

Energy Productivity and Efficiency of Lowland Rice (Var. PSB Rc18) Under Various Organic Nutrient Sources and Quantum Enhancers

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ABSTRACT

Energy analysis is not usually given much emphasis in crop production despite the latter's huge dependence on oil and fuel. This study was conducted for two cropping seasons to assess whether the use of various nutrient sources can increase yield, energy productivity, and use efficiency of lowland rice (PSB Rc18). All production inputs and activities were accounted and energy analysis was done using energy coefficients adopted by previous researchers. Parameters on grain yield, energy expenditures, energy productivity, efficiency, and intensity were taken. Rice applied with organic fertilizer from unenhanced composted cow manure (UECM) yielded significantly higher by 61% and 18 % than the untreated control and the full inorganic treatment, respectively. Quantum and organic nutrient sources spent 69.18-71.79 liter diesel oil equivalent (LDOE) ha⁻¹ which is 2-3 times lesser than the use of sole inorganic or combined with organic nutrient sources (142.13-225.74 LDOE ha⁻¹), thus giving significantly higher energy productivity and efficiency. Unenhanced composted cow manure was the most productive and efficient in terms of energy use by 1.59 and 3.73 times over the control and full inorganic treatment, respectively. Energy spent to produce a ton of unmilled rice was markedly reduced by 53% from organic fertilization due to lower energy intensities (15.95-25.16 LDOE t⁻¹ grain) than inorganic treatments (36.50-60.89 LDOE t⁻¹ grain). Hence, at this time of energy crisis and climate change, organic farming which includes use of quantum enhancers is a potential option in improving energy resource effectiveness of PSB Rc18.

Keywords: energy expenditure, productivity, efficiency and intensity, organic farming, and quantum enhancers

INTRODUCTION

The unstable energy cost really affects the current food production system. This is because most if not all of the field management operation and practices rely greatly on the use of fuel and oil. However, energy analysis is not given much emphasis in most crop production systems. Rahman and Barmon (2012) stressed the great importance of energy analysis in crop production since energy is being

utilized not only in farm machineries, human or draft animal power, electricity and diesel but also in the manufacture of fertilizers and pesticides. Rice production in particular is not an exception. It involves several energy spending activities that production techniques, which are resource efficient and with less energy expenditures, need to be looked into.

Organic, diversified and integrated farming systems (Mendoza, 2008), or with sustainable agricultural movement (Perlas, 1993 and Zamora, 1996), time tested approaches (Fernandez, 2000 and 2001) such as biodynamic farming, agrihotra among others are some ways to minimize cost and improve energy efficiency. This can also be done by reducing or eliminating the oil-base energy inputs in the production activities. The use of quantum enhancers such as BD 500 or Agrihotra ash is known to have a wide range of impact and multi dimensional effects (Steiner, 2005 and Wildfeuer, 2006). Even if it is applied at a very small amount, the mechanism lies more on the realm of subtle energy, where a close alignment of the non-physical world with physical reality exists (Perlas 1993, Dimaporo and Fernandez 2007). Accordingly, it acts fast even with a very small amount of substance applied. Variable results have been obtained with the effects of biodynamic preparations but in some they stimulated life both in soil and plants by improving soil quality, but lowering yield with greater net income than their conventional counterparts. On the other hand, agrihotra ash has positive energies that destroy negative energies thus help purify the atmosphere.

Growing rice with less input on energy, chemical fertilizer or through organic/alternative approaches coupled with appropriate management strategies may enhance yield and productivity without harming the environment. Mendoza (2010) stressed the importance of ecologically sound and organic-chemical-free production practices as they will not only restore degraded soil and prevent environmental pollution from greenhouse gases but also lessen farmers' financial burden in adopting oil-dependent production venture. Often the conventional production system spent higher overall energy input than the organic production system due to its heavy reliance on energy intensive fertilizers and chemicals (Ziesemer 2007; Kaltsas *et al.*, 2007). In plantation crops, organic farming indicated lower energy consumption thus improved energy productivity and efficiency as well as lessened greenhouse gas emission than the conventional practice (Gundogmos 2006, Ziesemer 2007, Kaltsas *et al.*, 2007 and Kavargiris *et al.*, 2009). In sugarcane, Egle and Mendoza (2013) found that farm inputs accounted 42% of the total energy costs with urea getting the highest expenditure (93.7%). They found highest energy efficiency (6.87) when no N fertilizer was applied while lowest (4.21) when N fertilizer was applied at 300 kg ha⁻¹ + Bio-N®. In lowland rice, Bockari-Gevao (2005) in his study on different tillage systems also found that the total energy inputs spent excluding irrigation energy was 12,225,97 MJ ha⁻¹ with fertilizer and fuel use as the greatest energy consumer ha⁻¹ amounting to 63.2 % and 22.2%, respectively. While Hering (2006) reported a specific energy used by paddy rice at 5.87 MJ kg⁻¹, Nassiri and Singh (2009) likewise found electricity, fertilizer, and chemicals to constitute 72.8% of the total energy inputs. However, from production to the supermarket, Blengini and Busto (2009) stated that for a kg of white milled rice, it consumed 17.8 MJ of energy and 4.9 m³ of water and emitted 2.9 kg of CO₂.

This concern is getting more relevant in the Philippines being beset with climatic changes and instability of fuel prices which usually goes up than down. As a limited resource, the use of fossil energy must be efficiently used if not conserved to minimize CO₂ emission. Ziesemer (2007) stated that with low energy inputs as in organic systems, it has less green house gas emission but with greater potential to sequester carbon in biomass than in conventional systems. Effective energy use thereby leads to a sustainable crop production as this implied financial savings, preserved fossil resources, and reduced air pollution (Banaeian *et al.*, 2010). There is a need to assess the yield, energy use, intensity, productivity, and efficiency of growing lowland rice (PSB Rc18) with various nutrient applications, hence this study.

MATERIALS AND METHODS

Soil Sampling and Analysis

Composite soil samples were taken from the experimental area prior to land preparation at a depth of 0-20 cm. These were processed and analyzed at the Soils Research Testing and Plant Analysis Laboratory (SRTPAL) of the Dept. of Agronomy and Soil Science and at Central Analytical Services Laboratory (CASL), VSU, Visca, Baybay, Leyte for soil pH, organic matter, total N, extractable P, and exchangeable K. Another set of soil samples were collected from each treatment plot every after harvest for the analysis of the aforementioned parameters. The experimental site had a pH of 5.53, 3.30% OM, 0.22% N, 2.46 and 199.35 mg kg⁻¹, extractable P and exchangeable K, respectively. This soil is strongly acidic, has medium amounts of organic matter, available N, and exchangeable potassium but with very low extractable P (Landon, 1991).

Experimental Design and Treatments

The experiment was conducted for two cropping seasons in Bryg. Pangasugan, Baybay City, Leyte. It was laid out in Randomized Complete Block Design (RCBD) with three replications with plots measuring 3.75 m x 5 m and with 1.0 m alleyway between replications and treatment plots. The nutrient sources and time of application of the various treatments are shown in Table 1.

Chemical fertilizers such as urea (45% N), solophos (20% P₂O₅), and muriate of potash (60% K₂O) were used in T₂, T₃, T₄, and T₅ where all of the P, ½ of K and 1/3 of N were applied prior to transplanting while the remaining amount of N was equally sidedressed one month after transplanting and at panicle initiation. For cow manure (unenanced composted or enhanced composted), the actual amount applied was based on dry weight basis at 5 tons ha⁻¹ and incorporated into the specified plots two weeks before transplanting. While cow manure was procured at the same time, unenhanced composting implied that the material just underwent natural composting for 3 weeks while composting in T₇, T₈ and T₉, was enhanced by sprinkling indigenous microorganism (IMO) at the rate of 1 L in 50 L water per 1000 kg cow manure, mixed or turned weekly and allowed to decompose for three weeks. After this period, the enhanced composted materials were already decomposed thus easy to handle while the unenhanced ones were not yet fully decomposed and still had foul odor.

Table 1. Treatment description and time of application.

Treatments	Description	Time Of Application
T ₁	Control (no fertilizer applied)	
T ₂	Full rate chemical fertilizer (70-60-30 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹)	Applied before transplanting, at 1month after transplanting and at panicle initiation
T ₃	Half rate chemical fertilizer (35-30-15 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹ + 5 t ha ⁻¹ Composted cow manure (CCM)	Inorganic fertilizer applied similar to T ₂ while CCM was applied 2 weeks before transplanting
T ₄	Half rate chemical fertilizer (35-30-15 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + 25 g ha ⁻¹ BD 500	Inorganic fertilizer applied similarly to T ₂ while Biodynamic (BD) 500 applied at transplanting and seedlings were dipped in BD 500 solution before transplanting
T ₅	Half rate chemical fertilizer (35-30-15 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + 30 g ha ⁻¹ Agnihotra ash (Aash)	Inorganic fertilizer applied similar to T ₂ while Aash at transplanting
T ₆	5 t ha ⁻¹ unenhanced composted cow manure (UECCM) for 3 weeks	2 weeks before transplanting
T ₇	5 t ha ⁻¹ enhanced composted cow manure (ECCM)	2 weeks before transplanting
T ₈	5 t ha ⁻¹ ECCM + 25 g ha ⁻¹ BD 500	ECCM was applied 2 weeks before transplanting; BD 500 applied at transplanting and seedlings were dipped to BD 500 solution before transplanting
T ₉	5 t ha ⁻¹ ECCM + 30 g ha ⁻¹ Agnihotra ash (Aash)	CCM applied 2 weeks before transplanting;Aash at transplanting
T ₁₀	4 L ha ⁻¹ Indigenous microorganism (IMO)	At final land preparation
T ₁₁	25 g ha ⁻¹ BD 500 alone	Prior to transplanting and seedlings were dipped to BD500 solution before transplanting
T ₁₂	30 g ha ⁻¹ Agnihotra ash alone	Prior to transplanting, 15 and 30 days after transplanting

BD 500 and Agnihotra ash were considered quantum enhancers. These were applied at very small quantity since both were expected to have fast, wide range and multi dimensional effects being part of a science based on life forces (Steiner 2005, Wildfeuer 2006). BD 500 is one preparation of biodynamic farming obtained from Don Bosco Youth Center, Makilala, North Cotabato. This was derived from cow dung placed inside a cow horn and buried under the soil for 6 months. Previous research results showed that some preparation promoted soil quality by improving soil microbial properties and crop root growth. Lower yield was obtained but in terms of profitability it is equal or higher than the conventional practice (Reganold 1995; Jayasree and George 2006). On the other hand, Agnihotra ash was obtained by burning dried cow dung and ghee (unsalted clarified butter) plus brown rice grains in a copper pyramid while the mantra was sung during exact sunrise or sunset time. Prior to application, both quantum

enhancers were separately stirred vigorously in water to form a deep vortex for 5 minutes, reversed and repeated 4 times for 20 minutes. The potentized solution was sprayed once into the soil prior to transplanting (Valdez and Fernandez 2008; Don Bosco Youth Center, Inc. Undated) while the potentized ash was allowed to stand for 3 days (Angeles, 2008) before spraying. Rice seedlings in the BD 500 treatments were also dipped in BD 500 solution before transplanting. This preparation as a product of Homa therapy will help clean polluted atmosphere due to its positive energy (Paranjpe, 2010). Indigenous Microorganism (IMO) was prepared from cooked rice which was allowed to develop molds under a shady place for three days then fermented with sugar at 1:1 ratio for 1 week and filtered. The filtrate was mixed in a desired quantity of water at the rate of 4 L ha⁻¹ and sprayed to the soil during final land preparation.

Seedbed Preparation and Transplanting

Rice seedlings were raised following a modified dapog method where pre-germinated seeds of PSB Rc18 were sown in a winow lined with banana leaves and placed with about an inch of topsoil. Seedlings were allowed to germinate and were transplanted 12 days after sowing at 2 seedlings hill⁻¹ at a distance of 25 cm x 25 cm. Missing hills were replanted 5 days after transplanting. The newly transplanted area was drained with water for 3 days to minimize golden apple snail infestation.

Care and Management

Irrigation water was applied four days after transplanting and was maintained to a depth of 2-3 cm thereafter until two weeks prior to harvest. Golden snail was controlled by releasing ducks one week before transplanting and by handpicking thereafter. Rotary weeding was done 10 days after transplanting and two weeks thereafter. Weeds within the hill were removed by handweeding. Rice plants were sprayed with fresh milk and honey (400 mL carabao fresh milk and 150 mL honey ha⁻¹) at 10 days interval between the vegetative to heading stages. This preparation was known to help increase natural enemies of insects and relieve stress of plants (Valdez and Fernandez, 2008; Don Bosco Diocesan Youth Center, Inc.; undated).

BD 508 which was derived from fresh silica-rich horsetail was sprayed three times during the vegetative phase to prevent fungal diseases as well as tungro infection. Fresh horsetail at the rate of 4 cups ha⁻¹ was cut into smaller pieces, pounded and soaked overnight in water prior to its application. For the full chemical treatment (T₂), Karate (50 g L Lambda cyhalotrin) was sprayed at 14 days after transplanting and at 10-day interval during the entire vegetative phase and at heading stages at the rate of 2 tbs per 16 L water.

Harvesting

This was done when 90% of the grains in the panicles had ripened. The grains were threshed, cleaned and sundried to 14% MC before weighing.

Energy Accounting

The procedures in energy analysis and the energy coefficients of the materials used and activities done were based from the handbook of Pimentel (1980) and from relevant literatures of Mendoza (2007), Mendoza and Samson (2002), and that one adopted by Bocari-Gevao (2005) and Egle and Mendoza (2013). All production inputs such as fuel, fertilizers, pesticides, seeds, etc. were recorded and all activities from land preparation to harvesting and post harvest operation such as threshing and drying were properly accounted.

The specific energy used (e.g. for fuel) per hectare for a specific field operation was computed by multiplying the average fuel use by its energy coefficient as follows:

$$DE = AFU \times EC$$

where:

DE = Specific direct energy use (fuel) for a field operation, Mcal ha^{-1}

AFU = Average fuel use per working hour, l ha^{-1}

EC = Specific energy value per liter of fuel, Mcal l^{-1}

For machinery, this equation was the basis (Moerschner and Gerowitz 2000 as cited by Bochari-Gevao *et al.*, 2005):

$$EID = TW \times \frac{EC}{LS} \times h \times RU$$

where:

EID = specific indirect energy for machinery use for a field operation, Mcal ha^{-1}

TW = total weight of the specific machine, kg

EC = energy coefficient of a specific machinery, Mcal kg^{-1}

LS = life span of machinery

h = number of hours in operation

RU = number of runs

The indirect energy per unit area for production inputs such as fertilizers, seeds, and other materials was expressed as:

$$EI = \text{Rate} \times EC$$

where:

EI = indirect energy input, Mcal ha^{-1}

Rate = application rate of input, kg ha^{-1}

EC = energy coefficient of material used, Mcal kg^{-1}

The energy values of the following direct fossil fuel based energy inputs were taken from published literatures of Pimentel (1980); Pimentel *et al.* (1983); Cox and Atkins (1979); Mendoza (2005) and Egle and Mendoza (2013) as follows: for chemical fertilizer: N= $24.54 \text{ Mcal kg}^{-1}$; P= $2.30 \text{ Mcal kg}^{-1}$; K = $1.60 \text{ Mcal kg}^{-1}$; Pesticides= 99.9 Mcal L^{-1} ; Diesel oil= $10.109 \text{ Mcal l}^{-1}$; and Machinery = 18 Mcal kg^{-1} . For the indirect fossil fuel energy based inputs, labor energy value at $0.303 \text{ Mcal hr}^{-1}$ (Kuether and Duff 1980 as cited by Mendoza 2005) and rice grain energy value at

4.0 Mcal kg⁻¹ at 12% moisture content (Mendoza 2005). The labor energy input for each operation in rice production was estimated using the following:

$$LE = \frac{M \times TIME}{AREA} \times LEF$$

where:

- LE = Labor energy, Mcal ha⁻¹
- M = Number of man days working hours
- TIME = operating time, h day⁻¹
- AREA = Operating area, ha
- LEF = labor energy factor, Mcal h⁻¹

Energy Productivity

Energy productivity was computed by dividing the grain yield by the energy inputs from either indirect fossil fuel energy input (IFFEI) or total energy inputs (TEI):

$$\text{Energy productivity}_{\text{IFFEI}} \text{ (kg grain/LDOE)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Total IFFEI in LDOE}}$$

$$\text{Energy productivity}_{\text{TEI}} \text{ (kg grain/LDOE)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{TEI in LDOE}}$$

where:

- IFFEI = indirect fossil fuel energy based
- TEI = total energy input
- LDOE = liter diesel equivalent

Energy Efficiency

Energy efficiency (Ee) or energy balance was determined as the ratio of the energy output to the energy input. If the Ee, is greater than 1, this means that the production system is gaining energy, otherwise it is losing energy.

$$Ee = \frac{e_o}{e_i}$$

where:

- Ee = energy efficiency or energy balance
- e_o = energy output, MJ ha⁻¹
- e_i = energy input intensity, MJ ha⁻¹

Energy Intensity

Energy intensity for both IFFEI and TEI were calculated by dividing the total LDOE spent per unit quantity of grain produced as follows:

$$\text{Energy intensity}_{\text{IFFEI}} \text{ (LDOE kg}^{-1}\text{ grain)} = \frac{\text{IFFEI (LDOE)}}{\text{Grain yield (kg ha}^{-1}\text{)}}$$

$$\text{Energy intensity}_{\text{TEI}} (\text{LDOE kg}^{-1} \text{ grain}) = \frac{\text{TEI (LDOE)}}{\text{Grain yield (kg ha}^{-1}\text{)}}$$

To have a better grasp of the unit, the energy equivalent in MJ or Mcal was converted to liter diesel equivalent (LDOE) using the following:

$$1 \text{ LDOE} = 11.414 \text{ Mcal}, \quad 1 \text{ LDOE} = 38.4 \text{ MJ} = 38.4 \times 10^6 \text{ J} \quad (\text{Mendoza 2008})$$

The averaged grain yields of two croppings were used as basis in the calculation of energy productivity, efficiency and intensity.

RESULTS AND DISCUSSION

Grain Yield of PSB Rc18 Rice Grown in Various Nutrient Sources and Quantum Enhancers

Figure 1 shows that grain yield of PSB Rc18 across 2 seasons was significantly highest when rice was applied with unenhanced composted cow manure (T_6). However, this was comparable to those applied with inorganic fertilizer at full rate (T_2) and at half dose combined with enhanced composted cow manure (T_3). This was followed by those applied with combined inorganic fertilizer (half dose) + quantum enhancers (T_4 and T_5) and those applied with combined or sole organic nutrient sources or quantum enhancers and the control.

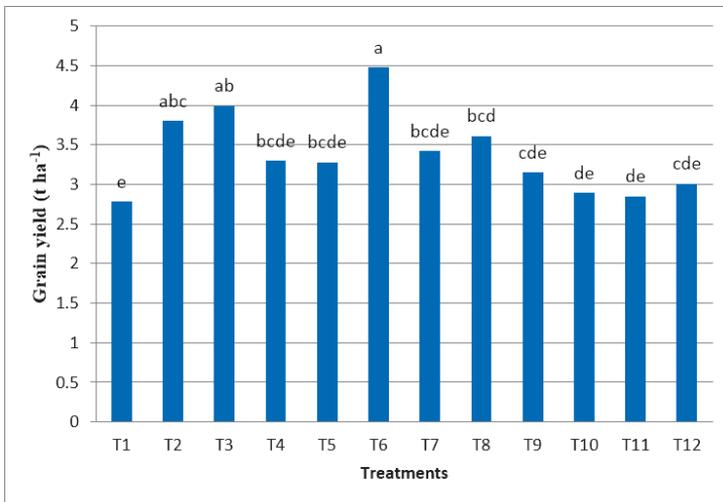


Fig. 1. Grain yield of lowland rice (var. PSB Rc18) across two seasons as influenced by various nutrient sources and quantum enhancers.

Legend:

T_1 -control; T_2 = 70-60-30 kg N, P₂O₅, K₂O ha⁻¹; T_3 = 35-30-15 kg N, P₂O₅, K₂O ha⁻¹ + 5 t ha⁻¹ enhanced composted cow manure (ECCM); T_4 = 35-30-15 kg N, P₂O₅, K₂O ha⁻¹ + BD 500; T_5 = 35-30-15 kg N, P₂O₅, K₂O ha⁻¹ + 30 g ha⁻¹ Agnihotra ash; T_6 = 5 tons ha⁻¹ unenhanced composted cow manure; T_7 = 5 t ha⁻¹ ECCM; T_8 = 5 t ha⁻¹ ECCM + 25 g ha⁻¹ BD 500; T_9 = 5 t ha⁻¹ ECCM + Agnihotra ash; T_{10} = 4 L ha⁻¹ IMO; T_{11} = 25 g ha⁻¹ BD 500; and T_{12} = 30 g ha⁻¹ Agnihotra ash

The application of unenhanced composted cow manure had significantly higher yields due to its markedly higher grain filling rates (151.21 kg d^{-1}) comparable with those applied with the full rate of chemical fertilizer (126.25 kg d^{-1}) and those with $\frac{1}{2}$ rate chemical fertilizer + ECCM (134.60 kg d^{-1}) than the rest of the treatments. The least grain filling rate was noted with those applied with lone quantum enhancers and the control.

The higher amount of N supplied with unenhanced composted cow manure & inorganic fertilizer could have attributed to this response. This conforms with the findings of Fageria (2006) and Yang and Zhang (2005) that high N rates usually delayed plant senescence thus enhanced grain filling which increased grain yield, better harvest index, and higher water use efficiency. Results of soil analysis after the second cropping also showed an increase in organic matter, nitrogen, and phosphorus content in plots applied with unenhanced composted cow manure. The higher microbial count in unenhanced composted cow manure could have also released growth promoting hormones which enhanced growth, development as well as yield production.

The superior contribution of various yield components namely: more productive tillers hill¹, longer panicles with denser grains per panicle, and heavier seed weight consequently resulted in appreciably higher grain yield of said treatment.

Energy Expenditures and Energy Productivity of PSB Rc18 Rice Grown in Various Nutrient Sources and Quantum Enhancers

The energy expenditures of the second crop with various nutrient sources at $1184.66 \text{ Mcal ha}^{-1}$ or 103.79 liter diesel oil equivalent (LDOE) ha^{-1} were relatively higher compared to the first crop at $1127.24 \text{ Mcal ha}^{-1}$ or $98.76 \text{ LDOE ha}^{-1}$ (Table 2). But due to significantly higher yield obtained during the second cropping, the energy productivity were 12% and 11% higher in both the direct fossil fuel energy based input (FFEI) and total energy input (TEI), respectively. This higher energy productivity may also mean lower energy use to produce a given quantity of rice.

Regardless of season, the total energy input for both croppings was highest with the application of the full rate of inorganic fertilizer ($225.74 \text{ LDOE ha}^{-1}$) or $2576.60 \text{ Mcal ha}^{-1}$ wherein 87% was used for FFEI ($195.70 \text{ LDOE ha}^{-1}$) while 13% ($30.04 \text{ LDOE ha}^{-1}$) was spent for the indirect fossil fuel energy inputs (IFFEI). This was followed by those treated with half rate of inorganic fertilizer in combination with either enhanced composted cow manure ($144.10 \text{ LDOE ha}^{-1}$) or with quantum enhancers of either BD 500 or agnihotra ash at 142.13 - $142.35 \text{ LDOE ha}^{-1}$. Organic treatments of unenhanced or enhanced composted cow manure, with the latter applied alone or combined with quantum enhancers and IMO spent lower total energy ranging from 69.18 - $71.79 \text{ LDOE ha}^{-1}$. The untreated control and those with Quantum enhancers had the lowest energy expenditures ranging from 68.77 - $69.40 \text{ LDOE ha}^{-1}$.

Most of the energy expenses on direct fossil fuel energy input were generally spent for the manufacture of fertilizer materials which amounted to about 56% of the total energy cost (Fig. 2a). Fuel which was used to run machineries from production to post production activities ranked second which comprised 16 % of the total energy cost. Of the three (3) fertilizer nutrients, nitrogen spent the highest

energy cost which was 44% of the total energy input (Fig 2b). This made the inorganically-treated plots to be generally less productive in terms of energy use. This conforms to the findings of Bautista and Minowa (2010) that these inorganic inputs usually accounted the highest, reaching to about 80% of the total production inputs including seeds in all the farming systems tested. In sugarcane, N use from urea also accounted the highest at 93.7% (Egle and Mendoza, 2013). The high energy expenses incurred with chemical fertilizer application made it the least energy efficient among the nutrient sources in terms of fossil fuel energy input and total energy input spent in the study. This also implies higher monetary requirement for the purchase of fossil fuel and oil. Although the inorganic treatment obtained a comparably high yield with those applied with unenhanced composted cow manure, its higher energy consumption led to the lower productivity of the system than the organic-treated plots. This further implies that the yield obtained with inorganic fertilizer application under the condition of the study did not compensate for the higher energy input it spent.

Table 2. Energy expenditures and energy productivity of lowland rice (var. PSB Rc18) across seasons as influenced by application of various organic nutrient sources and quantum enhancers.

Treatments	Energy Expenditures				Energy Productivity	
	FFEI	IFFEI	TEI		FFEI	TEI
	(LDOE ha ⁻¹)	(LDOE ha ⁻¹)	(LDOE ha ⁻¹)	(Mcal ha ⁻¹)	(kg grain LDOE ⁻¹)	
SEASON						
Dry	68.54	30.22	98.76	1127.24	60.68 b	36.64 b
Wet	73.27	30.52	103.79	1184.66	68.00 a	40.72 a
Mean	70.90	30.37	101.27	1155.95	64.32	38.66
NUTRIENT SOURCES						
T ₁ = Control (0-0-0)	39.79	28.98	68.77	784.88	69.74 c	40.35 c
T ₂ = 70-60-30 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹	195.70	30.04	225.74	2575.60	19.91 d	17.16 e
T ₃ = 35-30-15 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹ + 5 t ha ⁻¹ ECCM	112.30	31.80	144.10	1644.76	35.53 d	27.69 d
T ₄ = 35-30-15 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹ + 25 g ha ⁻¹ BD 500	112.30	29.83	142.13	1622.27	29.36 d	23.19 de
T ₅ = 35-30-15 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹ + 30 g ha ⁻¹ AAsh	112.30	30.05	142.35	1624.78	29.16 d	23.01 de
T ₆ = 5 t ha ⁻¹ UECCM	39.78	30.16	69.94	798.30	112.58 a	64.04 a
T ₇ = 5 t ha ⁻¹ ECM	39.78	31.37	71.15	812.11	86.01 bc	48.08 bc
T ₈ = 5 t ha ⁻¹ ECM + 25 g ha ⁻¹ BD 500	39.78	31.79	71.57	816.90	90.71 b	50.42 b
T ₉ = 5 t ha ⁻¹ ECM + 30 g ha ⁻¹ AAsh	39.78	32.01	71.79	819.41	79.14 bc	43.87 bc
T ₁₀ = 4 L ha ⁻¹ IMO	39.78	29.40	69.18	789.62	72.65 c	41.77 bc
T ₁₁ = 25 g ha ⁻¹ BD 500	39.78	29.40	69.18	789.62	71.60 c	41.16 bc
T ₁₂ = 30 g ha ⁻¹ AAsh	39.78	29.62	69.40	792.13	75.71 bc	43.39 bc
Mean	70.90	30.37	101.27	1155.95	64.32	38.68
CV (%)					13.09	12.48

Means in a column followed by a common letter or without designation are not significantly different at 5% level, HSD.

Aash – agnihotra ash; BD– biodynamic ; ECCM – enhanced composted cow manure; UECCM – unenhanced composted cow manure ; IMO – indigenous microorganism

Energy Efficiency and Energy Intensity of Rice Grown in Various Nutrient Sources and Quantum Enhancers

Energy efficiency (Ee) is the ratio of Mcal energy output ha^{-1} (grain yield) to Mcal energy input ha^{-1} suggesting for the amount of energy produced per unit energy used. Results indicated that the second cropping had significantly higher energy efficiency than the first cropping. Across croppings, markedly highest energy efficiency was obtained with application of unenhanced composted cow manure at 32.76 Mcal output Mcal^{-1} input and 18.63 Mcal output Mcal^{-1} input for FFEI and TEL, respectively (Table 3). This was followed by those supplied with other organic nutrient sources and quantum enhancers. The least was derived from the application of either pure inorganic fertilizers or when combined with enhanced composted cow manure or quantum enhancers. The result means that for every Mcal of energy used in unenhanced composted cow manure treatment, 32.76 and 18.63 Mcal were produced which were almost 6 and 4 times more efficient as compared to the application of full rate inorganic fertilizer for FFEI and TEL, respectively. However, the former is just 1.37 and 1.53 times higher in terms of FFEI than the other organic sources of fertilizers (21.13-26.39 Mcal grain Mcal^{-1} energy) and quantum enhancers (20.83-22.02 Mcal grain Mcal^{-1} energy), respectively. The findings indicate that the use of organic-based inputs or quantum enhancers were more energy efficient than using inorganic fertilizers. Similarly, in some other crops, organic farming not only reduced energy consumption which in turn had higher energy productivity and efficiency but also mitigate environmental impacts due to lesser greenhouse gas emission as compared to the conventional practice (Gundogmos 2006, Ziesemer 2007, Kaltsas *et al.*, 2007 and Kavargiris *et al.*, 2009). The high energy expenses incurred with chemical fertilizer application (T_1) made it the least energy efficient among the nutrient sources in terms of FFEI (5.79 Mcal output Mcal^{-1} input) and total energy input (5.00 Mcal output Mcal^{-1} input).

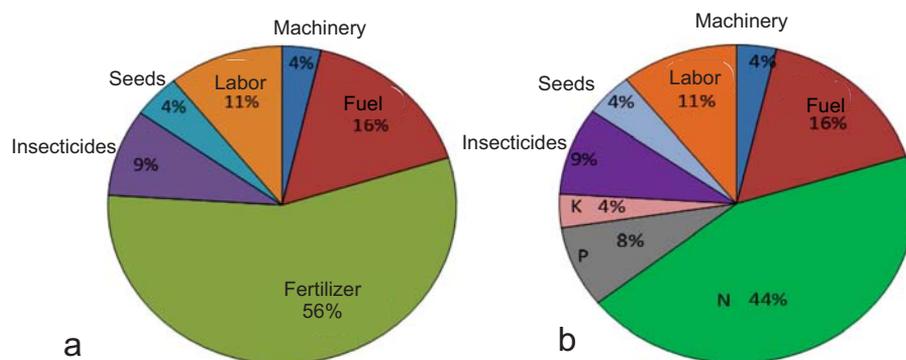


Figure 2. Energy utilization of production inputs (a) and fertilizer nutrients (b) in the conventional system.

Moreover, Karimi *et al.* (2008) reported that if energy is effectively used, this could mean financial savings and could lead to a sustainable agricultural production as fossil resources are preserved thus protect the environment. Application of full rate inorganic fertilizer also indicated that it was 2.35-3.50 times

less efficient than the untreated control (20.29 and 11.74 Mcal output mcal^{-1} energy for FFEI and TEI, respectively) in account of its higher energy expenditure. Thus, to increase energy balance or efficiency, ways of reducing the use of high energy inputs especially chemical fertilizers should be looked into to minimize energy cost. This is on top of the detrimental effects it can cause the soil and environment through emission of CO_2 or N_2O into the atmosphere during its manufacturing process. Aguilera *et al.* (2013) stated that use of organic nutrient sources is better than synthetic fertilizers for they not only increase organic matter content of soil and help manage waste but can mitigate climatic changes by reducing N_2O emissions by 23%.

Energy intensity (Ei) is an estimate of how much energy in terms of liter diesel oil equivalent (LDOE) was used to produce a kilo or a ton of grain. Results showed that significantly higher energy intensity was observed during the first cropping (31.36 LDOE t^{-1} grain) than the second cropping (29.31 LDOE t^{-1} grain) (Table 3). This could be accounted to the significantly lower yield obtained during the former cropping (3.20 t ha^{-1}) despite its relatively lower energy expenditures. However averaged over croppings results revealed that application of full rate inorganic fertilizers had significantly the highest energy intensity of 0.053 LDOE kg^{-1} grain and 60.89 LDOE t^{-1} grain for FFEI and TEI, respectively. This was followed by those applied with half rate of inorganic fertilizer + organic supplements and the least intense in terms of energy use was recorded from those treated with unenhanced composted cow manure and other sources of organic nutrients and quantum enhancers. This means that the inorganic treatment entails 3.82 times more energy intensity than the unenhanced composted cow manure treatment and 2.78 times than using the other organic amendments due to higher fuel and oil used to produce a ton of rice. This further implies that the energy spent to produce a ton of unmilled rice was reduced to as much as 64% with organic fertilization. These results conform to the findings of Mendoza (2005) that organic farming was not only the most energy efficient but also consumed the least amount of energy to produce a ton of unmilled rice. Application of quantum enhancer spent 24.42-25.16 LDOE ton^{-1} grain which is 59% reduction in energy use over the inorganic treatments. The control had an energy intensity of 24.94 LDOE ton^{-1} grain or 0.014 LDOE kg^{-1} grain which is comparable to the organic treatments and is 2.44 times lower than the application of full rate of inorganic fertilizer.

The measure of energy intensity is more relevant nowadays that the cost of fuel and oil are steadily rising. There is a need therefore to look for a more energy efficient nutrient source that will not only enhance yield and energy balance of the production system but will also reduce production cost. As a consequence this will lessen the capital constraint of the farmer. Substituting high energy intensive inputs to least costly fertilizers will offer desirable characteristics to soil which could be of great advantage. Organic fertilizers especially if they are locally available can be cheaper source of nutrients as they no longer incur high energy cost for manufacturing, hauling, and transport. This consequently can reduced the financial burden of most resource-poor farmers. Humus in OM helps improve the physical as well as the chemical and biological properties of soils which increase its water holding and cation exchange capacities (Sciallaba and Lindenlauf 2010; Rimando *et al.*, 2011). Results of soil analysis after the second cropping showed a relative increase in organic matter in organically treated plots which ranged from

4.29% over the initial determination with 3.30% only. With this premise, water and nutrient requirement of the crop may be reduced hence providing an added benefit to the farmer in terms of production cost.

A number of organic-based inputs are available as energy saving strategies that will reduce chemical fertilizer inputs (Karimi *et al.*, 2008). Since cattle are often integrated into the farmers' crop production system in the Philippines, their waste can be a good and cheap source of organic fertilizer. Estimates had shown huge amount of excreta ranging from 6-13 t year⁻¹ or a 455 kg dairy cow produced about 36 kg or 1.3 cubic feet of manure a day (Pulhin *et al.*, 1980; <http://www.watersheds.org/farm/lawson.htm>). With its use, substantial reduction in the purchase of inorganic fertilizers can be realized thus minimize energy and monetary expenditures. This further offers a more sustainable production system in the countryside.

Table 3. Energy efficiency and intensity of PSB Rc18 rice production across seasons as influenced by application of various organic nutrient sources and quantum enhancers.

Treatments	Energy Efficiency		Energy Intensity	
	FFEI	TEI	FFEI	TEI
	Mcal grain	Mcal energy ⁻¹	(LDOE kg ⁻¹ grain)	(LDOE t ⁻¹ grain)
SEASON				
Dry	17.65 b	10.66 b	0.021	31.36 a
Wet	19.78 a	11.84 a	0.021	29.31 b
Mean	18.71	11.25	0.021	30.33
NUTRIENT SOURCES				
T ₁ = Control (0-0-0)	20.29 c	11.74 c	0.014 d	24.94 c
T ₂ = 70-60-30 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹	5.79 d	4.99 e	0.053 a	60.89 a
T ₃ = 35-30-15 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹ + 5 t ha ⁻¹ ECCM	10.33 d	8.06 d	0.028 c	36.50 b
T ₄ = 35-30-15 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹ + 25 g ha ⁻¹ BD 500	8.54 d	6.75 de	0.035 b	44.17 b
T ₅ = 35-30-15 kg N, P ₂ O ₅ , K ₂ O ha ⁻¹ + 30 g ha ⁻¹ AAsh	8.48 d	6.69 de	0.035 b	43.96 b
T ₆ = 5 t ha ⁻¹ UECCM	32.75 a	18.63 a	0.009 d	15.95 d
T ₇ = 5 t ha ⁻¹ ECCM	25.02 bc	13.99 bc	0.012 d	21.00 cd
T ₈ = 5 t ha ⁻¹ ECCM + 25 g ha ⁻¹ BD 500	26.39 b	14.67 b	0.011 d	20.03 cd
T ₉ = 5 t ha ⁻¹ ECCM + 30 g ha ⁻¹ AAsh	23.01 bc	12.75 bc	0.013 d	23.39 cd
T ₁₀ = 4 L ha ⁻¹ IMO	21.13 c	12.15 bc	0.014 d	24.42 c
T ₁₁ = 25 g ha ⁻¹ BD 500	20.83 c	11.97 bc	0.015 d	25.16 c
T ₁₂ = 30 g ha ⁻¹ AAsh	22.02 bc	12.61 bc	0.014 d	23.58 cd
Mean	18.71	11.25	0.021	30.33
CV (%)	13.07	12.49	15.33	13.35

Means in a column followed by a common letter or without designation are not significantly different at 5% level, HSD.

AAsh – agnihotra ash; BD– biodynamic ; ECCM – enhanced composted cow manure; UECCM – unenhanced composted cow manure ; IMO – indigenous microorganism

CONCLUSIONS

Based on the results of the study, the following conclusions can be drawn:

1. The use of unenhanced composted cow manure produced significantly higher grain yield than the rest of the treatments though comparable with those applied with full dose inorganic fertilizers.
2. Application of organic fertilizers and quantum enhancers incurred lower energy expenditures than using inorganic fertilizers. This consequently resulted in markedly higher energy productivity than those applied with inorganic fertilizers and the untreated control with treatment on unenhanced composted cow manure as the most energy efficient and the least intense in terms of energy use. .
3. Application of quantum enhancers gave promise in increasing energy productivity and efficiency over the inorganic sources of nutrients, implying to be a valuable addition to organic farming.

RECOMMENDATIONS

It is recommended that follow up studies be done to reassess the energetics of lowland rice (PSB Rc18) treated with quantum enhancers and other nutrient sources in other agro-climatic conditions. There is also a need to verify the productivity and efficiency of quantum and other nutrient sources to other equally important upland crops.

ACKNOWLEDGEMENT

The first author would like to thank the Visayas State University and the Commission on Higher Education (CHED)-Higher Education Development Project-Faculty Development Program (HEDP-FDP) for the scholarship and the Agricultural Training Institute-EHRDP for the additional dissertation support in the conduct of this research.

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