertilizer as the yield increased from 83.13 to 95.00 and 103.13 t/ha when applied at the respective rates of 50, 125 and 312.5 kg/ha of N on a coarse-textured soil (Klinhoun, 2004). In addition, perlite used as soil amendment significantly increased cassava yield in Yasothon soil series (Thanimmarn et al., 2014) and Warin soil series (Phuniam, 2014) and enhanced well with chicken manure, giving the highest cassava fresh tuber yield in both soils. This study was undertaken with the aim at investigating the effect of sole application of chicken manure and perlite, and their combination, and chemical fertilizer on growth and yield of virgin cane, K 95-84 variety, planted in Korat soil series (Typic Paleustult) in addition with soil property changes as affected by soil amendment and chemical fertilizer applied. Results obtained from this study would be useful for sugarcane yield improvement in this particular soil because the soil has widely been used for growing sugarcane in the region but the yield is still rather poor due to the soil having low fertility level and inability to retain sufficient soil moisture for plant growth.

Materials and Methods

Method of this study comprised field experiment that was conducted in a farmer field at Ban Non Somboon, Kritsana subdistrict, Sikhio district, Nakhon Ratchasima province. The topography of an experimental site nearly flat with an elevation of 320 m above MSL. Average annual rainfall and temperature during the time of conducting the experiment were 1,386 mm/yr and 28°C, respectively. Soil representing the experimental area was classified as Typic Paleustult (Korat soil series). The soil had sandy texture in the top 0-30 cm and clay content increased with increasing depth within a soil profile. Organic matter content was low in an Ap1 horizon and very low in subsoils. Most plant nutrients were very low, indicating that the soil had low fertility level. Soil properties prior to conducting the experiment showed that soil pH was slightly acid in topsoil and strongly acid in subsoil. Soil organic matter content as well as total nitrogen, available phosphorus and available potassium was very low throughout the top 60 cm and cation exchange capacity was also very low in the top and subsoils (**Table 1**).

Table 1 Soil properties prior to conducting the experiment.

Soil parameter	Topsoil (0-30 cm)	Subsoil (30-60 cm)
pH (1:1 H_2O)[1/]	6.4	5.4
Organic matter (g/kg)[2/]	4.38	2.53
Total N (g/kg)	0.14	0.14
Available P (mg/kg)[4/]	3.91	1.11
Available K (mg/kg)[5/]	19.81	17.00
Extractable Ca ($cmol_c$/kg)[6/]	1.13	1.03
Extractable Mg ($cmol_c$/kg)[6/]	0.21	0.28
Extractable Na ($cmol_c$/kg)[6/]	0.14	0.13
Cation exchange capacity, CEC ($cmol_c$/kg)[7/]	2.13	2.50
Textural class[8/]	Sand	Sandy loam

[1/] pH (H_2O); [2/]Walkley and Black; [3/]Kjeldahl; [4/]Bray II; [5/]1 M NH_4OAc at pH 7.0; [6/]1 M NH_4OAc at pH 7.0; [7/]1 M NH_4OAc at pH 7.0; [8/]pipette method.

Sugarcane, K 95-84 variety, was planted at the early rainy season and harvested at 12 months of age. Split plot design with 4 replications was employed. Main plot consisted of soil amendments as follow; 1) no application, 2) and 3) chicken manure applied at the rate of 6.25 and 12.5 t/ha, respectively, 4) and 5) perlite applied at the rate of 0.625 and 1.25 t/ha, respectively, 6) the combination between chicken manure 6.25 t/ha and perlite 0.625 t/ha^{-1}, and 7) the combination between chicken manure 12.5 t/ha and perlite 1.25 t/ha. Soil amendments were broadcasted onto designed plots before the first plough. Properties of chicken manure and perlite used in this experiment are shown in **Table 2**. Subplot comprised two different rates of chemical fertilizer; 1) 18.8:18.8:18.8 kg/ha of $N:P_2O_5:K_2O$ as basal application and 147.5:32.5:52.5 kg/ha of $N:P_2O_5:K_2O$ as topdressing (Khumdech et al., 2011), and 2) 37.5:37.5:37.5 kg/ha of $N:P_2O_5:K_2O$ as basal application and 295:65:105 kg/ha of $N:P_2O_5:K_2O$ as topdressing. Topdressing was equally split and applied in the form of side dressing when the plant was 3 and 5 months old. Land preparation was done using 3-disc for the first plough followed by 7-disc plough and then ridging. Sugarcane was grown using 25 cm space-double-cane placement in between each ridge. Row spacing was 1.3 m. Sugarcane was harvested at 10 months of age while plant parameters such as fresh cane yield, aboveground fresh weight, number of internode, diameter of internode, number of cane, length of cane and commercial cane sugar (CCS) being measured and recorded at the time of harvest. Separated plant parts, leaf and tip, and cane, were collected at the harvesting time for plant analysis. Sugarcane yield, measured plant components, and soil properties were compared among treatments using the analysis of variance for statistical significance, and mean separation was done using SPSS program and Duncan's multiple range test (DMRT) with differences being tested at 0.01 and 0.05 levels of significance.

Table 2 Properties of soil amendments used in the experiment.

Properties	Perlite	Chicken manure	Properties	Perlite	Chicken manure
pH (1:5 H_2O)	7.7	7.0	Total Mg (g/kg)$^{3/}$	1.0	3.2
EC (1:5 H_2O, dS/m)	0.26	1.50	Total Na (g/kg)$^{3/}$	1.9	11.4
OM (g/kg)	nd*	406	Total Si (g/kg)$^{5/}$	322.1	nd*
CEC ($cmol_c$/kg)	20.1	65.1	Total Al (g/kg)$^{3/}$	80.1	nd*
Total N (g/kg)$^{1/}$	nd*	46.9	Total Fe (g/kg)$^{3/}$	0.20	0.30
Total P (g/kg)$^{2/}$	nd*	7.6	Total Zn (g/kg)$^{3/}$	0.40	0.50
Total K (g/kg)$^{3/}$	2.8	17.6	Total Cu (g/kg)$^{3/}$	0.10	0.04
Total Ca (g/kg)$^{3/}$	1.2	26.2	Total Mn (g/kg)$^{3/}$	0.30	0.50
Total S (g/kg)$^{3/}$	2.2	nd**			

nd* = not determined.

$^{1/}$ Digestion mixture (H_2SO_4-Na_2SO_4-Se mixture) and Kjeldahl method; $^{2/}$Digestion mixture (HNO_3-H_2SO_4-$HClO_4$ acid mixture) and Vanado-molybdate; $^{3/}$Digestion mixture (HNO_3-H_2SO_4-$HClO_4$ acid mixture); $^{4/}$Digestion acid mixture (HNO_3-$HClO_4$) and $BaSO_4$ turbidimatric; $^{5/}$ Digestion (conc. HNO_3) + Na_2CO_3 and Colorimetric.

Results

Effect of soil amendment and chemical fertilizer on fresh cane yield

The application of soil amendment had a positive effect on growth and yield of sugarcane. Sugarcane, K95-84 variety, showed better response to chicken manure than to perlite when used as soil amendment. The application of chicken manure at the rate of 12.5 t/ha (T3) highly significantly promoted the highest fresh cane yield of 103.01 t/ha, which was slightly higher, but with no statistical difference, than that obtained from the plot amended with the same organic amendment at the rate of 6.25 t/ha (T2) that gave the yield of 91.43 t/ha. These fresh cane yields were statistically similar to that of T6 (89.79 t/ha) and T7 (90.99 t/ha), a combination between chicken manure and perlite at two different rates (**Table 3**). The use of perlite as soil amendment (T4 and T5) gave fresh cane yield in the range of 69.59-76.81 t/ha of which applying this inorganic soil amendment at the rate of 0.625 t/ha still induced higher fresh cane yield than the control with no application of soil amendment (T1). It was evident that planting sugarcane in this Korat soil series without amending the soil the fresh cane yield of a virgin cane was considerably low (55.84 t/ha). The same trend was found in the case of aboveground biomass, fresh cane plus leaf and tip, that the application of chicken manure at the rate of 12.5 t/ha (T3) highly significantly stimulated the highest amount of 129.91 t/ha but with no statistical difference to the amount of 123.34 t/ha obtained from the plot amended with chicken manure and perlite at respective rates of 6.25 and 0.625 t/ha (T6). It was notable that the control without any soil amendment addition (T1) gave the lowest aboveground biomass of 75.59 t/ha (**Table 3**). Amending the soil with chicken manure at the rate of 12.5 t/ha (T3) and chicken manure 12.5 t/ha together with perlite 1.25 t/ha (T7) both significantly induced the highest number of cane, 67,969 and 63,672 cane/ha, respectively, although these amounts were not different from those obtained from other plots involving soil amendment. The control (T1) again gave the lowest number of 50,261 cane/ha (**Table 3**).

In the case of the response of sugarcane to chemical fertilizer, it was rather surprising that the application of 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O (F2), with no statistical difference, gave only slightly higher fresh cane yield of the virgin cane than did the addition of 166.25: 51.25: 71.25 kg/ha of N:P_2O_5:K_2O (F1), 86.54 compared to 78.44 t/ha, despite the latter rate being half amount of the former rate. Other plant parameters also showed no difference as affected by different rates of major plant nutrient added in the form of chemical fertilizer. In addition, there was no clear interaction between soil amendment and chemical fertilizer applied. With no statistical difference, the combination between chicken manure 12.5 t/ha and 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O (T3F2) tended to give the highest fresh cane yield of 106.68 t/ha followed by the same amount of chicken manure with half quantity of chemical fertilizer as of F2 that gave the fresh cane yield of 99.35 t/ha, nevertheless; the lowest yield was detected in the plot with no use of soil amendment, 53.15 t/ha with the application of 166.25:51.25:71.25 kg/ha of N:P_2O_5:K_2O (T1F1) and 58.53 t/ha with the addition of 332.5: 102.5: 142.5 kg/ha of N:P_2O_5:K_2O (T1F2).

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Table 3 Effect of soil amendment and chemical fertilizer on yield and plant components of sugarcane, K95-84 variety, planted in Korat soil series.

Treatment	FCY	ABG	NC	CL	CD	NI	CCS
	(-------------t/ha-------------)		No./ha	(---------cm---------)		No./cane	(%)
Main plot: soil amendment							
T1	55.84^{d}	75.59^{d}	50261^{b}	202	2.9	20	13.6
T2	91.43^{ab}	100.26^{c}	58594^{ab}	222	2.9	20	12.9
T3	103.01^{a}	129.91^{a}	67969^{a}	224	3.0	21	13.1
T4	76.81^{bc}	90.94^{cd}	59636^{ab}	217	2.9	21	13.4
T5	69.59^{cd}	86.98^{cd}	57292^{ab}	199	2.7	20	13.5
T6	89.79^{ab}	123.34^{ab}	60287^{ab}	217	2.9	21	13.7
T7	90.99^{ab}	105.84^{bc}	63672^{a}	204	2.8	19	13.0
F-test	**	**	*	ns	ns	ns	ns
Subplot: rate of chemical fertilizer							
F1	78.44	96.93	18.48	59449	205	2.9	20
F2	86.54	106.75	20.20	59896	219	2.8	20
F-test	ns	ns	ns	ns	ns	ns	ns
Interaction: soil amendment * rate of chemical fertilizer							
F-test	ns	ns	ns	ns	ns	ns	ns
%CV	18.4	17.4	15.8	9.7	8.2	5.7	9.3

ns = non-significant; *, ** significantly different at 0.05 and 0.01 probability levels, respectively; means with different superscript letters within a column indicate a significant difference according to Duncan's multiple range test at $p \leq 0.05$.

No significant difference among rate of chemical fertilizer nor interaction at all between soil amendment and rate of chemical fertilizer, thus those results are not shown in the table.

T1 = no application of soil amendment; T2 = chicken manure 6.25 t/ha; T3 = chicken manure 12.5 t/ha; T4 = perlite 0.625 t/ha; T5 = perlite 1.25 t/ha; T6 = T2+T4; T7 = T3+T5

F1 = 166.25:51.25:71.25 kg/ha of N:P_2O_5:K_2O; F2 = 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O

FCY = fresh cane yield; ABG = aboveground biomass; NC = number of cane; CL = cane length; CD = cane diameter; NI = number of internode; CCS = commercial cane sugar

Effect of soil amendment and chemical fertilizer on plant nutrient concentration

Leaf and tip

In general, both chicken manure and perlite had clearer effect on plant nutrient concentrations in leaf and tip of sugarcane than did chemical fertilizer. The application of chicken manure at the rate of 12.5 t/ha together with perlite at the rate of 1.25 t/ha (T7) highly significantly induced the highest N, P and K concentrations in this plant part with the values of 14.10, 3.06 and 13.64 g/kg (**Table 4**). The sole application of 12.5 t/ha of chicken manure (T3) highly significantly stimulated the highest Ca and Fe concentration of 2.01 g/kg and 140 mg/kg, respectively, in leaf and tip of virgin cane. The use of perlite as soil amendment at the rate of 1.25 t/ha (T5) highly significantly gave the highest Si concentration of 13.76 g/kg and all plots amended with perlite (T4-T7) evidently induced much higher Si concentration in leaf and tip of virgin cane than those amended with only chicken manure (T2 and T3) and the control with no soil amendment addition (T1), having the range of 12.71-13.76 compared to 0.12-1.73 g/kg. It was not surprising that the concentration of plant nutrients with the exception of Mn and Zn in this plant part was the lowest in the control with no soil amendment incorporation during the first plough.

Different rates of chemical fertilizer only had the impact on P and Ca concentrations. The plot fertilized with 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O (F2) significantly promoted the higher P and Ca concentrations in leaf and tip of virgin cane than did the plot fertilized with 166.25:51.25:71.25 kg/ha of N:P_2O_5:K_2O (F1) with respective contents of 2.42 and 1.42 g/kg compared to 1.81 and 1.13 g/kg. There was no interaction between soil amendment and chemical fertilizer used on plant nutrient concentration in this plant part of virgin cane.

Table 4 Effect of soil amendment and chemical fertilizer on nutrient concentration in leaf and tip of sugarcane, K95-84 variety, planted in Korat soil series.

Treatment	N	P	K	Ca	Mg	Si	Fe	Mn	Zn	Cu
	(----------g/kg					----------)	(----------mg/kg			----------)
Main plot: soil amendment										
T1	5.60^{c}	1.51^{b}	7.35^{d}	0.60^{c}	1.12	0.12^{e}	30^{c}	74	9.4	5.1
T2	9.20^{b}	2.20^{ab}	12.07^{b}	1.42^{abc}	1.38	1.15^{d}	60^{bc}	19	12.5	7.1
T3	10.20^{b}	2.34^{ab}	11.20^{b}	2.01^{a}	2.25	1.73^{d}	140^{a}	162	10.5	10.6
T4	9.70^{b}	1.93^{b}	10.39^{c}	1.05^{bc}	1.46	12.71^{c}	50^{c}	116	10.8	6.5
T5	8.90^{b}	1.82^{b}	9.55^{c}	0.82^{c}	1.11	13.76^{a}	40^{c}	105	11.0	5.6
T6	9.02^{b}	2.04^{b}	10.89^{bc}	1.14^{bc}	1.39	12.84^{bc}	80^{bc}	125	10.9	5.8
T7	14.10^{a}	3.06^{a}	13.64^{a}	1.62^{ab}	2.02	13.54^{ab}	120^{ab}	14	13.8	7.4
F-test	**	**	**	**	ns	**	**	ns	ns	ns
Subplot: rate of chemical fertilizer										
F1	9.28	1.81^{b}	10.74	1.13^{b}	1.34	8.04	54	122	11.1	6.0
F2	9.78	2.42^{a}	10.71	1.42^{a}	1.73	7.84	94	128	11.4	7.7
F-test	ns	*	ns	*	ns	ns	ns	ns	ns	ns
Interaction: soil amendment * rate of chemical fertilizer										
F-test	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
%CV	28.6	33.7	21.3	58.1	61.9	8.9	73.0	51.3	34.4	84.8

ns = non-significant; *, ** significantly different at 0.05 and 0.01 probability levels, respectively; means with different superscript letters within a column indicate a significant difference according to Duncan's multiple range test at $p \leq 0.05$. No significant difference among interaction at all between soil amendment and rate of chemical fertilizer, thus those results are not shown in the table.

T1 = no application of soil amendment; T2 = chicken manure 6.25 t/ha; T3 = chicken manure 12.5 t/ha; T4 = perlite 0.625 t/ha; T5 = perlite 1.25 t/ha; T6 = T2+T4; T7 = T3+T5

F1 = 166.25:51.25:71.25 kg/ha of N:P_2O_5:K_2O; F2 = 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O

Cane

In a similar fashion to the concentration of plant nutrient in leaf and tip of virgin cane, soil amendment had clearer effect than did chemical fertilizer applied. The significantly greatest major plant nutrient, N, P and K, concentrations in cane with the values of 6.94, 1.94 and 4.14 g/kg, respectively, were found when the soil was amended with chicken manure at the rate of 12.5 t/ha together with perlite at the rate of 1.25 t/ha (T7). The highest Fe concentration of 116.25 mg/kg was similarly affected by this addition. This combination at both rates (T6 and T7) also highly significantly induced the highest Ca (0.29-0.31 g/kg) and Mg (0.86-0.98 g/kg) concentrations in cane (**Table 5**). In the case of Mn and Zn concentrations in cane, all plots amended with these two soil amendments significantly showed higher values than did the control (T1) while Si concentration in cane highly significantly had a similar trend to that in leaf and tip. Again, with no soil amendment incorporated the control had the least concentration of almost all plant nutrients in cane except only Cu.

Chemical fertilizer usage had significant effect on N, K and Mg concentration in cane of virgin cane. The addition of 332.5:102.5: 142.5 kg/ha of N:P_2O_5:K_2O (F2) induced the greater concentrations of these nutrients (5.61, 2.61 and 0.95 g/kg) in cane than did the use of 166.25:51.25:71.25 kg/ha of N:P_2O_5:K_2O (F1) that had the contents of 4.53, 2.14 and 0.71 g/kg, respectively. The application of chicken manure at the rate of 12.5 t/ha together with perlite at the rate of 1.25 t/ha interacted with the addition of 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O (T7F2), significantly inducing the highest N, K and Mg concentrations of 8.71, 4.82 and 1.14 g/kg, respectively, in cane of virgin cane while amending the soil with chicken manure at the rate of 12.5 t/ha together with 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O (T3F2) had an interaction on P concentration in cane, highly significantly promoting the highest value of 2.06 g/kg.

Table 5 Effect of soil amendment and chemical fertilizer on nutrient concentration in cane of sugarcane, K95-84 variety, planted in Korat soil series.

Treatment	N	P	K	Ca	Mg	Si	Fe	Mn	Zn	Cu
	(---------------------------------g/kg--------------------------------)						(-------------------mg/kg-------------------)			
Main plot: soil amendment										
T1	2.54d	1.32c	0.71d	0.05d	0.68c	1.23b	87.5ab	60.00b	8.50c	7.63
T2	4.96c	1.65abc	2.05c	0.18c	0.72bc	2.32b	83.75b	81.25ab	13.50ab	8.63
T3	5.13bc	1.81ab	3.08b	0.21bc	0.96a	2.41b	91.25ab	75.00b	13.00bc	9.25
T4	4.87c	1.62abc	1.82c	0.27ab	0.69c	13.24a	68.75b	80.00ab	12.38bc	8.50
T5	5.21bc	1.47bc	1.91c	0.20bc	0.92a	14.06a	81.25b	110.00a	12.88bc	7.88
T6	6.08b	1.65abc	3.12b	0.31a	0.86ab	11.52a	96.25ab	85.00ab	14.00ab	8.38
T7	6.94a	1.94a	4.14a	0.29a	0.98a	12.04a	116.25a	88.75ab	18.12a	9.00
F-test	**	*	**	**	**	**	*	*	*	ns
Subplot: rate of chemical fertilizer										
F1	4.53^{b}	1.53	2.14^{b}	0.20	0.71^{b}	7.97	89	86	14.3	8.8
F2	5.61^{a}	1.66	2.61^{a}	0.23	0.95^{a}	8.22	90	77	12.1	8.1
F-test	*	ns	*	ns	**	ns	ns	ns	ns	ns
Interaction: soil amendment * rate of chemical fertilizer										
T1F1	2.83^{f}	1.06^{c}	0.65^{f}	0.06	0.52^{de}	1.24	90	70	9.3	7.3
T2F1	5.34^{cde}	1.87^{abc}	1.72^{e}	0.19	0.74^{bc}	2.36	73	103	14.8	9.0
T3F1	5.01^{cde}	1.52^{abc}	2.56^{cd}	0.19	0.67^{cd}	2.57	73	53	11.3	8.8
T4F1	4.25^{de}	1.31^{bc}	1.94^{de}	0.28	0.46^{e}	12.72	70	90	14.0	9.0
T5F1	4.32^{de}	1.54^{abc}	1.81^{de}	0.20	0.92^{b}	13.34	78	118	14.0	8.8
T6F1	5.23^{cde}	1.72^{abc}	2.84^{bc}	0.24	0.84^{bc}	11.61	108	85	17.3	9.3
T7F1	5.16^{cde}	1.95^{ab}	3.32^{b}	0.26	0.82^{bc}	11.98	133	85	19.8	9.3
T1F2	2.32^{e}	1.64^{abc}	0.75^{f}	0.05	0.85^{bc}	1.36	86	50	7.8	8.0
T2F2	4.51^{cde}	1.94^{ab}	2.31^{cde}	0.18	0.70^{bcd}	2.22	95	60	12.3	7.8
T3F2	5.34^{cde}	2.06^{a}	3.54^{b}	0.23	1.24^{a}	2.32	110	98	14.8	9.8
T4F2	5.47^{cd}	1.82^{abc}	1.67^{e}	0.25	0.92^{b}	13.61	68	70	10.8	8.0
T5F2	6.25^{bc}	1.45^{bc}	1.98^{de}	0.20	0.93^{b}	14.65	85	103	11.8	7.0
T6F2	6.83^{b}	1.57^{abc}	3.32^{b}	0.37	0.88^{bc}	11.43	85	85	10.8	7.5
T7F2	8.71^{a}	1.41^{bc}	4.82^{a}	0.33	1.14^{a}	11.94	100	93	16.5	8.8
F-test	**	**	*	ns	**	ns	ns	ns	ns	ns
%CV	17.7	19.8	19.1	33.8	20.6	33.4	29.6	31.9	33.5	57.4

ns = non-significant; *, ** significantly different at 0.05 and 0.01 probability levels, respectively; means with different superscript letters within a column indicate a significant difference according to Duncan's multiple range test at $p \leq 0.05$.
T1 = no application of soil amendment; T2 = chicken manure 6.25 t/ha; T3 = chicken manure 12.5 t/ha; T4 = perlite 0.625 t/ha; T5 = perlite 1.25 t/ha; T6 = T2+T4; T7 = T3+T5
F1 = 166.25:51.25:71.25 kg/ha of N:P_2O_5:K_2O; F2 = 332.5:102.5:142.5 kg/ha of N:P_2O_5:K_2O

Effects of soil amendment and chemical fertilizer on the relationship between plant nutrient concentration and virgin cane components

Pearson correlation coefficient (2-tailed) was done to establish the relationship between nutrient concentration and virgin cane components (**Table 6**). Nitrogen, P, Ca, Mg, Fe and Mn concentrations in leaf and tip of virgin cane showed a highly positive correlation with fresh cane yield (r = 0.38**, 0.36**, 0.51**, 0.37**, 0.43** and 0.45**, respectively). In the case of aboveground biomass, major plant nutrient concentration in this plant part had no correlation but Ca, Mg, Fe and Mn concentrations highly significantly showed a positive correlation with this plant part of virgin cane (r = 0.48**, 0.36**, 0.50** and 0.36**, respectively). Potassium, Ca, Mg, Fe and Mn concentrations in leaf and tip of virgin cane also had a relationship with number of cane, having significantly positive correlations as follow; r = 0.32*, 0.30*, 0.33*, 0.28 and 0.31*, respectively. There was only Ca concentration that showed a significantly positive correlation with cane length (r = 0.31*) while Zn concentration having a significantly negative correlation with this plant part (r = -0.29*). The latter was also found in the context of number of internode (r = -0.33*). No correlation between plant nutrient concentrations in

Table 6 Correlation between nutrient concentration in plant parts and plant components of virgin cane.

Concentration	Pearson's r (N=56)						
Leaf and Tip	FCY	ABG	NC	CL	CD	NI	CCS
N	0.38**	0.24	0.24	0.14	-0.03	0.03	-0.09
P	0.36**	0.26	0.18	0.19	-0.06	0.06	-0.11
K	0.21	0.12	0.32*	-0.05	-0.10	-0.13	-0.07
Ca	0.51**	0.48**	0.30*	0.31*	0.06	0.30*	-0.05
Mg	0.37**	0.36**	0.33*	0.16	0.06	0.14	0.02
Fe	0.43**	0.50**	0.28*	0.19	0.09	0.14	0.06
Mn	0.45**	0.36**	0.31*	0.21	0.00	0.16	-0.01
Zn	-0.15	-0.21	-0.13	-0.29*	0.01	-0.33*	-0.16
Cu	0.22	0.29*	0.14	0.05	0.18	0.08	0.20
Si	-0.01	0.01	0.09	-0.10	-0.14	-0.06	0.07
Cane	FCY	ABG	NC	CL	CD	NI	CCS
N	0.27*	0.28*	0.17	0.07	-0.11	-0.03	-0.15
P	0.11	0.15	0.08	0.01	0.00	-0.02	-0.18
K	0.33*	0.41**	0.27*	-0.02	0.02	-0.10	-0.16
Ca	0.39**	0.38**	0.32*	0.20	-0.13	0.22	-0.24
Mg	0.40**	0.42**	0.24	0.37**	-0.29*	0.30*	-0.19
Fe	-0.01	0.14	-0.20	-0.10	0.23	-0.02	0.04
Mn	0.24	0.10	0.04	0.33*	-0.21	0.39**	0.05
Zn	-0.25	-0.21	-0.10	-0.47**	0.10	-0.45**	0.01
Cu	-0.34**	-0.27*	-0.38**	-0.44**	0.36**	-0.35**	0.14
Si	-0.12	-0.10	0.01	-0.21	-0.13	-0.18	0.17

* significant correlation, ** highly significant correlation

FCY = fresh cane yield; ABG = aboveground biomass; NC = number of cane; CL = cane length; CD = cane diameter; NI = number of internode; CCS = commercial cane sugar leaf and tip and CCS was found.

In the case of nutrient concentration in cane of virgin cane, N, K, Ca and Mg concentrations significantly had a positive correlation with fresh cane yield (r = 0.27*, 0.33*, 0.39** and 0.40**, respectively) whereas Cu concentration highly significantly had a negative correlation with fresh cane yield (r = -0.34**). A similar trend was found in the case of aboveground biomass with a positive correlation (r = 0.28*, 0.41**, 0.38** and 0.42**, respectively) with N, K, Ca and Mg concentrations and a negative correlation (r = -0.27**) with Cu concentration. Potassium and Ca significantly had a positive correlation (r = 0.27* and 0.32*, respectively) with cane length while Cu concentration having a negative correlation (r = -0.38**). Calcium concentration played a part in cane length, highly significantly having a positive correlation (r = 0.37**) with this plant part which in contrast to Zn and Cu concentrations that showed a negative correlation (r = -0.47** and -0.44**, respectively) with cane length of virgin cane. Most of minor and micronutrient concentrations had a negative correlation with cane diameter and number of internode while all nutrient concentrations in cane having no correlation with CCS.

Discussion

Effects of soil amendment and chemical fertilizer on growth and yield of sugarcane and nutrient concentration in plant parts

The results illustrated that growing sugarcane in this Korat soil series of which the texture of topsoil was sandy can obtain a satisfactory fresh cane yield by using chicken manure as soil amendment. This coincided with previous studies (Khodphuwiang et al., 2006; Prasantree et al., 2006; Khumdech et al., 2011). As the soil having low fertility status (**Tables 2**), applying chemical fertilizer is needed but the efficiency of fertilizer usage is poor. This is because the soil has low ability to retain plant nutrient, having coarse texture and very low CEC with low organic matter content as of other sugarcane growing soils in the northeast (Sumitra, 1996).It has long been known that chicken manure is one of the most desirable soil amendments because it contains macro- and microelements needed for plant growth (Woomer and Swift, 1991; Nicholson et al., 1996; Prasad, 1996; Chen et al., 2001). Chicken manure can slowly supply plant nutrients (**Table 2**) throughout a growing period of sugarcane and also high organic matter content (406 g/kg) in this manure can improve soil physical property as previously studied (Obi and Ebo, 1994). Furthermore, this manure had CEC of 65.1 $cmol_c$/kg, thus it should increase nutrient retainability of this coarse-textured soil, resulting in better yield response of virgin cane.

In the case of using perlite as soil amendment, fresh cane yield from perlite amended plot showed inferior level to that of chicken manure-amended plot. Nevertheless, the application of this inorganic amendment still gave greater yield than did the control with no application of soil amendment. This is because perlite has a porous, light-weight, sterile, physically stable silicate with good thermal insulation properties, and a neutral pH. Expanded perlite has a low bulk density and high surface area (Shackley, 1992; Breese and Barker, 1994; **doğan** and Alkan, 2004). It also has rather high CEC (20.1 $cmol_c$/kg) as shown in **Table 2**. As a result, this inorganic material can have a positive contribution to sugarcane as shown by some studies. Silber et al. (2010) reported that the effects on plants by the chemical composition of perlite were found to be significant, especially in enhancing the water-soluble P, Ca and Mg concentrations. In horticultural applications, perlite is used throughout the world as a component of soilless growing mixes where it provides aeration and optimum moisture retention for superior plant growth (Matkin, 2005) and Gul *et al*. (2005) reported that the use of perlite growing medium led to increasing plant growth, higher N and K contents in plant tissues of lettuce (*Lactuca sativa var. longifolia*).

In the context of the combination between chicken manure and perlite used together as soil amendment, it was proved successful, giving higher cassava fresh tuber yield when applied together than when applied solely, with cassava grown in a rather similar type of soils, Warin soil series with sandy texture topsoil (Phuniam, 2014) and Yasothorn soil series (Thanimmarn et al., 2014), in the northeast but located in higher position of the landscape. However, the result obtained from this study showed no better response by sugarcane than sole application of chicken manure. It might be due to a different plant or the position of the landscape that in this case soil moisture is more prolonged during the year and/or groundwater level is shallower than those two soils.

In the case of plant nutrient concentration, tt is clear that plant nutrients, especially those major and minor plant nutrients, composed in chicken manure played a vital part in plant nutrient concentration in both plant parts of sugarcane. Greater fresh cane yield from the plot amended with chicken manure was consistent greater concentration of plant nutrients in both plant parts. This is similar to the study of Khumdech et al. (2011). In the case of perlite, the concentration of most nutrients in sugarcane plant parts was generally lower than that in the case of chicken manure but clearly higher than that obtained from control, indicating that this inorganic amendment can directly or indirectly help the plant to take up more nutrient from the soil. In addition, it is more interesting that perlite evidently induced much greater silicon in plant tissues than did chicken manure as it contained large amount of 322.1 g/kg of total Si (Table 2). As reported that Si, although it is not an essential element, plays some roles in the growth of sugarcane (Savant et al., 1999; Plodsunthia et al., 2017), using perlite as soil amendment can be crucial in this context. The reason for this plant response or yield increase is not fully understood, but several mechanisms have been proposed. Some studies indicated that sugarcane yield responses to silicon may be associated with induced resistance to biotic and abiotic stresses, such as disease and pest resistance, Al, Mn, and Fe toxicity alleviation, increased P availability, reduced lodging, improved leaf and stalk erectness, freeze resistance, and improvement in plant water economy.

Conclusions

Growing sugarcane, K95-84 variety, in Korat soil series which had a sandy texture in topsoil, fresh cane yield of virgin cane was very low and yield response to rates of chemical fertilizer, recommended rate and 2-time of recommended rate, was barely different in a statistical aspect. Amending the soil with chicken manure or perlite gave much higher fresh cane yield and plant nutrient concentration with the yield best responding to the application of chicken manure at the rate of 12.5 t/ha of which it would give farmer the highest profit, considering an increased proportion of cane and the cost of chicken manure applied. Considering obtained fresh cane yield of virgin cane, the effect of chicken manure was superior to perlite, however, the amount applied of the former was ten-time higher, and the combination of these tow soil amendments show inferior outcome to sole application of chicken manure. In addition, sugarcane yield components positively correlated with nutrient concentrations, especially the concentrations of nitrogen, phosphorus, calcium, magnesium, iron, and manganese in leaf and tip , and nitrogen, potassium, calcium, magnesium in cane of virgin cane.

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K	0.21	0.12	0.32*	-0.05	-0.10	-0.13	-0.07
Ca	0.51**	0.48**	0.30*	0.31*	0.06	0.30*	-0.05
Mg	0.37**	0.36**	0.33*	0.16	0.06	0.14	0.02
Fe	0.43**	0.50**	0.28*	0.19	0.09	0.14	0.06
Mn	0.45**	0.36**	0.31*	0.21	0.00	0.16	-0.01
Zn	-0.15	-0.21	-0.13	-0.29*	0.01	-0.33*	-0.16
Cu	0.22	0.29*	0.14	0.05	0.18	0.08	0.20
Si	-0.01	0.01	0.09	-0.10	-0.14	-0.06	0.07
Cane	FCY	ABG	NC	CL	CD	NI	CCS
N	0.27*	0.28*	0.17	0.07	-0.11	-0.03	-0.15
P	0.11	0.15	0.08	0.01	0.00	-0.02	-0.18
K	0.33*	0.41**	0.27*	-0.02	0.02	-0.10	-0.16
Ca	0.39**	0.38**	0.32*	0.20	-0.13	0.22	-0.24
Mg	0.40**	0.42**	0.24	0.37**	-0.29*	0.30*	-0.19
Fe	-0.01	0.14	-0.20	-0.10	0.23	-0.02	0.04
Mn	0.24	0.10	0.04	0.33*	-0.21	0.39**	0.05
Zn	-0.25	-0.21	-0.10	-0.47**	0.10	-0.45**	0.01
Cu	-0.34**	-0.27*	-0.38**	-0.44**	0.36**	-0.35**	0.14
Si	-0.12	-0.10	0.01	-0.21	-0.13	-0.18	0.17

* significant correlation, ** highly significant correlation

FCY = fresh cane yield; ABG = aboveground biomass; NC = number of cane; CL = cane length; CD = cane diameter; NI = number of internode; CCS = commercial cane sugar

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