J Bangladesh Agril Univ 18(S1): 811–815, 2020 https://doi.org/10.5455/JBAU.12597

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Special issue: International Conference on Sustainable Agriculture (ICSA) 2019

Effects of Organic and Inorganic Fertilizers on Soil Chemical Properties and the Production of Cocoa (*Theobroma cacao* L.) in Madai, Kunak, Sabah

M. Boney[1]✉, A. Azwan[2], R. Haya[1], M.A. Mohd Dandan[2]

[1]*Malaysian Cocoa Board, Cocoa Research and Development Centre, Mile 10, Apas Road, P.O. Box No. 60237, 91012, Tawau, Sabah, Malaysia*

[2]*Faculty of Sustainable Agriculture, Universiti Malaysia Sabah, Locked Bag No.3, 90509 Sandakan, Sabah, Malaysia*

ARTICLE INFO

Article history
Received: 05 Jan 2020
Accepted: 18 Aug 2020
Published: 30 Nov 2020

Keywords
Cocoa, Organic fertilizers, Soil chemical properties,

Correspondence
Muda Boney
✉: boneymuda@koko.gov.my

ABSTRACT

The global demand for crop production has led to an increased in the use of inorganic fertilizer. However, single and long-term use of inorganic fertilizer negatively affects the environment and soil structure. Alternatively, organic materials can be composted and used as fertilizer. Although organic fertilizers have low nutrient concentration and solubility, they slowly release nutrients, making them available for a more extended period. Moreover, the waste by-products such as biomass and manure from plantations and livestock farms are readily available in abundance. Therefore, this study was conducted to determine the effects of four organic fertilizers (chicken manure, cow manure, empty fruit bunch, and cocoa pod husk) and inorganic fertilizer as a control on the soil chemical properties and production of cocoa. We found that organic fertilizers, at their optimal application rate, yielded similar cocoa dried beans production with inorganic fertilizer. Furthermore, we found that there was no difference in the soil chemical properties between the treatments. Hence, this study has demonstrated that organic fertilizers could improve soil chemical properties and eventually increase cocoa production.

Introduction

Fertilizers are organic or inorganic materials added to the soil to supply plants with certain essential elements to grow (Panda, 2010). They have played an essential role in increasing crop production, including cocoa. The global consumption of fertilizers is steadily increasing every year as demand from growers is continuously rising significantly for inorganic fertilizers. However, with the increasing price of inorganic fertilizers and adverse effects on the environment and soil structure, the best alternative is using organic fertilizers optimally.

Organic materials are naturally occurring materials of biological or mineral origin (Allen, 2010). Although organic materials are low in nutrient concentration or solubility, or both, the slow release of nutrients makes them available for a more extended period. In plantation and livestock farming, there is an abundance of waste by-products (biomass and manure) readily available to be used as a source of nutrients. These organic materials contain various essentials nutrients and can improve soil physical and chemical properties, nutrient holding and buffering capacity, and enhance microbial activities (Suzuki, 1997).

Thong and Ng (1978) reported that cocoa's nutrient uptake is relatively high (400 kg N, 40 kg P and 500 kg K with 5-years old matured cocoa). However, some of these requirements have been met through the appropriate use of cocoa pod husk, poultry manure, and mineral fertilizer in Southwestern Nigeria (Ayeni et al., 2008). Another study also showed the effectiveness of nutrient-rich oil palm residues, coconut husks, and other agricultural wastes in cocoa plantation (Sharifuddin and Zaharah, 1987). These studies indicate that steady improvement in soil productivity and crop performance could be achieved by applying organic materials such as crop residues and livestock. Therefore, this study was conducted to determine the effects of four organic fertilizers (chicken manure, cow manure, empty fruit

Cite This Article
Boney, M, Azwan, A., Haya, R., Mohd Dandan, M. A. 2020. Effects of Organic and Inorganic Fertilizers on Soil Chemical Properties and the Production of Cocoa (*Theobroma cacao* L.) in Madai, Kunak, Sabah. *Journal of Bangladesh Agricultural University*, 18(S1): 811–815. https://doi.org/10.5455/JBAU.12597

bunch, and cocoa pod husk) and inorganic fertilizer on cocoa production and the soil chemical properties. It is expected that the results of this study could persuade cocoa farmers to use organic fertilizers in their farms.

Materials and Methods

The trial was conducted at the Malaysian Cocoa Board Research and Development Centre in Madai, Kunak, Sabah, Malaysia and arranged in a Randomized Complete Block Design (RCBD) with three replicates. Seven years old cocoa trees from Clone BR 25 were used. Fertilizer treatments were based on cocoa nutrient uptake – 400 kg N, 40 kg P and 500 kg K on 5-years old matured cocoa. The treatments were; T1 – Mix straight fertilizer (0.86 Mg ha^{-1} yr^{-1} Urea (46% N) + 0.086 Mg ha^{-1} yr^{-1} TSP (46% P_2O_5) + 1.0 Mg ha^{-1} yr^{-1} MOP (50% K_2O), T2 – Chicken manure (3% N, 1% P, 2% K = 13.3 Mg ha^{-1} yr^{-1}, T3 – Cow manure (2% N, 1% P, 2% K = 20.0 Mg ha^{-1} yr^{-1}), T4 – Empty fruit bunch (1.5% N, 0.02% P, 1.28% K = 26.6 Mg ha^{-1} yr^{-1}), and T5 – Cocoa pod husk (2.18% N, 2.15% P, 3.54% K = 18.3 Mg ha^{-1} yr^{-1}). Each treatment was applied four times per year onto 35 trees. The experimental size was about 0.5 ha. Beans were removed from harvested pods and fermented in a wooden box for five days with a turn on day 3. The fermented beans were sun-dried for seven days until the moisture content dropped to 6 to 7%. Samples of the dried beans from each treatment were taken to the laboratory for analyses. All experimental plots were given similar agronomic practices, which included pruning and applications of weedicide and pesticide. Parameters recorded were as follows:

Pod and bean analysis

Pod analysis was conducted based on Haya et al. (2007). Five ripe pods were sampled out from each plot during peak harvest measured for length, diameter and width of pods (cm), the weight of harvested pods (kg), average number of beans/pod, single dry bean weight (g), and pod index (number of pods to produce 1 kg dry beans).

Yield production

Yield production was measured based on Osman et al. (1994). The number of pods per tree was taken to determine the production of pods. Successful pods having a perimeter of 20–25 cm were counted and marked with blue paint. The number of pods then recorded every month, starting from 2 months after all treatments were applied. Mature pods were harvested twice a month or 10-14 days interval, and the total number of harvested mature pods was recorded to determine the actual yield of harvested mature pods.

Soil and leaf sampling

Soil and leaf samplings were conducted based on Denamany & Rosinah (1994). Soil samples were taken from two depths, 0–20 cm and 20–40 cm. Leaf sample was taken from the fourth leaf of the last maturing flush. Both soil and leaf samples were taken before the first application of treatments and at the end of the project. All samples were sent to an accredited laboratory for nutrient analysis.

Results

Effects of fertilization treatments on coca pod and bean quality

All treatments did not affect pod quality parameters such as length, diameter, width, and weight ($p>0.05$) (Table 1). Treatments such as T1 and T5, however, slightly increased pod weight with the mean value ranged from 408.0 g to 412.7 g, which was beyond the expected average pod weight of 395.0 g. Such an increase in weight is likely to have a positive effect on the quality of the bean. These pod characteristics were probably the least factor that could affect the yield production, they are, nevertheless, important in cocoa breeding. (Wood & Lass, 1985).

There was no significant difference between the treatments on bean quality parameters such as the number of beans per pod, average of dry bean weight, and pod value ($p>0.05$). However, the number of beans per pod for T1 was found significantly higher (32.7) than the other treatments ($p<0.05$). However, such a number of beans is still considered low as the average number of beans per pod is 40. It was also found that the average dry bean weight for all treatments was between 0.79 g to 0.92 g, which was less than the expected average bean weight of 1.00 g. Therefore, based on the results, all treatments have a relatively higher pod value ranging from 38 to 56, which was beyond the range of an acceptable pod value of 25 and below, which could also affect the yield of cocoa production. According to Mainstone and Thong (1978), potassium is consistently associated with increased fresh pod weight. They also reported that potassium was the factor in increasing the number of pods and decreasing the weight of the pod contents by reducing either the mucilage weight, or the number of beans, or the bean weight, which correlate with pod value. Therefore, the high pod value for all treatments could be due to the availability and sufficient uptake of potassium in both soil and leaf, respectively.

Effect of fertilization treatments on yield production

Generally, pods can be harvested throughout the year; however, there are two main fruiting seasons for cocoa, depending on the climate condition. According to our data, the rainfall distribution pattern at the experimental site was uniform throughout the year, with a mean of nearly 2000 mm (Table 2). Furthermore, it clearly showed that the peak months of cropping for all treatments in Figure 1 were less pronounced and appeared to be the same (July–September and December–March). This similar crop pattern is more substantial when it is expressed to an average of dried bean per month, whereas it shows no significant difference (p>0.05) between the treatments (Figure 2). Otherwise, the yield production for 21 months after its first application had shown that the effect of treatments on the yield production for total cumulative dried bean appeared to be consistent throughout the study. However, the highest production was in T1 (2042.4 kg ha^{-1}) followed by T4 (1921.3 kg ha^{-1}), T2 (1571.1 kg ha^{-1}), T3 (1519.7 kg ha^{-1}) and the lowest production, T5 (1367.0 kg ha^{-1}) (Figure 1). These varying results, however, gave no significant difference between the treatments (p>0.05). It is reasonable to assume that all treatments produced the same results because there was no significant difference observed in yield. The differences in yield production of the treatments have mainly relied on other yield components such as pod yield per tree (PYT), pod value (Pod Value), average dry bean weight (ADBW), and bean number per pod (BNP).

The study by Yadav et al. (2013) on cow manure, Adeniyan and Ojeniyi (2005) on chicken manure, Sharifuddin and Zaharah (1987) on the empty fruit bunch, and Ayeni (2008) on cocoa pod husk had indicated that organic materials produced more significant or similar yield production compared with inorganic fertilizer. Similar results were obtained in this study. Our study demosntrated that organic materials such as cow manure, chicken manure, empty fruit bunch, and cocoa pod husk had consistently produced a positive yield production that comparable with conventional or inorganic fertilizer as indicated in the result. Therefore, such yield consistency should help a better understanding of organic materials' vital role to improve the crop yield, particularly in cocoa plantations.

Effect of fertilization treatments on soil nutrients

Soil nutrient analysis after treatments applied (Table 3) indicated that there was no significant difference (p>0.05) in all nutrient levels due to treatments. In contrast, soil pH was found lower and might affect some plant nutrients' availability during this study. However, soil nitrogen concentration was lower than the adequate range, where the mean value was ranging from 0.09 % to 0.15 %. Besides, topsoil has the highest nitrogen concentration, while below it, not much nutrition is acquired. All treatments had less than the adequate range (>15.0 ppm) for phosphorus with a mean value between 2.80 ppm to 13.25 ppm. As for potassium, all treatments showed higher concentration nutrients than the adequate range (0.24 cmol kg^{-1}), ranging between 0.44 cmol kg^{-1} to 0.59 cmol kg^{-1}. Organic materials release their nutrients slowly by breaking down the material to ammonium (mineralization) through microbial activity in the soil (Ann et al., 2017). The production of ammonium will affect soil pH. Also, lime was applied to the soil twice annually to adjust the soil pH, but it often takes a year or more before a response can be seen even under perfect conditions. It is known that the optimum pH for cocoa is 6.5, and the soils within the range of 5.5–7.0 should be selected where major nutrients and trace elements will be available. If the acidity increased, the major nutrients, phosphorus in specific, become less available, while others like iron, manganese, copper, and zinc could increase, possibly creating toxicity. In this study, organic materials treatments such as cow and chicken manure, empty fruit bunch, and cocoa pod husk have positively affected the soil nutrients. The high availability of potassium in both top and subsoil for the organic amendment was as good as the soil treated by inorganic fertilizer. This observation was agreed by Akanbi et al. (2014), which stated that organic fertilizer application had a significant impact, particularly on soil nutrients, organic matter, and pH in cocoa crops.

Table 1. Effect of different organic and inorganic fertilization treatments on the pod and bean qualities in cocoa

Variables	T1	T2	T3	T4	T5
Pod length (cm)	16.12 ± 0.71^{a}	15.68 ± 0.43^{a}	15.94 ± 0.40^{a}	15.55 ± 0.79^{a}	16.11 ± 0.49^{a}
Pod diameter (cm)	24.87 ± 0.80^{a}	24.49 ± 0.64^{a}	24.44 ± 0.98^{a}	23.93 ± 1.11a	24.62 ± 0.20^{a}
Width (cm)	7.77 ± 0.23^{a}	7.64 ± 0.23^{a}	7.67 ± 0.24^{a}	7.74 ± 0.10^{a}	7.72 ± 0.08^{a}
Weight of pod (g)	412.7 ± 40.21^{a}	389.5 ± 28.66^{a}	379.7 ± 30.48^{a}	380.3 ± 42.15^{a}	408.5 ± 18.58^{a}
Number of beans/pod	32.70 ± 1.50^{a}	26.00 ± 1.34^{b}	30.45 ± 0.46^{ab}	26.93 ± 0.64^{b}	27.19 ± 1.53^{ab}
Average dry bean weight (g)	0.92 ± 0.13^{a}	0.79 ± 0.06^{a}	0.90 ± 0.03^{a}	0.85 ± 0.04^{a}	0.87 ± 0.09^{a}
Pod value	38.19 ± 7.64^{a}	56.19 ± 8.94a	39.37 ± 2.98^{a}	48.48 ± 2.98^{a}	45.82 ± 7.19^{a}

Means (± S.E.) with the same letter (superscript) within rows are not statistically different using Tukey's at P > 0.05 probability level. Treatments - T1–Mixture of inorganic fertilizers, T2 – Chicken manure, T3 – Cow manure, T4 –Empty fruit bunch, and T5 – Cocoa pod husk.

Table 2. Rainfall distribution per month from the year 2015 – 2016

Month	Rainfall distribution (mm)	
	2015	2016
January	593.8	47.0
February	45.0	63.1
March	113.1	102.2
April	63.9	102.0
May	130.4	127.8
June	165.6	120.5
July	70.9	127.7
August	130.5	224.5
September	63.9	244.6
October	107.7	272.6
November	188.4	215.8
December	223.7	217.6
Total	**1896.9**	**1865.4**

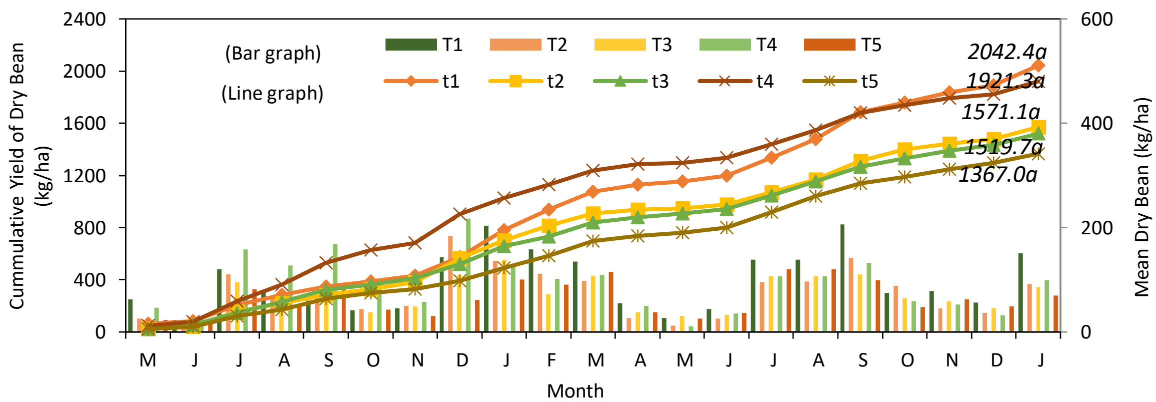

Figure 1. Crop pattern and its cumulative yield production as affected by different fertilization treatments. Means with the same letter are not statistically different using Tukey's at p>0.05 probability level. Crop pattern: - T1– Mixture fertilizer, T2 – Chicken manure, T3 – Cow manure, T4 –Empty fruit bunch and T5 – Cocoa pod husk; Cumulative yield dry bean: - t1– Mixture fertilizer, t2 – Chicken manure, t3 – Cow manure, t4 –Empty fruit bunch and t5 – Cocoa pod husk

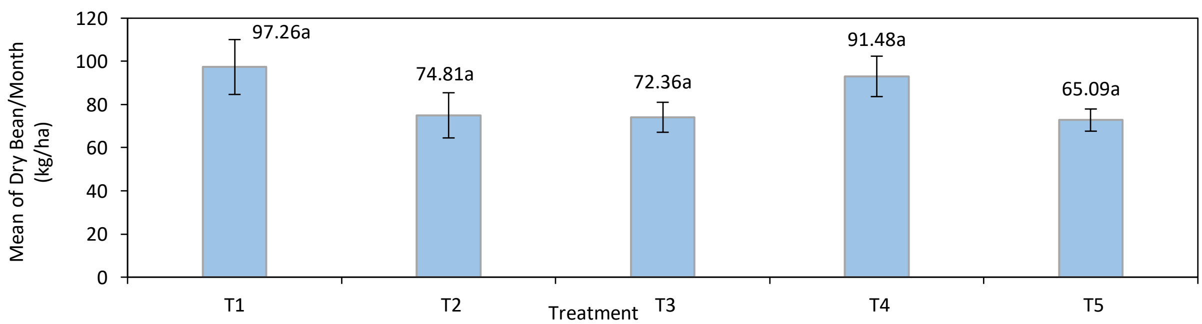

Figure 2. Mean of dried bean per month for 21 months period. Means with the same letter are not statistically different using Tukey's at p>0.05 probability level. Treatments - T1– Mixture fertilizer, T2 – Chicken manure, T3 – Cow manure, T4 –Empty fruit bunch and T5 – Cocoa pod husk.

Table 3. Adequate range; and soil pH, Total N, Available P, and Exchangeable K in different soil depth under different fertilization treatments

Treatment	pH (H_2O)		Total N (%)		Available P (ppm)		Exch. K (cmol (+) kg^{-1})	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Optimum range*	5.5 -6.5		> 0.16		> 15		> 0.24	
T1	4.60 ± 0.15[a]	4.53 ± 0.18[a]	0.12 ± 0.01[a]	0.09±0.006[a]	8.40 ± 3.20[a]	1.43 ± 0.71[a]	0.56 ± 0.05[a]	0.51 ± 0.06[a]
T2	4.46 ± 0.03[a]	4.50 ± 0.11[a]	0.14 ± 0.02[a]	0.11 ± 0.02[a]	13.35±6.05[a]	3.05 ± 1.85[a]	0.56 ± 0.12[a]	0.44 ± 0.07[a]
T3	4.37 ± 0.08[a]	4.43 ± 0.09[a]	0.09±0.006[a]	0.11 ± 0.02[a]	2.80 ± 0.70[a]	1.45 ± 1.15[a]	0.59 ± 0.15[a]	0.50 ± 0.03[a]
T4	4.67 ± 0.16[a]	4.53 ± 0.09[a]	0.15 ± 0.01[a]	0.10 ± 0.03[a]	6.60 ± 0.70[a]	1.05 ± 0.35[a]	0.49 ± 0.04[a]	0.50 ± 0.09[a]
T5	4.37 ± 0.06[a]	4.30 ± 0.15[a]	0.13 ± 0.01[a]	0.09 ± 0.02[a]	8.80 ± 2.70[a]	2.57 ± 1.28[a]	0.57 ± 0.10[a]	0.56 ± 0.11[a]

Means with the same letter (superscript) within columns are not statistically different using Tukey's at P > 0.05 probability level. (mean ± S.E.); *Source: Wong, I. F. T. (1974) (revised) – Soil-crop suitability classification for Peninsular Malaysia, Soils and Analytical Services Bulletin Nr.1, Ministry of Agriculture, Kuala Lumpur)

Conclusion

Our study has shown that organic materials' application produces comparable results with inorganic fertilizer, particularly on the pod and bean characteristics and cocoa yield production. The nutrient status of the soil was also almost related to the efficacy of the organic materials' availability and uptake. Organic fertilizers increase the soil pH and make the nutrient available for an extended period to plants. Finally, this study has highlighted the utilization of organic materials in the cocoa plantation is feasible, particularly for the smallholders.

Acknowledgement

The authors wish to thank the Ministry of Science, Technology and Innovation (MOSTI), Malaysia, the financial support (Project No. 06-03-13-SF0119), and the Director-General of MCB for her permission to publish this paper. Appreciation is also extended to the Head of Section of Cocoa Upstream Technology Division, Dr. Rozita Osman, for her critical reading and comments for the paper. Sincere thanks are also extended to Mr. Jenrry Sompokon, Mr. Mohd. Yusof Mohd. Yunus and all field staff, for their excellent assistance in the fieldwork.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Adeniyan, O. N and Ojeniyi, S. O. 2005. Effect of poultry manure, N.P.K 15:15:15 and combination of the reduced levels on maize growth and soil chemical properties. *Nigerian Journal of Soil Science*. 15:34-41

Akanbi, O. S. O, Ojeniyi, S. O, Famaye, A. O., Ipinmoroti, R. R, Oloyede, A. A, Oyewumi, I. K., Ayegbonyin, K, Adejobi, K. B, and Idrisu, M. 2014. Soil nutrients and cocoa seedling performance as influenced by plant residue ash and NPK fertilizer addition on a depleted soil in Ibadan, south western, Nigeria. *International Research Journal of Agricultural Science and Soil Science* 4 (1):1–4. http://dx.doi.org/10.14303/irjas.2013.077

Allen, V. B. 2010. Science and Technology of Organic Farming. CRC Press, Taylor and Francis Group.

Ayeni, L.S. M.T. Adetunji, S.O. Ojeniyi, S.B. Ewulo and A.J. Adeyemo, 2008. Comparative and cumulative effect of cocoa pod husk ash and poultry manure on soil and nutrient contents and maize yield. *America-Eurasian Journal of Sustainable Agriculture*, 2: 92–97.

Denamany, G. and Rosinah R. 1994. Kaedah pengambilan serta pemprosesan sample tanah dan daun untuk analisa. Konvensyen Kakitangan Bahagian Penyelidikan Koko */ Kelapa*, pp. 1-10. Institut Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI).

Mainstone, B. J. and Thong, K. C. 1978. Fertilizer responses over six years from planting of mono-crop cocoa on a Bungor series soil. Proceeding of the International Conference on Cocoa Coconuts, Kuala Lumpur 1978: 243-61.

Haya, R., Kelvin, L., Francis, A., Nuraziawati, M. Y. and Mohd. Jaafar, H. 2007. Manual on cocoa breeding scheme, trial designs and data recordings. Malaysian Cocoa Board, Kota Kinabalu.

Osman, Y., Abdullah, O. and Nik Aziz, N.M., 1994. Kaedah pengambilan data pertumbuhan dan hasil koko untuk penyelidikan dalam bidang agronomi. Konvensyen Kakitangan Bahagian Penyelidikan Koko / Kelapa, pp. 1-5. Institut Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI).

Panda, S.C. 2010. Rice Crop Science. India: Agrobios.

Sharifuddin, H.A.H. and Zaharah, A. R., 1987. Utilization of natural and agricultural waste products in Malaysian agriculture. Paper presented at the Organic Farming Conference, Khon Kaen, Thailand.

Suzuki, A. 1997. Fertilization of rice in Japan. Japan FAO Association, Tokyo, Japan

Thong, K. C. and Ng, W.C., 1978. Growth and nutrient composition of monocrop cocoa plants on inland Malaysian soils. Proceedings of the International Conference on Cocoa and Coconuts. Kuala Lumpur, Malaysia, June 21-24, 1978. pp. 262-286

Wong, I. F. T. 1974 (revised) – Soil-crop suitability classification for Peninsular Malaysia, Soils and Analytical Services Bulletin Nr.1, Ministry of Agriculture, Kuala Lumpur

Wood G. A. R. and Lass, R. A., 1985. Cocoa – Fourth Edition. Tropical Agriculture Series. Longman Group Limited.

Yadav A., Gupta R. and Garg V. K., 2013. Organic manure production from cow dung and biogas plant slurry by vermicomposting under field conditions. *International Journal of Recycling of Organic Waste in Agriculture*, 2:21. https://doi.org/10.1186/2251-7715-2-21