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# Utilization of Distillery Slop for Sugar Cane Production and Environmental Pollution Reduction

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**Abstract**

The research aimed to study the effect of distillery slop and chemical fertilizer on soil fertility, growth and yield of sugar cane. The field experiment was conducted on Mahasarakam soil series, using the K 88-92 variety of sugar cane. The results showed that distillery slop significantly increased some nutrients in soil, particularly potassium, magnesium, sulfur and chloride. The results also showed that application of distillery slop did not affect most of the physical properties of soil. Only the saturated hydraulic conductivity was significantly decreased under non-application of fertilizer. Under the application of distillery slop, chemical fertilizer had no significant effect on the yield and the juice quality of sugar cane for both crop years. However, under non-application of distillery slop in the first crop year, application of 21-0-0 and 20-20-0 fertilizer had a significant effect on cane yield. With the application of chemical fertilizer, distillery slop had an influence on the yield of sugar cane in both crop years while different doses of slop did not make any significant difference on cane yield. The average yields of the first crop year were 126.7, 195.6, 203.0 and 187.2 ton/hectare and those of the second crop year were 85.0, 150.0, 150.8 and 142.4 ton/hectare after the application of 0, 187.5, 375 and 562.5 $m^3$/hectare, respectively. The results also showed that application of distillery slop did not have any significant effect on juice quality for both crop years. Investigation of slop trace under the ground surface indicated that application of distillery slop did not affect the quality of underground water as the deepest level of trace was only 50 centimeters.

***Keywords :*** distillery slop, sugar cane, environmental pollution

## 1. Introduction

Distillery slop is the waste water from alcohol distilleries having Biological Oxygen Demand (BOD) as high as 87,500 mg/litre (Tasanee and Somboon, 2004). According to the Industrial Department Act B.E. 2539, the content of BOD after treatment must not exceed 80 mg/litre. This causes a big burden to the distilleries, since the cost of treating slop to meet such requirement is very high. However, past studies on the properties of slop have shown that distillery slop contains a high content of plant nutrients such as potassium, magnesium, calcium, sodium, zinc, copper, iron, manganese and organic matter (Panabwuthikul, 1999; Jadhav and Savant, 1975; Shauma, 2001; Recault, 1990). Various researchers have reported that crops show good response to distillery slop application (Ajmal and Khan, 1983; Jadhav and Savant, 1975; Joshi *et al*., 1994; Zalawadia and Raman, 1994). It would therefore be beneficial for both the agricultural sector and the distilleries if slop could be used directly in agriculture. The main objective of this research is to study the effect of distillery slop on the yield of sugar cane and its impact on soil properties.

## 2. Materials and Methods

Sugar cane stems – K 8892 variety were used in the experiment. A total of 75.6 $m^3$ of distillery slop was employed for placing on the experimental plots as assigned. Chemical fertilizers: 46-0-0, 18-46-0 and 0-0-60 which were delivered by Saksiam Corporation (Thailand) Company Limited and were produced in Egypt, Mexico and Republic of Belarus, respectively were used as sources of nitrogen, phosphorus and potassium for mixing the trial fertilizers namely 21-0-0; 20-20-0 and 13-13-21. Various chemicals were required for laboratory analysis of slop and soil samples.

Experimental fields were prepared and divided into 3 blocks of 896 m2 each comprising 4 main plots of 224 $m^2$. Each main plot was then divided into 4 sub-plots of 56 $m^2$. Main plot treatments comprised of 4 kinds of fertilizer: 0-0-0 ($F_1$), 21-0-0 ($F_2$), 20-20-0 ($F_3$), 13-13-21 ($F_4$) and sub-plot treatments were 4 doses of slop: 0 ($S_1$), 0.01875 $m^3/m^2$ ($S_2$), 0.0375 $m^3/m^2$ ($S_3$), 0.05625 $m^3/m^2$ ($S_4$). These treatments were randomly assigned to main plot and Sub-plot within each block as shown in Fig. 1.

**Block 1**

| $F_2$ | $F_4$ | $F_1$ | $F_3$ |
|---|---|---|---|
| $S_4$ | $S_1$ | $S_1$ | $S_3$ |
| $S_2$ | $S_3$ | $S_2$ | $S_2$ |
| $S_1$ | $S_2$ | $S_3$ | $S_1$ |
| $S_3$ | $S_4$ | $S_4$ | $S_4$ |

**Block 2**

| $F_3$ | $F_2$ | $F_4$ | $F_1$ |
|---|---|---|---|
| $S_4$ | $S_3$ | $S_1$ | $S_1$ |
| $S_1$ | $S_1$ | $S_2$ | $S_3$ |
| $S_3$ | $S_2$ | $S_3$ | $S_4$ |
| $S_2$ | $S_4$ | $S_4$ | $S_2$ |

**Block 3**

| $F_2$ | $F_4$ | $F_1$ | $F_3$ |
|---|---|---|---|
| $S_3$ | $S_1$ | $S_1$ | $S_4$ |
| $S_4$ | $S_2$ | $S_3$ | $S_1$ |
| $S_1$ | $S_3$ | $S_2$ | $S_2$ |
| $S_2$ | $S_4$ | $S_4$ | $S_3$ |

Figure 1 Allocation of main plot and sub-plot treatments

In the first crop year, the distillery slop was placed on sub-plots as assigned and were left idle for 40 days. The cutting stems of sugar cane were then planted in each sub-plot, 6 rows per plot. Each row was 8 meter long and the distance between rows was 1.4 meters. Application of fertilizers was carried out twice at an equal rate of 18.75 g/m$^2$. The first application was at the time of planting and the second application was at 60 days afterwards. Following the harvest of first crop of sugar cane, the distillery slop was placed for the second crop year. Application of fertilizer was done in the same manner as it was in the first crop year with the exception that the first portion was applied on the 40$^{th}$ day after placing slop.

Samples of slop were taken before placing on the experimental plots in both crop years and were analyzed biologically by the dilution plate count method (Lorch *et al.*,1995) and chemically by the methods as described in the Standard methods for the examination of water and waste water (APHA. AWWA. WPCF., 1985). Soil samples were collected from each sub-plot at four different occasions, *viz*., at 40 days after placing slop in the first crop year; at harvest time of first crop year; at the 40$^{th}$ day after placing slop in the second crop year, and at harvest time of second crop year. These soil samples were analyzed for biological properties using the dilution plate count method, and for physical and chemical properties, using the methods as described in the Manual for analyses of soil, water, fertilizer, plant and soil improvement material samples, and for analyses of commodity for standard certifying (Office of Science for Land Development , 2004).

Biological pest control was used with parasites. Weed control was done by cultural control method. Yields of both crop years were harvested and weighed within each sub-plot. Samples of sugar cane stems were taken from each sub-plot and the juice quality were then analyzed by measuring the percentage of total soluble solid (Brix) and percentage of sucrose content (Pol) in sugar cane juice, using Refractometer and Polarimeter, respectively. Also measuring was the percentage of sugar cane fiber. The commercial cane sugar (CCS) was then calculated using the following fomular:

$$CCS = 0.9433\ P1\ (100\text{-}F)/100 - \tfrac{1}{2}\,[0.9660\ B1(100\text{-}F)/100 - 0.9433\ P1(100\text{-}F)/100]$$

Where P1 = % Pol in 1st expressed juice
B1 = % Brix in 1st expressed juice
F = % cane Fiber

All data collected were analyzed using the Analysis of Variance methods for the Split Plot design with IRRI STATISTICS VERSION 3/93 program.

Investigation of slop traces under the ground surface of those plots that did not receive fertilizer was done at the end of second crop year by observing the seepage of slop through the ground as indicated by its color.

## 3. Results and Discussion

### *3.1 Chemical and biological properties of slop*

High contents of following nutrients were found containing in the slop for the first and second crop years, respectively: nitrogen 0.13 and 0.18%, potassium 1.35 and 1.98%, magnesium 0.17 and 0.18%, sulfur 0.10 and 0.54%, calcium 0.11 and 0.26%, chloride 0.60 and 0.97%, total dissolved solid 7.0% and 5.1%, suspended solid 0.5 and 2.8%, total solids 7.6 and 7.9% and volatile solids 4.2 and 3.2%. Heavy metals – cadmium and lead were detected in a very low content for the first and second crop years, respectively: cadmium 0.5 ppm and non-detected, lead 0.83 and 0.15 ppm. Total bacteria and total fungi were found in the small amount (6.00 and 7.14 log no./ml for bacteria and 4.27 and 4.83 log no./ml for fungi) while toxic substance residues in the form of organophosphate, organochlorines and carbamate were not detectable. The C/N ratios were calculated to be 41:1 and 31:1 in the first and second crop year, respectively, which indicated that distillery slop is likely to be suitable for improving soil fertility.

### *3.2 Influence of distillery slop on soil fertility*

The results of chemical and biological analyses of soil revealed that, after 40 days of slop application in the first crop year, slop had influence on pH, EC (electrical conductivity), % OM (organic matter), K, Mg, Mn, Fe, S, Cl and total bacteria and still had on pH, EC, K, Mg, Fe, S and Cl at the time of harvesting. For the second crop year under fertilizer condition, slop placing especially at higher doses was found to have significant effect on pH, EC, K, Mg, Mn, Fe and Cl after 40 days of application. At harvest time of the second crop year, the slop still had influence on pH, EC, K, Mg and Fe. Also affected at this time was S and total bacteria. The mean values of these parameters are presented in Tables 1 - 4. From the results of analyses, it was evident that the distillery slop which was in alkaline condition (pH 8-9), could help adjust the soil condition from acidity (pH 5.3-5.8) to mild alkalinity (pH 6.0-8.5) which is suitable for sugar cane plantation. Moreover, slop placing could help improve the fertility of soil as indicated by the increase of EC and nutrient elements in response to slop effect. It should be noted that there was no significant effect of slop on the two heavy metals in the soil namely Lead and Cadmium. In addition, no toxic residues, neither organochlorine, organophosphate nor carbamate groups, could be detected, which indicated that slop placing in sugar cane fields was not harmful to the environment.

The results of physical analyses of soil revealed that soil before placing slop had following characteristics: Saturated hydraulic conductivity (K-sat) between 0.18-13.66 cm/hr with the average of 3.57 cm./hr.; Available Water Capacity (AWC) between 2.23 – 3.88% with the average of 3.00%; Bulk density (Db) between 4.50-1.78 g/$m^3$ with the average of 1.63 g/$m^3$. After 40 days of placing slop in first crop year, it was found that only the 0.05625 $m^3/m^2$ dose of slop had any influence on the saturated hydraulic conductivity of soil. The average value of K-sat was low, down to 0.98 cm/hr, compared to that of 4.72 cm/hr for non slop placing. However, the rate of K-sat still was at the moderate level (Faculty of Soil Science Department, 2005) which was appropriate for sugar cane plantation. No significant effect of slop was found on AWC and Db characteristics. The average values of AWC and Db were 3.26% and 1.64 g/$m^3$, respectively. At harvest time of second crop year, no significant effect of slop was found on any of these physical properties. The mean values of K-sat, AWC and Db were found to be 1.78 cm/hr, 4.66% and 1.61 gm/$m^3$, respectively.

### *3.3 Influence of distillery slop on cane yield*

With the presence of slop, application of fertilizer did not have any significant effect on cane yield of both crop years. However, with the absence of slop, application of 21-0-0 and 20-20-0 gave higher yield in the first crop year than that of non fertilizer. Under fertilizer application condition, there was a significant effect of slop on cane yield for both crop years. However, there was no significant difference among the three doses of slop. The average yield of first crop year sugar cane were 126.7, 195.6, 203.0 and 187.2 ton/hectare and those of second crop year were 85, 150, 150.8 and 142.4 ton/hectare for the application of 0, 0.01875, 0.0375 and 0.05625 $m^3/m^2$, respectively. The graphic presentation of cane yield under slop placing and fertilizer application for both crop years was given in Fig. 2 & 3.

### *3.4 Effect of slop on juice quality of sugar cane*

Under fertilizer application condition, slop placing had no influence over the juice quality of sugar cane. The average values of juice quality parameters as measured by % total soluble solid (Brix), % sucrose content (Pol), % Fiber and % commercial cane sugar (CCS) were 19.6%, 16.2%, 9.7% and 12.2%, respectively for the first crop year and were 19.2%, 15.6%, 9.6% and 11.6% for the second crop year.

### *3.5 Environmental pollution*

The deep levels of slop seepage through the ground as indicated by its brown color for those investigated plots are shown in Table 5. As the deepest level was found at 50 cm below ground surface of the plot receiving highest dose of slop, it may be concluded that slop placing at 0.0562.5 $m^3/m^2$ or less would not cause environmental pollution, particularly the underground water.

## 4. Conclusion

It is concluded that distillery slop has chemical, physical and biological properties that are appropriate to use directly in sugar cane production, especially with K

Table 1. Mean values of soil properties parameters being influenced by slop at 40th day after slop placing in first crop year

| Doses of Slop ($m^3/m^2$) | pH | EC (mS/cm) | %OM | K (ppm) | Mg (ppm) | Mn (ppm) | Fe (ppm) | Cu (ppm) | S (ppm) | Cl (ppm) | Total bacteria (log no./gm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 5.3 a | 0.036 a | 0.70 a | 120.7 a | 57.5 a | 41.1 a | 46.2 a | 0.48 a | 77.2 a | 15.7 a | 5.54 a |
| 0.01875 | 6.0 b | 0.117 b | 0.83 b | 575.4 b | 62.4 a | 60.2 b | 43.4 a | 0.47 a | 104.8 ab | 124.2 b | 5.70 ab |
| 0.0375 | 6.9 c | 0.246 c | 0.87 b | 1152.2 c | 114.2 b | 78.5 c | 64.8 b | 0.58 b | 125.6 bc | 301.0 c | 5.70 ab |
| 0.05625 | 7.2 c | 0.358 d | 0.90 b | 1446.5 c | 147.5 b | 75.3 c | 77.4 b | 0.58 b | 154.6 c | 319.7 c | 5.76 b |
| Mean | 6.3 | 0.189 | 0.83 | 823.7 | 93.9 | 63.7 | 57.9 | 0.53 | 115.6 | Cl | 4.19 |

Table 2 Mean values of soil properties parameters being influenced by slop at harvest time of first crop year

| Doses of Slop ($m^3/m^2$) | pH | EC (mS/cm) | K (ppm) | Mg (ppm) | Fe (ppm) | S (ppm) | Cl (ppm) |
|---|---|---|---|---|---|---|---|
| 0 | 5.5 a | 0.021 a | 185.53 a | 42.43 a | 52.97 a | 34.85 a | 10.52 a |
| 0.01875 | 6.4 b | 0.038 ab | 465.93 ab | 97.27 b | 43.15 b | 43.15 b | 10.53 a |
| 0.0375 | 6.8 b | 0.057 bc | 477.80 ab | 139.84 c | 36.96 b | 42.49 b | 14.31 ab |
| 0.05625 | 7.1 b | 0.078 c | 626.62 b | 170.87 d | 37.22 b | 47.17 b | 23.31 b |
| Mean | 6.4 | 0.048 | 438.97 | 112.60 | 42.58 | 41.91 | 14.67 |

Remark: Means within the same column having the same letter are not significantly different at 5% level

Table 3. Mean values of soil properties parameters being influenced by slop at 40th day after slop placing in second crop year

| Doses of Slop ($m^3/m^2$) | pH | EC (mS/cm) | K (ppm) | Mg (ppm) | Mn (ppm) | Fe (ppm) | Cl (ppm) |
|---|---|---|---|---|---|---|---|
| 0 | 5.5 a | 0.389 a | 53.3 a | 30.9 a | 29.64 a | 42.58 a | 13.2 a |
| 0.01875 | 7.7 b | 0.534 b | 946.7 b | 210.5 b | 33.77 ab | 29.76 b | 374.1 b |
| 0.0375 | 8.1 bc | 0.330 b | 1065.6 b | 239.2 bc | 36.89 b | 30.64 b | 439.5 b |
| 0.05625 | 8.5 c | 0.454 b | 1124.7 b | 268.9 c | 28.11 a | 28.32 b | 453.3 b |
| Mean | 7.5 | 0.427 | 797.6 | 187.4 | 32.10 | 32.83 | 320.0 |

Table 4. Mean values of soil properties parameters being influenced by slop at harvest time of second crop year

| Doses of Slop ($m^3/m^2$) | pH | EC (mS/cm) | K (ppm) | Mg (ppm) | Fe (ppm) | S (ppm) | Total bacteria (log no./gm) |
|---|---|---|---|---|---|---|---|
| 0 | 5.8 a | 0.020 a | 21.4 a | 21.6 a | 49.8 a | 19.8 a | 7.18 a |
| 0.01875 | 7.0 b | 0.037 a | 269.8 b | 85.8 b | 33.4 b | 16.8 ab | 7.04 ab |
| 0.0375 | 7.2 b | 0.047 ab | 408.0 bc | 114.4 c | 30.8 b | 12.7 b | 6.92 b |
| 0.05625 | 7.3 b | 0.071 b | 608.4 c | 122.4 c | 25.7 b | 14.7 b | 6.92 b |
| Mean | 6.8 | 0.043 | 326.9 | 86.0 | 34.9 | 16.0 | 7.01 |

Remark: Means within the same column having the same letter are not significantly different at 5% level

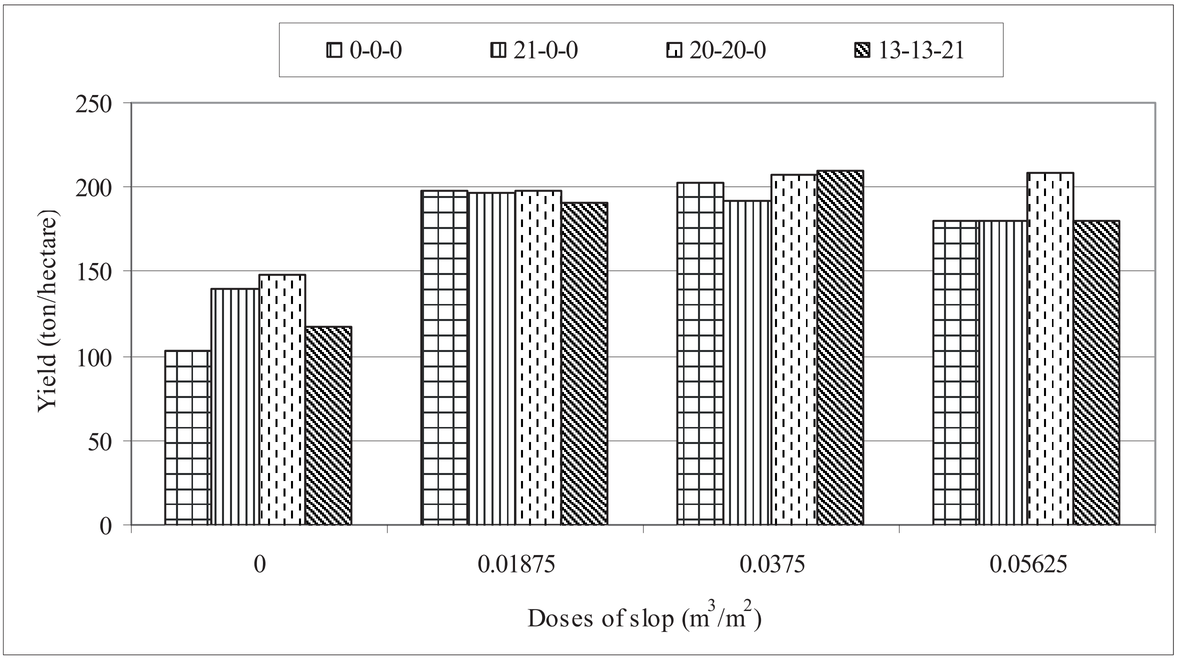


Figure 2 Yield of first crop year sugarcane under slop placing and fertilizer application

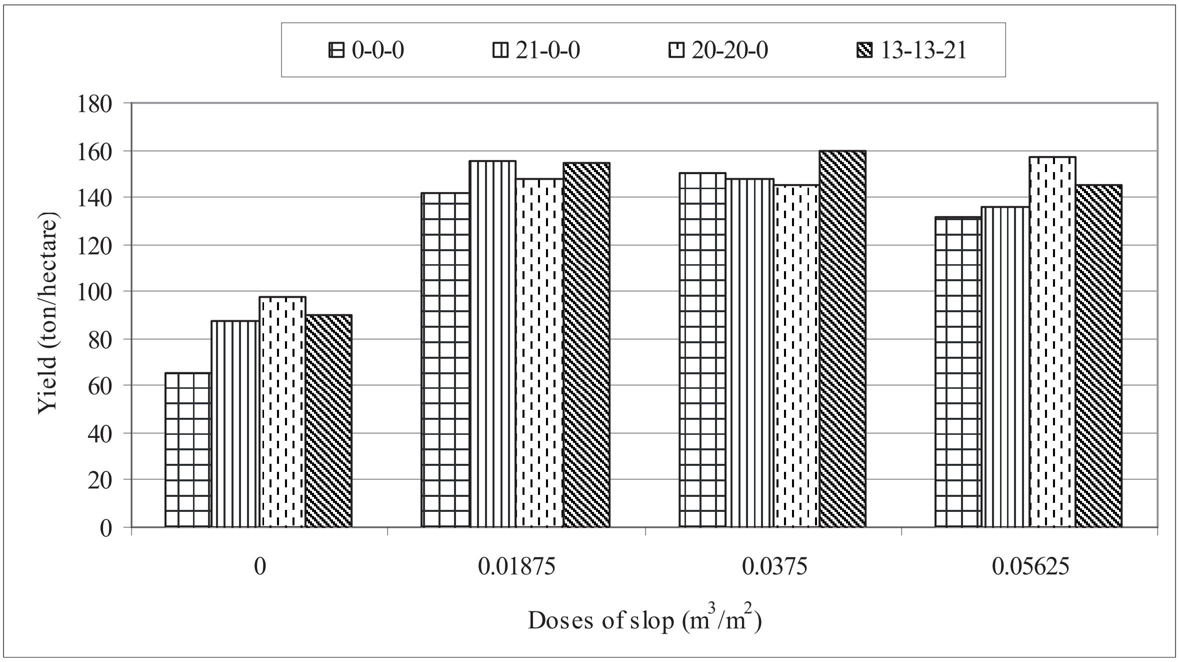


Figure 3 Yield of second crop year sugarcane under slop placing and fertilizer application

Table 5 Deep levels of slop trace under the ground surface of investigated plots

| Doses of slop ($m^3/m^2$) | Deep levels (centimeters) | | | Average |
|---|---|---|---|---|
| | Block 1 | Block 2 | Block 3 | |
| 0.01875 | 28 | 28 | 34 | 30 |
| 0.0375 | 47 | 37 | 43 | 42 |
| 0.05625 | 38 | 48 | 50 | 45 |

88-92 variety and Mahasarakham soil series. The most appropriate dose of slop is 0.0375 $m^3/m^2$ which should be recommended to the agriculturists.

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