MACRONUTRIENTS ABSORPTION AND SURFACE RUNOFF LOSSES UNDER DIFFERENT FERTILIZING TREATMENTS IN SUGARCANE FIELDS

Hấp thụ chất dinh dưỡng đa lượng và rửa trôi bề mặt trong điều kiện bón phân khác nhau trên ruộng mía

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TÓM TẮT

Thí nghiệm được tiến hành để đánh giá hàm lượng chất dinh dưỡng trong đất, trong cây và sự hấp thụ dinh dưỡng của mía sau khi bón vinasse làm phân bón lỏng. Ảnh hưởng của bón vinasse tới môi trường và đánh giá rủi ro cũng được nghiên cứu. Ba công thức được sử dụng trong thí nghiệm gồm CK1 (không bón phân + 105,0 t/ha nước), CK2 (181,7; 450,0 và 1.327,5 kg/ha tương ứng N, P_2O_5 và K_2O, + 105,0 t/ha nước) và vinasse (75,0 t/ha vinasse + 166,7 kg/ha P_2O_5 + 30,0 t/ha nước). Bón vinasse làm giảm hàm lượng N nhưng tăng hàm lượng P và K trong thân mía so với đối chứng. Bón vinasse cũng làm tăng hàm lượng P và K tổng số trong đất, và giảm sự mất mát N, P và K do rửa trôi bề mặt. Tóm lại, sử dụng vinasse làm phân bón lỏng cung cấp đủ P và K cho sinh trưởng và phát triển của mía, cải thiện hàm lượng chất hữu cơ trong đất và giảm sự mất mát N, P và K do rửa trôi bề mặt nhờ tăng khả năng giữ chất chất dinh dưỡng của đất.

Từ khóa: Dinh dưỡng đa lượng, hấp thụ, rửa trôi, vinasse.

SUMMARY

The present experiment was conducted to assess the soil and plant nutrient content and their uptake by sugarcane plants after applying vinasse as liquid fertilizer. The impact of vinasse application on environment and risk assessment of its application has also been studied. Three treatments used in the experiment were CK1 (no fertilizer + 105.0 t/ha water), CK2 (181.7, 450.0 and 1327.5 kg/ha of N, P_2O_5 and K_2O, repectively + 105.0 t/ha water) and vinasse (75.0 t/ha vinasse + 166.7 kg/ha P_2O_5 + 30.0 t/ha water). The vinasse treatment decreased N content and increased P and K content in sugarcane plants compared to controls. It also enhanced total P and K content in soil, and decreased the surface runoff losses for N, P and K. In conclusion, the use of vinasse as liquid fertilizer supplied sufficient amount of P and K for the growth and development of sugarcane crop, improved the soil organic matter content and reduced the N, P and K losses through surface runoff water by enhancing the nutrient retention capacity of the soil.

Keywords: Absorption, macronutrients, runoff losses, vinasse.

1. INTRODUCTION

The modern agricultural practices, particularly the use of agro-chemicals and inorganic manures, have been recognized as one of the most important sources of water contamination (Parry, 1998). Chemical fertilizers are most commonly added to the soils to replace its nutrients taken up by agricultural crops. The surplus amount of fertilizer through surface runoffs from agricultural fields causes pollution to water sources. The surface runoff losses from agricultural cropping systems have been extensively studied over the past few decades (Simard et al., 2000). Studies have shown that the loss of nutrients from soil through surface runoff is affected by many factors including climate, soil characteristics, extent of land use, and chemical applications (Gafur et al., 2003; Puustinen et al., 2005).

Impact of these fertilizers on the soil's physical and chemical health and environmental problems such as increasing water pollutions alarmed the scientific community to explore the environment-friendly use of organic fertilizers and the recycling of plant biomass and/or agriculture industry byproducts. In a recent study, use of N or P as compound organic fertilizer substantially reduced their runoff losses from hill slope orchards in Southern China (Zeng et al., 2008). Sugarcane vinasse is liquid organic waste of alcohol refinery. Disposal of untreated vinasse is very difficult due to its acidic nature and toxic heavy metal content. Usually, its pH value ranged from 4.0-4.8. The chemical and biochemical oxygen demand of untreated vinasse have been recorded in range of 100-130 and 57-67 g/L, respectively (Deng, 1995). However, most elements and compounds in vinasse are useful to crops, *e.g.*, N, K, Ca, Mg, S, and organic matter (OM). Recently, the application of treated vinasse in sugarcane fields has been found to be the most effective disposal of it, which besides protecting the environment, also fulfill the fertilizer and irrigation requirements (Bao, 1992). Though, many studies have been performed to study the effects of vinasse application on growth, development and production of sugarcane and physical properties of soil (You et al., 2009; Jiang et al., 2010), only a few refer to its impact on the surface runoff of nutrients. The main purpose of present study was to assess the nutrient losses through surface runoff after the vinasse application, to observe its effect on soil and plant nutrient content and their uptake by sugarcane.

2. MATERIALS AND METHODS

2.1. Location of experiment and the materials

The experiment was conducted at Cane Sugar Industry Office Experimental Base located in Changping, Fusui (22°39′N, 107°55′E), Guangxi, China from 29 January to 20 December in 2007. The rainfall status in Changping Town during the experimental duration is shown in Table 1.

The sugarcane variety GT21 was used in the current studies. The soil used in the experiment was a typical latosolic red soil, the chemical properties of which are given in Table 2. The chemical properties of vinasse and chemical fertilizer are shown in Table 3.

Table 1. Mean rainfall monthly of experimental site in 2007

Month	1	2	3	4	5	6	7	8	9	10	11	12	Tot.
Rainfall (mm)	0.0	26.3	49.9	47.8	48.0	24.4	51.1	200.5	140.8	0.0	0.0	17.2	606.0

Table 2. Chemical properties of basic soil

Total N (%)	Total P (%)	Total K (%)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	pH	OM (%)	HA (%)	Available Cu (mg/kg)	Cl$^-$ (mg/kg)
0.08	0.08	0.60	140.00	17.00	126.00	4.51	3.01	5.09	0.43	62.50

Table 3. Chemical properties of vinasse and chemical fertilizer

Fertilizer	Total N (%)	Total P_2O_5 (%)	Total K_2O (%)	Available N (%)	Available K (%)	pH	OM (%)	Total Cu (mg/kg)	Cl$^-$ (%)
Vinasse	0.60	0.02	3.37	0.23	0.40	5.61	5.83	4.27	1.03
Calcium magnesium phosphate	—	18.00	—	—	—	—	—	24.86	—
Urea	46.30	—	—	—	—	—	—	—	—
KCl	—	—	60.00	—	—	—	—	—	45.32

2.2. Experimental design

A field experiment was conducted with randomized blocks design of 9 plots in three replicates. The plot was 30 m^2 (5 m length and 6 m width) in size with 5 rows in each (1.2 m row spacing). Each row was planted with 70 sugarcane buds. Three treatments used in the experiment were: CK1 (no fertilizer + 105.0 t/ha water), CK2 (181.7, 450.0 and 1327.5 kg/ha of N, P_2O_5 and K_2O, repectively+105.0 t/ha water) and vinasse (75.0 t/ha vinasse + 166.7 kg/ha P_2O_5 + 30.0 t/ha water). The fertilizer sources for N, P_2O_5, and K_2O were urea, calcium magnesium phosphate and KCl, respectively. Calcium magnesium phosphate fertilizer was applied before planting (Jan 29, 2007), and the sugarcane setts were planted on Jan 30, 2007. The fields were irrigated with vinasse and water after one month of planting (Feb 1, 2007). Nitrogen (urea) and potassium (KCl) were applied at the time of tillering (May 29, 2007), and sugarcane was harvested on Dec 20, 2007. Normal crop cultural practices were performed throughout the experiment.

2.3. Calculation of data and statistical analysis

Different indices in soil and sugarcane samples were analyzed at various growth stages of sugarcane using the methods as described by Lu (2000). The analysis of vinasse, chemical fertilizers and runoff water were performed by the methods as described in The Manual of Chinese Fertilizer and Soil Opsonin Standardizing Technology Committee (2000). The formulas used for calculation of mean nutrient concentration, total nutrient loss and total runoff volume are as follows:

$$\text{Mean nutrient concentration } (C_m) = \sum_{i=1}^{8} C_i \,/8$$

$$\text{Total nutrient losses} = \sum_{i=1}^{8} C_i * V_i$$

$$\text{Total runoff volume } (V_t) = \sum_{i=1}^{8} V_i$$

The data were processed with univariate analysis of variance (ANOVAR) using SPSS 11.5 Windows statistical software (SPSS, Chicago, IL, USA).

3. RESULTS AND DISCUSSION

3.1. Effect of different treatments on the nutrient content of sugarcane

The total N content in sugarcane leaf and stem was higher in CK1 compared to other treatments, while CK2 possessed higher total N content in juice compared to the former and vinasse treatments. Interestingly, the total P content in leaf and juice, and total K in all aboveground parts of sugarcane were highest in plants treated with vinasse (Table 4). These results suggested that organic N content in sugarcane vinasse was not easily solubilized in soil and therefore, could not be absorbed by sugarcane. The N utilization efficiency of sugarcane in case of vinasse treatment was found lower than that of the P and K. At the same time, most of the inorganic form of P and K in vinasse was available, and absorbed easily by the plants than in the other treatments. This higher availability of P and K in vinasse treated plants might be attributed to the improved soil physical properties such as bulk density, aggregation, colloid properties, permeability and hydraulic conductivity, due to vinasse application. These results were found to be in accordance with Huang et al. (2006).

Table 4. Nutrient absorption in different components of sugarcane plant treated with different fertilizers in sugarcane field

Sample	Treatment	Total N (%)	Total P (%)	Total K (%)
Leaf of sugarcane	CK1	1.37±0.02 a	0.13±0.01 cB	1.64±0.17 bA
	CK2	1.04±0.07 b	0.14±0.02 bAB	2.03±0.12 aA
	Vinasse	1.08±0.16 ab	0.17±0.02 aA	2.16±0.27 aA
Stem of sugarcane	CK1	0.99±0.06 aA	0.05±0.01 a	0.50±0.03 cC
	CK2	0.76±0.06 bB	0.05±0.00 a	0.74±0.06 bB
	Vinasse	0.52±0.03 cC	0.05±0.00 a	1.23±0.07 aA
	Treatment	Total N (g/L)	Total P (mg/L)	Total K (%)
Juice of sugarcane	CK1	1.48±0.10 bB	38.97±3.11 cB	0.14±0.02 cB
	CK2	1.93±0.11 aA	48.42±4.33 bA	0.32±0.04 bA
	Vinasse	1.48±0.13 bB	52.78±3.58 aA	0.41±0.03 aA

(Different capital and small alphabets in the same column represent significant difference at 1 and 5%, respectively. The same is followed subsequently)

3.2. Effects of different treatments on the nutrient content of soil

It has been observed that the N, P and K contents in soil decreased gradually with the growth of sugarcane plants, and the soils treated with CK1 showed maximum decrease indicating insufficient/unavailable N content in the soil of CK1 (Fig.1). Data showed that the total N and K contents in soil of CK2 treatment increased sharply at elongation stage of sugarcane due to application of N and K fertilizer at this stage (Fig. 1a and c). At maturity stage of sugarcane, no significant differences in total N content were observed amongst soils of vinasse and CK2 treatments. The total P and K contents in soil of vinasse treatment were higher than those of CK2. However, as expected, the total N, P and K contents in soil of CK1 were the lowest among all treatments throughout the experiment.

3.3. Effects of different treatments on the surface runoff water volume and nutrient concentration of soil

The total runoff volume therein all treatments ranged from 1093.08 to 6518.00 L/ha during May to Jul., and then significantly increased (4559.46-37392.88 L/ha) during Aug. to Oct., 2008 due to heavy rainfall (Table 5).

The total surface runoff water volume from soils treated with vinasse was significantly lower than other two treatments from May 22 to Oct. 23, 2008 except for Jun.14. The highest volume of runoff water was recorded in CK2 followed by CK1. Further, among all the nutrients, P content was the least (0.05 to 0.47 mg/L) observed in runoff water in all the three treatments. The N and K content in runoff water ranged from 1.10-14.05 and 0-4.00 mg/L, respectively (Table 5).

The amount of K was also found higher in runoff water from soils treated with vinasse compared to other treatments. In a similar studies, sewage sludge supply decreased runoff volume remarkably by improving water retention capacity of soil (Ojeda et al., 2003; Ojeda et al., 2006).

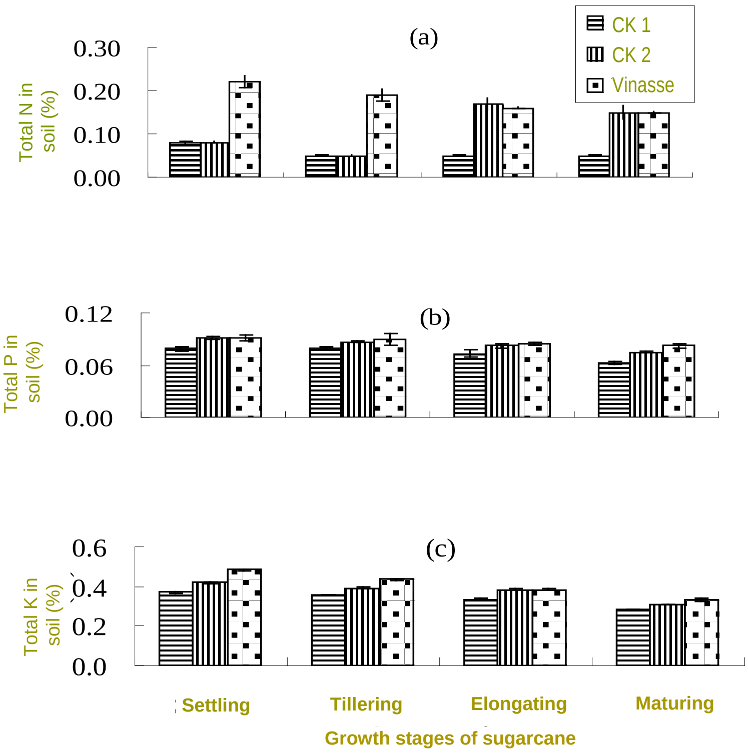

Figure. 1 Total N, P and K content in soils treated with different fertilizers at various growth stages of sugarcane

Table 5. Volume and macronutrient concentrations of runoff water from soils treated with different fertilizers

Sampling Date (y.m.d)	Treat- ment	Runoff volume (L/ha)	Total N (mg/L)	Total P (mg/L)	Total K (mg/L)
08.05.22	CK1	3191.39	4.53±0.04 aA	0.21±0.03 b	0.00±0.00 bB
	CK2	5618.00	1.70±0.00 cB	0.29±0.06 a	0.20±0.14 bB
	Vinasse	1475.42	2.65±0.21 bB	0.21±0.03 b	1.56±0.00 aA
08.5.29	CK1	1475.42	3.10±0.00 a	0.35±0.06 b	0.32±0.00 cC
	CK2	2079.15	3.85±0.49 a	0.47±0.03 a	2.95±0.07 bB
	Vinasse	1763.72	4.75±0.78 a	0.42±0.03 ab	3.82±0.00 aA
08.6.14	CK1	1475.42	1.75±0.07 bB	0.05±0.00 b	0.00±0.00 cC
	CK2	1213.89	1.10±0.00 cB	0.08±0.00 a	0.30±0.01 bB
	Vinasse	1918.03	4.05±0.21 aA	0.05±0.00 b	1.00±0.04 aA
08.7.10	CK1	1475.42	14.05±1.06 aA	0.21±0.04 a	3.00±0.08 a
	CK2	1763.72	11.45±0.21 aA	0.06±0.01 b	3.00±0.65 a
	Vinasse	1093.08	2.95±0.21 bB	0.07±0.00 b	1.00±0.07 b
08.8.16	CK1	37392.88	2.20±0.00 b	0.22±0.01 aA	2.95±0.07 a
	CK2	37392.88	3.50±0.14 a	0.13±0.01 bAB	3.10±0.14 a
	Vinasse	29842.99	2.60±0.14 b	0.04±0.01 cB	3.00±0.01 a
08.8.31	CK1	19180.75	4.53±0.07 b	0.21±0.03 b	1.44±0.07 C
	CK2	19346.10	7.20±0.28 a	0.25±0.00 b	3.50±0.00 B
	Vinasse	14586.14	7.25±0.78 a	0.33±0.01 a	4.00±0.00 A
08.9.21	CK1	7432.09	2.20±0.28 a	0.26±0.00 aA	1.85±0.07 bB
	CK2	7628.72	1.65±0.07 a	0.11±0.01 cC	2.00±0.00 bB
	Vinasse	5073.86	2.00±0.00 a	0.15±0.00 bB	3.00±0.00 aA
08.10.23	CK1	7432.09	3.90±0.28 a	0.21±0.01 a	1.90±0.17 a
	CK2	11080.84	2.60±0.14 b	0.13±0.00 b	3.00±0.07 a
	Vinasse	4559.46	3.75±0.07 a	0.14±0.00 b	3.00±0.61 a

Table 6. Mean concentration and quantity of loss of macronutrients through runoff water in soils treated with different fertilizers

Item	Treatment	Total N	Total P	Total K	Total runoff volume (mg/L)
Mean concentration (mg/L)	CK1	4.53±0.08 a	0.22±0.00 a	1.44±0.02 c B	79055
	CK2	4.13±0.01 a	0.19±0.01 b	2.26±0.04 b A	86123
	Vinasse	3.75±0.28 a	0.18±0.00 b	2.55±0.08 a A	60313
Total loss (g/ha)	CK1	256.83±1.04 b AB	17.32±0.68 a A	170.70±2.09 b B	79055
	CK2	350.65±0.56 a A	14.55±0.68 b A	245.04±5.59 a A	86123
	Vinasse	233.87±17.57 b B	8.48 ±0.33 c B	188.82±3.19 b B	60313

Table 7. Balance of nutrients in soils treated with different fertilizers

Item	Input (kg/ha)			Output (g/ha)			Runoff loss rate (%)		
	CK1	CK2	Vinasse	CK1	CK2	Vinasse	Ck1	Ck2	Vinasse
N	0	450.000	450.000	256.830	350.650	233.870	-	0.078	0.052
P_2O_5	0	181.700	181.700	39.663	33.320	19.419	-	0.018	0.011
K_2O	0	1327.500	1327.500	205.694	295.273	227.528	-	0.022	0.017

The total runoff volume, mean nutrient concentration and total nutrient losses are given in Table 6. It was found that the mean concentrations of N and P and total N, P and K losses in runoff water of vinasse treated soil were lower compared to other two treatments. The concentrations of total N, P and K in runoff were recorded in range of 3.0-5.0, 0.1-0.3 and 1.0-3.0 mg/L, respectively. Blicher-Mathiesen et al. (2006) also showed that total concentrations of N and P in runoff were more than 0.35 and 0.1 mg/L, respectively. Chenu et al. (2000) reported cohesion of soil aggregates through the binding of mineral particles by organic polymers present in the vinasse. They also suggested that the addition of organic matter through vinasse can enhance physical enmeshment of soils by fine roots or growth of fungal mycelia. Cui et al. (2006) showed that organic matter can reduce positive electric charge capacity of soil, and enhance the adsorption of NH_4^+. Hua et al. (2005) reported that organic molecules can promote P adsorption in red soil evidently. These studies together with our results suggested the enhancement of nutrient and water retention capacity of soil after vinasse application and therefore reduction in N and P losses through runoff water. However, potassium is easily soluble in water and therefore its losses through surface runoff can not be minimized to a great extent. In the present study, the mean P concentration in runoff water was lower than the Standard value (SEPAC 2002, total N 2.0 mg/L, total P 0.4 mg/L) in water of river or lake, but that of N concentration was higher.

3.4. Balance of nutrients in soils treated with different fertilizers

It may be concluded from the results of our experiment that the rates of N, P and K losses through surface runoff in vinasse treated soils were lower than those in CK2 (Table 7). The rate of total N losses through surface runoff was the highest, followed by losses of K and P, due to the fact that NH_4^+-N and K^+ are soluble and easy to be taken off by surface runoff water. However, P is easily adsorbed by organic matter or combined with calcium or magnesium and forms deposition (Liu et al., 2005), therefore, it is hard to be affected by surface runoff water. Ghidey and Alberts (1999) observed that less than 5% of the total N applied to the soil was lost *via* surface runoff. Losses of total P, recorded each year in a four year experiments, reached the maximum of only 2 kg/ha total P (Smith et al., 2001). In the present study, the rates of total N, P, and K losses through surface runoff were recorded as less than 1% of nutrients input.

In conclusion, the use of vinasse as liquid fertilizer suuficiently provides P and K for the growth and development of sugarcane crop, improves the soil organic matter content and reduces the N, P and K losses through surface runoff water by enhancing the nutrient retention capacity of the soil.

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