International Journal of Plant & Soil Science
12(6): 1-8, 2016; Article no.IJPSS.28704
ISSN: 2320-7035

SCIENCEDOMAIN *international*
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Effectiveness of Rural Waste Materials as Natural Fertilizers on Sustainable Soil Fertility and Productivity in Myanmar

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Authors' contributions

This work was carried out in collaboration between all authors. Author PPM designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author PPM managed the literature searches, analyses of the study and author MTS managed the experimental process and author WWA identified the species of plant. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/28704
Editor(s):
(1) Eliana L. Tassi, Institute of Ecosystem Studies, National Research Council (ISE-CNR), Italy.
Reviewers:
(1) Amardeep Singh, Central Soil and Materials Research Station, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, India.
(2) Sangare Gaston, Sahelian Center, ICRISAT, Niamey, Niger.
Complete Peer review History: http://www.sciencedomain.org/review-history/16180

Original Research Article

Received 31st July 2016
Accepted 4th September 2016
Published 14th September 2016

ABSTRACT

This research aimed to study the effect of waste materials from rural area as natural organic fertilizers on the soil fertility and crop production. Three natural fertilizers (defatted sesame meal; DSM, bat guano; BG and wood ash) and one commercial organic fertilizer (vedagro) were applied in radish (*Raphanus sativas* L.) cultivation at the Hinthada Township (at 17°38 ' latitudes north and 95°27 ' longitude east), Ayeyarwady Region, Myanmar in 2013. Initial soil was found medium in K, moderately low in N, Mg, very high in Ca, P and the texture was assigned as silt loam and moderately alkaline. Three fertilizer treatments viz., DSM +Ash (1:1w/w), natural (1:1:1 w/w of DSM+BG+Ash) and Vedagro along with control (no fertilizer) were applied. The nutrient value and growth parameters in radish and the NPK contents of the soil after harvesting are also providing high results in the natural fertilizer treatment as well as Vedagro treatment. From these results, it can be inferred that application of this natural fertilizer can prevent soil nutrient depletion by cultivation of the plants and other environmental factors. These waste materials are available on or near the farm and recommended as cost effective and beneficial organic fertilizers.

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Keywords: Soil properties; radish (Raphanus sativas L.); natural waste materials; soil nutrient sustainability; nutritional quality.

1. INTRODUCTION

In Myanmar, the current practice in agriculture is basically chemical-based farming that makes a considerable contribution to the degradation of our natural resources, particularly soils. The use of chemical fertilizers which will constantly accelerate expiration of organic substances can be destroying the balance of nutrients in the soil, giving rise to a variety of plant diseases. Although Myanmar has no urgent, serious problem regarding of environmental pollution owing to a sparsely populated area and least industrial development, solid waste management is currently regarded as one of the most immediate environmental issues. In the rural area, though the form of waste is predominantly organic and biodegradable yet it has become a major problem to the overall sustainability of the ecological balance.

Moreover, the domestic fertilizer industry in Myanmar is concentrated around the production of urea fertilizer from the abundant sources of natural gas in the country. As requirement for plant nutrients, phosphate and potash fertilizers are imported. Although imports of fertilizers are liberalized to the private sector, most of farmers are unable to acquire sufficient amount of fertilizer due to financial constraints. According to the report from 2005-2006 to 2009-2010, domestic supply of fertilizers amounted to 4,000 to 8,000 tons even though the requirement of fertilizers varies from 2.73 to 3.00 million tons depending upon the annual sown areas [1].

Nowadays, organic-based agricultural production is a rapidly emerging technology all over the world, which partly solves waste disposal problems through conversion of biodegradable wastes into organic compost; this ensures the availability of organic fertilizer for crop production. The organic fertilizers used in this study are defatted sesame meal, bat guano, wood ash and vegadro fertilizers where the first three are natural waste organic fertilizers and the last is commercial organic fertilizer.

Sesame seed (*Sesamum indicum* L.) is an important oil seed crop. Sesame is grown in tropical zones as well as in temperate zones and many countries produce and export this product, mainly China, Japan, India, Cameroon, Egypt, Senegal, Brazil and Iran. The seeds are typically crushed intact for the oil. The residue Sesame oilcake contains on an average 32% crude protein, 8-10% oil, total oil and albuminoids of 40-42% and rich in essential amino acids namely methionine and cystine [2]. Bat guano refers to excrement from bats. In many parts of the world, bat guano is widely used as fertilizer due to the high nitrogen content in the feces and urine and it has some nematocidal effects. Wood ashes contain all the mineral elements that were in the wood. Potassium, calcium and magnesium carbonate or oxides are present in comparatively large quantities giving the ashes a strongly alkaline reaction which can neutralize acid soils. Organic fertilizer “Vedagro” contains organic matter with minimum 45%, nitrogen (N) with minimum 10% and potassium K_2O min 3.5%. The vedagro fertilizer has sweet flavor of molasses in addition it also has nutrient content much more than molasses for the reason that the fermentation created amino acids (including aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrocine, phenylalanine, lycine, arginine) vitamin, mycelium protein and other special elements in nutrition [3].

The research aimed to demonstrate the achievability of growing vegetable using organic fertilizer as the major source of plant nutrients. Specifically, it aimed to (a) distribute knowledge on solid waste composting in rural area for the preparation of organic fertilizer, and (b) determine the efficacy with which organic fertilizer generates major nutrients for crop production and its effect on some soil physical properties.

2. MATERIALS AND METHODS

The study area is located in Zakartan ward, Hinthada Township (at 17°38' latitude north and 95°27' longitude east), Ayeyarwady Region, Myanmar (Fig. 1). It was conducted during the 2013 September and December cropping season. The mean annual rainfall and average temperature were also monitored in the prescribed zone.

2.1 Fertilizers Preparation

Three organic fertilizers namely defatted sesame meal, bat guano, wood ash were collected

naturally from Seik-kyi village, Kyone Pyaw Township, Ayeyarwady Region on September, 2013. The sesame seed samples were cleaned manually by removing all the foreign matter such as stones, dirt and broken seeds. They were washed in abundant water before drained on a sieve. Traditional pressing method was used to extract the oil from sesame seed. The residue or defatted sesame meal was collected and dried at room temperature. This defatted sesame meal was soaked with water for about 3 or 4 days until to get decayed defatted sesame meal. The colonies of bat dwelling in an abandoned tree in Seik kyi village and this tree is nearby cassava plantations, paddy fields and small stretches of wood land. Droppings (guano) deposited beneath the roosting colony were collected for the plant growth study. Wood ash was easily collected from the wood burning stoves of Seik-kyi village. In this area, most of the housewives usually use the branches or stems of *Albizia labbeck* Benth., *Annona muricata* L. and *Bridelia retusa* (L.) Spreng. to cook the food in their kitchen. Commercial organic fertilizer "Vedagro" was collected from local market and it was produced from Vedan Vietnam Enterprise com., Ltd.

2.1.1 Determination of physicochemical properties of selected fertilizers

The physicochemical parameters: moisture, total nitrogen, P_2O_5, K_2O, calcium, magnesium, sulphur and organic matter content, of the four kinds of organic fertilizers and soil were determined at Department of Agriculture (Land Use), Ministry of Agriculture and Irrigation, Yangon. The moisture content of fertilizers was determined by oven dry method. The pH value of samples was measured by using pH meter. The total nitrogen of the samples was measured by using Kjeldahl's method. Available phosphorus was determined by the phosphorus extraction method [4].

The determination of available potassium is based on the ammonium acetate extraction method. Available potassium is measured by flame photometer. The exchangeable potassium is determined by flame emission spectroscopy (wavelength 766.5 nm). The samples were analyzed for concentrations of water soluble Ca^{2+}, Mg^{2+} using EDTA titration method [5]. Organic matter content of the soil was determined by the wet combustion procedure of Walkely and Black [6].

2.2 Soil Sample Preparation

Surface soil (~ 100 kg) was thoroughly mixed with 50 kg of rice husk char to provide representative soil sample. Then physical and chemical properties of soil sample were determined using AOAC method [7] at Department of Agriculture (Land Use), Ministry of Agriculture and Irrigation.

2.3 Radish Seed Sample Preparation

Radish (*Raphanus sativus* L.) seeds were bought from Padathar market, Hinthada Township and then the radish seeds were directly used in the soil for cultivation purposes.

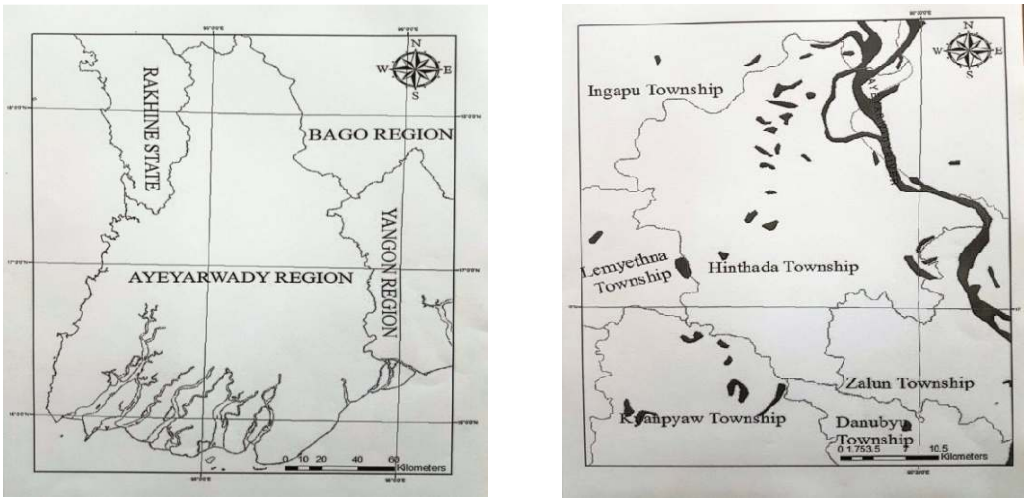
2.4 Radish Cultivation Process

Firstly, twelve pots were bought from Padathar Market, Hinthada Township for the experiment (triplicate). All pots were same size and the dimension of each pot was 41 cm diameter, 21 cm height and 119 cm pot girth. Approximately 10 kg of soil was put into each pot and the groove about 2.5 cm depth was dug on the surface layer of the soil and this groove was made circle shape with 15 cm diameter in each pot. Three to four seeds were put at the points along the groove and each point was 5 cm distance to each another.

Radishes grow best in full sun and light sandy loams with pH 6.5-7.0. Pot I, II, III, and IV were brought into the farm 1st week of October, 2013. First pot was assigned control pot which contains only soil without fertilizer. It was called as control (**Pot I**). The second pot was designed for soil and organic fertilizer namely defatted sesame meal and wood ash. This pot was named as DSM+Ash or **Pot II**. The third pot was prepared with soil and organic fertilizer; defatted sesame meal, bat guano and wood ash. It was assigned as natural or **Pot III**. The last pot was put soil and vedagro fertilizer and designed as vedagro or **Pot IV**. After 3 days of seeding, small seedlings came out from the seeds.

On the 1st of December, the radish roots in pot IV (Vedagro treatment) would be ready to harvest quite rapidly (30 days after root growing). At 10th and 16th December, the radish roots were pulled from pot II, III and pot I soil. After harvesting, the soil residue from the pot I, II, III and IV were collected and then, dried at room temperature. The characteristics of soil after harvesting were

determined at Department of Agriculture (Land Use), Yangon. After harvesting, the roots from the pot I, II, III and IV were removed from the plants and washed the radish roots. Among them, 0.5 kg of each fresh radish root was used to determine the nutritional values: moisture, protein, fat, ash, carbohydrate, fiber and calorie content, at Myanmar Food Processors and Exporters Association (MFPEA), Yangon. Then 0.1 kg of fresh radish root from each pot was used to determine the vitamin C content in the department of chemistry, Hinthada University.



(a) **(b)**

Fig. 1. Location Maps of the studied area showing; (a) Map of Ayeyarwady Region, Myanmar (b) Map of Hinthada Township

Fig. 2. Photographs of soil collection after harvesting of radish roots and soil collection

Table 1. Rainfall and average temperature in Hinthada township at 2013

Month	Average rainfall(mm)	Average temperature(℃)	Month	Average rainfall(mm)	Average temperature(℃)
January	0.5	24.5	July	424.2	27.2
February	0.76	24.1	August	591.6	27.0
March	0.5	27.2	September	256.5	27.8
April	19.8	29.3	October	467.4	27.7
May	148.33	30.7	November	17.78	26.8
June	417.32	27.7	December	1.016	25.2

3. RESULTS AND DISCUSSION

In the field study area, the mean annual rainfall was about 196 mm while the average temperature ranged between 29 to 31℃. The cultivation time was ranged from September to December, so that the average rainfall and temperature were ranged 185.674 mm and 26.9℃.

3.1 Physicochemical Properties of Organic Fertilizers

Physicochemical properties of various fertilizers were presented in Table 2. According to these data, the moisture content of vedagro was significantly less than that of the other three fertilizers. Vedagro is a commercial organic fertilizer pellet so that it was packed with plastic whereas the other three natural fertilizers such as defatted sesame meal, bat guano and wood ash were not pellets and their moisture contents were relatively high. The total nitrogen content in vedagro fertilizer was greater than in the other three natural fertilizers. The content of phosphorus in wood ash was greater than in the other three fertilizers. Wood ash is a good source of phosphorous and some micronutrients because it is composed of many major and minor elements needed by the tree for plant growth and extracted from the soil and atmosphere during the tree's growth cycle [8].

The value of potassium in vedagro and wood ash are higher than the values for other two natural fertilizers. Because of its high potential, ash was applied as a raw material resource for the production of acidic soil improvers. The wood ash was rich in non-burned carbon which most probably is due of the content of non-burned wood particles and coals. The vedagro fertilizer has sweet flavor of molasses in addition it also has nutrient content much more than molasses for the reason that the fermentation created amino acids. The content of total Ca in wood ash is significantly greater than in the other three natural fertilizers. Due to the presence of calcium in comparatively large quantities, the ashes gave a strongly alkaline reaction which can neutralize acid soils. The value of wood ashes as a plant food depends mostly on the potassium content [9].

The total Mg content in the defatted sesame meal and bat guano was not detectable. The results obtained showed that the total S content in defatted sesame meal is smaller than in the other three fertilizers because they are stable radical intermediate which prevent various food ingredients from oxidation [10]. The organic matter content in vedagro was greater than in the three organic fertilizers because it has very rich organic matter with the highest nutrient contents in its class.

3.2 Characteristics and Physicochemical Properties of before Fertilized Soil

The characteristics and physicochemical properties of before fertilized soil were shown in Table 3. Soil texture contained the percentage of sand (10.20%), silt (71.35%) and clay (17.00%). This type of soil is more suitable for cultivation because of possessing higher content of silt. Soil pH value was found to be 7.8. Soil pH value was higher than the acceptable pH range to grow the most commercial crops because the best pH for growing plants is round 6.4. The representative soil that was used in this study was the type of moderately alkaline. The empirical data pointed out that the moisture content is 2.25%. The moisture occupies in the larger spaces of the soil to provide plant roots with water and air. The moisture content of soil sample was sufficient for the cultivation of plant. The empirical data pointed out that high in exchangeable Ca (18.19 meq/100 g), medium in Mg (1.29 meq/100 g) and low in K (0.23 meq/100 g) indicating that the soil is the alkaline soil and tends to reduce the uptake of K and Mg. Magnesium helps the movement of sugar within the plant [11]. Sufficient amount of potassium increases the size of grains or seeds and improves the quality of fruits and vegetables. The deficient K causes the shriveled seeds or fruits [12]. The contents of total nitrogen and phosphorus are 0.16% and 27.21 ppm respectively. An abundance of nitrogen promotes rapid growth with a greater development of green leaves and stems. The presence of sufficient available phosphorus is required for seed formation and crops maturity.

3.3 Variation of Soil Properties after Radish Cultivation

All organic fertilizers treatments except commercial fertilizer, vedagro, increased moisture content, available potassium, available P, exchangeable K, Ca and Mg relative to the control treatment (Table 4). The analysis of the fertilizers used indicated it had considerable percentages of N, P, K, Ca and Mg; hence, nutrients released by the waste material should

Table 2. Physicochemical properties of various fertilizers

Test Parameter (%)	Fertilizers			
	Vedagro	Wood ash	Bat guano	Defatted sesame meal
Moisture	2.954	45.724	43.87	57.731
Total N	10.608	0.386	1.609	1.379
Total P_2O_5	1.037	5.221	0.183	0.284
Total K_2O	5.13	4.608	0.422	0.343
Total Ca	3.847	13.08	0.769	1.539
Total Mg	0.093	1.867	-	-
Total S	2.508	0.664	0.65	0.051
Organic matter	38.781	1.737	0.709	11.067

have contributed to improving nutrient availability to radish on the infertile soils and invariably supported higher growth parameters.

Table 3. Characteristics and physicochemical properties of before fertilized soil

Test parameter	
Texture	**Silt loam**
Sand (%)	10.20
Silt (%)	71.35
Clay (%)	17.00
pH	7.8
Moisture Content (%)	2.25
Ca (meq/100 g)	18.19
Mg (meq/100 g)	1.29
K (meq/100 g)	0.23
Total Nitrogen Content (%)	0.16
Total Phosphorus Content (ppm)	27.21
Potassium Content (mg/100 g)	11.05

Because of their deep root system, rapid root extension, and heavy N feeding, radishes are excellent scavengers of residual N. Radishes take up N from both the topsoil and from deeper soil layers, storing the N in their shoot and root biomass. However, radish residues decompose and release N rapidly compared with other crops. More research is needed to identify strategies for optimizing recycling of the N scavenged by radish cover crops. Radishes are excellent accumulators of P and K (root dry matter commonly contains more than 0.5% P and 4% K), and high levels of soil test P have been measured following radish cover cropping, particularly within 1–1.5 inches of radish root holes [13]. The application of natural fertilizer scored best among all the treatments in terms of the content of exchangeable Ca, Mg, total nitrogen, total phosphorus and total potassium content. The results of soil physicochemical parameters suggested that high and sustained NPK contents could be obtained after radish cultivation by natural organic fertilizers.

Table 4. Physicochemical properties of post harvest soil

Test Parameter	Control	DSM+Ash	Natural	Vedagro
pH	8.37	8.45	8.70	8.13
Moisture Content (%)	3.51	5.92	8.42	3.13
Ca (meq/100 g)	23.3	34.6	42.9	24.6
Mg (meq/100 g)	2.7	2.0	2.7	1.3
K (meq/100 g)	1.1	1.3	1.4	0.7
Total N Content (%)	0.28	0.31	0.34	0.38
Total P Content (ppm)	126.4	121.6	161.2	104.4
K content (mg/100 g)	51.6	61.2	64.8	33.5

Table 5. Summary showing yield parameters of fresh radish root

Type of Fertilizer	Root wt. (g)		Root length(cm)		Root girth (cm)	
	range	Ave.± SD	range	Ave.± SD	range	Ave.± SD
Control	15-76	33.4± 15	6-26	19.4±6.8	5-11	7.6±2.4
DSM+Ash	38-215	109±19	14-23	17.0± 3.9	10-15.5	12.4±2.3
Natural	38-384	153.6±27.6	10-26	18.0± 3.2	9-17.5	13.7±3.4
Vedagro	76-323	168.8±35.8	13-23	17.4±2.9	10-14.5	12±1.1

Control DSM+Ash Natural Vedagro

Fig. 3. Photograph of radish root products by different fertilizers

Table 6. Some nutritional values of fresh radish root by various fertilizers

Parameter	Control	DSM+Ash	Natural	Vedagro
Moisture (%)	93.57	94.40	93.38	93.74
Protein (%)	0.45	0.56	0.47	0.41
Fat (%)	0.05	0.03	0.06	0.01
Ash (%)	1.12	0.81	1.00	0.79
Carbohydrate (%)	2.97	3.52	3.39	4.99
Fiber (%)	1.84	0.68	1.70	0.06
energy (kcal/100 g)	15	20	15	22
Vit. C content (mg/kg)	16.7	14.7	17.9	16.3

3.4 Growth Parameters and Nutrients of Radish

The growth parameters of fresh radish (Fig. 3) (above) using various fertilizers from Pot I, II, III and IV are shown in Table 5.

The root from Pot I was found to be longest, however, the root lengths in Pot II and IV are nearly the same and shorter than pot III. Relative to control, all fertilizer treatments increased root weight about 3 times, 4.6 times and 5 times for DSM+Ash, natural and vedagro fertilizers. All of the natural and commercial fertilizers were found to be effective in the growth of root weight in radish cultivation. Moreover, the largest root girth was observed in Pot III and smallest root girth was observed in Pot I. All of the fertilizer treatments for root girth were detected as almost 2 times higher than control treatment.

The nutritional values of fresh radish root from four pots were observed in Table 6. (above) The moisture, protein and calorie contents were also found no significantly difference in all fresh radish roots. The fat content of radish root in Pot IV was lower than that of the other radish roots.

The content of carbohydrate from Pot IV was the highest because the contents of protein, fat, ash and fiber of radish roots from Pot IV were the lowest compared with other three pots. Total vitamin C content of fresh radish root was found to be highest in Pot III followed by Pot I, IV and II. So, natural fertilizer used in Pot III was found the best treatment for radish cultivation

4. CONCLUSION

In this research, study on the utilization of natural waste materials (defatted sesame meal, bat guano and wood ash) for sustaining soil health and organic-based crops production were performed in radish cultivation. It was found that the mean annual rainfall is about 196 mm while the average temperature ranged between 24℃ to 31℃ in the prescribed zone. The organic fertilizers had relatively high N and P and good percentages of K and Ca. Initial soils were very low in Mg, nitrogen, moderately low K_2O and high in Ca, P and the soil was assigned as moderately alkaline. After harvesting the radish, results show that relative to control, the natural fertilizers treatments increased soil N, P, K and Mg significantly. The soil pH was found to be increased in all types of treatments after cultivation. This study reveals that the root weight was observed as similar results for vedagro and natural treatments and then followed by DSM+Ash and control. In addition, the calories and vitamin C contents of radishes were observed to be nearly the same for all treatments. The observation of this research contributes that these waste materials not only reduce the cost of fertilizer but serve as the ultimate solution for restoring the lost fertility of agricultural soils as well as crop production; and they can be recommended

as organic fertilizers to sustained soil and productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/16180