BIBLIOGRAPHY

ROSADO, DANIEL HECTOR D. OCTOBER 2009. Influence of Vermicomposts Developed from Different Substrates on Lettuce (*Lactuca sativa*) cv. Romaine and Potato (*Solanum tuberosum*) cv. Solibao. Benguet State University, La Trinidad, Benguet.

Adviser: Wilma L. Marquez, MSc

ABSTRACT

There were two sets of experimental set-ups to determine the influence of vermicompost on the yield and quality of lettuce and potato including its effects on the soil. Specifically, the study aimed to (1) determine the effect of vermicompost developed from different substrates on the yield and quality of lettuce and potato; (2) determine the influence of vermicompost developed from different substrates on some physical and chemical properties of soil.

The application of vermicompost developed from different substrates did not affect the different agronomic parameters such as initial height and final height, total yield, shelf-life and weight loss of lettuce. As to the soil physical properties, the bulk density was improved by vermicompost applied. On the other hand, the organic matter, nitrogen, phosphorus, potassium and cation exchange capacity of the soil were affected by vermicompost application. The OM and N contents of the soil were improved by vermicompost derived from mixtures of sawdust and cow manure. The P and CEC of the soil were improved by applying vermicompost derived from sawdust and hog manure mixtures, while the K content was improved from vermicompost obtained from sawdust and horse manure mixture.

On the potato trial, vermicomposts obtained from the different substrates affected the marketable yield, non-marketable yield, total yield, and dry matter content (DMC) of tubers. Application of vermicompost derived from mixture of sawdust and cow manure improved the

marketable yield and total yield of potato. Moreover, lowest non-marketable tubers were obtained from this mixture. The DMC was highest from tubers harvested from plots applied with vermicompost from sawdust and hog manure mixture. The WHC was improved by vermicompost obtained from the different mixtures of sawdust and animal manure. The pH, OM, N, and CEC of the soil were improved by the application of vermicompost obtained from the different substrate mixture.

TABLE OF CONTENTS

	Page
Bibliography	i
Abstract	i
Table of Contents	iii
INTRODUCTION	1
REVIEW OF LITERATURE	4
Effect of Organic Matter, Organic Fertilizer, and Vermicompost	4
Soil Physical Properties	4
Soil Chemical Properties	6
Soil Biological Properties	9
Effect of Organic Matter, Organic Fertilizer, and Vermicompost	11
Plant Growth and Yield of Crops	11
Nutrient Content of Animal Manure	13
MATERIALS AND METHODS	14
RESULTS AND DISCUSSION	22
LETTUCE	22
Growth Parameters	22
Initial Plant Height	22
Final Plant Height	23
Yield Parameter	23
Total Yield	23

Post Harvest Qualities 24

Shelf-life of Lettuce 24

Percent Weight Loss of Lettuce 25

Physical Properties of the Soil After harvest 26

Bulk Density (Db) of the Soil 26

Water Holding Capacity (WHC) of the Soil 27

Chemical Properties of the Soil After Harvest 29

Final Soil pH 29

Organic Matter (OM) Content of the Soil 30

Total Nitrogen (N) Content of the Soil 31

Available Phosphorus (P) Content of the Soil 32

Exchangeable Potassium (K) Content of the Soil 33

Cation Exchange Capacity (CEC) of the Soil 34

Return on Investment 35

POTATO 37

Yield Parameters 37

Marketable Yield 37

Non-Marketable Yield 38

Total Yield of Potato 38

Quality Parameter 39

Dry Matter Content (DMC) of Potato 39

Physical Properties of the Soil After Harvest 40

Bulk Density (Db) of the Soil 40

Water Holding Capacity (WHC) of the Soil 41

Chemical Properties of the Soil After Harvest 43

Final Soil pH 43

Organic Matter (OM) Content of the Soil 44

Total Nitrogen (N) Content of the Soil 45

Available Phosphorus (P) Content of the Soil 46

Exchangeable Potassium (K) Content of the Soil 47

Cation Exchange Capacity (CEC) of the Soil 48

Return on Investment 49

SUMMARY, CONCLUSION AND RECOMMENDATION 51

Summary 51

Conclusion 52

Recommendations 53

LITERATURE CITED 54

APPENDICES 56

INTRODUCTION

Lettuce is common name for members of an herbaceous genus of the daisy family, particularly the garden lettuce (*Lactuca sativa*). It is one of the most popular salad vegetables and an important farm crop. Garden lettuce is grown in well-drained, crumbly soil, rich in organic fertilizer. Rows are planted 30 to 38 cm (12 to 15 in) apart and thinned frequently after the plants reach a height of 5 cm (2 in). Lettuce is native to northern temperate regions. Within the Philippine setting, Lettuce is one of the most important salad crops. It is grown commercially in some parts of the country like Benguet and it is produced for local market and home use. Lettuce is eaten raw and is served as salad combined with tomato, cucumber, potato and other vegetables. It is also an ingredient in making sandwiches and it is used as decorations for foods. Lettuce also contains 95 % water and a fair source of minerals and a high content of vitamin A.

Potato (informally tattie, tater, spud, tato, pota, spudzie, papa or tate) is the term which applies either to the starchy, tuberous vegetable crop from the various subspecies of the perennial plant *Solanum tuberosum* of the Solanaceae, or nightshade, family, or to the plant itself. Potato is the worlds most widely grown tuber crop, and the fourth largest food crop in terms of fresh produce – after rice, wheat, and maize (corn). As the worlds most widely grown tuber crop, it is also grown in the northern part of the Philippines specifically Benguet, Mountain Province and other nearby provinces. It is marketed for the preparation of dishes in restaurants and households.

Today's Agriculture is the promotion of environmentally sound ideas to create good sites for agricultural productions of crops together with the conservation of soils to produce good yields and one of this is the use of composts. According to a study conducted on the fate of heavy metals and organic contaminants in leaf lettuce and broccoli heads grown under field condition using six products of compost including three feedstocks (Urban Plant Debris (UPD), Biosolids/UPD (Bio), and Municipal Solid Waste (MSW), composts are physically, chemically, and biologically safe (Shiralipour, 2008).

Organic fertilizers minimize expenses and there's an abundant resource within the locality. It can minimize or lower the cost of farm inputs, particularly on fertilizer application. An application of organic (such as compost or vermicompost) will help so much in the maintenance of soil fertility, by improving the soil physical and chemical properties, such as structure, tilt and aeration, and moisture movement and retention.

Vermicompost (also called worm compost, vermicast, wormcastings, worm humus or worm manure) is the end-product of the breakdown of organic matter by some species of earthworm. It is a nutrient-rich, organic fertilizer and soil conditioner. Subler, Edwards, and Metzger (1998) claimed that vermicompost had significantly greater cumulative microbial activity than the composts. By its ability to support microbial life, it provides plant with nutrients already in plant available forms which is broken down by the help of these microorganisms (Wikipedia, 2008).

The study was conducted to:

1. Determine the effect of vermicompost developed from different substrates on the yield and quality of lettuce representing leafy vegetable and potato, a tuber crop;

2. Determine the influence of vermicompost developed from different substrates on some physical and chemical properties of soil.

The study was conducted at the Soil Science Experimental Area, College of Agriculture, Benguet State University, La Trinidad Benguet from December 2008 to June 2009.

REVIEW OF RELATED LITERATURE

Effect of Organic Matter, Organic Fertilizer, and Vermicompost

Soil Physical Properties

Brady and Weil (1996) stated that humus tends to give surface horizons dark brown to black colors. Granulation and aggregate stability are encouraged, especially by the non-humic fractions of soil organic matter. Plasticity, cohesion, and stickiness of clayey soils are reduced, making these soils easier to manipulate. Soil water retention is also improved, since organic matter increases both infiltration rate and water-holding capacity.

Funderberg (2001) claimed that organic matter is stable on soil. Organic matter behaves somewhat like sponge, with the ability to absorb and hold up to 90 % of its weight in water. A great advantage of the water holding capacity of organic matter is that the matter will release most of the water that it absorbs to plants. In contrast, clay holds great quantities of water, but much of it is unavailable to plants.

Organic matter causes soil to clump and form soil aggregates, which improves soil structure. With better soil structure, permeability (infiltration of water through the soil) improves, in turn improving the soil's ability to take up and hold water.

Funderberg (2001) claimed that data used in the universal soil loss equation indicate that the increasing soil organic matter from 1 to 3 % can reduce erosion 20 to 33 % because of increased/improved water infiltration and stable soil aggregate formation caused by organic matter.

The major medium in the improvement of granular and crumb type aggregate formation in surface soil horizons is organic matter, which not only bind but also lightens and expands making possible the porosity so characteristic of individual soil aggregates (Brady, 1984).

Organic matter is of much importance on modifying the effect of clay on soil structure. An actual chemical union may take place between the decaying organic matter and the clay particles. Moreover, the high adsorptive capacity of humus for water intensifies the disruptive effects of temperature changes and moisture fluctuations. The granulation of clay soil apparently cannot be promoted adequately without the presence of a certain amount of humus.

A result of a study conducted that soils amended with vermicomposts had significantly greater soil bulk density in comparison to control plots but with the increased rates of vermicompost, bulk density was reduced. Compost addition caused a significant increase of bulk density due to the more porosity added to the soil (Bazzoffi et al., 1998 as cited by Azarmi, Giglou and Taleshmikail, 2008). The total porosity was improved by the used of vermicompost. The greater porosity in the soil treated with vermicompost was due to the increase in the amount of rounded prose (Marinari et al. 2000 as cited by Azarmi, Giglou and Taleshmikail, 2008). Pagliali et al., (1980) as cited by Azarmi, Giglou and Taleshmikail (2008) reported that the increase in porosity has been attributed to increase number of pores in the 30-50 um and 50-500 um size ranges and a decrease in number of pores greater than 500 um.

Soil Chemical Properties

It is well established that certain organic compounds are absorbed by higher plants. Plants can absorb a very small portion of their nitrogen and phosphorus needs as soluble organic compounds. Various growth promoting compounds such as vitamins, amino acids, auxins, and gibberellins are formed as organic matter decays. These substances may at times stimulate growth in both higher plants and microorganisms.

Brady and Weil (1996) claimed that because humus has CEC two to thirty times as great (per kg) as that of the various types of clay minerals, it generally accounts for 20-90 % of the cation-absorbing power of mineral soils. Like clays, humus colloids hold nutrient cations (potassium, calcium, magnesium) in easily exchangeable form. Organic acids associated with humus also accelerate the release of nutrient elements from mineral structures. In addition, Nitrogen, Phosphorus, Sulfur, and micronutrients are stored as constituents of soil Organic Matter until released by mineralization.

Certain components of soil humus chelate or otherwise form complexes with metal ions. Some of these metal ions are micronutrient (Iron, Zinc) and are made more available to plants because they are kept in soluble, chelated form. In the case of Aluminum ions, which are toxic to plants in very acid soils, Organic matter alleviates the toxicity by binding the Aluminum ions in non exchangeable forms.

Funderberg (2001) stated that organic matter is a reservoir of nutrients that can be released to the soil. Each percent of organic matter in the soil releases 20 to 30 lbs of nitrogen, 4.5 to 6.6 lbs of P_2O_5, and 2 to 3 lbs of sulfur per year. The nutrient release occurs predominantly in the spring and summer, so summer crops benefit more from organic matter mineralization than winter crops.

The chemical properties of the humus and clay are probably effective in the organization and the later stabilization of aggregates.

Brady and Weil (1996) stated that composting provides a means of effectively and safely storing organic materials until it is convenient to apply them to soils. As a result of CO_2 losses and settling, the volume of composted organic materials decreases to 30-50% during the composting process. The smaller volume of material may greatly ease the handling and eventual use of the organic matter as soil amendment or potting medium. As raw organic materials are humified in a compost pile, the CEC of the organic matter increases to about 50-70cmol/kg of compost.

In 1998, Metzger claimed that the worm castings or fecal material produced by the worms is a rich source of a variety of essential plant nutrients and are less variable and much more stable.

(Kale 2003) stated that earthworm castings are the pool of concentrated nutrients. Total nitrogen, organic matter, nitrate nitrogen, phosphorus, potassium, sodium, and magnesium were at higher level in castings than in the surrounding soil.

A result of a study conducted that soils amended with vermicomposts showed that the total N concentration in the soil was significantly affected by vermicompost treatments. There have been other reports of increase of N in soil after application of vermicompost (Nethra et al., 1999 as cited by Azarmi, Giglou and Taleshmikail, 2008). Soils treated with vermicompost at the rate of 15 tons/ha had significantly more P as compared to control plots. This implied that the continuous inputs of P to the soil were probably from slow release from vermicompost and release of P was due largely to the activity of soil microorganism (Arancon et al., 2006 as cited by Azarmi, Giglou and

Taleshmikail, 2008). Marinari et al., 2000 as cited by Azarmi, Giglou and Taleshmikail, 2008 showed similar increases in soil P after application of organic amendments. The enhancement of phosphatase activity and physical breakdown of material resulted in greater mineralization (Sharpley and Syres, 1997 as cited by Azarmi, Giglou and Taleshmikail, 2008). In their experiment the more available P probably could have contributed to decrease in soil pH caused from application of vermicompost. The soil available K increased significantly with rising vermicompost rate. Application of vermicompost at rate of 15, 10, and 5 tons/ha increased available K in their treatments at 58, 46, and 34%, respectively in comparison to control plots. The selective feeding of earthworms on organically rich substances which breakdown during passage through the gut, biological grinding, together with enzymatic influence on finer soil particles, were likely responsible for increasing the different forms of K (Rao et al., 1996 as cited by Azarmi, Giglou and Taleshmikail, 2008). The increase of soil organic matter resulted in decrease K fixation and subsequent increase K availability (Olk and Cassman, 1993 as cited by Azarmi, Giglou and Taleshmikail, 2008). Vermicompost contains most nutrients in plant available forms such as phosphates, exchangeable calcium and soluble potassium (Orozeo et al., 1996 as cited by Azarmi, Giglou and Taleshmikail, 2008). The addition of vermicompost in soil change soil pH. The highest and lowest pH values were observed at the rate of 0 and 15 tons/ha vermicompost, respectively. (Atiyeh et al., 2001 as cited by Azarmi, Giglou and Taleshmikail, 2008) reported that the increase of vermicompost rate in the soil resulted in the decrease in soil pH. Maheshwarapa et al., 1999 as cited by Azarmi, Giglou, and Taleshmikail (2008) reported that the increase of the content of vermicompost decreased soil pH. Azarmi, Giglou and Taleshmikail (2008) reported that addition of 5, 10 and 15 tons/ha vermicompost in soil had significant positive effect on uptake of element nutrients such as P, K, Fe, and Zn.

Soil Biological Properties

One study carried out in Japan found that the application of livestock manure and other organic materials resulted in a more diverse root fungal flora. Solid materials produced more diversification than liquid ones (Wikipedia, 2008).

Organic matter greatly affects the biology of the soil because it provides the main food for the community of heterotrophic soil organisms.

Kale (2003) stated that organic amendment is essential to enhance the biological processes in soil and the application of organic manure to agricultural lands primarily contributes to health of soil and secondarily acts as nutrient provider to crops.

Weir (1946) said that decay of organic matter aids decay of mineral particles where organisms which cause the decomposition of the soil organic matter perform a two-fold work. They not only bring about the necessary changes in the organic matter to provide available nitrogen and mineral elements for use by plants, but in an indirect way they aid in the liberation of mineral elements contained in the mineral soil particles. This is explained through the fact that in all organic decay, acids are formed which is effective agents in dissolving mineral matter.

Composted diseased stems of adzuki bean infected with brown rot mixed with straw and other waste products eliminated most of the pathogenic organisms (Wikipedia, 2008).

Wikipedia claimed that vermicompost is richer in many nutrients than composts produced by composting methods. It is also rich in microbial life which help breakdown nutrients already present in the soil into plant-available forms. Worm castings also contains worm mucus which keeps nutrients from washing away with the first watering and holds moisture better than plain soil.

Edwards and Arancon (2007) claimed that vermicomposts can be used in pollutant bioremediation for organic contaminants and heavy metals. The microbial degradation of the organic pollutants is accelerated dramatically and the heavy metals become irreversibly bound into the humic materials that are formed, so they are not available to plants.

Vermicompost had significantly greater cumulative microbial activity than the composts (Subler, Edwards, and Metzger, 1998). The nature of the microbial processes are quite different in vercomposting and composting, the active phase of composting is characterized by thermophilic bacteria, whereas the active phase of vermicomposting is characterized by mesophilic bacteria and fungi, which are stimulated and encourage by the activity of earthworms.

Kale (2003) stated that microorganisms present in vermicompost are considered to inactivate and suppress the growth of pathogens.

(Kale 2003) added that earthworms probably form the major soil invertebrates that contribute to recycling of organic matter. Organic debris breaks down rapidly after they are fed to these organisms and subjected to the enzymatic activity in their gut. Primary decomposers initiate the decomposition process and secondary decomposers like earthworms further catalyze the process by fragmenting the organic residues and increasing the surface area for further decomposition by micro flora. Release of the part of CO_2 in the process of respiration, production of mucus and nitrogenous excrements enhance the level of nitrogen and lowers' the C/N ratio. They selectively feed on the decomposing particulate matter and they defecate the partially digested material on the soil surface as mucus coated castings.

Furthermore, Kale (2003) added that earthworms contribute to distribution of surface litter, spatial heterogeneity and microbial activity. Appropriate use of fertilizers is essential to maintain the soil faunal populations that are essential for restoration of soil quality and productivity. In addition, having cover crops and reduction in use of pesticides will improve the soil faunal density especially the earthworm population.

Vermicast contains a highly active biological mixture of bacteria, enzymes, remnants of plant matter and animal dung as well as earthworm cocoons (damp) (Bhawan 2002).

Kale (2003) claimed that earthworm's activity is always associated with the microflora in the organic material used for vermicomposting and in the final product as vermicompost. It is the interrelationship and interaction of primary and secondary decomposers in the decomposer chain. He added that soil micro flora and fauna contribute to soil physical properties like aggregate stability, porosity, bulk density, and water holding capacity. They also contribute to chemical processes like solubilization and mobilization of nutrients.

Effect of Organic Matter, Organic Fertilizer, and Vermicompost

Plant Growth and Yield of Crops

Over a longer period of time in the application of organic materials such as livestock manure and crop residues have been found to bring about a gradual improvement in soil productivity and crop performance (Wikipedia, 2008). A recent study carried out on five crops in Japan showed that application of organic matter enhance root growth and nutrient uptake, resulting in higher yields.

Enabling fruit and seed pits to germinate in vermicompost easily, it also improves physical structure of soil, enriching soil in micro-organisms, adding plant hormones (such as auxins and gibberillic acid), adding enzymes (such as phosphatase and cellulase), attract deep burrowing earthworms already present in the soil, improving water holding capacity, enhance plant growth and crop yield, and improving root growth and crop yield (Wikipedia, 2008).

Edwards and Arancon (2007) claimed that certain species of earthworms feed preferentially on organic matter and have been adopted for the vermiculture processing of organic wastes into vermicomposts. In the process, the earthworms use microorganisms growing on wastes for their nutrition but also promote microbial activity dramatically in the vermicomposts produced. Vermicomposts can be used as plant growth media or soil amendments in greenhouse or field. They promote plant germination, growth, flowering, and yield dramatically. They can also be used as aqueous extracts termed 'teas' that can be watered or sprayed on to be plants. They promote plant growth, independent of nutrients because of the plant growth regulators produced by the microorganisms that became adsorbed by the humates (indole acetic acid, gibberellins, kinetin, humates and fulvates).

Metzger (1998) claimed that vermicompost sustained plant quality for a substantial period of time after seedling emergence. In other words, incorporation of vermicompost in media used to grow bedding plants may help to maintain crop quality and salability even after the plants reach the garden center.

Metzger (1998) showed that plants grown in vermicomposts –amended media still grow better than those grown in unamended media with similar nutritional levels. Furthermore, the promotive effect of vermicomposts on growth is lost if it is sterilized and can not be restored by adding additional nutrients.

The incorporation of vermicompost in a commercial potting mix resulted in faster growth, increased in height, and higher fresh weights for a variety of bedding plants. The optimal amount of vermicompost need to produce positive results was relatively low: between 10 and 20 % by volume. In addition, the incorporation of vermicompost in the media essentially eliminated the need for additional fertilizer in the production of tomato plugs.

Subler, Edwards, and Metzger (1998) stated that vermicompost have the potential for improving plant growth when added to soil or container media.

<u>Nutrient Content of Animal Manure</u>

Rodale (2000) stated that horse manure is about half as rich as chicken manure, richer in organic matter than cow manure. Fresh horse manure contain 0.70% of N, 0.30% of P, and 0.60% of K; fresh cow manure contain 0.25% of N, 0.15% of P, and 0.25% of K; and hog manure contain 0.061% of N, 0.02865% of P, and 0.1070% of K. Estimate nutrient content of manure are available from the number of published source, but nutrient composition varies widely between farm due to differences in animal species, age of animal, feed ratio, type and amount of bedding, storage structure, and manure handling.

MATERIALS AND METHODS

Materials

The materials used in the study were lettuce seedlings (*Romaine*); potato seed tubers (*Solibao*); Vermicomposts were taken from different substrates such as sawdust, sawdust + cow manure, sawdust + hog manure, sawdust + horse manure were used pust-composted. Identifying tags and other necessary materials needed in the study such as farm implements and laboratory equipments were used.

Methodology

An area of 190 square meters was properly prepared by dividing it into three blocks and in each block with 5 plots having a dimension of 1x 10 meters and again divided for the two crops as illustrated bellow. Border plots were also included in between blocks.

The experiment was laid out following the simple Randomized Complete Block Design (RCBD) with three replication.

The vermicomposts treatments from different substrates were as follows:

Treatments	Fertilizer (vermicompost substrate)
Lettuce	
V_1	Control, no fertilizer
V_2	Sawdust Alone
V_3	Sawdust + Cow Manure
V_4	Sawdust + Hog Manure
V_5	Sawdust + Horse Manure

Potato

V_1	Control, no fertilizer
V_2	Sawdust Alone
V_3	Sawdust + Cow Manure
V_4	Sawdust + Hog Manure
V_5	Sawdust + Horse Manure

The different substrates were decomposed using the vermicomposting technology for 2-3 months. The vermicast were used at the rate of 20 t/ha and applied aweek before planting.

The seedlings for lettuce were the *Romaine* variety, commercially marketed in organic stores and the potato variety used was *Solibao* which was found to be appropriate for organic production. The two crops were planted at the same time in the experimental area. The planting distance for lettuce was at 20 cm x 20cm between hills and rows and for potato was at 30 cm x 30 cm between hills and rows.

The number of plants was maintained by replanting the dead or weak seedling with desirable ones one week after planting. All other agricultural management practices were employed such as irrigation and weeding until for the successful growing of lettuce and potato.

The data gathered were the following:

A. Growth and Yield Parameters

1. Initial plant height (cm). This was taken by random sampling. Ten sample plants were measured from ground level to the tip by using a ruler one week after planting.

2. Final plant height (cm). The same ten sample plants used in the initial plant height were measured from ground level to the tip by using a ruler 60 days after planting.

3. Marketable yield per plot (kg/5m^2). The total tuber yield were obtained by measuring the weight of all desirable tubers per 5m^2 plot without defect such as malformed, very small, and pest damaged or those that can be sold to the market.

4. Non-Marketable yield per plot (kg/5m^2). This was taken by getting the weight of tubers with defect that can not be sold to the market.

5. Computed total yield (t/ha). This was taken by converting the yield per 5m^2 plot into t/ha.

$$t/ha = \frac{kg/ha}{1000}$$

$$Kg/ha = \frac{\text{total weight per plot x 10,000}}{\text{area of experimental plot}}$$

a. where = 5m^2 area of experimental plot, and 10,000m^2 is the area of one hectare

B. Quality Parameters

Lettuce

1. Shelf-life (days). This was the number of days from storage at ambient temperature or normal room temperature up to the time unfit for consumption.

2. Weight loss. This was taken by subtracting the initial weight of three lettuce plant per plot to their final weight.

Potato

3. Tuber dry matter content (DMC). About three tubers were selected from the marketable tubers representing the different tuber sizes for the determination of DMC. These were sliced, placed in bags, and then placed in the oven for drying at 70 ºC for 3 days. The DMC was computed using the following formula:

$$\% MC = \frac{FW - ODW}{FW} \times 100$$

$$\% DM = 100\% - \% MC$$

Where: FW = Fresh weight

ODW = Oven dried weight

C. Initial and Final Physical Properties of soil

1. Bulk density of the soil (g/cm³). The Bulk Density was determined by using the core method. The Bulk Density was computed using the following formula:

$$Db = \frac{\text{weight of oven dry soil (gm)}}{\text{volume of the soil sample (cm}^3)}$$

2. Water holding capacity of the soil (mL/g). The amount of water retained by a unit weight of dry soil was measured. The Water Holding Capacity of the soil was calculated using the formula:

Water retained = volume of water added (ml) – volume of water collected (ml)

$$\text{Water Holding Capacity} = \frac{\text{water retained (ml)}}{\text{Oven Dry Weight of soil (g)}}$$

D. Initial and Final Chemical Properties of Soil

4. pH of the soil. The pH of the soil was determined by using the electrometric method (10:10 soil: distilled water).

5. Organic matter (OM) content of the soil (%). The Organic Matter content was determined using Walkley-Black Method. The formula used for the computation of percent OM is as follows:

$$\% \text{ OM} = \frac{6.9(S - T)}{S} \times 100$$

Where: 6.9 = constant number

S = ml of the ferrous solution required for Blank

T = ml of ferrous solution required for the Sample

6. Total nitrogen (N) content of the soil (%). This was computed based on the Organic Matter content, a considered procedure since it is assumed that the

Nitrogen is derived only on the Organic Matter since no inorganic source of N was applied. The following formula was used:

$$\% \text{ N} = \% \text{ OM } (0.05).$$

Where: % OM = the computed OM Value of the soil.

0.05 = constant value

7. Available phosphorus (P) content of the soil (ppm). The Phosphorus content of the soil was determined through the Bray No.2 Method. The concentration of P was computed as follows:

$$\text{ppm P} = \text{ppm P in solution} \times \frac{25}{2} \times \frac{20}{2.85\text{g}}$$

8. Exchangeable potassium (K) content of the soil. The Potassium content of the soil was determined by using the Flame Photometer.

9. Cation Exchange Capacity (CEC) of the soil (m.e/100g). The CEC was determined through the Ammonium Acetate method. The formula used in computing CEC is:

$$CEC = \frac{(S - B) \times N \times 100}{W}$$

Where: W = Oven Dry Weight of sample in grams

S = Volume of H_2SO_4 used in sample

B = Volume of H_2SO_4 used in blank

N = normality of H_2SO_4

10. Return on investment (ROI). The economic analysis was separately computed for the two crops. The level or value that is considered economically feasible is when the ROI value is positive. This was taken by dividing the net income with total expenses multiplied by one hundred or:

$$ROI = \frac{\text{Gross Income} - \text{Total expenses}}{\text{Total Expenses}} \times 100$$

Physical Properties of Vermicomposts

The physical analysis of vermicomposts is shown in Table 1. Vermicompost from sawdust alone has the lowest Db as compared to the other vermicomposts developed from different substrates which proves the vermicomposts can improved the soil Db by granulation. Vermicomposts developed from the mixture of sawdust + manures gained higher Db than vermicompost from sawdust alone which indicates that mixing manures with sawdust tend to increase Db.

Highest WHC was obtained from vermicompost developed from substrates sawdust + cow manure while the lowest WHC was obtained from sawdust alone. This result means that sawdust + cow manure holds more water than the other vermicomposts formulations. In addition, sawdust mixed with different manures increased the WHC of the soil.

Table 1. Bulk density and water holding capacity of vermicomposts

SUBSTRATE	BULK DENSITY (g/cm^3)	WATER HOLDING CAPACITY (mL/g)
V_1 Sawdust alone	0.77	0.38
V_2 Sawdust + Cow Manure	0.93	0.94
V_3 Sawdust + Hog Manure	0.96	0.91
V_4 Sawdust + Horse Manure	0.93	0.93

Chemical Properties of Vermicomposts

The chemical analysis of vermicompost is shown in Table 2. Highest pH, OM, N, P, and K was obtained from sawdust + horse manure while the lowest pH, OM, N, P, and K was obtained from vermicompost developed from sawdust alone. The rest of the vermicomposts developed from different formulations with the addition of different manures have higher pH, OM, N, P, and K than vermicompost developed from sawdust alone which indicates that mixing sawdust and different manures as substrates of vermicompost were significant on improving chemical properties of vermicompost or vermicast.

Table 2. pH, organic matter (OM), total nitrogen (N), available phosphorus (P), and exchangeable potassium (K) of vermicomposts

SUBSTRATE	pH	OM (%)	N (%)	P (ppm)	K (ppm)
V_1 Sawdust alone	5.68	0.217	0.21	0.13	0.09
V_2 Sawdust + Cow Manure	6.83	1.79	1.79	1.35	1.96
V_3 Sawdust + Hog Manure	6.54	1.79	1.79	1.16	1.71
V_4 Sawdust + Horse Manure	6.97	2.12	2.12	1.46	2.01

RESULTS AND DISCUSSION

Lettuce

Growth Parameters

Initial plant height. Initial height of lettuce which was gathered seven days after planting is presented in Table 3. Height ranged from 10.04 to 11.37cm with the tallest observed from plants grown in sawdust amended plot. The application of vermicomposts developed from different substrates did not significantly affect the initial height of lettuce. Based from the unfertilized plot (control) there is a decrease in height of the plants treated with the vermicompost substrates, this could be attributed by the effect of the incorporation of the vermicompost developed from different substrates.

Table 3. Initial height of lettuce as affected by vermicomposts developed from different substrates

TREATMENT		INITIAL HEIGHT (cm)
V_1	Control (No Fertilizer)	10.88[a]
V_2	Sawdust Alone	11.37[a]
V_3	Sawdust + Cow Manure	10.67[a]
V_4	Sawdust + Hog Manure	10.65[a]
V_5	Sawdust + Horse Manure	10.04[a]

Means with the same letter are not significantly different at 5% level DMRT.

Final plant height. There were no significant differences between treatments on the final lettuce height (Table 4). Unfertilized plot (control) has the lowest mean of 20.34 compared to the substrates which indicates that application of vermicomposts developed from different substrates result to higher height of the plants. Application of vermicompost from substrate sawdust + hog manure has the highest mean.

Yield Parameter

Total yield. The application of vermicomposts developed from different substrates did significantly affect the total yield of lettuce (Table 5). However, unfertilized plot (control) registered the lowest mean yield while the amended plots yielded higher which indicates that the application of the different amendments effected an increase in total yield of lettuce. Application of vermicompost developed from sawdust + hog manure and sawdust alone with means 17.39 and 16.67t/ha registered the highest yields. The

Table 4. Final height of lettuce as affected by vermicomposts developed from different substrates

TREATMENT		FINAL HEIGHT (cm)
V_1	Control (No Fertilizer)	20.34[a]
V_2	Sawdust Alone	20.54[a]
V_3	Sawdust + Cow Manure	21.05[a]
V_4	Sawdust + Hog Manure	21.10[a]
V_5	Sawdust + Horse Manure	20.57[a]

Means with the same letter are not significantly different at 5% level DMRT.

application of vermicomposts developed from substrates sawdust + horse manure and sawdust + cow manure with means of 14.49 and 14.73t/ha had yielded the lowest among the fertilized plots. This result did not match the vermicomposts analysis wherein vermicomposts from sawdust + horse manure and sawdust + cow manure have the highest physical and chemical analysis. It could be noted that incorporation of vermicomposts developed from different substrates in the soil resulted a variable differences in the nutrient content of the soil as compared to the vermicast analysis. The differences could be due to further decomposition of the vermicast by microorganisms upon incorporation.

Table 5. Total yield of lettuce as affected by vermicomposts developed from different substrates

TREATMENT		YIELD PER PLOT $kg/5m^2$	TOTAL YIELD (t/ha)
V_1	Control (No Fertilizer)	5.58	11.16^b
V_2	Sawdust Alone	8.34	16.67^a
V_3	Sawdust + Cow Manure	7.36	14.73^{ab}
V_4	Sawdust + Hog Manure	8.69	17.39^a
V_5	Sawdust + Horse Manure	7.25	14.49^{ab}

Means with the same letter are not significantly different at 5% level DMRT.

Postharvest Qualities

Shelf-life of lettuce. The application of vermicomposts developed from different substrates did not significantly affect the shelf life of lettuce (Table 6). The unfertilized plot (control) gave the longest mean shelf life of 6.67 days compared to the application of amendments which had a shelf life of 6.00 to 6.33 days. It can be noted that the application of vermicomposts developed from different substrates decreased the shelf life of lettuce.

Table 6. Shelf life of lettuce as affected by vermicomposts developed from different substrates

TREATMENT		SHELF-LIFE (days)
V_1	Control (No Fertilizer)	6.67^a
V_2	Sawdust Alone	6.00^a
V_3	Sawdust + Cow Manure	6.33^a
V_4	Sawdust + Hog Manure	6.00^a
V_5	Sawdust + Horse Manure	6.33^a

Means with the same letter are not significantly different at 5% level DMRT.

Percent weight loss of lettuce. The application of vermicomposts developed from different substrates did not significantly affected the weight loss of stored lettuce (Table 7). However, the unfertilized plot (control) has the lowest mean compared to those applied with vermicomposts from different substrates. Application of vermicompost from sawdust + hog manure has the highest weight loss of 196.3% while the control gains the lowest weight loss of 134.0% which indicate that there is more water content of lettuce due the application of vermicompost developed from different substrates.

(Wikipedia, 2008) Vermicompost adds plant hormones and enzymes, enhance plant growth and crop yield and improving root growth. This could result to broader leaves and more dense head of lettuce contributed by the application vermicomposts derived from sawdust and animal manure mixture which could explain why more weight is loss.

Table 7. Weight loss of lettuce as affected by vermicomposts developed from different substrates

TREATMENT		WEIGHT LOSS (%)
V_1	Control (No Fertilizer)	134.0^{b}
V_2	Sawdust Alone	156.3^{ab}
V_3	Sawdust + Cow Manure	161.7^{ab}
V_4	Sawdust + Hog Manure	196.3^{a}
V_5	Sawdust + Horse Manure	158.7^{ab}

Means with the same letter are not significantly different at 5% level DMRT.

Physical Properties of the Soil After Harvest

Bulk density (Db) of the soil. As shown in Table 8, from the initial of 1.22 g/cm^3, bulk density (Db) decreased in all of the treatment plots including the unfertilized plot (control). For the unfertilized plot (control), it could be attributed by tillage wherein there is a decrease of Db by the loosening of the soil.

The application of vermicomposts developed from different substrates significantly affected the bulk density of the soil after harvest. Application of vermicompost developed from substrate sawdust alone resulted to the lowest mean which indicates that the substrate affected the soil to become loose. This result conforms to the findings of Aboen (2009) that the vermicompost from sawdust alone has the lowest Db (Table 1). Tangueid (2000) as cited by Anas (2008) stated that the final bulk density of the soil significantly affected by the different rates of organic fertilizer. In addition, Brady and Weil (1996) stated that granulation and aggregate stability are encouraged, especially by the non-humic fractions of soil organic matter. Plasticity, cohesion, and stickiness of clayey soils are reduced, making these soils easier to manipulate.

Table 8. Bulk density (Db) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		Db (g/cm^3)
V_1	Control (No Fertilizer)	1.15^a
V_2	Sawdust Alone	1.01^b
V_3	Sawdust + Cow Manure	1.11^a
V_4	Sawdust + Hog Manure	1.14^a
V_5	Sawdust + Horse Manure	1.11^a
Initial Value		1.220

Means with the same letter are not significantly different at 5% level DMRT.

<u>Water holding capacity (WHC) of the soil</u>. There was no significant difference on the initial water holding capacity (WHC) between treatments (Table 9).

The application of vermicomposts developed from different substrates had no significant effect on the water holding capacity of the soil after harvest although WHC values increased from the initial. Though not significantly different from the other treatments, the application of vermicompost developed from substrate sawdust + horse manure resulted to highest WHC as compared to the other treatments including the control. In addition, vermicompost from sawdust + horse manure is second to have the highest mean WHC in the vermicomposts analysis of Aboen (2009) (Table 1) so it could be that its incorporation to the soil gave the highest WHC. Given also that the area is clay loam, the slight increase of WHC may be contributed by the nature of vermicompost to have a high water holding capacity Pittaway (2000) as cited by Anas (2008). Furthermore, Bhawan (2002) as cited by Lagman (2003) claimed that vermicompost increases the ability of the soil to hold water. Soil water retention is also improved, since

Table 9. Water holding capacity (WHC) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		WHC (mL/g)
V_1	Control (No Fertilizer)	0.69^a
V_2	Sawdust Alone	0.73^a
V_3	Sawdust + Cow Manure	0.74^a
V_4	Sawdust + Hog Manure	0.73^a
V_5	Sawdust + Horse Manure	0.75^a
Initial Value		0.68

Means with the same letter are not significantly different at 5% level DMRT.

organic matter increases both infiltration rate and water-holding capacity (Brady and Weil, 1996).

Chemical Properties of the Soil After Harvest

Final soil pH. From an initial of 6.5, soil pH decreased to a range of 6.2 to 6.5 (Table 10). The application of vermicomposts developed from different substrates did not significantly affected the pH of the soil after harvest. However, soil pH from the amended plots showed higher values while the control (no amendment added) showed the lowest. Application of vemicompost developed from substrate sawdust + hog manure gave the highest mean which differed from the control but not with the other amended plot.

The lowering of the soil pH could be due to cation absorption or it could be due to acidity contributed by the further decomposition of organic matter. Mader (2004) discussed that decaying organic matter which is humus supplies nutrients to plants, and

Table 10. Final soil pH as affected by vermicomposts developed from different substrates

TREATMENT		SOIL pH
V_1	Control (No Fertilizer)	6.2^{b}
V_2	Sawdust Alone	6.4^{ab}
V_3	Sawdust + Cow Manure	6.3^{ab}
V_4	Sawdust + Hog Manure	6.5^{a}
V_5	Sawdust + Horse Manure	6.3^{ab}
Initial Value		6.5

Means with the same letter are not significantly different at 5% level DMRT.

its acidity also leaches minerals from rocks and therefore retaining positively charged minerals until plant uptake occurs. In all organic decay, acids are formed which is effective agents in dissolving mineral matter (Weir, 1946). It could be that this minerals were taken up by plants leaving behind the negatively charge ions causing the soil to be acidic or the formation of acids aids in acidification of the soil.

Organic matter (OM) content of the soil. From the initial organic matter (OM) content of the soil at 1.88%, OM content was increased by the addition of soil amendments (Table 11). On the other hand OM decreased to 1.75% on the unfertilized plot (control).

The application of vermicomposts developed from different substrates significantly affected the organic matter content of the soil. Application of vermicompost developed from substrate sawdust + cow manure gained the highest mean which indicates

Table 11. Organic matter content (OM) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		OM (%)
V_1	Control (No Fertilizer)	1.75[b]
V_2	Sawdust Alone	2.63[a]
V_3	Sawdust + Cow Manure	2.98[a]
V_4	Sawdust + Hog Manure	2.62[a]
V_5	Sawdust + Horse Manure	2.57[a]
Initial Value		1.88

Means with the same letter are not significantly different at 5% level DMRT.

that it has the highest amount of humus added to the soil. In comparison, vermicomposts from substrates sawdust, sawdust + hog manure and sawdust + horse manure also significantly affected the humus of the soil.

It was observed that all of the amended plot resulted to higher OM than the initial OM content whereas the control decreased. The significant increase of the OM on the amended plot can be due to the application of vermicomposts developed from different substrates because it contains humus. The decrease of OM from initial to control could be attributed by the further degradation of OM when incorporated in the soil.

Total nitrogen (N) content of the soil. The initial nitrogen (N) content of the soil at 0.094% decreased to 0.0867% in the unfertilized plot (control) (Table 12). It could be that the slight decrease is attributed by plant uptake of available N.

The application of vermicompost developed from different substrates has a significant effect on the N percentage of the soil. Among the treatments, application of vermicompost from substrate sawdust + cow manure gained the highest mean of N but all of the substrates gave no significant difference to the N content of the soil including the control. Hart, J., Strik, B., White, L. and Yang, W. (2006) stated that sawdust contains little N so, soil microbes require N for sawdust decomposition, and they are more efficient at using soil N than plants. These results to the depletion of N to plants due to further degradation of sawdust added in the formulation of vermicompost which causes no significant differences from control to the amended plots.

Table 12. Total Nitrogen (N) content of the soil as affected by vermicomposts developed from different substrates

TREATMENT		TOTAL NITROGEN (%)
V_1	Control (No Fertilizer)	0.0867[a]
V_2	Sawdust Alone	0.1300[a]
V_3	Sawdust + Cow Manure	0.1467[a]
V_4	Sawdust + Hog Manure	0.1333[a]
V_5	Sawdust + Horse Manure	0.1333[a]
Initial Value		0.094

Means with the same letter are not significantly different at 5% level DMRT.

Even there were no significant differences of N content of the soil, there is still an increase of N by the application of vermicomposts developed from different substrates after harvest which conform to the study of Azarmi, Giglou and Taleshmikail (2008) that there is an increase of N by vermicompost application. The slight increase of N content of the soil could be also due to the nutrient content of the manures added as substrates of the vermicompost. Brady (1985) revealed that manure is an effective source of nutrients for most crops and those with relatively high N requirement are most likely to respond to its application.

Available phosphorus (P) content of the soil.Table 13 shows that from the initial phosphorus (P) content of the soil at 63.06ppm, it decreased to 23.65ppm on the control plot. All of the treatments resulted to a decrease P content after harvest, which could be attributed to plant uptake.

Table 13. Available Phosphorus (P) content of the soil as affected by vermicomposts developed from different substrates

TREATMENT		AVAILABLE PHOSPHORUS (ppm)
V_1	Control (No Fertilizer)	23.65[c]
V_2	Sawdust Alone	21.48[c]
V_3	Sawdust + Cow Manure	25.30[bc]
V_4	Sawdust + Hog Manure	44.71[a]
V_5	Sawdust + Horse Manure	28.99[b]
Initial Value		63.06

Means with the same letter are not significantly different at 5% level DMRT.

The application of vermicomposts developed from different substrates significantly affected the P content of the soil. Application of vermicompost from substrate sawdust + hog manure has the highest mean of 44.71ppm P which differed to the other treatments.

In relation to the vermicomposts analysis of Aboen (2009) (Table 2) vermicompost from sawdust alone has the lowest P content which matches the results of the study but sawdust + horse manure in vermicompost analysis has the highest P content which does not match the result of the study which is probably due to the incorporation of the vermicompost to the soil and the further decomposition caused by microorganisms.

Exchangeable potassium (K) content of the soil. Generally, all of the amended plots showed an increase in K content after harvesting the lettuce crop (Table 14). Initial potassium (K) content of the soil at 239ppm is higher than the control with 170.8ppm which indicates the decrease of K content of the soil which could be attributed to plant uptake of K.

Table 14. Exchangeable Potassium (K) content of the soil as affected by vermicomposts developed from different substrates

TREATMENT		EXCHANGEABLE POTASSIUM (ppm)
V_1	Control (No Fertilizer)	170.8[c]
V_2	Sawdust Alone	268.5[b]
V_3	Sawdust + Cow Manure	265.7[b]
V_4	Sawdust + Hog Manure	232.7[bc]
V_5	Sawdust + Horse Manure	393.2[a]
Initial Value		239.0

Means with the same letter are not significantly different at 5% level DMRT.

The application of vermicomposts developed from different substrates significantly affected the K content of the soil after harvest. Application of vermicompost from substrate sawdust + horse manure resulted to a highest mean of 393.2ppm which is higher than the initial whereas the control showed the least, even lower than the initial. This could be caused by released of K by the substrates and the uptake of K by the plants. In comparison, other substrates varied from substrate sawdust + horse manure they are significantly higher than the control.

Cation exchange capacity (CEC) of the soil. From the initial CEC of the soil at 0.16m.e./100gsoil, all the treatment plots showed an increase in their CEC including the control (Table 15).

Table 15. Cation exchange capacity (CEC) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		CEC (m.e./100gsoil)
V_1	Control (No Fertilizer)	3.54[c]
V_2	Sawdust Alone	9.60[b]
V_3	Sawdust + Cow Manure	15.40[a]
V_4	Sawdust + Hog Manure	4.07[c]
V_5	Sawdust + Horse Manure	1.63[c]
Initial Value		0.16

Means with the same letter are not significantly different at 5% level DMRT.

The application of vermicomposts developed from different substrates significantly affected the CEC of the soil. Application of vermicompost from substrate sawdust + cow manure has the highest mean which differs with the other substrates. The lowest CEC of 1.63m.e./100gsoil was gained from the application of vermicompost developed from substrates sawdust + horse manure.

Return on investment. The ROI of Lettuce production using vermicomposts developed from different substrates is presented in Table 16. Application of vermicompost from sawdust + hog manure had the highest ROI of 12.57%. Among the various vermicomposts formulations, application of vermicompost from sawdust + horse manure had the lowest ROI of -6.40%. Among the amended plots, the highest ROI was obtained from the unfertilized soil of 93.59%. This results means that for every peso investment there is 12.57 centavo returned for the application of vemicompost developed from sawdust + hog manure, - 6.40 centavo loss for the application of sawdust + horse manure, and 93.59 centavo returned for the unfertilized plot. This result implies that no fertilization gained more pesos; however cost of vermicompost contributed to the decreased ROI.

The high ROI of the unfertilized plot could be the result of presently available nutrients in the soil after planting. Upon further cropping, nutrients could be depleted by

Table 16. Return on investment (ROI) of lettuce production as affected by vermicomposts developed from different substrates (15 m2)

TREATMENTS	PRODUCTON COST (Php)				
	CONTROL	SAWDUST	SAWDUST + COW MANURE	SAWDUST + HOG MANURE	SAWDUST + HORSE MANURE
Expenses (Php)					
Cleaning	20	20	20	20	20
Land Preparation	20	20	20	20	20
Planting	10	10	10	10	10
Watering	30	30	30	30	30
Hill-up	10	10	10	10	10
Weeding	30	30	30	30	30
Tractor	22.50	22.50	22.50	22.50	22.50
Seed (Romaine)	36	36	36	36	36
Vermicompost Fertilizer		300	300	300	300
Total Expenses	178.5	478.5	478.5	478.5	478.5
Gross Income	137.36	198.73	219.19	178.24	195.81
ROI	93.59	7.95	- 4.70	12.57	- 6.40

Prevailing price is Php 25.00/kilogram

plant uptake so the application of organic amendments especially vermicompost developed from substrate sawdust + hog manure can rectify this problem.

Potato

Yield Parameters

Marketable yield. The application of vermicomposts formulations and sawdust alone significantly affected the marketable yield per plot (Table 17). The application of vermicomposts developed from substrates sawdust + cow manure, sawdust, sawdust + horse manure gains the highest means at 2.09kg/plot, 1.89kg/plot, and 1.86kg/plot, respectively. Plants fertilized with vermicompost from substrate sawdust + hog manure yielded a mean of 1.70kg/plot which was the lowest among the amended plots.

Table 17. Marketable yield of potato as affected by vermicomposts developed from different substrates

TREATMENT		MARKETABLE YIELD ($kg/5m^2$)
V_1	Control (No Fertilizer)	1.31^{b}
V_2	Sawdust Alone	1.89^{a}
V_3	Sawdust + Cow Manure	2.09^{a}
V_4	Sawdust + Hog Manure	1.70^{ab}
V_5	Sawdust + Horse Manure	1.86^{a}

Means with the same letter are not significantly different at 5% level DMRT.

Non-marketable yield. The application of vermicomposts developed from different substrates had a highly significant effect on the non-marketable yield. Vermicompost formulation using sawdust + cow manure which produced the highest marketable yield produced the lowest non-marketable yield (Table 18).

Among the amended plots, those applied with vermicompost developed from sawdust + horse manure as substrate yielded the heaviest non-marketable tuber yield of 0.38kg/5m^2 which was significantly higher than the other treatments.

Total yield of potato. The different vermicomposts formulations significantly increased the total yield of potato (Table 19). The application of vermicomposts from substrate sawdust + cow manure and vermicompost from sawdust + horse manure produced the highest mean yield while the lowest mean yield among the vermicomposts formulations was obtained from substrate sawdust + hog manure. The unfertilized plot

Table 18. Non-marketable yield of potato as affected by vermicomposts developed from different substrates

TREATMENT		NON-MARKETABLE YIELD (kg/5m^2)
V_1	Control (No Fertilizer)	0.21^b
V_2	Sawdust Alone	0.25^b
V_3	Sawdust + Cow Manure	0.21^b
V_4	Sawdust + Hog Manure	0.25^b
V_5	Sawdust + Horse Manure	0.38^a

Means with the same letter are not significantly different at 5% level DMRT.

Table 19. Total yield of potato as affected by vermicomposts developed from different substrates

TREATMENT		TOTAL YIELD (t/ha)
V_1	Control (No Fertilizer)	2.95[b]
V_2	Sawdust Alone	4.23[a]
V_3	Sawdust + Cow Manure	4.73[a]
V_4	Sawdust + Hog Manure	4.12[a]
V_5	Sawdust + Horse Manure	4.73[a]

Means with the same letter are not significantly different at 5% level DMRT.

(control) produced the lowest mean yield which proves the effect of vermicompost in improving yield.

Even though the vermicomposts developed from different substrates significantly affected the total yield of potato, the total yield is still low. This may resulted to the longer days during the conducted of the study wherein longer days results to a lower yield because potato requires shorter days to produce a higher yield.

Quality Parameter

Dry matter content (DMC) of potato. Vermicompost formulation using sawdust + hog manure as substrate significantly produced tubers with higher DMC (Table 20). The DMC of 21.22% from vermicompost developed from sawdust + hog manure was significantly different from that of the control and vermicompost from sawdust + horse

Table 20. Dry matter content (DMC) of potato as affected by vermicomposts developed from different substrates

TREATMENT		DMC (%)
V_1	Control (No Fertilizer)	19.66[bc]
V_2	Sawdust Alone	20.79[ab]
V_3	Sawdust + Cow Manure	20.64[abc]
V_4	Sawdust + Hog Manure	21.22[a]
V_5	Sawdust + Horse Manure	19.58[c]

Means with the same letter are not significantly different at 5% level DMRT.

manure which had the DMC of 19.66% and 19.58%, respectively. The use of this organic fertilizer can enhance the processing quality of potatoes.

Physical Properties of the Soil after Harvest

Bulk density (Db) of the soil. The initial bulk density of the soil was higher at 1.22g/cm^3 compared to the values gathered after harvest (Final) (Table 21). The decrease in Db could be attributed to the incorporation of organic matter like the vermicompost. Tillage could be also a factor since during tillage; soils are cultivated and turned upside down especially the use of a tractor wherein it causes the soil to become loose for planting.

The bulk densities of the soil were not affected by the application of vermicompost developed from different substrates. The application of vermicomposts

Table 21. Bulk density (Db) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		Db (g/cm^3)
V_1	Control (No Fertilizer)	1.15[a]
V_2	Sawdust Alone	1.17[a]
V_3	Sawdust + Cow Manure	1.15[a]
V_4	Sawdust + Hog Manure	1.14[a]
V_5	Sawdust + Horse Manure	1.13[a]
Initial Value		1.22

Means with the same letter are not significantly different at 5% level DMRT.

developed from sawdust + hog manure and sawdust + horse manure with means of 1.14 and 1.13g/cm^3 shows a slight decrease of bulk density. Application of vermicompost from sawdust + cow manure with a mean of 1.15g/cm^3 is the same with the unfertilized plot (control) and application vermicompost from sawdust with a mean of 1.17g/cm^3 was slightly higher as compared to the control. The increasing and decreasing trend of Db could be due to the application of the vermicomposts developed from different substrates.

<u>Water holding capacity (WHC) of the soil</u>. The initial water holding capacity (WHC) from amended plots was a little bit higher compared to the control (Table 22). While all plots applied with vermicomposts formulations resulted to higher WHC compared to the initial.

Table 22. Water holding capacity (WHC) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		WHC (mL/g)
V_1	Control (No Fertilizer)	0.68^{b}
V_2	Sawdust Alone	0.72^{ab}
V_3	Sawdust + Cow Manure	0.74^{ab}
V_4	Sawdust + Hog Manure	0.73^{ab}
V_5	Sawdust + Horse Manure	0.75^{a}
Initial Value		0.68

Means with the same letter are not significantly different at 5% level DMRT.

The application of vermicomposts developed from different substrates significantly affected the WHC of the soil. Plots applied with vermicompost from substrate sawdust + horse manure have the highest mean of 0.75mL/g while vermicompost from substrates sawdust + cow manure, sawdust + hog manure and sawdust alone differed. It can be noted that there is an increase of WHC with the application of vermicompost developed from different substrates. Pittaway (2001) as cited by Anas (2008) declared that vermicompost have a very high water holding capacity. Brady (1984) stated that humus has a high adsorptive capacity for water which intensifies the disruptive effect of temperature changes and moisture fluctuations.

Chemical Properties of the Soil After Harvest

Final soil pH. The initial soil pH was higher compared to the final pH gathered after potato harvest (Table 23). The decrease of pH from initial compared to the unfertilized plot could be due to the precipitation which brings about acid rain during the conduct of the study.

Application of vermicomposts formulations significantly affected the final soil pH. A higher pH of soils applied with vermicomposts formulations as compared to the control was noted. Application of vermicompost developed from substrate sawdust + hog manure has the highest mean pH of 6.03 which differed from the other vermicomposts formulations. The same trend was observed from the lettuce experiment, which emphasizes the role of plant absorption in its effect on soil pH.

Table 23. Final Soil pH as affected by vermicomposts developed from different substrates

TREATMENT		SOIL pH
V_1	Control (No Fertilizer)	5.6^{c}
V_2	Sawdust Alone	5.7^{bc}
V_3	Sawdust + Cow Manure	5.7^{bc}
V_4	Sawdust + Hog Manure	6.0^{a}
V_5	Sawdust + Horse Manure	5.8^{b}
Initial Value		6.5

Means with the same letter are not significantly different at 5% level DMRT.

Organic matter (OM) content of the soil. Soil analysis as revealed in Table 24 shows that the final OM content has increased from the initial of 1.88% to a range of 2.06% to 2.49%. This could be attributed to the application of vermicompost and also to the incorporation of some organic matters from weeds during tillage.

The vermicomposts developed from different substrates significantly affected the OM content of the soil. Unfertilized plot (control) has the lowest mean compared to the amended plots which also indicates that there is an increase of OM on the application of vermicompost from the different substrates. Application of vermicomposts from substrate sawdust + hog manure and sawdust + cow manure gained the highest OM content at 2.490% and 2.360%, respectively. The application of the other vermicomposts formulations did not differ significantly to the control. The increase in OM is due largely

Table 24. Organic matter content (OM) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		OM (%)
V_1	Control (No Fertilizer)	2.06[b]
V_2	Sawdust Alone	2.27[ab]
V_3	Sawdust + Cow Manure	2.36[a]
V_4	Sawdust + Hog Manure	2.49[a]
V_5	Sawdust + Horse Manure	2.26[ab]
Initial Value		1.88

Means with the same letter are not significantly different at 5% level DMRT.

on the application of vermicomposts. The castings is rich in water soluble plant nutrients, and contains more than 50 % more humus than what is normally found in the topsoil (Bhawan, 2002).

Total nitrogen (N) content of the soil. From the initial N content of the soil, an increase in N content was noted as compared to the to the final soil N content including the control (unfertilized) plot (Table 25).

The vermicomposts developed from different substrates significantly affected the Nitrogen content of the soil after harvest. Unfertilized plot (control) has the lowest mean as compared to the plots applied with vermicomposts which indicate the increase of N with the application of different amendments. Plots applied with vermicomposts from sawdust + hog manure and sawdust + cow manure with means 0.1245% and 0.1180%,

Table 25. Total Nitrogen (N) content of the soil as affected by vermicomposts developed from different substrates

TREATMENT		TOTAL NITROGEN (%)
V_1	Control (No Fertilizer)	0.1028^{b}
V_2	Sawdust Alone	0.1135^{ab}
V_3	Sawdust + Cow Manure	0.1180^{a}
V_4	Sawdust + Hog Manure	0.1245^{a}
V_5	Sawdust + Horse Manure	0.1128^{ab}
Initial Value		0.094

Means with the same letter are not significantly different at 5% level DMRT.

respectively contained higher nitrogen. The increase in nitrogen content of the soil through the application of vermicompost can be attributed by the chemical characteristic of vermicompost that it contains five times the available nitrogen.

There is a significant effect of N in potato research that could be due to further decomposition of sawdust (due to longer crop maturity) as compared to the lettuce research (shorter maturity) which is not significantly affected by N. Harkin, (1969) stated when wood fines are mixed into the soil, bacterial action decomposes the cellulosic portion of the wood within 2 months to a year, depending on soil structure and consistency, temperature, and moisture.

Available phosphorus (P) content of the soil. There was an increase in the phosphorus (P) content of the soil from initial which is 63.06ppm to a range of 105.1ppm (lowest among the substrates) to 140.3ppm (highest among the substrates) (Table 26).

Table 26. Available Phosphorus (P) content of the soil as affected by vermicomposts developed from different substrates

TREATMENT		AVAILABLE PHOSPHORUS (ppm)
V_1	Control (No Fertilizer)	126.0^{ab}
V_2	Sawdust Alone	128.8^{ab}
V_3	Sawdust + Cow Manure	126.9^{ab}
V_4	Sawdust + Hog Manure	140.3^{a}
V_5	Sawdust + Horse Manure	105.1^{b}
Initial Value		63.06

Means with the same letter are not significantly different at 5% level DMRT.

The vermicomposts developed from different substrates used in the treatments did not significantly affected the P content of the soil. However, application of vermicompost from substrate sawdust + hog manure showed the highest P content of 140.3ppm. This could be attributed to the amendments applied and the favorable pH of the soil treated with vermicompost from substrate sawdust + hog manure which has the highest pH at 6.03. The maximum availability of P generally occur at pH 6-7 and heavy application of OM such as manure, plant residues and etc., to soil with high pH not only supplies P but OM decomposition provides acidic compounds which increase availability of mineral forms of P in the soil.

According to (Brady and Weil, 1996) Nitrogen, Phosphorus, Sulfur and micronutrients are stored as constituents of soil organic matter until released by mineralization. Furthermore, organic acids associated with humus also accelerate the release of nutrient element from mineral structure.

<u>Exchangeable potassium (K) content of the soil</u>.Soil Potassium contents after potato harvest were lower than the initial K content of 239ppm which could be attributed by plant uptake of available K (Table 27).

The different vermicomposts formulations had no significant effect on the final K content of the soil. However, the application of vermicompost from sawdust + horse manure showed the highest K content of 145.8ppm K as compared to the other amended plots including the control.

Table 27. Exchangeable Potassium (K) content of the soil as affected by vermicomposts developed from different substrates

TREATMENT		EXCHANGEABLE POTASSIUM (ppm)
V_1	Control (No Fertilizer)	102.8[a]
V_2	Sawdust Alone	116.3[a]
V_3	Sawdust + Cow Manure	111.3[a]
V_4	Sawdust + Hog Manure	136.7[a]
V_5	Sawdust + Horse Manure	145.8[a]
Initial Value		239.0

Means with the same letter are not significantly different at 5% level DMRT.

Cation exchange capacity (CEC) of the soil. From the initial CEC of 0.16m.e./100gsoil, final CEC increased to a range of 0.21 to 1.08 m.e./100gsoil (Table 28).

The application of vermicomposts formulations significantly increased the CEC of the soil. Application of vermicompost from substrate sawdust + hog manure gained the highest CEC at 1.08 m.e/100g soil while the lowest CEC was obtained from the unfertilized plot (control) with 0.21m.e/100g.

Table 28. Cation exchange capacity (CEC) of the soil as affected by vermicomposts developed from different substrates

TREATMENT		CEC (m.e/100g)
V_1	Control (No Fertilizer)	0.21[c]
V_2	Sawdust Alone	0.25[c]
V_3	Sawdust + Cow Manure	0.54[b]
V_4	Sawdust + Hog Manure	1.08[a]
V_5	Sawdust + Horse Manure	0.47[b]
Initial Value		0.16

Means with the same letter are not significantly different at 5% level DMRT.

Return on investment. The effect of vermicomposts obtained from different substrates on the ROI of potato is presented in Table 29. Even though there is a negative ROI, application of vermicompost from sawdust + cow manure had the highest ROI of -62.78% among the substrates while the highest ROI was obtained in the unfertilized soil (control). This results means that for every peso investment there is -62.78 centavo loss on the application of vermicompost from sawdust + cow manure and -52.47 centavo loss on the unfertilized soil (control). The low ROI could be the effect of some factors such as the action of rainfall and typhoons during the month of study.

Even though there is a higher ROI on the control the application or organic amendments are advisable due to its long term effect on the soil. The accumulation of organic amendments such as vermicompost on the first year of cropping would reduce the organic fertilizer application on the following years so the reduction of organic amendments would be the reduction of total expenses. Furthermore, the accumulation also of organic amendments would result also to the accumulations of slowly available nutrients which cause a long term effect on the production of crops and creating a fertile soil.

The negative ROI in the vermicomposts amended plots is due mainly on the high cost and high application rate of vermicompost. The rate of application at 20t/ha is needed when it is the sole source of nutrients and when the soil is on its first stages toward organic production or when the soil fertility is not yet improved.

Table 29. Return on investment (ROI) of potato production as affected by vermicomposts developed from different substrates (15 m^2)

TREATMENTS	PRODUCTON COST (Php)				
	CONTROL	SAWDUST	SAWDUST + COW MANURE	SAWDUST + HOG MANURE	SAWDUST + HORSE MANURE
Expenses (Php)					
Cleaning	20	20	20	20	20
Land Preparation	20	20	20	20	20
Planting	10	10	10	10	10
Watering	25	25	25	25	25
Hill-up	10	10	10	10	10
Weeding	30	30	30	30	30
Tractor	30	30	30	30	30
Seed tubers (potato)	144	144	144	144	144
Vermicompost Fertilizer		300	300	300	300
Total Expenses	289	589	589	589	589
Gross Income	137.36	198.73	219.19	178.24	195.81
ROI	- 52.47	- 66.26	- 62.78	- 69.74	- 66.76
Prevailing price is Php 35.00/kilogram					

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

There were two sets of experimental trials to determine the influence of vermicompost developed from different substrates on Lettuce (*Lactuca sativa*) cv. Romaine and Potato (*Solanum tuberosum*) cv. Solibao including its effects on soil properties. The study especifically aimed to (1) determine the influence of vermicompost developed from different substrates to the yield and quality of lettuce and potato; (2) determine the influence of vermicompost developed from different substrates on some physical and chemical properties of soil.

The study was conducted at the experimental area of Department of Soil Science, College of Agriculture, Benguet State University, La Trinidad, Benguet from January 2008 to July 2009.

Influence of vermicomposts developed from different substrates on the growth and yield of lettuce. Vermicomposts application obtained from different substrates did not affect the initial height, final height, yield, shelf life, and weight loss of lettuce.

Influence of vermicomposts developed from different substrates on some physical properties of soil under lettuce production. The vermicomposts developed from different substrates affected the bulk density of the soil while it did not affect the water holding capacity of the soil after harvest.

Influence of vermicomposts developed from different substrates on some chemical properties of soil under lettuce production. Even though vermicomposts from different substrates did not affect the pH of the soil, it affected the OM, N, P, K, and CEC of the soil after harvest.

Influence of vermicomposts developed from different substrates on the growth and yield of potato. Vermicomposts application obtained from different substrates affected the marketable yield, non-marketable yield, total yield, and dry matter yield of potato.

Influence of vermicomposts developed from different substrates on some physical properties of soil under potato production. The vermicomposts derived from different substrates did not affect the bulk density of the soil while it affected the water holding capacity of the soil after harvest.

Influence of vermicomposts developed from different substrates on some chemical properties of soil under potato production. Vermicomposts obtained from different substrates affected the soil pH, OM, N, and CEC while it did not affect the P and K content of the soil.

Conclusion

Lettuce

The vermicomposts from different substrates did not affect the yield and quality of lettuce but it provides the following data.

The vermicomposts from different substrates affected Db, OM, N, P, K, and CEC of the soil. Application of vermicompost with sawdust + cow manure increased in OM, N content, and CEC after harvest; application of vermicompost with sawdust + hog manure increased in P content of the soil after harvest; and application of vermicompost with sawdust + horse manure increased in K content of the soil after harvest.

The application of vermicomposts developed from different substrates has a good effect on some physical and chemical properties of the soil while in contributes to changes in growth, quality and yield of lettuce. The vermicomposts formulations especially the addition of manure gave more progressive results in lettuce production.

Potato

The vermicomposts from different substrates affected the yield and quality of potato providing more the following data.

The vermicomposts from different substrates affected the WHC, pH, OM, N, and CEC of the soil. Application of vermicompost from sawdust + hog manure increased pH, OM and N content of the soil after harvest; Application of vermicompost with sawdust + horse manure increased WHC of the soil after harvest.

In comparison with the lettuce study application of the vermicomposts formulations gave a desirable result to some physical, chemical properties of soil and also has a good effect to quality and yield of potato. The application mainly of vermicomposts developed from sawdust + manure gave a significant result. Vermicomposts are good soil amendments especially the addition of manure in its formulation.

<u>Recommendations</u>

Based on the results findings and conclusion, the following recommendations were drawn:

1. Vermicomposts derived from different mixtures of sawdust and manure can be used for improving the yield and quality of potato (Solibao C.V.)

2. Application of vermicomposts obtained from the different mixture is recommended for the improvement of soil physical and chemical properties.

3. A follow-up study is also recommended to verify the results and findings.

LITERATURE CITED

ABOEN, R. Jr. 2009. Vermicompost production as influenced by different animal manure and earthworm densities. BS Thesis BSU, La Trinidad, Benguet.

ANAS, R.C. 2008. Influence of activator on chicken manure utilization by garden pea and on some properties of the soil. BS Thesis BSU, La Trinidad, Benguet.

AZARMI, R., M.T.GIGLOU, and R.D. TALESHMIKAIL,. 2008. Influence Vermicompost on Soil Chemical and Physical Properties in Tomato (*Lycopersicume sculentum*) Field. Retrieved 18 August 2008 from: http://www.academicjournals.org/ajb/PDF/pdf2008/18july/Azarmi%et%20al.pdf

BHAWAN, J. 2002. Pyramid Vermicast. The Pyramid Farm. Rajusthan India.

BRADY, N. C., and R. R. WEIL. 1996. The Nature and Properties of Soils. Prentice Hall, Upper Saddle River, New Jersey 07458. Pp. 383,395

BRADY, N. C. 1984. The Nature and Properties of Soils. New York.

BRADY, N. C. 1985. The Nature and Properties of Soils. New York.

EDWARDS, C. A. and N. Q. ARANCON. 2007. The Science of Vermiculture: Earthworms in Organic Waste Management. Retrieved 18 September 2008 from: http://www.biosci.ohiostate.edu/~soilecol/Earthworms%20and%20Vermiculture%20Publications/THE%20SCIENCE%20OF%20VERMICULTURE.pdf

FUNDERBERG, E. 2001. What is Vermicompost? Retrieved 14 August 2008 from: http://www.noble.org/Ag/Soils/OrganicMatter/Index.htm

HART, J., B.STRIK, L. WHITE, and W. YANG. 2006. Nutrient Management for Blueberries in Oregon. Retrieved October 18, 2009 from http://extension.oregonstate.edu/catalog/pdf/em/em8918.pdf

HARKIN, J. M. 1969. Uses for Sawdust, Shavings, and Waste Chips. Retrieved October 18, 2009 from http://www.fpl.fs.fed.us/documnts/fplrn/fplrn208.pdf

KALE, R. D. 2003. Research on Earthworms in India with Special Reference to Vermiculture. Retrieved 14 August 2008 from: http://www.wormsphilippines.com/docs/Rsearch%20on%Earthworm%20in%India%20By%20Dr.%20Kale.htm

LAGMAN, C. Jr. A. 2003. Performance of selected horticultural crop using formulated vermicompost as growing medium. BS Thesis BSU, La Trinidad, Benguet.

MADER, S. S. 2004. Biology Book. 8th Ed. New York: Mc Graw Hill Company, Inc. P. 463

METZGER, J. 1998. Growing Plants with Worm Poop: Vermicompost as an Amendment for Soil less Media. Retrieved 14 August 2008 from: http://floriculture.osu.edu/archive/apr98/vermicom.html

North Carolina Cooperative Extension Service 1997. Earthworm Castings as a Plant Growth Media. NC State University. Retrieved 18 August 2008 from: http://www.bae,ncsu.edu/topic/vermicomposting/vermiculture/castings.html

RODALE, C. 2000. Rodale's All-new Encyclopedia of Organic Gardening. An Illustrated Guide to Organic Gardening Composting. Retrieved August 14, 2008 from www.plantea.com/manure.htm

SHIRALIPOUR, A. 2008. Compost Utilization and Fate of Heavy Metals and Organic Contaminants in Vegetable Production. Retrieved 18 August 2008 from: http://www.oardc.ohio-state.edu/michel/effectonsoilqua.htm

SUBLER, S., EDWARDS, C. A. AND METZGER, J. 1998. Comparing Vermicompost and Compost. Retrieved 18 August 2008 from: http://www.jetcompost.com.reference/july98.htm

Wikipedia. 2008. Organic Fertilizer. Retrieved on 18 August 2008 from: http://en.wikipedia.org/wiki/Organic_fertilizer

Wikipedia. 2008. Vermicompost. Retrieved on 18 August 2008 from: http://en.wikipedia.org/wiki/Vermicompost

WEIR, W. W. 1946. Productive Soils. Copyright, 1946, by J. B. Lippincott Company.

APPENDICES

LETTUCE

APPENDIX TABLE 1. Initial plant height (cm)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	10.22	11.09	11.33	32.64	10.88
V_2	10.70	12.26	11.16	34.12	11.37
V_3	12.09	11.05	8.86	32.00	10.67
V_4	10.34	12.01	9.60	31.95	10.65
V_5	9.72	11.94	8.47	30.13	10.04
TOTAL	53.07	58.35	49.42	140.84	
MEAN	10.61	11.67	9.88		10.72

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	8.063	4.032			
TREATMENT	4	2.754	0.689	0.643^{ns}	3.84	7.01
ERROR	8	8.567	1.071			
TOTAL	14	19.384				

ns - not significant CV = 9.65 %

APPENDIX TABLE 2. Final plant height (cm)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	20.21	19.41	21.40	61.02	20.34
V_2	19.17	21.09	21.37	61.63	20.54
V_3	21.39	20.17	21.59	63.15	21.05
V_4	20.13	21.98	21.98	63.29	21.10
V_5	20.10	19.97	21.63	61.70	20.57
TOTAL	101.00	101.82	107.97		
MEAN	20.20	20.36	21.59		

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	5.805	2.903			
TREATMENT	4	1.35	0.337	0.7343^{ns}	3.84	7.01
ERROR	8	3.676	0.460			
TOTAL	14	10.831				

ns - not significant CV = 3.27 %

APPENDIX TABLE 3. Total yield (t/ha)

TREATMENTS	BLOCK			TOTAL	MEAN
	I	II	III		
V_1	6.22	13.46	13.80	33.48	11.16
V_2	12.08	21.04	16.90	50.02	16.67
V_3	13.12	15.88	15.18	44.18	14.73
V_4	16.90	18.98	16.28	52.16	17.39
V_5	13.12	13.80	16.56	43.48	14.49
TOTAL	61.44	83.16	78.72	223.32	
MEAN	12.29	16.63	15.74		14.89

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F	
					0.05	0.01
BLOCK	2	52.67	26.34			
TREATMENT	4	70.53	17.63	3.62^{ns}	3.84	7.01
ERROR	8	38.97	4.87			
TOTAL	14	162.17				

ns - not significant CV = 14.82 %

APPENDIX TABLE 4. Shelf-life (days)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	7	7	6	20	6.67
V_2	6	6	6	18	6.00
V_3	7	6	6	19	6.33
V_4	6	6	6	18	6.00
V_5	7	6	6	19	6.33
TOTAL	33	31	30	94	
MEAN	6.6	6.2	6.0		6.3

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.933	0.467			
TREATMENT	4	0.933	0.233	1.75^{ns}	3.84	7.01
ERROR	8	1.067	0.133			
TOTAL	14	2.933				

ns - not significant CV = 5.83 %

APPENDIX TABLE 5. Weight loss (%)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	99	144	159	402	134.00
V_2	115	214	140	469	156.33
V_3	150	166	169	485	161.67
V_4	175	195	219	589	196.33
V_5	144	156	176	476	158.67
TOTAL	683	875	863	2421	
MEAN	136.60	175.00	172.60		161.4

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	4627.2000	2313.600			
TREATMENT	4	6012.9333	1503.233	2.7802^{ns}	3.84	7.01
ERROR	8	4325.4670	540.683			
TOTAL	14	14965.6000				

ns - not significant CV = 14.41 %

APPENDIX TABLE 6. Bulk density (Db) of the soil (g/cm^3)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	1.13	1.15	1.16	3.44	1.15
V_2	1.04	1.08	0.9	3.02	1.01
V_3	1.11	1.11	1.11	3.33	1.11
V_4	1.12	1.14	1.15	3.41	1.14
V_5	1.14	1.09	1.11	3.34	1.11
TOTAL	5.54	5.57	5.43	16.54	
MEAN	1.11	1.11	1.09		1.10

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.002	0.001			
TREATMENT	4	0.037	0.009	4.500*	3.84	7.01
ERROR	8	0.018	0.002			
TOTAL	14	0.057				

* - significant CV = 4.29 %

APPENDIX TABLE 7. Water holding capacity (WHC) of the soil (mL/g)

TREATMENTS	BLOCK			TOTAL	MEAN
	I	II	III		
V_1	0.69	0.66	0.71	2.06	0.69
V_2	0.76	0.77	0.67	2.20	0.73
V_3	0.74	0.77	0.71	2.22	0.74
V_4	0.74	0.71	0.74	2.19	0.73
V_5	0.75	0.75	0.75	2.25	0.75
TOTAL	3.68	3.66	3.58	10.92	
MEAN	0.74	0.73	0.72		0.73

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F	
					0.05	0.01
BLOCK	2	0.001	0.001			
TREATMENT	4	0.007	0.002	2.0000^{ns}	3.84	7.01
ERROR	8	0.009	0.001			
TOTAL	14	0.017				

ns - not significant CV = 4.51 %

APPENDIX TABLE 8. Final soil pH

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	6.2	6.1	6.3	18.6	6.2
V_2	6.7	6.2	6.3	19.2	6.4
V_3	6.6	6.1	6.3	19.0	6.3
V_4	6.5	6.4	6.5	19.4	6.5
V_5	6.4	6.2	6.3	18.9	6.3
TOTAL	32.4	31.0	31.7	95.1	
MEAN	6.5	6.2	6.3		6.3

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.196	0.098			
TREATMENT	4	0.123	0.031	2.0667^{ns}	3.84	7.01
ERROR	8	0.117	0.015			
TOTAL	14	0.436				

ns - not significant CV = 1.91 %

APPENDIX TABLE 9. Organic matter (OM) content of the soil (%)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	1.24	1.87	2.15	5.26	1.75
V_2	2.81	2.64	2.44	7.89	2.63
V_3	2.87	2.87	3.19	8.93	2.98
V_4	2.53	2.56	2.76	7.85	2.62
V_5	2.10	2.91	2.69	7.7	2.57
TOTAL	11.55	12.85	13.23	37.63	
MEAN	2.31	2.57	2.65		7.53

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.31	0.155			
TREATMENT	4	2.458	0.615	7.6875**	3.84	7.01
ERROR	8	0.643	0.080			
TOTAL	14	3.411				

** - highly significant CV = 11.30 %

APPENDIX TABLE 10. Total Nitrogen (N) content of the soil (%)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	0.06	0.09	0.11	0.26	0.09
V_2	0.14	0.13	0.12	0.39	0.13
V_3	0.14	0.14	0.16	0.44	0.15
V_4	0.13	0.13	0.14	0.40	0.13
V_5	0.11	0.15	0.14	0.40	0.13
TOTAL	0.58	0.64	0.67	1.89	
MEAN	0.12	0.13	0.13		0.13

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.001	0.000			
TREATMENT	4	0.006	0.002	6.6667**	3.84	7.01
ERROR	8	0.002	0.000			
TOTAL	14	0.009				

** - highly significant CV = 11.99 %

APPENDIX TABLE 11. Available Phosphorus (P) content of the soil (ppm)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	23.65	24.56	22.74	70.95	23.65
V_2	21.48	19.72	23.23	64.43	21.48
V_3	25.34	23.16	27.51	76.01	25.30
V_4	42.11	47.30	44.71	134.12	44.71
V_5	32.49	25.48	28.99	86.96	28.99
TOTAL	145.07	140.22	147.18	432.47	
MEAN	29.01	28.04	29.44		28.83

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	4.975	2.487			
TREATMENT	4	1036.303	259.076	41.5245**	3.84	7.01
ERROR	8	49.913				
TOTAL	14	1091.190				

** - highly significant CV = 8.67 %

APPENDIX TABLE 12. Exchangeable Potassium (K) content of the soil (ppm)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	164.50	164.50	183.50	512.50	170.83
V_2	227.00	216.00	362.50	805.50	268.50
V_3	306.00	252.00	239.00	797.00	265.67
V_4	194.00	252.00	252.00	698.00	232.67
V_5	393.50	408.00	378.00	1179.50	393.17
TOTAL	1285.00	1292.50	1415.00	3992.5	
MEAN	257.00	258.50	283.00		266.17

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	2130.833	1065.417			
TREATMENT	4	79036.167	19759.042	9.4985**	3.84	7.01
ERROR	8	16641.833	2080.229			
TOTAL	14	97808.833				

** - highly significant CV = 17.14 %

APPENDIX TABLE 13. Cation exchange capacity (CEC) of the soil (m.e/100g soil)

TREATMENTS	BLOCK			TOTAL	MEAN
	I	II	III		
V_1	3.54	3.70	3.37	10.61	3.54
V_2	9.30	9.90	9.60	28.80	9.60
V_3	17.49	15.40	13.31	46.20	15.40
V_4	4.57	3.57	4.07	12.21	4.07
V_5	0.30	0.52	0.07	0.89	0.29
TOTAL	35.2	33.09	30.42	98.71	
MEAN	7.04	6.62	6.08		6.58

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F	
					0.05	0.01
BLOCK	2	0.455	0.228			
TREATMENT	4	379.86	94.965	42.2772**	3.84	7.01
ERROR	8	17.97	2.246			
TOTAL	14	398.285				

** - highly significant CV = 21.89 %

Table 14. Return on investment (ROI) of lettuce production as affected by vermicomposts developed from different substrates (15 m2)

TREATMENTS	PRODUCTON COST (Php)				
	CONTROL	SAWDUST	SAWDUST + COW MANURE	SAWDUST + HOG MANURE	SAWDUST + HORSE MANURE
Expenses (Php)					
Cleaning	20	20	20	20	20
Land Preparation	20	20	20	20	20
Planting	10	10	10	10	10
Watering	30	30	30	30	30
Hill-up	10	10	10	10	10
Weeding	30	30	30	30	30
Tractor	22.50	22.50	22.50	22.50	22.50
Seed (Romaine)	36	36	36	36	36
Vermicompost Fertilizer		300	300	300	300
Total Expenses	178.5	478.5	478.5	478.5	478.5
Gross Income	137.36	198.73	219.19	178.24	195.81
ROI	93.59	7.95	- 4.70	12.57	- 6.40

Prevailing price is Php 25.00/kilogram

POTATO

APPENDIX TABLE 15. Marketable yield of potato ($kg/5m^2$)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	1.00	1.25	1.67	3.92	1.31
V_2	1.75	1.84	2.09	5.68	1.89
V_3	2.00	1.92	2.34	6.26	2.09
V_4	1.34	1.42	2.34	5.10	1.70
V_5	1.84	2.00	1.75	5.59	1.86
TOTAL	7.93	8.43	10.19	26.55	
MEAN	1.59	1.69	2.04		1.77

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.564	0.282			
TREATMENT	4	1.031	0.258	4.3255*	3.84	7.01
ERROR	8	0.477	0.477			
TOTAL	14	2.072				

* - significant CV = 13.79 %

APPENDIX TABLE 16. Non-marketable yield of potato (kg/5m^2)

TREATMENTS	BLOCK			TOTAL	MEAN
	I	II	III		
V_1	0.21	0.25	0.17	0.63	0.21
V_2	0.25	0.25	0.25	0.75	0.25
V_3	0.25	0.21	0.17	0.63	0.21
V_4	0.25	0.25	0.25	0.75	0.25
V_5	0.33	0.38	0.42	1.13	0.38
TOTAL	1.29	1.34	1.26	3.89	
MEAN	0.26	0.27	0.25		0.26

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F	
					0.05	0.01
BLOCK	2	0.0007	0.0004			
TREATMENT	4	0.0564	0.0141	11.75**	3.84	7.01
ERROR	8	0.0098	0.0012			
TOTAL	14	0.0669				

** - highly significant CV = 13.36 %

APPENDIX TABLE 17. Total yield (t/ha)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	2.16	3.00	3.68	8.84	2.95
V_2	3.84	4.18	4.68	12.70	4.23
V_3	4.50	4.68	5.02	14.20	4.73
V_4	3.84	3.34	5.18	12.36	4.12
V_5	4.34	5.50	4.34	14.18	4.73
TOTAL	18.68	20.70	22.90	62.28	
MEAN	3.74	4.14	4.58		4.15

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	1.781	0.8905			
TREATMENT	4	6.386	1.5965	4.9466*	3.84	7.01
ERROR	8	2.582	0.32275			
TOTAL	14	10.749				

* - significant CV = 13.68 %

APPENDIX TABLE 18. Dry matter content (DMC) of potato (%)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	19.15	19.15	20.67	58.97	19.66
V_2	20.55	19.64	22.18	62.37	20.79
V_3	20.23	19.18	22.52	61.93	20.64
V_4	20.79	21.22	21.66	63.67	21.22
V_5	19.78	18.42	20.55	58.75	19.58
TOTAL	100.50	97.61	107.58	305.69	
MEAN	20.10	19.52	21.52		20.38

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	10.525	5.263			
TREATMENT	4	6.320	1.58	4.4134*	3.84	7.01
ERROR	8	2.866	0.358			
TOTAL	14	19.711				

* - significant CV = 2.94 %

APPENDIX TABLE 19. Bulk density (Db) of the soil (g/cm^3)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	1.23	1.10	1.13	3.46	1.15
V_2	1.20	1.15	1.16	3.51	1.17
V_3	1.17	1.18	1.11	3.46	1.15
V_4	1.15	1.17	1.11	3.42	1.14
V_5	1.12	1.16	1.12	3.40	1.13
TOTAL	5.87	5.76	5.62	17.25	
MEAN	1.17	1.15	1.12		1.15

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.006	0.003			
TREATMENT	4	0.002	0.0005	0.5^{ns}	3.84	7.01
ERROR	8	0.011	0.001			
TOTAL	14	0.02				

ns - not significant CV = 3.21 %

APPENDIX TABLE 20. Water holding capacity (WHC) of the soil (mL/g)

TREATMENTS	BLOCK			TOTAL	MEAN
	I	II	III		
V_1	0.69	0.66	0.68	2.03	0.68
V_2	0.76	0.72	0.67	2.15	0.72
V_3	0.74	0.77	0.71	2.22	0.74
V_4	0.74	0.71	0.73	2.18	0.73
V_5	0.75	0.75	0.75	2.25	0.75
TOTAL	3.68	3.61	3.54	10.83	
MEAN	0.74	0.72	0.71		0.72

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F	
					0.05	0.01
BLOCK	2	0.002	0.001			
TREATMENT	4	0.010	0.002	3.9835*	3.84	7.01
ERROR	8	0.005	0.001			
TOTAL	14	0.016				

* - significant CV = 3.41 %

APPENDIX TABLE 21. Final soil pH

TREATMENTS	BLOCK			TOTAL	MEAN
	I	II	III		
V_1	5.5	5.4	5.9	16.8	5.6
V_2	5.6	5.5	5.9	17.0	5.7
V_3	5.7	5.5	5.9	17.1	5.7
V_4	6.0	6.0	6.1	18.1	6.0
V_5	5.7	5.8	6.0	17.5	5.8
TOTAL	28.5	28.2	29.8	86.5	
MEAN	5.7	5.6	5.9		5.7

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F	
					0.05	0.01
BLOCK	2	0.289	0.145			
TREATMENT	4	0.353	0.088	9.7778**	3.84	7.01
ERROR	8	0.071	0.009			
TOTAL	14	0.713				

** - highly significant CV = 1.63 %

APPENDIX TABLE 22. Organic matter (OM) content of the soil (%)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	1.96	2.05	2.16	6.17	2.06
V_2	2.44	2.27	2.10	6.81	2.27
V_3	2.40	2.38	2.30	7.08	2.36
V_4	2.55	2.58	2.34	7.47	2.49
V_5	2.13	2.30	2.34	6.77	2.26
TOTAL	11.48	11.58	11.24	34.30	
MEAN	2.30	2.32	2.25		2.29

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.012	0.006			
TREATMENT	4	0.302	0.076	4.75*	3.84	7.01
ERROR	8	0.130	0.016			
TOTAL	14	0.445				

* - significant CV = 5.58 %

APPENDIX TABLE 23. Total Nitrogen (N) content of the soil (%)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	0.0980	0.1025	0.1080	0.3085	0.1028
V_2	0.1220	0.1135	0.1050	0.3405	0.1135
V_3	0.1200	0.1190	0.1150	0.3540	0.1180
V_4	0.1275	0.1290	0.1170	0.3735	0.1245
V_5	0.1065	0.1150	0.1170	0.3385	0.1128
TOTAL	0.5740	0.5790	0.5620	1.7150	
MEAN	0.1148	0.1158	0.1124		0.1143

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	0.00002	0.00001			
TREATMENT	4	0.0007	0.0002	4.000*	3.84	7.01
ERROR	8	0.0004	0.00005			
TOTAL	14	0.0011				

* - significant CV = 6.06 %

APPENDIX TABLE 24. Available Phosphorus (P) content of the soil (ppm)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	117.59	129.87	130.57	378.03	126.01
V_2	106.53	121.45	152.33	380.31	126.77
V_3	115.13	153.07	112.50	380.70	126.90
V_4	117.23	152.33	151.28	420.84	140.28
V_5	89.51	114.78	111.09	315.38	105.13
TOTAL	545.99	671.50	657.77	1875.26	
MEAN	109.198	134.30	131.554		125.02

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	1895.736	947.868			
TREATMENT	4	1908.568	477.142	2.5396^{ns}	3.84	7.01
ERROR	8	1503.023	187.878			
TOTAL	14	5307.327				

ns - not significant CV = 10.96 %

APPENDIX TABLE 25. Exchangeable Potassium (K) content of the soil (ppm)

TREATMENTS	BLOCK I	BLOCK II	BLOCK III	TOTAL	MEAN
V_1	86.0	100.0	122.5	308.5	102.83
V_2	88.5	138.0	122.5	349.0	116.33
V_3	86.0	128.5	119.5	334.0	111.33
V_4	148.5	145.0	116.5	410.0	136.67
V_5	91.5	197.5	148.5	437.5	145.83
TOTAL	500.5	709.0	629.5	1839.0	
MEAN	100.1	141.8	125.9		122.60

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	TABULATED F 0.01
BLOCK	2	4428.9	2214.45			
TREATMENT	4	3883.767	970.942	1.6252^{ns}	3.84	7.01
ERROR	8	4779.433	597.429			
TOTAL	14	13092.1				

ns - not significant CV = 19 .94 %

APPENDIX TABLE 26. Cation exchange capacity (CEC) of the soil (m.e/100g soil)

TREATMENTS	BLOCK I	II	III	TOTAL	MEAN
V_1	0.21	0.34	0.07	0.62	0.21
V_2	0.35	0.25	0.14	0.74	0.25
V_3	0.65	0.54	0.43	1.62	0.54
V_4	1.15	1.08	1.00	3.23	1.08
V_5	0.50	0.43	0.47	1.40	0.47
TOTAL	2.86	2.64	2.11	7.61	
MEAN	0.57	0.53	0.42		0.51

ANALYSIS OF VARIANCE

SV	DF	SS	MS	F VALUE	TABULATED F 0.05	0.01
BLOCK	2	0.059	0.03			
TREATMENT	4	1.456	0.364	78.6542**	3.84	7.01
ERROR	8	0.037	0.005			
TOTAL	14	1.522				

** - highly significant CV = 13.41 %

Table 27. Return on investment (ROI) of potato production as affected by vermicomposts developed from different substrates (15 m^2)

TREATMENTS	PRODUCTON COST (Php)				
	CONTROL	SAWDUST	SAWDUST + COW MANURE	SAWDUST + HOG MANURE	SAWDUST + HORSE MANURE
Expenses (Php)					
Cleaning	20	20	20	20	20
Land Preparation	20	20	20	20	20
Planting	10	10	10	10	10
Watering	25	25	25	25	25
Hill-up	10	10	10	10	10
Weeding	30	30	30	30	30
Tractor	30	30	30	30	30
Seed tubers (potato)	144	144	144	144	144
Vermicompost Fertilizer		300	300	300	300
Total Expenses	289	589	589	589	589
Gross Income	137.36	198.73	219.19	178.24	195.81
ROI	- 52.47	- 66.26	- 62.78	- 69.74	- 66.76

Prevailing price is Php 35.00/kilogram