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Effect of Integrated Nutrient Use on the Energetics and Economics of Sugarcane Production in Negros, Philippines

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ABSTRACT

Sound management of soil nutrients is necessary in improving the productivity of sugarcane monoculture. Different fertilizers have advantages and limitations, thus, it is imperative to frame out a strategy for the judicious combination of these nutrient sources. This study determined the effect of using organic amendments and microbial inoculant on the energetics and economics of sugarcane production under acid upland soil. Field experiment involving twelve treatments using 'Phil 2004-1011' sugarcane variety was carried in acid Typic Hapludand soil. The recommended N rate (RR_N) was reduced to 75, 50 and 25% with subsequent application of mudpress to satisfy the full N recommendation.

Bagasse ash and microbial inoculant were used to supplement the nutrient sources. Reducing the recommended N rate with subsequent application of mudpress, bagasse ash and microbial inoculant produced the highest cane and sugar yield. Application of 25% RR_N from inorganic fertilizer + 75% RR_N from mudpress + bagasse ash + microbial inoculant had the highest energy efficiency and cane yield per joule. Utilization of 50% RR_N IF: 50% RR_N MP + BA + MI produced the most sugar yield per joule. Better return on investment and benefit-cost ratio were obtained from the application of 50% RR_N from inorganic fertilizer: 50% RR_N from mudpress. In conclusion, the combined use of inorganic, organic, and biofertilizers can improve cane yield and energy efficiency. Integrated use of inorganic and organic fertilizers can increase economic efficiency.

Keywords — Agronomy and soil fertility, integrated nutrient use, experimental design, Philippines

INTRODUCTION

Strategies to increase the productivity of small sugarcane farms are vital for developing the Philippine sugarcane industry as a whole. In upland areas where sugarcane is monocropped, intensive cultivation without addition of nutrients and organic matter to the soil is considered to be a contributor to the widespread occurrence of acid upland soils (NAP, 2004). Better use of available inputs by rationalizing the use of NPK, especially N fertilizer could increase output of sugarcane farmers (Padilla-Fernandez & Nuthall, 2009). Fertilizer is an inevitable input in sugarcane production which when properly calibrated and timed can provide essential nutrients toward achieving high yields (McCray & Mylavarapu, 2010).

Inorganic fertilizer has been widely utilized because of its immediate effect, availability and easy handling. However, the negative environmental impact and soaring cost of inorganic fertilizer became a public concern. On the other hand, mudpress or filter cake as a waste product has great potential to supply nutrients in addition to its favorable effects on physico-chemical and biological properties of soil (Shankaraiah & Murthy, 2005). Boiler or bagasse or mill ash is one of the wastes obtained from sugar mill during the process of sugar manufacturing. The sugarcane pulp or bagasse is burned under boilers for heating the juice. The material left after the burning of bagasse is ash, which is rich in K_2O and may then be used as fertilizer (Cosico, 1985). Ash can also be a valuable amendment

(Hackett, Easton & Duff, 1999). To enhance the effect of organic fertilizers in soil properties, microbial inoculant is used which is a promising tool by which synthetic fertilizer use might be decreased in the cultivation of sugarcane (Villegas & Paterno, 2008).

The complete substitution of inorganic fertilizers with organic fertilizers is not possible to fulfill the large crop nutrient demand (Chatterjee, Bandyopadhyay, & Jana, 2014). Therefore, it is inevitable to frame out a strategy for judicious combination of sources of nutrients, which will not only augment the efficiency of both the sources, but will also minimize the ill effect of over use of chemicals. For sustainable sugarcane production, it is not just neither chemical fertilizers nor organic manures alone, but their integrated use has been observed to be highly beneficial (Shankaraiah & Murthy, 2005).

While sugarcane, a high-yielding, perennial C4 crop species, remains to be the cheapest source of caloric energy food, it also requires huge amounts of energy to grow in the farm (Mendoza, Samson & Helwig, 2001) and process the cane in the mill (Corpuz & Aguilar, 1990). This is because, unlike many other tropical upland crops grown in the Philippines, sugarcane production and cane stalk processing in the mill are machine-dependent (Mendoza & Samson, 2002). This makes sugarcane production a subject for many energy analysis today.

This paper aimed to establish the effect of using organic amendments and microbial inoculant on the cane and sugar yield, as well as on the energetics and economics of sugarcane production under acid upland soil.

MATERIALS AND METHODS

A field experiment in Randomized Complete Block Design was established in an acid upland soil classified as Typic Hapludand (Carating, Galanta & Bacatio, 2014) in Isabela, Negros Occidental (10^0 10.101' N, 122^0 59.223' E). The twelve treatments employed were: T1 – Control (no fertilizer application), T2 - Recommended rate (RR_N) at 140-105-520 kg N-P_2O_5-K_2O ha^{-1} using inorganic fertilizer (IF), T3 - RR_N + lime, T4 - 75% RR_N IF:25% RR_N MP, T5 - 75% RR_N IF:25% RR_N MP + BA, T6 - 75% RR_N IF:25% RR_N MP + BA + MI, T7 - 50% RR_N IF:50% RR_N MP, T8 - 50% RR_N IF:50% RR_N MP + BA, T9 - 50% RR_N IF:50% RR_N MP + BA + MI, T10 - 25% RR_N IF:75% RR_N MP, T11 - 25% RR_N IF:75% RR_N MP + BA, and T12 - 25% RR_N IF:75% RR_N MP + BA + MI. Before application, soil amendments such as mudpress and bagasse ash were analyzed for NPK content (Table 1). The amount of mudpress used to satisfy the remaining recommended N rate was computed based on its total N content. Bagasse ash was applied at 10 t ha^{-1}. BioGroe™ was used as microbial inoculant which contains plant growth promoting bacteria. Except for the control, all treatments received the same amount of inorganic fertilizer P (105 kg P_2O_5 ha^{-1}) and K (520 kg K_2O ha^{-1}).

Table 1. Nutrient analysis of sugar mill wastes used as organic amendments.

Amendment	%N	$\%P_2O_5$	$\%K_2O$
Mudpress	0.55	0.22	0.22
Bagasse ash	0.02	0.22	1.40

Phil 2004-1011 sugarcane variety was planted in 20m x 8m plots. The cultural and management procedures for sugarcane production as provided in Sugar Regulatory Administration Sugarcane Production Manual (SRA-OPSI, 2004) were followed. Cane and sugar yield were taken at harvest.

For energetics, data on the duration of each farm operation and the quantities of each input (machinery, fuel, fertilizers, pesticides, irrigation water, labor, and sugarcane stem cuttings) were recorded and entered into Excel spreadsheets. All inputs were converted to energy units using the energy coefficients adapted from several published literature applicable to Philippine setting.

To come up with the total energy supplied (input), direct and indirect energy quantities were calculated. According to M. S. Alam, M. R. Alam and Islam (2005), direct energy covers human and animal labor, and fuel used in the sugarcane production while indirect energy includes energy embodied in sugarcane stem cuttings, fertilizers, pesticides and machinery. The following formulas were used to compute for energy inputs:

$$\text{Total Energy Input} = DEI_{\text{fuel}} + DEI_{\text{human}} + DEI_{\text{animal}} + IEI_{\text{stem cuttings}} + IEI_{\text{fertilizers}} + IEI_{\text{pesticides}} + IEI_{\text{irrigation}} + IEI_{\text{tractor}} + IEI_{\text{machine}} + \text{solar energy incident}$$

Energy output, the energy generated from the products (sugarcane stalks, cane points, and cane trash), was computed using this formula:

$$\text{Total Energy Output} = EO_{\text{sugarcane stalks}} + EO_{\text{cane points}} + EO_{\text{trash}}$$

Then, energy analysis of sugarcane production was done by determining the energy efficiency and energy productivity using the formula of Karimi, Rajabi Pour, Tabatabaeefar and Borghei (2008) and Mendoza and Samson (2002):

$$\text{Energy efficiency} = \frac{Energy\ generated\ (output)}{Energy\ supplied\ (input)}\ x\ 100$$

$$\text{Energy productivity} = \frac{Sugarcane\ output}{Energy\ supplied\ (input)}$$

Evaluation of the financial viability of the different treatments was done by accounting for the gross return, total cost, and net income considering all activities made, resources employed and materials used. The economics of production was determined by computing the benefit-cost ratio (BCR) and return on investment (% ROI) using the formula:

$$\text{Benefit-cost ratio} = \frac{Gross\ value\ of\ production}{Total\ cost\ of\ production}$$

$$\text{Return on Investment (\%)} = \frac{Net\ Profit}{Total\ Expenses}\ x\ 100$$

RESULTS AND DISCUSSION

Cane yield

It is shown in Table 2 that the application of inorganic fertilizers (IF), mudpress (MP), bagasse ash (BA) and microbial inoculant (MI) significantly affected the cane yield. Plots fertilized with 25% RR_N IF: 75% RR_N MP + BA + MI produced the highest cane yield of 120.24 TC ha^{-1}. Likewise, comparably high cane yields were obtained from plots applied with the following fertilizer combinations: 50% RR_N IF: 50% RR_N MP + BA + MI, 25% RR_N IF: 75% RR_N MP + BA, 75% RR_N IF: 25% RR_N MP + BA + MI, 25% RR_N IF: 75% RR_N MP, 50% RR_N IF: 50% RR_N MP + BA, 50% RR_N IF: 50% RR_N MP. Although most of the fertilized and amended treatments can be characterized as high tonnage (100 TC ha^{-1} and above cane yield), the yield obtained from this experiment is lower from the average yield recorded in 4 locations (SRA, 2014).

Results obtained from this study conform to the report of Chatterjee et al. (2014) where yield attributing characters were significantly influenced by the combined application of inorganic, organic, and biological sources of nutrients. Also, increasing application of mudpress resulted to increasing cane yield of sugarcane (Bangar, Parmar, & Maini, 2000; Tiwari & Nema, 1999; Quilloy, 1983 as cited in SRA-OPSI, 2004).

The positive effect of microbial inoculant in improving yield characters of sugarcane supports the findings of Sundara, Natarajan and Hari (2002). Application of plant growth promoting rhizobacteria (PGPR) improved crop yield through the increase in the availability of nutrients in the rhizosphere, solubilization of phosphates, production of siderophore which helps facilitate the transport of certain nutrients (notably iron), and positive effects on root growth and morphology (Vessey, 2003). Another mode of action of some PGPR was the production of 1-aminocyclopropane-1-carboxylate (ACC) deaminase, an enzyme which could cleave ACC, the immediate precursor to ethylene in the biosynthetic pathway. ACC deaminase activity would decrease ethylene production in the roots of host plants and result in root lengthening (Glick, Penrose & Li, 1998).

Table 2. Cane and sugar yield of Phil 2004-1011 sugarcane variety applied with inorganic fertilizer, organic amendments, and microbial inoculant in an acid upland soil

Treatments	**Cane Yield ($TC\ ha^{-1}$)** **	**Sugar Yield ($LKg\ ha^{-1}$)** **
T1 - Control (no fertilizer application)	69.73e	126.41d
T2 - RR_N IF	93.27d	185.58c
T3 - RR_N IF + lime	99.39cd	208.10bc
T4 - 75% RR_N IF: 25% RR_N MP	105.08bcd	220.81ab
T5 - 75% RR_N IF: 25% RR_N MP + BA	105.39bcd	218.74ab
T6 - 75% RR_N IF: 25% RR_N MP + BA + MI	114.39ab	235.34ab
T7 - 50% RR_N IF: 50% RR_N MP	107.76abc	226.74ab
T8 - 50% RR_N IF: 50% RR_N MP + BA	110.04abc	232.25ab
T9 - 50% RR_N IF: 50% RR_N MP + BA + MI	117.09ab	240.13a
T10 - 25% RR_N IF: 75% RR_N MP	110.95abc	216.89ab
T11 - 25% RR_N IF: 75% RR_N MP + BA	116.85ab	222.57ab
T12 - 25% RR_N IF: 75% RR_N MP + BA + MI	120.24a	235.83ab

***=highly significant; CV (cane yield) =6.61; CV (sugar yield) = 6.79; means having same letter are not significantly different at the 5% level by DMRT*

Sugar yield

The application of inorganic fertilizer, organic amendments, and microbial inoculant significantly influenced sugar yield (Table 2). Highest sugar yield of 240.13 LKG ha^{-1} was obtained from plots applied with 50% RR_N IF: 50% RR_N MP + BA + MI. However, the results indicated no significant difference among sugar yields obtained from plots applied with MP, BA and MI as soil amendments. Relatively low sugar yields were produced by crops fertilized with RR_N IF and those applied with lime.

Application of phosphorus solubilizing bacteria improved juice quality and sugar yields (Sundara et al., 2002). As to the impact of nitrogen fertilization on quality of sugarcane, juice quality declined beyond the application of N at 195.5 kg ha-[1] (Hemalatha, 2015). Probably with increased dose of N, there is an increased activity of enzymes which is responsible for degradation of sucrose and changing it into glucose and fructose (Singh & Mohan, 1994).

Energetics of Production

Energy analysis accounts for the magnitude of energy used and generated in the course of sugarcane production. It considers both the direct and indirect energy inputs, while energy output was derived from energy generated through sugarcane stalks, cane points, and trash.

Table 3 shows that the highest energy used (63,383,390 MJ ha^{-1}) and highest energy generated (2,479,468.853 MJ ha^{-}1) were recorded from plots applied with 25% RR_N IF: 75% RR_N MP + BA + MI. Since minimal farm input and operations were involved, the control treatment (unfertilized plot) registered the lowest energy expenditure (63,028,714 MJ ha^{-1}) and lowest energy output (1,417,189.432 MJ ha^{-1}).

It is also manifested that application of 25% RR_N IF: 75% RR_N MP + BA + MI was the most energy efficient treatment (3.91%) and the most energy productive in terms of producing 1.90 ton cane per joule used. Likewise, application of 50% RR_N IF: 50% RR_N MP + BA + MI was found to be the most energy productive treatment in terms of generating 3.79 LKg sugar per joule used. Control treatments where no fertilizer and amendments were applied appeared to be the least energy efficient and least energy productive both in terms of cane and sugar production.

Economics of Production

The highest expense of 175,319.20 Php ha^{-1} was incurred when using 25% RR_N IF: 75% RR_N MP + BA + MI (Table 4). This cost consisted of 56% due to farm labor, 38% due to farm inputs and 6% due to land rental. The lowest cost of 85,004.25 Php ha^{-1} was spent in the control treatment.

In terms of gross income, the highest total return amounting to 258,117.96 Php ha^{-1} was recorded from the application of 50% RR_N IF: 50% RR_N MP + BA + MI, while the least total revenue of 136,648.12 Php ha^{-1} was obtained from the unfertilized and unamended treatment. This result basically followed the trend obtained from sugar yield data being the most significant economic output of sugarcane production.

Net income accounting which reflects the difference between total returns and total costs revealed that the highest net gain of 102,982.16 Php ha^{-1} was derived from the application of 50% RR_N IF: 50% RR_N MP + BA. The lowest net income of 51,643.87 Php ha^{-1} was obtained from unfertilized and unamended plot.

Return on investment (ROI) describes the ratio of net income to total expenses. Highest ROI value of 72.55 was derived from the application of 50% RR_N IF: 50% RR_N MP. This means that as much as 72 pesos can be gained for every peso investment when using this fertilizer combination. The lowest ROI value of 33.68 was recorded from the application of RR_N IF + lime, indicating that among the treatments, this was the least profitable.

As to the benefit-cost ratio (BCR), the same findings were obtained with that of ROI computation. Since higher BCR value means more benefits or revenues than cost or expenses, this indicates a more profitable venture. The highest benefit-cost ratio of 1.73 was accounted from the application of 50% RR_N IF: 50% RR_N MP. Use of RR_N IF + lime in sugarcane resulted to the lowest BCR value of 1.34 which signifies the least profitable treatment. An investigation on the impact of N fertilization on quality of sugarcane under fertigation reported a BCR value of as high as 3.63 (Hemalatha, 2015).

Table 3. Energy analysis of sugarcane production applied with inorganic fertilizer, organic amendments and microbial inoculant in an acid upland soil.

TREATMENTS	TOTAL INPUT ENERGY (MJ ha^{-1})	TOTAL OUTPUT ENERGY (MJ ha^{-1})	ENERGY EFFICIENCY (%)	ENERGY PRODUCTIVITY	
				Cane Yield (t J^{-1})	Sugar Yield (LKg J^{-1})
T1 - Control (no fertilizer application)	63,028,714	1,417,189.432	2.25	1.11	2.01
T2 - RR_N IF	63,065,736	1,926,477.385	3.05	1.48	2.94
T3 - RR_N IF + lime	63,074,389	2,064,269.602	3.27	1.58	3.30

TREATMENTS	TOTAL INPUT ENERGY (MJ ha^{-1})	TOTAL OUTPUT ENERGY (MJ ha^{-1})	ENERGY EFFICIENCY (%)	ENERGY PRODUCTIVITY	
				Cane Yield (t J^{-1})	Sugar Yield (LKg J^{-1})
T4 - 75% RR_N IF: 25% RR_N MP	63,171,014	2,179,856.930	3.45	1.66	3.50
T5 - 75% RR_N IF: 25% RR_N MP + BA	63,173,641	2,272,915.703	3.60	1.67	3.46
T6 - 75% RR_N IF: 25% RR_N MP + BA + MI	63,176,568	2,381,586.987	3.77	1.81	3.73
T7 - 50% RR_N IF: 50% RR_N MP	63,274,357	2,246,968.050	3.55	1.70	3.58
T8 - 50% RR_N IF: 50% RR_N MP + BA	63,277,381	2,306,751.121	3.65	1.74	3.67
T9 - 50% RR_N IF: 50% RR_N MP + BA + MI	63,280,013	2,432,875.464	3.84	1.85	3.79
T10 - 25% RR_N IF: 75% RR_N MP	63,377,691	2,308,794.483	3.64	1.75	3.42
T11 - 25% RR_N IF: 75% RR_N MP + BA	63,381,190	2,405,518.190	3.80	1.84	3.51
T12 - 25% RR_N IF: 75% RR_N MP + BA + MI	63,383,390	2,479,468.853	3.91	1.90	3.72
Mean	**63,222,007**	**2,201,889.350**	**3.48**	**1.67**	**3.39**

Table 4. Cost and return analysis of Phil 2004-1011 sugarcane variety applied with inorganic fertilizer, organic amendments and microbial inoculant in an acid upland soil.

TREATMENTS	TOTAL COSTS (Php)	TOTAL RETURNS (Php)	NET INCOME (Php)	RETURN ON INVESTMENT	BENEFIT-COST RATIO
T1 - Control (no fertilizer application)	85,004.25	136,648.12	51,643.87	60.75	1.61
T2 - RR_N IF	131,396.65	200,053.28	68,656.63	52.25	1.52
T3 - RR_N IF + lime	167,075.60	223,339.02	56,263.42	33.68	1.34
T4 - 75% RR_N IF: 25% RR_N MP	138,370.25	236,771.31	98,401.06	71.11	1.71
T5 - 75% RR_N IF: 25% RR_N MP + BA	142,493.25	234,819.31	92,326.06	64.79	1.65
T6 - 75% RR_N IF: 25% RR_N MP + BA + MI	169,980.30	252,783.34	82,803.04	48.71	1.49
T7 - 50% RR_N IF: 50% RR_N MP	140,870.90	243,067.03	102,196.13	72.55	1.73

TREATMENTS	TOTAL COSTS (Php)	TOTAL RETURNS (Php)	NET INCOME (Php)	RETURN ON INVESTMENT	BENEFIT-COST RATIO
T8 - 50% RR_N IF: 50% RR_N MP + BA	145,894.20	248,876.36	102,982.16	70.59	1.71
T9 - 50% RR_N IF: 50% RR_N MP + BA + MI	172,722.85	258,117.96	85,395.11	49.44	1.49
T10 - 25% RR_N IF: 75% RR_N MP	143,286.15	233,797.51	90,511.36	63.17	1.63
T11 - 25% RR_N IF: 75% RR_N MP + BA	149,329.30	239,935.00	90,605.70	60.68	1.61
T12 - 25% RR_N IF: 75% RR_N MP + BA + MI	175,319.20	254,379.81	79,060.61	45.10	1.45
Mean	**146,811.91**	**230,215.67**	**83,403.76**	**57.73**	**1.58**

CONCLUSION

The use of mudpress, bagasse ash, and microbial inoculant significantly enhanced the cane and sugar yield of sugarcane. Reducing the recommended N rate up to 75% with subsequent application of mudpress, bagasse ash, and microbial inoculant can improve cane and sugar yield through timely release of nutrient with crop demand. Likewise, the combined use of inorganic, organic, and biofertilizers can improve energy efficiency. Integrated use of inorganic and organic fertilizers can increase economic efficiency. Thus, integrated nutrient management is recommended for sustainable, energy-efficient and economically feasible sugarcane production.

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