Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.4, No.13, 2014

Residual Effect of Compost on Ethanol Production of Sweet Soghum [*Sorghum bicolor* (L.) Moench] Varieties and Soil Organic Carbon at Dryland Farming Area in Bali, Indonesia

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The research was funded by the Directorate General for Higher Education of Republic of Indonesia and the Udayana University through its research and service institution (LPPM) 2013.

Abstract

Increasing ethanol production of sweet sorghum have been receiving much attention under this era of finding new sustainable sources of bioenergy. Compost did not significantly affect biomass and ethanol production of four sweet sorghum varieties planted in 2012, therefore the objective of the 2013 experiment was to study the residual effect of compost applied in 2012 on ethanol production of sweet sorghum [*Sorghum bicolor* (L.) Moench] varieties and on soil organic carbon. The experiment was designed as randomized complete block with three replications and two treatment factors (rate of compost residues and sweet sorghum varieties) were in factorial arrangement. The compost residues were in the rates of 0, 10, 20, 30 t ha^{-1} (similar to rates applied in 2012), while the varieties were Super Sugar, Sugar Graze, SG-1A and Local Belu NTT. Super Sugar and Local Belu were the varieties used in 2012. The experiment was conducted from June until November 2013 at dryland farming area of Jimbaran, Badung Bali, Indonesia. Results of the experiment showed that residual effect of compost and the interaction effect between the two factors were not significant on ethanol content, sugar yield, juice production, ethanol production ha^{-1} and on soil organic carbon. Those parameters were only affected significantly ($P<0.05$) by variety. The highest ethanol production (1314.87 l ha^{-1}) was given by SG-1A, which was not significantly different from those of Super Sugar and Sugar Graze varieties (920.41 l ha^{-1} and 1257.92 l ha^{-1}). The highest stem ethanol content (91.31%) was produced by SG-1A, and the lowest (90.40%) was given by Local Belu variety. Low (<1.0%) soil organic carbon content was found in whole experiment. In conclusion, that high ethanol production could not be expected from residual effect of compost alone especially under low soil fertility.

Keywords: Residual effect, Compost, Ethanol, Sweet sorghum, Soil organic carbon

1. Introduction

Energy resources from fosils has been decreasing every year. Therefore the finding of new and sustainable bioenergy resources is extremely important. A number of crops produce not only foods (Anglani, 1998), feeds (Fazaeli *et al*.,2006), fibers (Murray *et al*., 2008) but also as sources of energy, such as sweet sorghum, corn, sugar cane, wheat, sugar beet, sweet potato, cassava and others (Reddy *et al*., 2005; Drapco *et al*., 2008). Sorghum classified as cereal for foods, feeds with sweet stems (Almodares *et al*., 2008a). Sweet sorghum, like grain sorghum, also produces grain as much as 3 - 7 t ha^{-1} (Almodares & Mostafafi, 2006), but the essential of sweet sorghum was not from the grain but the stem with high sugar content (Almodares *et al*., 2008b). Generally, the sugar yield in the stem could achieve 54 - 69 t ha^{-1} (Almodares *et al*., 2008b). The sugar content in juice of the stem varies with variety (Almodares *et al*., 1994). Brix among varieties vary in the range of 14.32 – 22.35% (Almodares & Sepahi, 1996).

Application of manure or composted manure can result in increased soil concentrations of nutrients and organic matter (Chang *et al*., 1991; Eghball, 2002). The residual effects of increased nutrients and organic matter in soil following manure or compost application on crop yield and soil properties can last for several years (Mugwira, 1979; Wallingford *et al*., 1975). Residual effects of manure application can maintain crop yield level for several years after manure or compost application ceases since only a fraction of the N and other nutrients in manure or compost become plant available in the first year after application (Motavalli *et al*., 1989; Eghball *et al*., 2002). Residual effects of organic materials on soil properties can contribute to improvement in soil quality for several years after application ceases (Ginting *et al*., 2003).

Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma & Mittra, 1991), supporting better root development, leading to higher crop yields (Abou El-Magd *et al*., 2005). Improvement of environmental, conditions and public health as well as the need to reduce costs of fertilizing crops are also important reasons for advocating increased use of organic materials (Seifritz, 1982). The soil fertility status is improved by activating the soil microbial biomass

(Belay *et al*., 2001). To meet nutrient requirement of the crops, organic fertilizers are, however, required in rather large quantities. Application of organic manures plays a direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization, thereby improving both the physical and the biological properties of the soil (Abou El-Magd *et al*., 2006).

Organic manures decompose to give humus which plays an important role in the chemical behavior of several metals in soils through the flavonic and humic acids contents, which have the ability to retain the metals in complex and chelate forms (Abou El-Magd *et al*., 2006). Organic manures also improve the water holding capacity of the soil; improve the soil structure and the soil aeration (Belay *et al*., 2001). Cow manures increase soil moisture retention and availability, P, K and Na in the top 0-20 cm of soil, although organic materials were not influenced (Silva *et al*., 2006). The results of the 2012 experiment showed that rates of compost applied (10, 20 and 30 t ha^{-1}) did not show any significant different effect on biomass and ethanol production of four sweet sorghum varieties compared to control (Agung *et al*., 2013). It was assumed that at that time compost had not been decomposed completely and therefore some nutrients were expected to be available for the following crops (Ginting *et al*., 2003).

Study on residual effect of organic fertilizer on following crops has been reviewed in corn (Ramamurthy & Shivashankar, 1996), in wheat (Patidar & Mali, 2002) and in *Brassica juncea* L. (Rao & Shaktawat, 2002). Although Negro *et al*. (1998) studied the residual effect of compost on productivities of sweet sorghum, but limited information is available on the residual effects of or compost on ethanol production of sweet sorghum. The present experiment was conducted to evaluate the residual effects of compost on ethanol production of sweet sorghum and soil organic carbon in dryland farming area of Jimbaran, Badung, Bali.

2. Materials and Method

The experiment was conducted at dryland farming area at Jimbaran village, Badung regency, Bali province, Indonesia at the dryland farming areas of Jimbaran, Bali, Indonesia (008° 44' 45"S-115°10' 09"E, 3 m above sea level) from June to November 2013. The land has been used for the similar experiment in 2012. Results of soil analysis before this 2013experiment indicated pH of 6.3 (slightly acid), organic-C of 0.74% (very low), total N total of 0.10% (low), available P of 7.66 mg kg^{-1}(very low), available K of 0.32 me 100g^{-1}(low), soil moisture at field capacity of 20.84% (Laboratory of Soil Chemistry, Faculty of Agriculture Brawijaya University, 2012).

The experiment was designed as randomized complete block with three replicates. Two treatment factors were sweet sorghum variety [Super Sugar or KCS105 (Homma *et al*., 2010), Sugar Graze, SG-1A and Local Belu NTT] and rates of compost residues (0, 10, 20 and 30 t ha^{-1}). Plant spacing was 70 cm x 20 cm. Harvest was done 45 days after heading. There were no organic or inorganic fertilizers applied in 2013. Stem and leaf fresh weights were determined from 1.26 m^2 quadrant then converted to hectare. The average of stem sugar content (brix) was measured using hand refractometer from nine plants in the quadrant (Agung *et al*., 2013) while the ethanol content (%) was determined through fermentation and distillation in the laboratory and read using gas chromatography (Analytical Laboratory of Udayana University, 2013). Sugar yield was calculated from the difference between stem FW ha^{-1} and bagasse DW ha^{-1}. Juice production (l ha^{-1}) was determined from stem juice volume collected from the quadrant and coverted to hectare. Ethanol production (l ha^{-1}) was the result of multiplication between juice production and ethanol content. Soil organic carbon after the experiment was analyzed using the method of Wilkley and Black in the laboratory (Laboratory of Soil Chemistry, Faculty of Agriculture Brawijaya University, 2013).

3. Results and Discussion

3.1 Residual Effects of Compost

Results of the experiment indicated that there was no significant residual effect of organic fertilizer applied one year ago on the stem and leaf fresh weights (biomass), stem sugar yield, sugar content (brix), ethanol content and ethanol production. This was associated with very little nutrients were available for the crop considered from the very low concentration of nutrients available in the soil (section 2), which indicated that there was very little organic carbon and other nutrients were released from the decomposition of compost applied in 2012. Negro *et al*. (1998) also reported that no residual effect of compost applied in plot experiment of sweet sorghum for three years. Chalk *et al*. (2012) explained that the value of compost as a source of N for a second or subsequent crop in a rotation is quite low. It was only 2-3% of the ^{15}N labelled compost applied to the wheat was recovered by a following crop of barley (Thompsen, 2001). Low recoveries of ^{15}N labelled compost were found in the second and third successive crops of paddy rice (Nishida *et al*., 2008) and vegetables (Ebid *et al*. 2008). There was a direct effect of cattle manure on green ear yield and grain yield of corn, but the residual effect was not significant (Silva, 2004). Observation on the abscence of residual effect of cattle manure on corn grain yield has been done by other researchers (Minhas *et al*., 1994). Sharma *et al*. (1996) and Brar *et al*.(2001) have verified the residual effect of manure on the absorption of nutrients, and that was associated with manure quality, mineralization intensity and utilization by a given crop (L e Silva *et al*., 2006). In the present experiment the absence of residual effect of compost, although it was significant only on bagasse dry weight, was possibly due to low rates of compost causing lower soil nutrient availability to sweet sorghum crop.

3.2 Effects of Variety

The two varieties tested in 2012 (Super Sugar or KCS 105 and Local Belu) were used in the present experiment. Variables of biomass (stem and leaf) FW and bagasse DW were significantly ($P<0.05$) affected by variety (Table 1). The effects of variety were also significant on stem sugar yield, ethanol content, sugar and ethanol production but not on the sugar content (brix) (Table 2).

Table 1. Effect of sweet sorghum variety and rates of compost residues on stem and leaf fresh weight and bagasse dry weight ha^{-1}

Treatments	Stem FW (t ha^{-1})	Leaf FW (t ha^{-1})	Bagasse DW (t ha^{-1})
Variety			
Super Sugar	3.28 ab	1.44 b	0.89 b
Sugar Graze	4.25 a	1.98 a	1.48 a
SG-1A	4.38 a	1.99 a	0.68 c
Local Belu	2.66 b	0.76 c	0.76 bc
5%LSD	0.299*	0.166*	0.174
Rates of compost residues (t ha^{-1})			
0	2.96 a	1.32 a	0.79 c
10	3.41 a	1.58 a	0.89 bc
20	3.94 a	1.55 a	1.01 ab
30	4.26 a	1.79 a	1.12 a
5%LSD	-	-	0.174

Notes: Means followed by the same letters in the same column are not significantly different at 5% LSD. *value at $\sqrt{x+0.5}$ transformation.

3.2.1 Stem, leaf fresh weights and bagasse dry weight

The SG-1A, Sugar Graze and Super Sugar had insignificantly different high stem FW (4.38, 4.25 and 3.28 t ha^{-1} respectively), but only the first two varieties have stem FW significantly 37.97% and 37.41% higher than Local Belu (Table 1). Leaf fresh weight (FW) (1.99 t ha^{-1}) of SG-1A was not significantly different from that of Sugar Graze, however the leaf FW of the two varieties were significantly higher than those of Super sugar and Local Belu. Although the stem FW of SG-1A and Sugar Graze varieties were not significantly different, the bagasse dry weight (DW) of Sugar Graze was respectively 54.05%, 39.86% and 48.65% higher than those of SG-1A, Super Sugar and Local Belu (Table 1). The stem and leaf FW measured in the present experiment were 81.98% and 83.82% lower than those found in the 2012 experiment, in which Super Sugar or KCS105 gave the highest 18.2 t ha^{-1} and 8.9 t ha^{-1} respectively compared to those (3.28 t ha^{-1} and 1.44 t ha^{-1}) produced in the present experiment.

3.2.2 Sugar yield and juice production

Sweet sorghum juice is known to contain different amount of sugars depending on the type of cultivar (Prasad *et al*., 2007). Stem sugar yield of SG-1A variety was the highest (3.70 t ha^{-1}) among varieties although it was not significantly higher than that of Sugar Graze (Table 2). Mutepe *et al.* (1995) reported that Sugar Graze produced the second highest total sugar content among four varieties tested in South Africa. The sugar yield of SG-1A was 35.40% and 51.08% higher than those of Super Sugar and Local Belu respectively. The SG-1A variety also produced the highest (2271.92 l ha^{-1}) juice production (volume of juice) although it was not significantly higher than that of Sugar Graze (Table 2). The juice production of SG-1A variety was higher than those of Super Sugar and Local Belu. Lower soil nutrient availability (due to no compost and other fertilizers application) in the present experiment resulted in lower juice production, which was shown by those of the later varieties (1003.58 l ha^{-1} and 721.03 l ha^{-1}) compared to those (7832.7 l ha^{-1} and 934.5 l ha^{-1}) given by Super Sugar and Local Belu respectively in 2012 experiment (Agung *et al*., 2013). The significantly lower (81.98% and 83.82%) juice production measured in the present experiment (Table 2) compared to those produced in 2012 experiment was associated with lower stem and leaf FW (Table 1). Reddy (2006) reported that ethanol from stalk cane juice of sweet sorghum is 1400 l ha^{-1} which is over that of maize (0 l ha^{-1}), although potential of sweet sorghum to produce ethanol is 5400 l ha^{-1} (Xuan & Tokunaga, 2012).

Table 2. Effect of sweet sorghum variety and rates of compost residues on brix, ethanol content, sugar yield, juice production and ethanol production ha^{-1}

Treatments	Brix	Ethanol content	Sugar yield	Juice production	Ethanol production
	(^{0})	(%)	(t ha^{-1})	(l ha^{-1})	(l ha^{-1})
Variety					
Super Sugar	10.83 a	91.25 ab	2.39 b	1003.58 b	920.41 ab
Sugar Graze	10.83 a	90.70 bc	2.77 ab	1386.13 ab	1257.92 a
SG-1A	11.08 a	91.31 a	3.70 a	2271.92 a	1314.87 a
Local Belu	10.50 a	90.49 c	1.81 b	721.03 b	652.73 b
5%LSD	-	0.561	0.326*	11.711*	7.110*
Rates of compost residues (t ha^{-1})					
0	10.50 a	90.71 a	2.16 a	870.05 a	790.83 a
10	10.83 a	90.96 a	2.52 a	1055.62 a	966.47 a
20	10.75 a	91.08 a	2.93 a	1265.76 a	1152.39 a
30	11.17 a	90.99 a	3.06 a	2191.22 a	1236.23 a
5%LSD	-	-	-	-	-

Notes: Means followed by the same letters in the same column are not significantly different at 5% LSD. *value at $\sqrt{x+0.5}$ transformation.

3.2.3 Sugar content (brix), ethanol content and ethanol production

The sugar contents (brix) of the four varieties were not significantly different (P>0.05) with the average of 10.81 (Table 2). In 2012 expriment, the average brix recorded was 17.25 with the highest brix given by Super Sugar variety (Agung *et al*., 2013). Almodares & Sepahi (1996) reported that brix vary among varieties in the range of 14.32 – 22.35.

The ethanol content of SG-1A variety was the highest (91.31%), but it was not significantly different from that of Super Sugar (Table 2). The SG-1A variety produced 0.66% and 0.89% higher ethanol content than those of Sugar Graze and Local Belu respectively. The SG-1A, Sugar Graze and Super Sugar produced insignificantly different high ethanol production (1314.87, 1257.92 and 920.41 l ha^{-1}) but significantly higher than that produced by Local Belu (Table 2). The ethanol production of the SG-1A variety was 50.36% higher than that of Local Belu. The sugar content measured in the present experiment was 17.25% lower than that recorded in 2012 experiment, in which the highest value (18.9%) was given by Super Sugar or KCS105 and the lowest value (17.4%) was produced by Local Belu variety (Agung *et al*., 2013). The higher sugar content measured in 2012 was associated with higher nutrient available for the crop due to the application of N, P, K and compost fertilizers applied, while in the present experiment there was no fertilizer applied at all. The ethanol contents measured in the present experiment were lower than those found in the 2012 experiment with highest value (94.1%) given by Super Sugar or KCS105 and the lowest value (93.7%) by Local Belu variety. In the 2012 experiment, the highest ethanol production (6493.3 l ha^{-1}) was measured on Super Sugar or KCS105, which was significantly higher than that (1060.1 l ha^{-1}) measured in Local Belu (Agung *et al*., 2013). Results of the present experiment showed that ethanol production under lower soil nutrient availability, due to no fertilizer application, was 85.8% lower than that under adequate soil nutrient availability in 2012. Thus, although sweet sorghum is known able to grow in marginal soil, a balance fertilizer should be applied if high ethanol production is expected.

3.2.4 Relationships between stem FW, sugar yield and ethanol production

The stem FW was linearly related to sugar yield with the regression equation $y= -0.401+0.488 X$; $R^2=0.853^{**}$; $r = 0.924$ (Figure 1) and to ethanol production with the regression equation $y= -0.651+0.837 X$; $R^2=0.805^{**}$; $r = 0.897$ (Figure 2). The relationship between stem FW and juice production found in 2012 experiment was indicated by the regression equation $Y= -299.78+396.98 x$; $R^2=0.955^{**}$; $r=0.977^{**}$ (Agung *et al*., 2013). Those relationships indicated that stem FW is linearly related to components of ethanol production of sweet sorghum.

3.2.5 Soil organic carbon, total N and pH

The effects of variety on soil organic carbon, the total N and pH were not statistically analyzed. Soil organic carbon and the total N measured at the end of experiment varied between treatments and were considered very low (average of 0.795% and 0.098% respectively). Meanwhile soil pH was in the average of 6.0 (Table 3).

Table 3. Soil organic carbon (SOC), total N and pH at harvest

Variety	Rates of compost residues	SOC	Total N	pH
	(t ha^{-1})	(%)	(%)	
Super Sugar	0	0.74	0.08	6.0
	10	0.89	0.09	5.9
	20	0.99	0.07	6.0
	30	0.64	0.09	6.2
Sugar Graze	0	0.87	0.12	5.8
	10	0.35	0.09	6.2
	20	0.75	0.11	6,1
	30	0.81	0.10	6.2
SG-1A	0	0.76	0.09	6.3
	10	0.81	0.10	5.9
	20	0.92	0.11	5.8
	30	0.88	0.10	6.0
Local Belu	0	0.72	0.09	6.9
	10	0.97	0.11	6.0
	20	0.72	0.10	6.0
	30	0.80	0.09	6.0

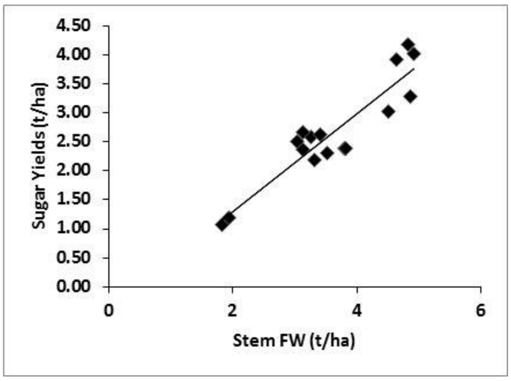

Figure 1. The relationship between stem FW (t ha^{-1}) and sugar yields (t ha^{-1})
$Y = -0.401+0.848 X$; $R^2=0.853^{**}$; $r=0.924^{**}$

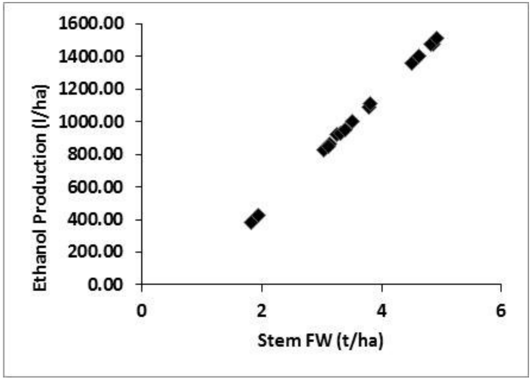

Figure 2. The relationship between stem FW (t ha^{-1}) and ethanol production (l ha^{-1}).
$Y = -0.651+0.837 X$; $R^2=0.805^{**}$; $r=0.897^{**}$

3.3. Effect of interaction between variety and rates compost residues

The interaction effect between the two treatment factors (variety and rates of compost residues) was also not significant (P>0.005) on all parameters measured. This was more due to non-significantly residual effect of compost.

4. Conclusion

The residual effect of compost applied in 2012 experiment did not show any significant effects on both ethanol production of sweet soghum and soil organic carbon in 2013 experiment. The C-organic and total N in the soil measured at harvest 2013 were mostly low (<1% and <0.1% respectively). The effect of variety was significant on biomass (stem, leaf and bagasse) FW, sugar yield, ethanol content, sugar and ethanol production (l ha^{-1}). The SG-1A had significantly higher stem and leaf FW and bagasse Dw than Local belu variety, but was not significantly different from those of Sugar Graze and Super Sugar (KCS105). The SG-1A and Super Sugar produced the highest stem ethanol content (91.31% and 91.25%), but high etanol productions (1314.87, 1257.92 and 920.41 l ha^{-1}) were produced by SG-1A, Sugar Graze and Super Sugar respectively. The lowest ethanol content (90.49%) was produced by Local Belu, which was not significantly different from that of Super Sugar variety. There were linear relationships (with R^2 = 0.853** and 0.805**) between stem FW and sugar yield and ethanol production respectively. Results of the experiment indicated that high etanol production could not be expected from the residual effect of compost moreover with no other fertilizers applied particularly under low soil fertility condition.

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