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Vermicomposting of sugarcane bagasse and rice straw and its impact on the cultivation of *Phaseolus vulgaris L.* in Guyana, South America

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The present study was carried out during the year 2006-2007 at University of Guyana, Georgetown. Experiments were aimed at production and quantitative comparison and rate of production of vermicomposts from sugar cane bagasse, rice straw, and a combination of sugar cane bagasse and rice straw. Results indicated that the combination of bagasse and rice straw showed the highest percentage of production. The vermicomposts were assessed for nutrient value and subjected to study on plant growth parameters of *Phaseolus vulgaris* L. and were compared with treatments using cow dung and chemical fertilizer. The results indicated that vermicompost is a competitive biofertilizer and showed better growth patterns in *Phaseolus vulgaris* L. than chemical fertilizers and can retain nutrients for longer period. *Phaseolus vulagris* L. with vermicompost had better fruit quality in terms of physical dimension, biochemical constituents. There was significant improvement in the soil quality in the experimental plots with treated with vermicompost produced from bagasse and rice straw [BV+RSV]. The combination treatment [BV+RSV] was the found to be better suggesting qualitative improvement in the physical and chemical properties of the soil, which is substantiated by T-test and composite index in comparison to control and chemical fertilizers.

Key words: Vermicomposting, sugarcane bagasse, rice straw, earthworms, microbial interaction, Guyana

Introduction

Compost is becoming an important aspect in the quest to increase productivity of food in an environmentally friendly way. Vermicomposting offers a solution to tonnes of organic agro-wastes that are being burned by farmers and to recycle and reuse these refuse to promote our agricultural

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development in more efficient, economical and environmentally friendly manner. Both the sugar and rice industries burn their wastes thereby, contributing tremendously to environmental pollution thus, leading to polluted air, water and land. This process also releases large amounts of carbon dioxide in the atmosphere, a main contributor to global warming together with dust particles. Burning also destroys the soil organic matter content, kills the microbial population and affects the physical properties of the soil (Livan and Thompson, 1997). Organic farming system is gaining increased attention for its emphasis on food quality and soil health. Vermicompost and vermiculture associated with other biological inputs have been actually used to grow vegetables and other crops successfully and have been found to be economical and productive (Ismail, 2005; Ansari and Ismail, 2008). The objective the study was to assess the plant productivity by the use of organic fertilizers in different combinations and the effect on soil physical and chemical parameters in comparison to control and chemical fertilizers.

Materials and methods

The present study was carried out during the year 2006-2007 at University of Guyana, Georgetown. The vermicomposting units were be set up at the University of Guyana compound.

Vermicomposting units were set up using vermitech pattern (Ismail, 2005). Plastic crates (60 cm x 45 cm x 45 cm) were used as the container and placed in a shaded elevated area as to facilitate the effective water drainage. A basal layer of vermibed comprising broken bricks then a layer of sand to the thickness of 6 to 7.5 cm was set up to ensure proper drainage. This was then covered with a layer of loamy soil up to the height of 15 cm, after it was moistened. Into this soil, 50 locally collected earthworms, *Eisenia foetida,* were inoculated. Small lumps of fresh or dry cattle dung was then scattered over the soil. The soil was then covered with 10 cm of agro waste. The entire unit was kept moist by sprinkling of water twice weekly and turned once weekly up to the 7^{th} week.

Three units were set up as follows:

Unit 1: 150 g Sugar cane bagasse + 1 kg of cow dung
Unit 2: 150 g Rice straw + 1 kg of cow dung
Unit 3: 75 g Rice straw + 75 g sugar cane bagasse + 1 kg cow dung

The vermicompost was then harvested and placed to air-dry for chemical analysis together with untreated soil and raw sugar cane bagasse and rice straw using standard procedure for pH, Organic carbon, Available nitrogen, Available phosphate, Calcium, and Magnesium (Homer, 2003). The analysis of the compost samples was done at Central Laboratory, Research Center, Agriculture Department, LBI Compound, GuySuCo. The analysis of food components from the plants and plant products were done at Food and Drug Analysts Department.

The pot experiments of *Phaseolus vulagris* L were placed using Randomized Block Design with replication for each treatment by using vermicomposts, cow dung, chemical fertilizers and chemical pesticide and a control. The pots were filled with sterilized dry soil (5 kg). Each pot was treated at the time of plantation, after three weeks and then just at the beginning of flowering period (4^{th} week) as follows:

Treatments:	Symbol	Amount added/ g
Soil	CON	No addition
Bagasse Vermicompost	BV	100
Rice Straw Vermicompost	RV	100
Bagasse + Rice Straw Vermicompost	BV + RSV	100
Cow Dung	CD	100
Chemical fertilizer (Urea)	CHM	13.6

Growth parameters (number of leaves, plant height, number and distance between nodes) were taken after five week. Upon maturity the fruits were harvested, counted, weighed and preserved for analysis. Plants were then uprooted to record physical parameters. Fruits were subjected to quantitative estimation of protein and fat. Soil samples were subjected to chemical analysis (pH, $EC_{w,}$ Organic carbon, Available nitrogen, Available phosphate, Calcium and Magnesium (Homer, 2003). Following statistical tools were applied to data recorded: t-Test and Composite index.

Results and discussion

The vermicomposts were harvested after a 50- day period for the first set. This period was reduced by 5 and 9 days, respectively for the other two harvests. There was consistent increase in the production of vermicomposts in each unit from each successive harvest (Table 1). This can be attributed to the increase in the population of the earthworms, each unit started with 300 earthworms. However, this increase was greater and even more consistent in the rice straw and bagasse + rice straw units. Composting of bagasse, rice straw and a combination of bagasse with rice straw were successful. However, the composting process of the combination was faster and the productivity was higher. For combination, the average productivity was 76% followed by rice straw with 74% and bagasse with 54%. Earthworms preferred cow dung along with plant litter and other plant debris in combination thereby converting it into the organic matter rich vermicompost at faster rate (Ansari, 2007; Ismail, 2005; Ismail 1997; Atiyeh *et al*., 2000; Edwards and Bohlen, 1996).

The pH remains slightly alkaline for all the samples but the most alkaline was the vermicompost from the combination of bagasse and rice straw BV +RSV (Table 2). Carbon is higher in CON as it was in undecomposed state. C: N ratio was observed to be 5.46, 6.91, 7.09 and 9.43 for RSV, BV + RSV, BV and CON, respectively. The C: N ratio is an indication of litter degradation in soils and it is an indicator of efficient and effective composting, the final value is important to determine the value of the finished compost as a soil amendment for growing crops. Carbon provides the primary energy source and nitrogen in critical for microbial growth. As the composting process proceeds the carbon content is expected to decrease because of it conversion to carbon dioxide while nitrogen is kept intact. Very high C: N ratio (above 80) greatly reduced the rate of natural composting. In this case, earthworms have effectively increased the rate and thus having a greater turnover (Stoffella and Kahn, 2000).

The greatest increase in plant height was observed with treatment BV+RSV followed by RSV then CD (Table 3). Vermicomposts contain more than just micro and macro nutrients; they also have essential growth promoter hormones like auxins, cytokinins, gibberllins, ethylene, and enzymes, vitamins that are microbially induced and excreted by earthworms along with useful microorganisms like bacteria (Ansari and Ismail, 2001; Edwards, 2004). Chemical fertilizers on the other hand constitute mainly macronutrients and soluble salts with no hormones. Also these nutrient have a high solubility rate as such a great deal is lost through leaching. This results in fast growth in the initial stages of planting and reduces subsequently due to lack of nutrients (Edwards and Bohlen, 1996; Stoffella and Kahn, 2000). Treatment CHM had a significant increase in the number of leaves followed by RSV, BV, BV + RSV then CD (Table 3). The highest number of leaves in CHM is due to availability of nitrogen and phosphate in the chemical fertilizer. These fertilizers serve the purpose of "quick fix" with no regards for future consequences. The leaves had a higher surface area and were much greener. CHM treatment plant appeared healthier at the beginning but fade out to yellowing, evidence of lack of nutrients (Lalitha *et al*., 2000; Stoffella and Kahn, 2000). The treatment BV + RSV had the thickest circumference because of its ability to retain nutrition for longer periods (Lalitha *et al*., 2000; Stoffella and Kahn, 2000). As with the number of leaves, the nodal count was also highest in the CHM treated plants followed BV + RSV, BV, RSV, and then CD (Table 3).

Leaf abscission was minimum in treatment BV+RSV (Table 3). Vermicomposts consisted of nutrient that would promote such growth or had microorganisms which made available the nutrients (Lalitha *et al*., 2000). It is evident that chemical fertilizer disrupts natural biological activity in the soil. Activity of Rhizobium/ nitrifying bacteria is affected and inhibited (Lalitha *et al*., 2000; Stoffella and Kahn, 2000, Ismail, 1995).

Table 1. Productivity of vermicomposts from the different materials.

Organic Material	Amount/ Kg	Cow dung / Kg	Average harvests / Kg	Average productivity/%
Bagasse	0.4	0.6	0.54 ± 0.14	54
Rice Straw	0.4	0.6	0.74 ± 0.02	74
Bagasse + Rice Straw	0.2 + 0.2	0.6	0.76 ± 0.02	76

The highest marketable yield of fruit was observed with treatment BV followed by RSV and BV + RSV (Table 4). Organic fertilizers have been known to promote growth of nitrogen fixing and phosphate solubilising bacteria. These are critical in plant overall growth thus, influencing fruit development (Stoffella and Kahn, 2000, Talashilkar and Power, 1998; Ismail, 1995). Protein content of the fruits was consistent for treatments CON, RSV, BV + RSV and CD while lower levels were observed in BV followed by CHM (Table 4). *Phaseolus vulgaris* L. is known to have high amount of protein content. The amount of fat present in the fruit was variable but consistent with all the treatments.

Soil pH significantly increased for all the vermicomposts treatments while CD had increase but not significant (Table 5). CHM resulted in a decrease in the pH thereby making the soil more acidic. Soil pH is one of the most important soil properties that affect the availability of nutrients. Macronutrients tend to be less available in soils with low pH and micronutrients tend to be less available in soils with high pH. Treatments BV + RSV, RSV and BV indicated significant increase in organic carbon (Table 6). Vermicomposts are rich in organic carbon content and have the ability to release these in to the soil very slowly. Significant increases in nitrogen were observed in BV may be attributed to enhanced activity of nitrogen fixing bacteria (Stoffella and Kahn, 2000; Lalitha *et al.,* 2000) (Table 7). Significant increase was observed for treatments BV + RSV and RSV with regards to phosphates (Table 8). It may be because of the presence of phosphate solubilizing bacteria, which increase the phosphate content of the soil. There were significant increases in magnesium concentration for BV + RSV, RSV and BV (Table 9). All the samples except CHM indicated an increase in calcium concentration though not significant.

CHM had reduced amount because what ever little was there used up and there no replacement because it is highly soluble in Ca^{2+} form (Stoffella and Kahn, 2000, Edwards and Bohlen, 1996) (Table 10). Thus vermicompost produced from combination of sugarcane bagasse and rice straw showed better results in terms of productivity of vermicompost and its subsequent application on *Phaseolus vulgaris* L in many plant growth parameters and productivity levels that is a result of nutrients available in vermicompost BV + RSV that played critical role in improving soil quality (Kale, 1998). The treatment BV + RSV was highly significant with improvement of soil physical and chemical properties. Composite index is shown in Table 11.

Generally, the physiochemical properties of the rice straw and the combinations were conducive and enhance growth and yield of *Phaseolus vulgaris* L. The final soil analysis also indicated signs of improvement in nutrient content. It cab be concluded that growth parameters for chemical grown crops and organically grown crops are comparable. Chemical fertilizers, especially nitrogen based, shown spectacular growth and productivity in the field but this is short lived. The high level of these chemical added to the soil are not usually absorbed completely by the plants. The balance cannot remain in the soil for the next season. They are either leached or formed complexes with high levels of metal ions to form undesirable complexes (Kale, 1998). Constant use of chemical fertilizer increases leaching because of depletion of organic carbon (Stoffella and Kahn, 2000). On the other hand, a vermicompost form fine stable granular organic matter that assist in the aeration, released mucus that are hygroscopic absorbs water and prevents water logging and improves water holding capacity. Vermicompost added to the soil releases nutrient slowly and consistently and enables the plant to absorb these nutrients more readily. Soils enriched with vermicompost provide additional substances that are not found in the chemicals (Ansari and Ismail, 2001; Kale, 1998).

Table 2. Physico-chemical analysis of cow dung and vermicomposts (mean ± SD).

Parameters	Con	BV	RSV	BV + RSV
pH(dSm^{-1})	7.40 ± 0.01	7.28 ± 0.03	7.51 ± 0.01	7.59 ± 0.01
EC	1733.33 ± 24.09	533.33 ± 4.16	615.67 ± 7.09	563.67 ± 5.51
Organic carbon%	17.95 ± 0.73	6.52 ± 0.56	6.24 ± 0.46	6.64 ± 0.66
Nitrogen (%)	1.90 ± 0.03	0.92 ± 0.04	1.14 ± 0.06	0.96 ± 0.05
Phosphate (ppm)	190.78 ± 5.37	143.16 ± 1.94	178.97 ± 8.79	156.51 ± 19.29
Calcium (ppm)	5.65 ± 0.21	5.51 ± 0.04	6.35 ± 0.73	5.05 ± 0.06
Magnesium (ppm)	17.29 ± 2.11	16.43 ± 0.72	18. 27 ± 2.02	14.66 ± 0.47
Potassium (ppm)	62.10 ± 0.46	147.83 ± 5.34	25.47± 2.27	174.00 ± 4.19
Zinc (ppm)	62.90 ± 0.21	69.96 ± 0.22	79.64 ± 0.36	68.90 ± 0.44
Iron (ppm)	36.32 ± 1.74	11.92 ± 0.93	12.17 ± 0.68	8.45 ± 0.50
Copper (ppm)	1.23 ± 0.05	0.52 ± 0.18	0.55 ± 0.07	0.42 ± 0.02
Manganese (ppm)	251.38 ± 4.89	59.69 ± 0.17	83.01 ± 0.45	54.19 ± 0.08

Table 3. Plant morphometry (mean ± SD).

Treatments	Plant Height (cm)	Number of leaves/plant	Plant circumference (cm)	Number of nodes/plant	Leaf abscission/ plant
CON	175.00 ± 15.72	67.00 ± 15.39	2.43 ± 0.21	21.67 ± 5.13	8.33 ± 0.58
BV	215.33± 14.64	92.00± 9.64	3.37 ± 0.31	30.00 ± 3.61	7.33 ± 1.53
RSV	247.67 ± 42.77	93.33 ± 1.53	3.73 ± 0.32	27.00 ± 6.08	7.33 ± 1.53
BV + RSV	250.67 ± 44.43	90.33 ± 8.62	3.99 ± 0.32	34.33 ± 153	6.67 ± 0.58
CD	227.67 ± 31.13	79.67 ± 8.62	2.30 ± 0.10	27.33 ± 3.79	7.67 ± 0.58
CHM	224.00 ± 73.78	111.00 ± 8.66	2.97 ± 0.12	36.33 ± 2.89	17.0 ± 1.41

Table 4. Biochemical analysis of fruit and marketable yield (Mean ± SD).

Treatments	Protein/%	Fat/%	Marketable yield (g/plant)
CON	31.71 ± 0.47	2.14 ± 0.00	9.32 ± 0.94
BV	25.40 ± 2.69	2.13 ± 0.16	12.57 ± 1.61
RSV	31.65 ± 11.67	2.07 ± 0.06	11.30 ± 1.52
BV + RSV	31.55 ± 0.04	2.61 ± 0.42	9.90 ± 3.32
CD	31.51 ± 0.75	2.45 ± 0.11	6.15 ± 5.66
CHM	21.52 ± 1.00	2.25 ± 0.06	7.05 ± 1.94

Table 5. Soil pH (Mean ± SD).

Treatments	**Initial soil**	**Final soil**	**Increase in pH**
CON	5.61 ± 0.04	5.61 ± 0.15	0.00
BV}	5.61 ± 0.04	6.11 ± 0.07	0.50
RSV	5.61 ± 0.04	6.19 ± 0.01	0.58
BV + RSV	5.61 ± 0.04	6.30 ± 0.10	0.69
CD	5.61 ± 0.04	5.85 ± 0.13	0.24
CHM	5.61 ± 0.04	5.31 ± 0.34	-0.30

Table 6. Organic carbon % (Mean ± SD).

Treatments	**Initial soil**	**Final soil**	**Increase in OC%**
CON	2.85 ± 0.71	6.53 ± 0.32	3.68
BV	2.85 ± 0.71	8.97 ± 0.69	6.12
RSV	2.85 ± 0.71	14.82 ± 1.53	11.97
BV + RSV	2.85 ± 0.71	18.68 ± 0.21	15.83
CD	2.85 ± 0.71	9.45 ± 2.67	6.60
CHM	2.85 ± 0.71	8.94 ± 0.97	6.09

Table 7. Available nitrogen % (Mean ± SD).

Treatments	**Initial soil**	**Final soil**	**Increase Available nitrogen %**
CON	0.90 ± 0.04	2.47 ± 0.3	1.57
BV	0.90 ± 0.04	3.52 ± 0.86	2.62
RSV	0.90 ± 0.04	2.38 ± 0.02	1.48
BV + RSV	0.90 ± 0.04	2.13 ± 0.41	1.23
CD	0.90 ± 0.04	1.87 ± 1.00	0.97
CHM	0.90 ± 0.04	1.94 ± 0.69	1.04

Table 8. Available phosphate (ppm) (Mean ± SD).

Treatments	**Initial soil**	**Final soil**	**Increase in Available phosphate**
CON	155.17 ± 26.15	20.17 ± 3.63	-135
BV	155.17 ± 26.15	159.65 ± 86.51	4.48
RSV	155.17 ± 26.15	307.65 ± 10.71	152.48
BV + RSV	155.17 ± 26.15	559.37 ± 85.83	404.2
CD	155.17 ± 26.15	60.30 ± 53.62	-94.87
CHM	155.17 ± 26.15	317.68 ± 106.29	-162.51

- indicates decrease

Table 9. Magnesium (ppm) (Mean ± SD).

Treatments	Initial soil	Final soil	Increase in Mg
CON	11.83 ± 0.62	14.80 ± 0.18	2.97
BV	11.83 ± 0.62	17.34 ± 0.50	5.51
RSV	11.83 ± 0.62	18.18 ± 0.81	6.35
BV + RSV	11.83 ± 0.62	19.36 ± 1.06	7.53
CD	11.83 ± 0.62	14.88 ± 0.00	3.05
CHM	11.83 ± 0.62	13.94 ± 0.85	2.11

Table 10. Calcium (ppm) (Mean ± SD).

Treatments	Initial soil	Final soil	Increase in Ca
CON	9.03 ± 0.19	9.75 ± 0.03	0.72
BV	9.03 ± 0.19	9.82 ± 0.86	0.79
RSV	9.03 ± 0.19	10.38 ±0.87	1.35
BV + RSV	9.03 ± 0.19	10.60 ± 0.51	1.57
CD	9.03 ± 0.19	15.80 ± 7.73	6.77
CHM	9.03 ± 0.19	9.01 ± 0.56	-0.02

- indicates decrease

Table 11. Composite index based on soil chemical analysis.

Treatments	pH	OC	N	P	Mg	Ca	Composite index	Rank
CON	*5*	*6*	*2*	*5*	5	*5*	*28*	*5*
BV	3	4	1	3	3	4	18	3
RSV	2	2	3	2	2	3	14	2
BV + RSV	1	1	4	1	1	2	10	1
CD	4	3	6	4	4	1	22	4
CHM	6	5	5	6	6	6	34	6

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