BIBLIOGRAPHY

GANASE, NANIE MICHELLE B. APRIL 2011. Azolla Compost Application on Some Soil Properties and Yield of Romaine Lettuce (*Lactuca sativa* L. cv. Xanadu). Benguet State University, La Trinidad, Benguet.

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ABSTRACT

The study was conducted to determine the: 1) effect of azolla compost on some soil properties; 2) effect of azolla compost on the growth and yield of the Romaine lettuce; and, 3) best rate of azolla compost for romaine lettuce production.

General observation on the effect of the different rates of azolla compost on plants is that it significantly affected the marketable and total yield of Romaine lettuce. Application of azolla compost at a rate of 12 tons/ha produced the highest marketable and total yield of Romaine lettuce.

Applications of different rates of azolla compost significantly increased the pH, organic matter, Cation Exchange Capacity (CEC) and total nitrogen content of the soil. Azolla compost applied at a rate of 12 tons/ha resulted to higher chemical properties of the soil.

Application of azolla compost improves the bulk density and water holding capacity of the soil.

The pest infestation and leaf spot infection were observed at 30 DAT and 37 DAT. At 30 DAT, there were more pests but lower rate of leaf spot infection. However, at 37 DAT lesser pest infestation but higher Leaf spot infection was noted.

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INTRODUCTION

All crops need nutrients like nitrogen, potassium, phosphorous and others. Some plants are nitrogen fixers like legumes and azolla. These plants abound in our surrounding and it is imperative to use these plants as bio-fertilizer which is a cheaper and renewable source of low cost plant nutrient and plays a major role in the Integrated Plant Nutrient Supply System. Use of azolla fern as a bio-fertilizer is advocated to minimize the dependency on chemical fertilizer.

Azolla is a floating aquatic fern that is naturally available mostly on moist soils like in rice paddies. It is capable of fixing atmospheric nitrogen in the soil to NH_4^+ and becomes available as soluble nitrogen for the crops and rice. It is abundant or available in our surroundings to be used as a biofertilizer (Wikipedia, 2006). Application of organic fertilizers like compost increases soil microorganism population activity and improves the soil organic matter (SOM) content. There are many organic materials that are being used for composting like grasses, sawdust, azolla, chicken manure and other decomposable materials that can be used as a fertilizer. Some researchers proved that compost improves the physical, chemical, and biological properties of the soil. Azolla maintain soil fertility and supplements nitrogen to crops for its growth and production.

Romaine or cos lettuce (*Lactuca sativa*) is a variety of lettuce which grows in a tall head of sturdy leaves with a firm rib down the center. Unlike most lettuces, it is tolerant to heat. As with other dark leafy greens, the antioxidants contained within romaine lettuce are believed to be of help. Romaine lettuce have nutritional value per 100 g (3.5 oz) of 72 kJ energy (17 kcal), 3.3 g carbohydrates, 2.1 g dietary fibre, 0.3 g Fat, 1.2 g protein, 95 g water, 290 μg (32%) vitamin A equiv., 136 μg (34%) folate (Vit.

B_9), 24 mg (40%) vitamin C, 33 mg (3%) calcium, 0.97 mg (8%) iron, 30 mg (4%) phosphorus, 247 mg (5%) potassium. It can grow in a wide range of soil types but prefer a slightly acidic soil with pH 6 to 6.5. It prefers cool weather and can survive a light frost. The nutrient requirement of lettuce are: (2.5-4.0%) N, (0.4-0.6%) P, (4.0-7.5%) K, (0.9-2.0%) Ca, (0.3-0.7%) Mg, (0.1-0.3%) S, (50-150 ppm) Fe, (25-50 ppm) Zn, (30-55 ppm) Mn, (5-10 ppm) Cu, (15-30 ppm) B, and (0.03 ppm) Mo (Wikipedia, 2010).

This study was conducted to determine the: 1) effect of azolla compost on some soil properties; 2) effect of the azolla compost on the growth and yield of romaine lettuce; and, 3) best rate of azolla compost for romaine lettuce production.

The study was conducted at the Organic Demo Farm (ODF) experimental area, Department of Soil Science, College of Agriculture, Benguet State University, La Trinidad, Benguet from October 2010 to March 2011.

REVIEW OF LITERATURE

Effect of Compost on Soil

There are many organic materials that are rich in nitrogen like azolla, sunflower and other plants that can be used as compost. The nitrogen is very much important in crops because if there will be insufficient nitrogen on the soil the plant will be yellow in color or it is wilted and also the other essential nutrients that will be needed by the plants like N, P, K, Ca, Mg and other essential elements.

According to Pile (1992), compost is the result of the activity of billions of tiny organisms that utilize the two main chemical components of organic matter-carbon and nitrogen in their life processes. It can be made from almost any kind of organic materials. Incorporating compost into the soil adds microorganisms and reinforces the resident microbial population, increasing their activity.

The compost is very important to improve soil fertility by soil management so that crop yields can be increased and then maintained at its higher level. A fertile soil is able to withstand erosion and meet the needs of the crop for moisture, air, nutrients, acidity and temperature. It helps to maintain or increase the amount of organic matter in the soil. It controls erosion of organic matter from the land surface by reducing the destructive force of the wind and water, protecting the surface of the soil by covering it with mulch, increasing the porosity of the soil. It also provides adequate levels of moisture to the crop by adding compost either as surface mulches or incorporation. It improves the soil structure to optimize soil aeration and to hold more water before drainage starts or water logging takes place. It increases nutrients that the plant requires.

It improves the soil pH and soil temperature. The soil temperature is reduced by high levels of organic matter to improve germination (Dalzell *et al.*, 2007).

Thompson (1973) stated that compost is a mixture of soil and decomposing organic matter often used by farmers as fertilizer. The use of compost results in humus formation and promotes good soil structure. It will release plant nutrients as it is spread on the soil.

Effect of Compost on Plant Growth

Cosico (2005) reported that plant growth increases as the supply and availability of nutrients increase. However, the increase in growth or yield is not proportional for every increase in nutrient level over a period of time. In addition, Brady and Weil (2008) revealed that the soil food web converts organically bound forms nitrogen, phosphorous, and sulfur into mineral forms that can be taken up by the plants.

As the microorganisms continue to decompose, organic matter in the soil contributes to the chemical reactions that benefit plants. Some of the microorganisms are nitrogen-fixing bacteria, which take nitrogen from the air and make it accessible to plants. It serves as a ready food source for the billions of soil microorganisms that convert the soluble compounds into a form that can be absorbed by the plant roots (Pile, 1992).

Chen and Wu (2005) stated that using compost is an effective way to increase healthy plant production, help save money, reduce the use of chemical fertilizers, and conserve natural resources. It enhances soil quality and increases crop production. In environment, there is pollution remediation and pollution prevention.

Azolla Composition

Azolla has high nitrogen content that makes it as a desirable organic fertilizer while its high protein content makes it as a good food supplement as well as food. Roughly, 100 kgs. fresh weight yield about 4-6 kgs. dried azolla. It decomposes rapidly because of its low C: N ratio (15-18:1). The recommended application rate on upland crops and vegetables is from 5 to 7 tons/ha of dried azolla. The nutrient content of azolla: N=3.0-5.0%, P=1.0 % and K= 2.0-3.0%. A range of elemental composition on a dry weight basis is as follows: N=1.96-5.30 %, P=0.16-1.59 %, K=0.31-5.97 %, Ca=0.45-1.70 %, Mg=0.22-0.66 %, S=0.22-0.73 %, Si=0.16-3.53, Na=0.16-1.31%, Cl=0.62-0.90 %, Al=0.04-0.59 %, Fe=0.04-0.59 %, Mn=66-2944 ppm, Cu=0-254 ppm, Zn=26-989 ppm (Khan, 1983).

Similarly, 10 tons of fresh azolla would provide the equivalent of 1 bag urea (50 kg/bag). On the decomposition this mass of azolla will release about 25-30 kg N/ha (PCARRD, 2006). Likewise, Khan (1988) also stated that Azolla as an organic fertilizer can be used in any form fresh, dry, or composted for fruits, vegetables and ornamental crops.

Ihoko (1985) as cited by Bentrez (1997) stated that the decomposition of organic materials is a digestive process of fungi, bacteria, and actinomycetes. These organisms work best when plenty of oxygen is available. The bacteria causing decay are found in the soil, air, water, manure and many other places. In order to hasten the decomposition process, it is common to pile organic raw materials with a sufficient supply of water and air that is to compost them. She also stated that the addition of azolla in increasing rates significantly increase the total N and available P contents and the percentage recovery.

The symbiotic nitrogen fixing capacity of algae cells in azolla plant is much higher than that of bacteroids in legume root nodules. The algae cell can fix about 450-600 k of nitrogen per hectare annually (NAAP, 1989) as cited by Masillem (1995).

Chimicag (1995) stated that azolla compost may be a good organic fertilizer for crops especially when used as a pure growth medium. When the azolla compost is limiting, amendment of azolla compost to the soil in any proportion is advisable as it improves most of the properties of the soil as well as the yield.

Effects of Azolla

Azolla traditionally grows under cool, wet conditions. The plant prefers a placid water surface, temperature between 20 and 35°C, water pH of 4.7 and rich in all essential plant nutrients except nitrogen, salt solution containing less than 0.3% exposure to greater than 25% full sunlight, long day length, and freedom from competitors, insects and diseases. Efforts to expand azolla use in the humid tropics have met with limited success and a host of environmental problems. High temperatures cause a change in pH and water circulation (Lumpkin, 1988) as cited by Masillem (1995).

Lumpkin and Plucknett (1986) reported that azolla helps to increase humus and organic nitrogen levels in the soil when it is incorporated. There is also some improvement in soil chemical and physical properties which will result in less energy required for tillage. Continuous azolla cultivation, humus and organic N will accumulate. It also improves the water holding capacity and cation exchange capacity of the soil. It releases nitrogen slowly than chemical fertilizers.

The Institute of Soils and Fertilizers in China found that azolla used as a green manure decreased specific gravity, increased porosity (3.7-4.2%), and increased organic matter in soils. Soil salt content was reduced by 0.014-0.048% (Western SARE, 2010).

Farmers all over the world have used compost, green manures and other organic residues as a major source of nitrogen to promote plant growth and increase crop production. Azolla has the potential of supplying part of the nitrogen requirement of crops through biological means. In approximately 75 days, a hectare of azolla can produce three layers of green manure. The value of this amounts to 25 kg nitrogen per hectare. The azolla can be harvested and either incorporated into soil or used in the preparation of compost. The Chemical Analysis of Azolla on a dry matter weight basis (% on dry matter basis) as follows: Ash=10.00, Crude fat=3.0-3.5, Crude protein=20-25, Soluble sugars=3.0-3.5, Starch=6.0-6.5, Chlorophyll-A=0.25-0.50 (Titus and Pereira, 2010).

<u>Effects of Azolla Fertilization on the Economy of Soil Nitrogen</u>

Crop plants respond to azolla fertilization exactly the same way as they do to other green manure crops. The nitrogen efficiency of azolla is almost comparable or slightly inferior to that of urea or ammonium sulfate. When azolla is incorporated into the soil, heterogeneous soil organisms act on it. As a result of enzymic digestion, the more complex proteins and allied compounds are simplified and hydrolyzed to ionic ammonium (NH_4^+) and nitrate (NO_3^-) forms which become easily available to crop plants as nitrogen source. As the decomposition proceeds, nitrogen is released. Release is thus gradual and continues for a long time which is an advantageous situation. Continuous use of azolla as green manure imparts on the soil a dark color and improves the physico-chemical and biological properties. The organic matter content is increased and consequently the nitrogen economy of the soil is improved (Khan, 1983).

METHODOLOGY

In composting, fresh azolla were gathered from the rice field and then piled and covered with plastic to prevent drying. After two (2) weeks the azolla compost was harvested and packed in sacks.

Seeds of romaine lettuce (var. xanadu) were sown on seedling trays. For easier identification of treatments in the field, the plots were staked with tags. Chemical reagents, laboratory equipments and glass wares were used in the analysis of nutrient elements.

The study was conducted in a 105 m^2 area at the organic demo farm experimental area from November 2010 to March 2011. The area was divided into twenty-one (21) plots measuring 1 m x 5 m representing seven (7) treatments and three (3) replications. The experimental design used was the randomized complete block design (RCBD).

The azolla compost was applied and thoroughly mixed into the soil before planting following the different rates (tons/ha):

T_1- Control (no compost)

T_2- 2

T_3- 4

T_4- 6

T_5- 8

T_6- 10

T_7- 12

Seeds previously sown in seedling trays were transplanted at a distance of 20 cm between hills and rows. Watering was done frequently to keep the plants moist and growing consistently.

Soil samples were collected before and after planting. The soil was analyzed for its nutrient contents and other soil properties.

The data gathered were the following:

A. Soil Analysis

Physical Properties of the Soil

1. Bulk density of the soil (g/cm^3). The method that was used for bulk density was the core sampling method.

2. Water holding capacity of the soil (ml/g). It was determined through saturation method, wherein water was allowed to saturate the soil in the core sampler with the bottom of the cylinder submerged in water to be saturated through capillarity.

$$WHC = \frac{\text{Volume of Water Retained (ml)}}{\text{Weight of Oven Dry Soil (g)}}$$

Chemical Properties of the Soil

1. Soil pH. The initial and final soil pH was determined using 1:2.5 0.01 M $CaCl_2$ solution by Electrometric Method.

2. Organic matter content of the soil (%). Organic matter content of the soil was analyzed using the Walkley-Black Method.

3. Total nitrogen (%). Nitrogen content of the soil was derived from the organic matter content of the soil by multiplying with 0.05.

4. Cation exchange capacity of the soil (m.e/100g). The ammonium acetate method was used using the formula:

$$\text{CEC (m.e./100 g soil)} = \frac{(S\text{-}B) \times N \times 100}{ODW}$$

Where: ODW- oven dry weight of sample in g

S- volume of standard H_2SO_4 used in sample

B- volume of standard H_2SO_4 used in blank

N- normality of H_2SO_4 used

B. Growth and Yield Parameters

1. Marketable yield ($kg/5m^2$). Yield was taken by weighing all harvested lettuce per plot excluding the non-marketable plants.

2. Non-marketable yield ($kg/5m^2$). Yield was taken by weighing all non-marketable (damaged) lettuce per plot.

3. Total yield ($kg/5m^2$). This is the weight of all harvested lettuce per plot which includes the marketable and non-marketable.

C. Pests and Diseases. The pests and diseases that was observed on the crop were recorded.

D. ROCE (%). This was taken by recording all the expenses and gross income and was computed using the formula:

$$\text{ROCE (\%)} = \frac{\text{Gross Income} - \text{Total Expenses}}{\text{Total Expenses}} \times 100$$

E. <u>Statistical Analysis</u>

The data gathered were statistically analyzed using the ANOVA. The significance between treatment means were analyzed using the Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Bulk Density of the Soil

The bulk density of the soil was not significantly affected by the different rates of azolla compost (Table 1). The lowest bulk density however, was obtained from the soil applied with 12 tons/ha azolla compost with a mean of 1.00 g/cm^3. The highest so far was obtained from the control with a mean of 1.13 g/cm^3. It was noted that the bulk density of soils at a range of 1.00 to 1.08 decreased from the initial value of 1.52 g/cm^3. These results show that soil application of azolla compost improves the structure of the soil which also promotes the porosity of the soil.

Table 1. Bulk density (Db) of the soil as affected by different rates of azolla compost

TREATMENT	Db OF THE SOIL (g/cm^3)
Control	1.13^a
2	1.08^a
4	1.06^a
6	1.06^a
8	1.05^a
10	1.03^a
12	1.00^a
Initial	1.52

Means with the same letter/s are not significantly different at 5% level by DMRT

Water Holding Capacity of the Soil

Water holding capacity of the soil was not significantly affected by the application of different rates of azolla compost as shown in Table 2. The application of 12 tons/ha azolla compost however, registered the highest mean of 0.75 ml/g and the lowest was from plots with no azolla compost. Further, the WHC of the soil compared to the initial of 0.32 ml/g, was doubled with the application of azolla compost. It is implied therefore that, azolla compost and the presence of a crop improves the water holding capacity of the soil as the case with the control plots.

Table 2. Water holding capacity (WHC) of the soil as affected by different rates of azolla compost

TREATMENT	WHC (ml/g)
Control	0.63[a]
2 tons/ha Azolla compost	0.65[a]
4 tons/ha Azolla compost	0.68[a]
6 tons/ha Azolla compost	0.70[a]
8 tons/ha Azolla compost	0.70[a]
10 tons/ha Azolla compost	0.71[a]
12 tons/ha Azolla compost	0.75[a]
Initial	0.32

Means with the same letter/s are not significantly different at 5% level by DMRT

Soil pH

Table 3 shows the effect of different rates of azolla compost as an organic fertilizer on the pH of the soil. Statistical analysis shows that different rates of azolla compost significantly increased the pH of the soil from the initial pH of 5.12. As the rate of azolla compost was increased, soil pH also increased. Plots applied with 12 tons/ha azolla compost registered the highest soil pH with a mean of 5.95 compared to the control with a mean of 5.62. The results agree with Khan (1983) and Lumpkin and Plucknett (1986) which states that azolla improves the physico-chemical and biological properties of the soil.

Table 3. Soil pH as affected by different rates of azolla compost

TREATMENT	SOIL pH
Control	5.62[d]
2 tons/ha Azolla compost	5.79[c]
4 tons/ha Azolla compost	5.82[bc]
6 tons/ha Azolla compost	5.78[c]
8 tons/ha Azolla compost	5.88[ab]
10 tons/ha Azolla compost	5.93[a]
12 tons/ha Azolla compost	5.95[a]
Initial	5.12

Means with the same letter/s are not significantly different at 5% level by DMRT

Organic Matter Content of the Soil

Organic matter content of the soil was significantly affected by the application of different rates of azolla compost (Table 4). The highest soil organic matter was obtained from the plots applied with 12 tons/ha azolla compost with a mean of 3.76% followed by 10 tons/ha azolla compost. However, the plots applied with 2 tons/ha, 4 tons/ha, 6 tons/ha azolla compost and control compared to the initial 3.34%, the organic matter content of the soil decreased due to cultivation and that OM was used by the plants. With regards to plots treated with 8 tons/ha to 12 tons/ha azolla compost, some OM remained and some were not absorbed by the plants. This result agrees with Dalzell *et al.*,2007, Khan 1983 and Western Sare 2010 who stated that compost improves soil fertility by soil management so that crop yields can be increased and then maintained at its higher level.

Table 4. Organic matter content of the soil as affected by different rates of azolla compost

TREATMENT	OM CONTENT OF THE SOIL (%)
Control	2.94[d]
2 tons/ha Azolla compost	3.09[d]
4 tons/ha Azolla compost	3.16[cd]
6 tons/ha Azolla compost	3.20[cd]
8 tons/ha Azolla compost	3.36[bc]
10 tons/ha Azolla compost	3.56[ab]
12 tons/ha Azolla compost	3.76[a]
Initial	3.34

Means with the same letter/s are not significantly different at 5% level by DMRT

Total Nitrogen Content of the Soil

Table 5 shows a highly significant effect of azolla rates on the total nitrogen content of the soil. The highest total nitrogen content of the soil was obtained by the application of 12 tons/ha with a mean of 0.188% compared to the initial with a mean of 0.167%. However, the plots applied with 2 tons/ha, 4 tons/ha and 6 tons/ha azolla compost and control, the nitrogen content decreased due to the cultivation that the nutrients from the azolla compost applied was released and absorbed by the romaine lettuce and the other rates were improved due to the higher rates of azolla compost applied. The statistical analysis shows that the azolla compost improves the nitrogen content of the soil. This result agrees with Masillem (1995) who stated that the azolla plant has the capacity to fix higher nitrogen by algae cells than that of bacteroids in legume root nodules.

Table 5. Total Nitrogen (N) content of the soil as affected by different rates of azolla compost

TREATMENT	TOTAL N (%)
Control	0.147[d]
2 tons/ha Azolla compost	0.155[d]
4 tons/ha Azolla compost	0.158[cd]
6 tons/ha Azolla compost	0.160[cd]
8 tons/ha Azolla compost	0.169[bc]
10 tons/ha Azolla compost	0.178[ab]
12 tons/ha Azolla compost	0.188[a]
Initial	0.167

Means with the same letter/s are not significantly different at 5% level by DMRT

Cation Exchange Capacity of the Soil

Table 6 shows the cation exchange capacity of the soil as affected by different rates of azolla compost applied. As the rates of azolla compost increase a corresponding increase in CEC is attained. Application of 12 tons/ha azolla compost registered the highest cation exchange capacity of the soil with a mean of 34.67 m.e/100g soil. The lowest mean on the other hand, was obtained from the untreated plants with a mean of

10.30 m.e/100g. Further, the CEC of the soil was improved from the initial of 10.06 m.e/100g soil as compared to the control. It seems that the presence of a crop has an affection on CEC. The cultivation of soil makes the microorganisms become active and improve the soil properties. And that application of the azolla compost as an organic fertilizer improves the CEC (Lumpkin and Plucknett, 1986).

Table 6. Cation Exchange Capacity (CEC) of the soil as affected by different rates of azolla compost

TREATMENT	CEC (m.e/100g)
Control	10.30[c]
2 tons/ha Azolla compost	10.80[c]
4 tons/ha Azolla compost	11.60[bc]
6 tons/ha Azolla compost	14.05[bc]
8 tons/ha Azolla compost	20.25[bc]
10 tons/ha Azolla compost	23.70[ab]
12 tons/ha Azolla compost	34.67[a]
Initial	10.06

Means with the same letter/s are not significantly different at 5% level by DMRT

Marketable Yield

The application of different rates of azolla compost greatly enhanced the yield of romaine lettuce plant (Table 7). The application of 12 tons/ha registered the highest mean of 7.44 kg/5m^2 followed by the application of 10 tons/ha with a mean of 7.10 kg/5m^2. The control yielded the lowest with a mean of 2.54 kg/5m^2 due to absence of azolla compost. As the rate of azolla compost increased the nitrogen content of the soil also increased that affected the yield.

Non- Marketable Yield

The non-marketable yield of Romaine lettuce as affected by the different rates of azolla compost is shown in Table 8. Lowest non-marketable yield was obtained from those treated with 4 tons/ha azolla compost with a mean of 0.60 kg/5m^2 followed by 2 tons/ha azolla compost with a mean of 0.61 kg/5m^2. The application of 12 tons/ha azolla compost registered the highest non-marketable yield due to pests and disease infestation.

Table 7. Marketable yield as affected by different rates of azolla compost

TREATMENT	MARKETABLE YIELD (kg/5m^2)
Control	2.54^{f}
2 tons/ha Azolla compost	4.70^{e}
4 tons/ha Azolla compost	5.28^{de}
6 tons/ha Azolla compost	5.86^{cd}
8 tons/ha Azolla compost	6.21^{bc}
10 tons/ha Azolla compost	7.10^{ab}
12 tons/ha Azolla compost	7.44^{a}

Means with the same letter/s are not significantly different at 5% level by DMRT

Table 8. Non-marketable yield as affected by different rates of azolla compost

TREATMENT	NON-MARKETABLE YIELD (kg/5m^2)
Control	0.72^{cd}
2 tons/ha Azolla compost	0.61^{d}
4 tons/ha Azolla compost	0.60^{d}

6 tons/ha Azolla compost	0.70[cd]
8 tons/ha Azolla compost	0.79[bc]
10 tons/ha Azolla compost	0.93[b]
12 tons/ha Azolla compost	1.13[a]

Means with the same letter/s are not significantly different at 5% level by DMRT

Total Yield

The total yield of Romaine lettuce as affected by the different rates of azolla compost as an organic fertilizer is shown in Table 9 and Figure 1. The highest harvested yield was obtained from plots applied with 12 tons/ha azolla compost with a mean of 8.56 $kg/5m^2$. All the means obtained from the plots applied with lower rates of azolla compost significantly differed from the control. The result shows that as the rate of azolla compost was increased, the total yield also increased. The result agrees with Cosico (2005) who stated that as the availability of nutrients increases the plant growth or yield also increase. Likewise, Chen and Wu (2005) stated that using compost is an effective way to increase healthy plant production.

Table 9. Total yield as affected by different rates of azolla compost

TREATMENT	TOTAL YIELD ($kg/5m^2$)
Control	3.25[e]
2 tons/ha Azolla compost	5.13[d]
4 tons/ha Azolla compost	5.88[cd]

6 tons/ha Azolla compost	6.56^{bc}
8 tons/ha Azolla compost	7.00^{b}
10 tons/ha Azolla compost	7.94^{a}
12 tons/ha Azolla compost	8.56^{a}

Means with the same letter/s are not significantly different at 5% level by DMRT

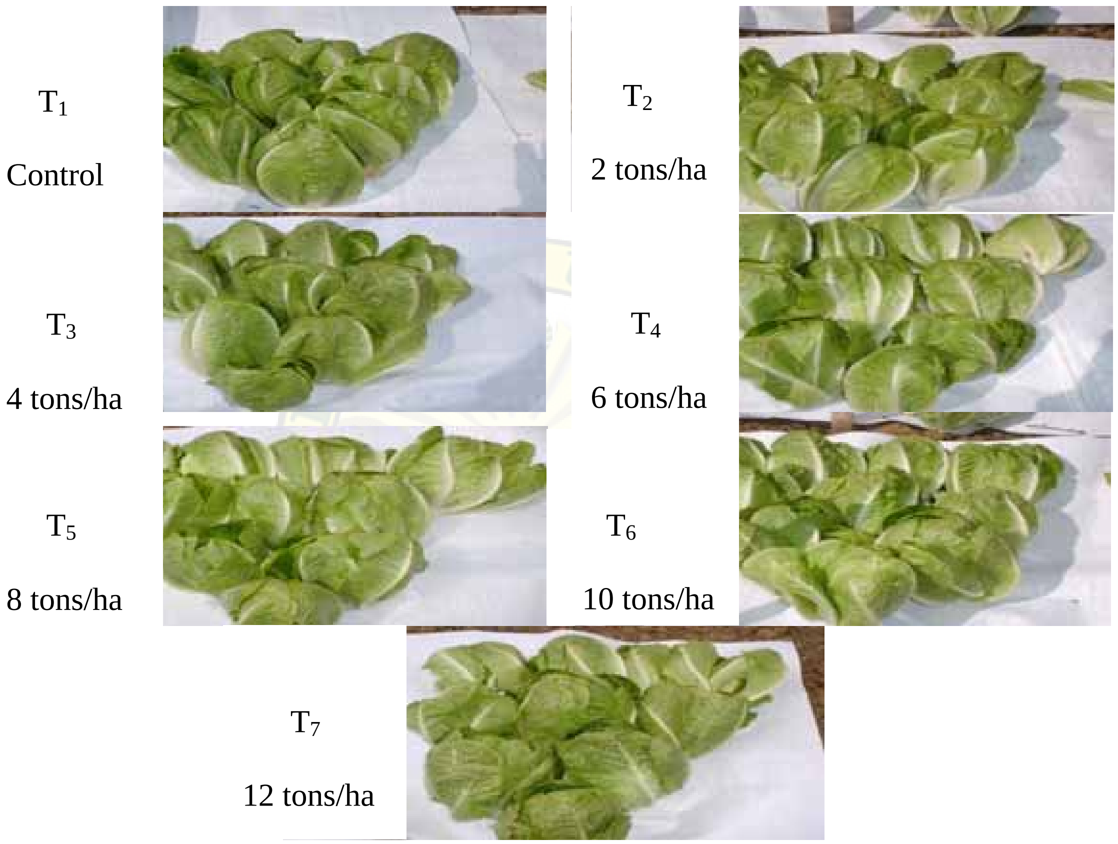

Figure 1. Total yield as affected by different rates of azolla compost ($kg/5m^2$)

<u>Pest Infestation 30 DAT and 37 DAT</u>

No significant effect of the different rates of azolla compost was observed on pest infestation 30 DAT and 37 DAT as presented in Table 10. At 30 DAT, 10 tons/ha azolla compost application showed the highest pest infestation with a mean of 1.70 followed by 8 tons/ha with a mean of 1.60. The pests observed were the cutworm, aphids, semi-lopper and slugs that affected the yield which resulted to increase in non-marketable yield.

However, at 37 DAT, 2 tons/ha azolla compost application had the highest infestation with a mean of 1.27 followed by the 12 tons/ha, 10 tons/ha and control with a mean of 1.23. The pest observed were the aphids and cutworm that affects the marketable and non-marketable yield. 30 DAT has the higher rate of pest infestation than the 37 DAT because in 37 DAT the romaine was already matured.

Table 10. Pest infestation 30 DAT and 37 DAT

TREATMENT	30 DAT	37 DAT
Control	1.57[a]	1.23[a]
2 tons/ha Azolla compost	1.57[a]	1.27[a]
4 tons/ha Azolla compost	1.53[a]	1.17[a]
6 tons/ha Azolla compost	1.40[a]	1.20[a]
8 tons/ha Azolla compost	1.60[a]	1.13[a]
10 tons/ha Azolla compost	1.70[a]	1.23[a]
12 tons/ha Azolla compost	1.50[a]	1.23[a]

Means with the same letter/s are not significantly different at 5% level by DMRT

Pest infestation rating: 1-no infection; 2- 1 to 25% infection; 3- 26 to 50% infection; 4-51 to 75% infection; 5- 76 to 100% infection

Leaf Spot Infection 30 DAT and 37 DAT

Table 11 shows the leaf spot infestation at 30 DAT and 37 DAT. No significant effect of the different rates of azolla compost was observed. At 30 DAT 12 tons/ha and 2 tons/ha azolla compost revealed the highest leaf spot infestation with a mean of 1.23 followed by the 4 tons/ha with a mean of 1.20. However, at 37 DAT the 10 tons/ha azolla compost obtained the highest leaf spot infestation with a mean of 1.53 followed by the 4 tons/ha and 12 tons/ha. The 37 DAT has the higher rate of leaf spot infestation because the disease affects wider area of romaine lettuce than the 30 DAT.

Table 11. Leaf spot infection 30 DAT and 37 DAT

TREATMENT	30 DAT	37 DAT
Control	1.17[a]	1.40[a]
2 tons/ha Azolla compost	1.23[a]	1.33[a]
4 tons/ha Azolla compost	1.20[a]	1.47[a]
6 tons/ha Azolla compost	1.10[a]	1.43[a]
8 tons/ha Azolla compost	1.13[a]	1.40[a]
10 tons/ha Azolla compost	1.17[a]	1.53[a]
12 tons/ha Azolla compost	1.23[a]	1.47[a]

Means with the same letter/s are not significantly different at 5% level by DMRT

Leaf spot rating: 1-no infection; 2- 1 to 25% infection; 3- 26 to 50% infection; 4- 51 to 75% infection; 5- 76 to 100% infection

Return on Cash Expenses

Higher return on cash expenses was noted from application of 12 tons/ha azolla compost with a value of 151.28%, due to higher marketable yield (Table 12). The control has the lowest yield that resulted to lowest return on cash expenses. Increasing rates of azolla compost as an organic fertilizer also gave corresponding increase in ROCE and this is attributed to the subsequent increase in the total marketable yield of romaine lettuce.

Table 12. Return on cash expenses (%)

TREATMENT	TOTAL YIELD (kg/15m^2)	GROSS INCOME (60/kg)	PRODUCTION COST	NET INCOME	ROCE (%)
Control	9.76	586.60	531.43	55.17	10.38
2 tons/ha Azolla compost	15.94	956.40	553.43	402.97	72.81
4 tons/ha Azolla compost	17.65	1059	565.43	493.57	87.29
6 tons/ha Azolla compost	19.69	1181.40	577.43	603.97	104.60
8 tons/ha Azolla compost	21.00	1260	589.43	670.57	113.77
10 tons/ha Azolla compost	23.82	1429.20	601.43	827.77	137.63
12 tons/ha Azolla compost	25.69	1541.40	613.43	927.97	151.28

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The experiment was conducted at the Organic Demo Farm Experimental area, College of Agriculture, Benguet State University, La Trinidad Benguet from October 2010 to April 2011 to determine the: 1.) effect of azolla compost on some soil properties; 2.) effect of the azolla compost on the growth and yield of Romaine lettuce; and, 3.) best rate of azolla compost for romaine lettuce production.

Results showed that application of different rates of azolla compost improved the bulk density and water holding capacity of the soil. Statistically, however there were no significantly differences among the treatments.

Similarly, application of different rates of azolla compost significantly increased the soil pH, organic matter content of the soil, Cation Exchange Capacity (CEC) and total nitrogen content of the soil.

Results showed that the different rates of azolla compost significantly increased the yield. Azolla compost applied at a rate of 12 tons/ha produced the highest marketable and total yield of Romaine lettuce.

Application of 12 tons/ha azolla compost had the highest return on cash expense.

Conclusions

The following conclusions were drawn from the results and findings:

1. Bulk density and water holding capacity of the soil was improved by the application of 12 tons/ha azolla compost.

2. Application of azolla compost at a rate of 12 tons/ha effected the highest

increase in soil pH, organic matter content, Cation Exchange Capacity and total nitrogen content of the soil.

3. Higher marketable yield of romaine lettuce was obtained from application of 12 tons/ha azolla compost.

Recommendations

It is recommended that application of azolla compost at a rate of 12 tons/ha can be practiced to improve the soil properties and gain higher yield of romaine lettuce. A follow-up study using increasing rates from the highest rate used is recommended to verify the results and findings.

LITERATURE CITED

BENTREZ, L. J. 1997. Effects of different rates of azolla on the decomposition of some organic materials. BS Thesis. Benguet State University. La Trinidad, Benguet. Pp. 4-7.

BRADY, N. C. and R. R. WEIL. 2008. The Nature and Properties of Soils. 11th ed. Pearson Education, Inc. Upper Saddle River, New Jersey 07458. P. 481.

CHEN, J. and WU, J. 2005. Compost Production. Food and fertilizer technology center. Taipei 106, Taiwan ROC. P. 2.

CHIMICAG, M. G. S. 1995. Azolla compost as a growth medium for celery. BS Thesis. Benguet State University, La Trinidad, Benguet. P. 33.

COSICO, W. C. 2005. Primer on Soil Science. University of the Philippines Los Baños College, Laguna. P. 101.

DALZELL, H.W., A. J. BIDDLESTONE, K. R. GRAY and K. THURAIRAJAN. 2007. Soil Management: Compost Production and Use in Tropical and Subtropical Environments. Food and Agriculture Organization of the United Nations. Daya Publishing House. Pp. 95-100.

KHAN, M.M. 1983. A Primer on Azolla Production and Utilization in Agriculture, 2nd ed. University of the Philippines at Los Baños (UPLB), PCARRD and SEARCA. Pp. 32, 34, 96-98, 116, 103.

KHAN, M. M. 1988. Azolla Agronomy. College of Laguna, Philippines. P. 105.

LUMPKIN, T.A. and PLUCKNETT, D.L. 1986. Azolla as a Green Manure: Use and Management in Crop Production, Series No. 5. United States of America. Westview Press, Inc. Pp. 112-113.

MASILLEM, J.P. 1995. The efficiency of azolla as organic fertilizer on lettuce grown in acidic Soil. BS Thesis. Benguet State University. La Trinidad, Benguet. Pp. 4-6.

PHILIPPINE COUNCIL FOR AGRICULTURE, FORESTRY AND NATURAL RESOURCES RESEARCH AND DEVELOPMENT. 2006. The Philippines Recommends for Organic Fertilizer Production and Utilization, series 92. Los Baños, Laguna, Philippines. P. 36.

PILE, R. E. 1992. Easy Composting. San Ramon, CA: Monsanto Company. Pp. 22, 28, 63-64.

TITUS, A. and G. N. PEREIRA. 2010. Azolla as a Biofertilizer in Coffee Plantations.

Retrieved August, 2010. from http://www.ineedcoffee.com/06/azolla/

THOMPSON, L. M. 1973. Soils and Soil fertility, 3rd ed. New York. Tata McGraw – Hill Publishing Company Ltd. Pp. 238-239.

WESTERN SARE. 2010. Sustainable and organic agriculture program. University of Hawaii - College of Tropical Agriculture and Human Resources. Retrieved August, 2010. from http://www.ctahr.hawaii.edu/sustainag/cc-gm/azolla.html.

WIKIPEDIA. 2006. Azolla. Retrieved October, 2010. from http://en.wikipedia.org/wiki/Azolla

WIKIPEDIA. 2010. Retrieved October 2010. from http://en.wikipedia.org/wiki/Romaine Lettuce.

APPENDICES

Appendix Table 1. Bulk density of the soil (g/cm^3)

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
T_1	1.28	1.11	1.01	3.40	1.13
T_2	1.18	0.96	1.11	3.25	1.08
T_3	1.14	1.01	1.02	3.17	1.06
T_4	1.01	1.14	1.04	3.19	1.06
T_5	1.14	1.08	0.94	3.16	1.05
T_6	1.05	1.05	0.98	3.08	1.03
T_7	0.98	1.03	0.99	3.00	1.00
TOTAL	7.78	7.38	7.09	22.25	
MEAN	1.11	1.05	1.01		1.06

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	TABULATED F 0.01
Block	2	0.0343	0.0171			
Treatment	6	0.0321	0.0053	0.87^{ns}	3.00	4.82
Error	12	0.0737	0.0061			
TOTAL	20	0.1401				

^{ns} = Not significant CV = 7.40%

Appendix Table 2. Water holding capacity of the soil (ml/g)

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
T_1	0.65	0.64	0.60	1.89	0.63
T_2	0.62	0.59	0.75	1.96	0.65
T_3	0.67	0.61	0.78	2.05	0.68
T_4	0.74	0.65	0.70	2.09	0.70
T_5	0.78	0.69	0.64	2.11	0.70
T_6	0.66	0.72	0.74	2.12	0.71
T_7	0.64	0.78	0.83	2.25	0.75
TOTAL	4.76	4.68	5.04	14.47	
MEAN	0.68	0.67	0.72		0.69

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.02	0.01			
Treatment	6	0.03	0.005	0.61^{ns}	3.00	4.82
Error	12	9.78	0.82			
TOTAL	20	9.83				

^{ns} = Not significant CV = 1.3%

Appendix Table 3. Soil pH

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN

T_1	5.48	5.58	5.79	16.85	5.62
T_2	5.75	5.71	5.90	17.36	5.79
T_3	5.80	5.76	5.91	17.47	5.82
T_4	5.67	5.79	5.89	17.35	5.78
T_5	5.84	5.88	5.92	17.64	5.88
T_6	5.87	5.91	6.01	17.79	5.93
T_7	5.89	5.94	6.02	17.86	5.95
TOTAL	40.30	40.57	41.44	122.31	
MEAN	5.76	5.80	5.92		5.82

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	TABULATED F 0.01
Block	2	0.1014	0.0507			
Treatment	6	0.22883	0.0381	16.79**	3.00	4.82
Error	12	0.0273	0.0023			
TOTAL	20	0.3575				

** = Highly significant CV = 0.82%

Appendix Table 4. Organic matter content of the soil (%)

	REPLICATION

TREATMENTS	I	II	III	TOTAL	MEAN
T_1	2.55	2.81	3.46	8.82	2.94
T_2	2.81	2.91	3.56	9.28	3.09
T_3	2.91	3.10	3.46	9.47	3.16
T_4	2.97	3.17	3.46	9.60	3.20
T_5	3.17	3.23	3.69	10.09	3.36
T_6	3.52	3.27	3.88	10.67	3.56
T_7	3.59	3.40	4.30	11.29	3.76
TOTAL	21.52	21.89	25.81	69.22	
MEAN	3.07	3.13	3.69		3.30

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	TABULATED F 0.01
Block	2	1.6146	0.8073			
Treatment	6	1.4620	0.2437	12.50**	3.002	
Error	12	0.2339	0.0195			
TOTAL	20	3.3105				

** = Highly significant CV = 4.24%

Appendix Table 5. Total nitrogen content of the soil (%)

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	0.128	0.141	0.173	0.442	0.147
T_2	0.140	0.146	0.178	0.464	0.155
T_3	0.146	0.156	0.173	0.475	0.158
T_4	0.149	0.159	0.173	0.481	0.160
T_5	0.159	0.162	0.185	0.506	0.169
T_6	0.176	0.164	0.194	0.534	0.178
T_7	0.180	0.170	0.215	0.565	0.188
TOTAL	1.078	1.098	1.291	3.467	
MEAN	0.154	0.157	0.184		0.165

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.0040	0.0020			
Treatment	6	0.0036	0.0006	12.23**	3.00	4.82
Error	12	0.0006	0.00005			
TOTAL	20	0.0082				

** = Highly significant CV = 4.26%

Appendix Table 6. Cation exchange capacity of the soil (m.e./100g)

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	10.5	10.3	10.1	30.90	10.30
T_2	11.1	10.8	10.5	32.40	10.80
T_3	11.8	11.6	11.4	34.80	11.60
T_4	17.6	14.05	10.5	42.15	14.05
T_5	28.5	20.25	12.0	60.75	20.25
T_6	36.5	23.7	10.9	71.1	23.70
T_7	50.8	34.7	18.5	104	34.67
TOTAL	166.80	125.4	83.90	376.10	
MEAN	23.83	17.91	11.99		17.91

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	490.8867	245.4433			
Treatment	6	1448.8964	241.4827	5.57**	3.00	4.82
Error	12	520.1100	43.3425			
TOTAL	20	2459.8931				

** = Highly significant CV = 36.76%

Appendix Table 7. Marketable yield (kg/5m^2)

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	2.44	1.91	3.26	7.61	2.54
T_2	3.87	5.13	5.11	14.11	4.70
T_3	4.39	5.83	5.63	15.85	5.28
T_4	5.34	6.14	6.11	17.59	5.86
T_5	5.44	6.87	6.31	18.62	6.21
T_6	5.73	7.87	7.44	21.04	7.01
T_7	6.37	7.81	8.13	22.31	7.44
TOTAL	33.58	41.56	48.39	117.13	
MEAN	4.80	5.94	6.91		5.58

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	6.4092	3.2046			
Treatment	6	48.2791	8.0465	37.93**	3.00	4.82
Error	12	2.5455	0.2121			
TOTAL	20	57.2338				

** = Highly significant CV = 8.26%

Appendix Table 8. Non-marketable yield (kg/5m^2)

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	0.75	0.72	0.68	2.15	0.72
T_2	0.63	0.50	0.70	1.83	0.61
T_3	0.50	0.55	0.75	1.80	0.60
T_4	0.66	0.61	0.83	2.10	0.70
T_5	0.75	0.63	1.00	2.38	0.79
T_6	0.83	0.76	1.19	2.78	0.93
T_7	1.13	1.00	1.25	3.38	1.13
TOTAL	5.25	4.77	6.40	16.42	
MEAN	0.75	0.68	0.91		0.78

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.2005	0.1002			
Treatment	6	0.6407	0.1068	3.75**	3.00	4.82
Error	12	0.0932	0.0078			
TOTAL	20	0.9344				

** = Highly significant CV = 11.27%

Appendix Table 9. Total yield (kg/5m^2)

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	3.19	2.63	3.94	9.76	3.25
T_2	4.50	5.63	5.81	15.94	5.31
T_3	4.89	6.38	6.38	17.65	5.88
T_4	6.00	6.75	6.94	19.69	6.56
T_5	6.19	7.50	7.31	21.00	7.00
T_6	6.56	8.63	8.63	23.82	7.94
T_7	7.50	8.81	9.38	25.69	8.56
TOTAL	38.83	46.33	48.39	133.55	
MEAN	5.55	6.62	6.91		6.36

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	TABULATED F 0.01
Block	2	7.2327	3.6164			
Treatment	6	56.3284	9.3881	48.33**	3.00	4.82
Error	12	2.3312	0.1943			
TOTAL	20	65.8923				

** = Highly significant CV = 6.93%

Appendix Table 10. Pest infestation 30 DAT

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	1.2	1.2	1.3	3.7	1.23
T_2	1.3	1.3	1.2	3.8	1.27
T_3	1.2	1.1	1.2	3.5	1.17
T_4	1.1	1.2	1.3	3.6	1.20
T_5	1.2	1.1	1.1	3.4	1.13
T_6	1.2	1.2	1.3	3.7	1.23
T_7	1.2	1.3	1.2	3.7	1.23
TOTAL	8.4	8.4	8.6	25.4	
MEAN	1.2	1.2	1.2		1.21

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.004	0.002			
Treatment	6	0.038	0.006	1.36^{ns}	3.00	4.82
Error	12	0.056	0.005			
TOTAL	20	0.098				

^{ns}=Not significant CV = 5.66%

Appendix Table 11. Pest infestation 37 DAT

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	1.4	1.7	1.6	4.7	1 .57
T_2	1.5	1.4	1.8	4.7	1.57
T_3	1.5	1.5	1.6	4.6	1.53
T_4	1.5	1.3	1.4	4.2	1.40
T_5	1.5	1.6	1.7	4.8	1.60
T_6	1.6	1.6	1.9	5.1	1.70
T_7	1.4	1.4	1.7	4.5	1.50
TOTAL	10.4	10.5	11.7	32.6	
MEAN	1.49	1.50	1.67		1.55

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.150	0.075			
Treatment	6	0.152	0.025	2.03^{ns}	3.00	4.82
Error	12	0.151	0.013			
TOTAL	20	0.453				

^{ns} = Not significant CV = 7.21%

Appendix Table 12. Leaf spot infection 30 DAT

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	1.2	1.0	1.3	3.5	1 .17
T_2	1.2	1.4	1.1	3.7	1.23
T_3	1.2	1.2	1.2	3.6	1.20
T_4	1.1	1.0	1.2	3.3	1.10
T_5	1.1	1.2	1.1	3.4	1.13
T_6	1.2	1.1	1.2	3.5	1.17
T_7	1.3	1.3	1.1	3.7	1.23
TOTAL	8.3	8.2	8.2	24.7	
MEAN	1.19	1.17	1.17		1.17

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.003	0.001			
Treatment	6	0.05	0.025	1.92^{ns}	3.00	4.82
Error	12	0.15	0.013			
TOTAL	20	0.20				

^{ns} = Not significant CV= 0.10%

Appendix Table 13. Leaf spot 37 DAT

TREATMENTS	REPLICATION I	II	III	TOTAL	MEAN
T_1	1.6	1.4	1.2	4.2	1 .40
T_2	1.5	1.3	1.2	4.0	1.33
T_3	1.5	1.3	1.6	4.4	1.47
T_4	1.4	1.5	1.4	4.3	1.43
T_5	1.3	1.4	1.5	4.2	1.40
T_6	1.7	1.5	1.4	4.6	1.53
T_7	1.5	1.3	1.6	4.4	1.47
TOTAL	10.5	9.7	9.9	30.1	
MEAN	1.5	1.4	1.4		1.43

ANALYSIS OF VARIANCE

SOURCE OF VARIANCE	DEGREES OF FREEDOM	SUM OF SQUARE	MEAN OF SQUARES	COMPUTED F	TABULATED F 0.05	0.01
Block	2	0.05	0.01			
Treatment	6	0.08	0.04	2.0^{ns}	3.00	4.82
Error	12	0.24	0.02			
TOTAL	20	0.37				

^{ns} = Not significant CV = 0.10%

PARTICULAR	TREATMENT (PhP) T_1	T_2	T_3	T_4	T_5	T_6	T_7
Production Cost:							

Seeds	46	46	46	46	46	46	46
Fertilizer	0	12	24	36	48	60	72
Gasoline	29	29	29	29	29	29	29
Garden tools:							
Grub hoe	6.43	6.43	6.43	6.43	6.43	6.43	6.43
Hose	20	20	20	20	20	20	20
Watering can	12	12	12	12	12	12	12
Tractor	29	29	29	29	29	29	29
Labor:							
Seedling Preparation	10	10	10	10	10	10	10
Land preparation	57	57	57	57	57	57	57
Fertilizer Application	0	10	10	10	10	10	10
Sowing	10	10	10	10	10	10	10
Watering	268	268	268	268	268	268	268
Weeding	29	29	29	29	29	29	29
Harvesting	15	15	15	15	15	15	15
TOTAL	531.43	553.43	565.43	577.43	589.43	601.43	613.43
Gross Income (60/kg)	586.60	956.40	1059	1181.40	1260	1429.20	1541.40
Net Income	55.17	402.97	493.57	603.97	670.57	827.77	927.97
ROCE (%)	10.38	72.81	87.29	104.60	113.77	137.63	151.28
Rank	7	6	5	4	3	2	1