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SOIL PROPERTIES OF AGRICULTURAL FARMS IN TWO AGRO-ECOLOGICAL ZONES OF THREE MUNICIPALITIES OF BENGUET

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ABSTRACT

The study was conducted in two agro-ecological zones of La Trinidad, Buguias and Atok, Benguet. The objectives of the study were to determine the physical and chemical properties of soils of agricultural farms; to determine the pesticide residues in soils and plants; and to determine toxic heavy metals in soils of agricultural farms. The two agro-ecological zones comprised of mid-mountain zone with elevation ranging from 1,100 to 1,500 meters above sea level represented by La Trinidad and Buguias, Benguet and high mountain zone with 1,600 to 2,000 meters above sea level elevation represented by Atok, Benguet.

For mid-mountain zone represented by La Trinidad, Benguet for wet season sampling and Buguias, Benguet for dry season sampling, most of the soil samples collected showed favorable values of bulk density, porosity, pH, organic matter, available phosphorus and exchangeable potassium for crop production. On the other hand, pesticide residue analysis on soil samples showed that only Cypermethrin and Chlorpyrifos have values higher than the maximum allowable concentrations. Toxic heavy metals like Mercury and Lead have values lower than maximum residual limit. Likewise, only Chlorpyrifos was detected in plants but its value is below the maximum allowable concentration.

For the high-mountain zone represented by Atok for wet and dry season sampling, the results of the analysis showed that values of bulk density, porosity, pH, organic matter, available phosphorus and exchangeable potassium are also found favorable for crop production. For pesticide residue analysis in soil, the samples were found to have residues of Dieldrin, Endosulfansulfate, Cypermethrin, Chlorotalonil, Cypermethrin and Deltamethrin. However, only Chlorothalonil and Cypermethrin were found to have values higher than the maximum allowable concentration. Mercury and Lead were found to have values below the maximum residual limit. No pesticide residues were detected in crops.

Keywords: *organic fertilizers, soil properties, physical properties, agricultural farms*

INTRODUCTION

Benguet is known for fresh agricultural produce such as semi-temperate vegetables, strawberry and potato due to the favorable environment for the growth and development of these crops. However, the high relative humidity in the area and optimum temperature also favor the development of several plant pathogens. Soil-borne plant pathogens are one of the major causes of economic loss in crop production. The environment plays important role in the population buildup of these plant pathogenic microorganisms. These environmental factors include temperature, humidity, physical and chemical of soils, *etc*. Previous studies revealed there is a direct influence of these different factors

on the development of the diseases (Trudgill and Phillips, 1997). When favorable conditions are present for the plant pathogens, disease occurrence would also be high which would lead to the increase in plant damage leading to significant reduction in yield in most crops. Slight change in these edaphic factors might also lead to the change in population density of the soil-borne plant pathogens.

Interference in the population build-up of these organisms might also have an effect in the damage reduction. Due to the nature of the terrain in the Cordillera, with mostly high sloping areas, studies on the population dynamics of soil-borne pathogens are lacking. Thus, information on the soils' physical and chemical properties that may affect changes in the pathogen population overtime in two agro-ecological zones in the Cordillera is urgently needed in the development of sustainable disease management strategies. This is necessary in order to improve crop productivity and therefore, farmers will be able to generate higher income.

The study was conducted to determine the physical and chemical properties of soil and to determine pesticide residues and toxic heavy metals in soil and plants in the two agro-ecological zones planted with selected crops.

MATERIALS AND METHODS

Soil samples were collected from agricultural farms in two agro-ecological zones in La Trinidad, Atok and Buguias, Benguet. The mid-mountain zone, with an elevation ranging from 1,100 to 1500 meters above sea level,is represented by La Trinidad, and Buguias, Benguet. Likewise, the high mountain zone, with an elevation of 1,600 to 2000 meters above sea level, is represented by Atok, Benguet.

The sampling sites for the mid mountain zone in La Trinidad include Barangay Balili, Bahong, Lubas, Swamp and Talingguroy and in Buguias, Barangay Loo, Bangao and Baculongan Sur were selected as sampling sites. For the high mountain zone in Atok, sampling sites were in Barangay Paoay and Cattubo.

The soil samples that were collected from the different various sampling sites for wet and dry season sampling were air dried at the Drying Room of the Department of Soil Science, Benguet State University. Once dried, the soil samples were pulverized using a wooden mallet. These were sieved, afterwhich these were placed in sealed containers. Soil clods were likewise set aside for the determination of bulk density of soils. Soil and plant samples for pesticide residues and toxic heavy metals, on the other hand, were collected and submitted at the Bureau of Plant Industry and Saint Louis University respectively for analysis.

RESULTS AND DISCUSSION

Soil Properties of Agricultural Farms in Mid-Mountain Zone in La Trinidad, Benguet (Wet Season Sampling)

Bulk density of soils. Bulk density depends on the structure, texture, and organic matter status of the soil (Biswas and Mukherjee, 1994). The bulk density of agricultural soils collected from La Trinidad, Benguet for the wet season sampling ranges from 1.02g/cm$_3$ to 1.58 g/cm$_3$ (Table 1). Most of the soil samples collected have bulk densities below 1.33 g/cm$_3$ which means that the soils are not compacted and have 50% pore spaces. Three sampling sites, on the other hand, have compacted soils. A soil with a bulk density above 1.33g/cm$_3$ is considered compacted. The application of organic matter in this soil is required to promote better aggregation and aeration in the soil in order to provide favorable environment for plant roots. Lower bulk densities are preferred for crop production.

Porosity of soils. Porosity or pore space refers to the volume of soil voids that can be filled by water and/or air. The porosity of the soils in La Trinidad, Benguet ranges from 31.67% to as high as 57.67% (Table 1). For crop production, 50% porosity is preferred. Colis (1997) reported that the normal range of mineral soils is 40% to 60% or even more if the organic matter content is high. This value indicates good air circulation and water percolation that favors good root penetration and nutrient absorption. Based from the table, out of 15

Table 1. Physical properties of agricultural soils in La Trinidad, Benguet-Wet Season Sampling

Sampling Area	Bulk Density (g/cm_3)	Porosity (%)
Balili (Legumes)	1.27	46.67
Balili (Legumes)	1.52	42.33
Balili (Broccoli)	1.02	56.57
Balili (Broccoli)	1.31	45.67
Balili (Broccoli)	1.28	43.33
Bahong (Rose)	1.58	31.67
Bahong (Rose)	1.28	42.67
Bahong (Rose)	1.28	47.67
Lubas (Chrysanthemum)	1.44	52.00
Lubas (Chrysanthemum)	1.14	52.00
Lubas (Chrysanthemum)	1.32	45.00
Lubas (Cabbage)	1.23	42.33
Talingguroy (Strawberry)	1.50	38.00
Swamp (Strawberry)	1.17	50.33
Swamp (Strawberry)	1.16	57.67

sampling sites, only 5 farms have porosity of more than 50%.

Soil pH. The pH of agricultural soils collected in La Trinidad, Benguet for wet season sampling is shown in Table 2. The data shows that pH values are extremely acidic (3.71) to slightly alkaline (7.79). Soils in Bahong, La Trinidad, Benguet where rose are planted registered the lowest pH value of 3.71 which is considered extremely acidic. This pH value can be attributed to the excessive application of inorganic fertilizers such as urea (46-0-0) and ammonium sulfate (21-0-0-24) by farmers. Through an interview, data showed that one of the farmers applied 25kgs of urea, 10kgs ammonium sulfate and 10kgs of flourish (granule fertilizer) to his $320m_2$ rose farm before planting. Twenty days after the first application, same amounts of urea and ammonium sulfate were applied. Another granule fertilizer was also applied when shoot bud appeared. Applying nitrogenous fertilizers to naturally acidic soils at rates in excess of plant requirements accelerate acidification (DENR, Australia, 2009).

The pH values of 5.5 to 7.0 are most suitable for vegetable crops. pH values lower than five requires liming to ensure better chemical condition for plant growth and development. In addition, pathogenic microorganisms and fungi tend to predominate in acidic soils.

Organic matter content of soil. The organic matter content of the different agricultural soils in La Trinidad for wet season sampling ranges from 2.07% to 4.57% (Table 2). According to BSWM (n.d.), these values are considered moderately adequate. Soil samples collected from Barangay Balili, La Trinidad, Benguet planted with Broccoli had the highest organic matter content of 4.57% while the lowest (2.07%) was obtained from the soils collected in Barangay Bahong planted with Rose. The high organic matter content value of the soil can be attributed to the application of organic fertilizers by farmers in the area. These are either in the form of compost organic fertilizers and chicken manure. Schinitzer (1991) stated that typical agricultural soils may contain 1-5% of organic matter on the upper 15 cm. BSWM (n.d.) reported that more than 4.5% OM in soil is considered adequate, between 2.1 to 4.5% is marginal and less than 2.0 and is deficient.

Available phosphorus content of soil. The available phosphorus content of the soil samples collected in La Trinidad, Benguet for wet season

Table 2. Chemical properties of agricultural soils in La Trinidad, Benguet-Wet Season Sampling

Sampling Area	Soil pH	Organic Matter Content (%)	Available phosphorus Content (ppm)	Exchangeable potassium Content (ppm)
Balili (Legumes)	7.79	3.39	80.37	127.00
Balili (Legumes)	4.96	3.66	66.17	72.67
Balili (Broccoli)	5.95	4.57	66.17	119.00
Balili (Broccoli)	5.89	3.84	70.77	152.67
Balili (Broccoli)	6.79	3.50	71.80	118.00
Bahong (Rose)	3.82	2.07	73.71	116.00
Bahong (Rose)	6.67	2.90	68.92	116.00
Bahong (Rose)	3.71	3.59	74.99	134.67
Lubas (Chrysanthemum)	5.77	3.78	70.23	127.00
Lubas (Chrysanthemum)	5.85	2.74	71.30	125.67
Lubas (Chrysanthemum)	5.16	3.49	69.44	127.00
Lubas (Cabbage)	4.23	3.99	75.99	66.00
Talingguroy (Strawberry)	3.98	2.65	19.70	82.00
Swamp (Strawberry)	4.94	3.01	89.24	122.33
Swamp (Strawberry)	5.07	4.12	94.25	162.00

sampling ranges from 19.7 ppm to 94.25 ppm (Table 2). The result indicates that majority of the soils in La Trinidad, Benguet have adequate amounts of phosphorus to meet the requirement of most crops. Except in Talingguroy, Wangal, La Trinidad, Benguet, the amount of phosphorus is 19.7 ppm which is considered marginal or moderately favorable for crops (BSWM, n.d.).

Phosphorus is an essential element second to nitrogen because of the relatively large amounts of phosphorus required by plants (Busman *et al*., 2002). Soils that contain phosphorus ranging from 30-40 ppm are considered sufficient (PCARRD, 1982).

Exchangeable potassium content of soil. Table 2 shows that the potassium contents of agricultural soils in La Trinidad, Benguet for wet season sampling ranges from 66 ppm K to 152.67 ppm K. BSWM (n.d.) reported that more than 150 ppm K in soil is considered adequate, 76 to 150 ppm is moderate, while less than 76 ppm is deficient. Based from the table, majority of the soil samples collected from Balili, La Trinidad, Benguet have sufficient amounts of potassium except for one soil sample. The soil collected from Lubas, La Trinidad, Benguet is deficient of potassium. The parent material of the soils in Lubas, La Trinidad, Benguet is limestone, which consist mainly of calcium carbonates with some impurities containing iron minerals (Laurean, 1999). This could have been the reason why the soil is deficient in potassium. Other than this, the low potassium content of the soil could also possibly due to crop removal.

Exchangeable potassium is an important source to replenish dissolved potassium supply in the soil which are continuously depleted through plant absorption (Thompson and Troeh, 1975). Riddle (2013) stated that exchangeable potassium is essential for vigorous growth, disease resistance, fruit and vegetable flavor and development and general plant function. Plant-available K is typically equivalent to only 0.1% to 0.2% of the total soil K (40 to 800 lbs/acre) (Spectrum Analytic Inc., 2013).

Pesticide Residue of Soil and Strawberry Plant

The pesticide residues of soil and strawberry plant samples from La Trinidad for wet season

sampling are shown in Table 3. The result shows that the soils planted with strawberry have residues of Cyhalothrin and Chlorpyrifos with values of 0.07 ppm and 0.26 ppm respectively. It was noted that Chlorpyrifos exceeded the maximum residual limit of 0.03 ppm set by the United States Environment Protection Agency (USEPA). Application of pesticides such as insecticides, fungicides and herbicides are common practice by farmers in the province.

Cyhalothrin belongs to a pesticide category of pyrethroids while chlorpyrifos is classified as organophosphates. Pyrethroids are the synthetic forms of pyrethrins. They are contact poisons and act on the nervous system of insects but unlike organophosphates, they do not inhibit cholinesterase activity. Pyrethrins are among the least toxic insecticides for mammals, in which they rapidly break down into inactive forms and pass from the body; therefore, they do not accumulate. On the other hand, organophosphate pesticides are generally biodegradable, and thus less likely to build up in soils and water. However, they are extremely toxic to humans, so great care must be used in handling and applying them. (Edwards, 1986).

Toxic Heavy Metal Content of Soil Sample from La Trinidad, Benguet

The toxic heavy metal contents of soil samples collected from La Trinidad for wet season sampling is shown in Table 4. Results revealed that the soils planted with strawberry have mercury and lead with corresponding values of 0.02 ppm and 51.39 ppm respectively which are below the maximum residual limit set by USEPA for mercury and lead.

There are two possible sources of mercury and lead in the soil. These are natural processes and human activity. Natural processes include weathering of rocks and volcanic activity while human activity includes mining, processing of raw materials, minerals and fossil fuels containing mercury and lead or used in products. Once released, mercury and lead enters the air, water and soil and can continue to move between them over long periods of time depending on its chemical form(www.greenfacts.org/en/mercury//1-2/ mercury-4.htm; www.nelar.net/Includes/Lead%20 in20Soil.pdf)

Soil Properties of of Agricultural Farms in Mid-Mountain Zone In Buguias, Benguet (Dry Season Sampling)

Bulk density of soils. Table 5 shows that majority of the agricultural soils in Buguias, Benguet for dry season sampling have bulk density values lower than 1.33g/cm3. The lowest bulk density was obtained in a farm from Baculongan Sur, Buguias, Benguet planted with Broccoli. In crop production, lower bulk densities are preferred because there is a balance of the solid and liquid spaces where water and air moves freely. Root growth is also favored due to spaces provided in between soil aggregate.

Porosity of soils. The porosity of agricultural soils in Buguias, Benguet for dry season sampling ranges from 33.45% to 70.85% (Table 5). The result indicates that majority of the soil samples have 50% and above porosity. Porosity of 50% and above is favorable for plant growth in terms of root growth and development. This value indicates good air circulation and water percolation that favors good root penetration.

Table 3. Pesticide residues of soil and strawberry plant of La Trinidad, Benguet

Sampling Area	Pesticide Analyzed (ppm)		Maximum Residual Limit (ppm)
Swamp (strawberry)-soil	Cyhalothrin	0.07	N/A[1]
	Chlorpyrifos	0.26	0.03
Swamp (strawberry)-plant		LOQ[2]	

[1]— No Available Data

[2]— Limit of Quantification for Organophosphates, Organochlorines and Pyrethroids is 0.01 ppm

Table 4. Toxic heavy metal content of soil sample from Trinidad, Benguet

Sampling Area	Toxic Heavy Metals Analyzed (ppm)		Maximum Residual Limit (ppm)
Swamp (strawberry)-soil	mercury	0.0253[2]	0.60
	lead	51.39[3]	350.00
Swamp (strawberry)-plant		N/A[1]	

[1]— No Available Data
[2]— Calculated from the calibration curve of mercury (r=0.9974)
[3]— Calculated from the calibration curve of lead (r=0.9999)

Table 5.Physical properties of agricultural soils in Buguias, Benguet-Dry Season Sampling

Sampling Area	Bulk density (g/cm3)	Porosity (%)
Loo (Potato)	1.43	36.00
Loo (Potato)	1.12	52.67
Loo (Potato)	1.24	43.33
Loo (Chinese Cabbage)	1.48	37.33
Loo (Chinese Cabbage)	1.12	58.00
Loo (Chinese Cabbage)	1.4	53.85
Loo (Cabbage)	1.19	43.67
Loo (Cabbage)	1.20	48.39
Loo (Cabbage)	1.28	44.76
Loo (Garden pea)	1.35	55.44
Loo (Garden pea)	1.36	56.43
Loo (Garden pea)	1.26	51.85
Loo (Broccoli)	1.26	50.33
Baculongan Sur (Chinese Cabbage)	1.40	38.03
Baculongan Sur (Chinese Cabbage)	1.58	70.85
Baculongan Sur (Chinese Cabbage)	1.41	59.49
Baculongan Sur (Garden pea)	1.30	40.51
Baculongan Sur (Garden pea)	1.5	61.48
Baculongan Sur (Garden pea)	1.58	65.29
Baculongan Sur (Cabbage)	1.15	52.65
Baculongan Sur (Cabbage)	1.09	55.34
Baculongan Sur (Cabbage)	1.47	66.22
Baculongan Sur (Broccoli)	1.04	53.23
Baculongan Sur (Broccoli)	1.10	44.00
Baculongan Sur (Broccoli)	1.55	64.85
Bangao (Carrot)	1.39	33.45
Bangao (Carrot)	1.27	55.70
Bangao (Carrot)	1.30	56.52
Bangao (Potato)	1.28	43.66
Bangao (Potato)	1.20	52.17
Bangao (Potato)	1.25	53.19

Continuation of Table 5...

Bangao (Garden pea)	1.13	54.66
Bangao (Garden pea)	1.45	54.51
Bangao (Garden pea)	1.09	43.95
Bangao (cabbage)	1.48	35.88
Bangao (cabbage)	1.32	55.46
Bangao (cabbage)	1.53	64.83

Soil pH. The pH of agricultural soils in Buguias, Benguet for dry season sampling has values ranging from 4.87 (very strongly acidic) to 6.67 (slightly acidic) (Table 6). Based from the results, majority of the sampling sites are within the pH range suitable for vegetable crops. Brady and Weil (2008) stated that generally the pH values suitable for vegetable crops are within the range of 5.5 to 7.0.

It was noted that soils in Baculongan Sur, Buguias planted with Garden pea had the lowest pH value of 4.87. This is considered very strongly acidic. This result confirms the findings of Panas (1996), Faroden (1998), and Miguel (1996) that the soil pH of most Benguet soils are acidic due to the effects of continues application of NH4-containing fertilizers applied by farmers coupled by heavy rainfall in the province during rainy months.

Organic matter content of soil. The organic matter content of the different agricultural soils in Buguias, Benguet for dry season sampling ranges from 2.53% to 4.67% (Table 6). The result indicates that majority of the samples collected are marginal or moderately favorable thus the need to apply organic fertilizer since these areas are continuously cultivated. The organic matter content of the soil can be improved with the application of organic fertilizer and compost (Schinister, 1991).

According to BSWM (n.d.) soil's containing 4.5% organic matter is considered adequate, 2.1% to 4.5% as marginal and less than 2% is deficient of Organic Matter.

Available phosphorus content of soil. The available phosphorus content obtained from different agricultural soils in Buguias, Benguet for dry season samplings ranges from 66.64 ppm to 124.35 ppm (Table 6). These values are considered adequate based on the soil fertility rating by BSWM (n,d). Further, PCARRD (1982) also reported that soil containing 30 to 40 ppm of phosphorus is considered sufficient for most crops.

Exchangeable potassium content of soil. Table 6 shows the exchangeable potassium content of the different agricultural soils in Buguias, Benguet for dry season sampling. The result shows that all the agricultural soils sampled in Buguias have moderate to adequate amounts of potassium. BSWM (n.d) reported that more than 150 ppm exchangeable potassium in soil is considered adequate, 76 ppm to 150 ppm as moderate, and less than 75 ppm as deficient.

Pesticide Residue of Soils in Cabbage and Potato Plant of Buguias, Benguet

The pesticide residues of the soils, cabbage and potato plants collected from Buguias for the dry season sampling were shown in Table 7. Soils planted with cabbage and potato samples have residues of Chlorpyrifos, an organophosphate, and Cyhalothrin and Cypermethrin, both pyrethroids. Result of the analysis showed that the values exceeded the maximum residual limits set by USEPA. The cabbage plants on the other hand have residues of chlorpyrifos with value of 0.04 ppm, which is near to the maximum residual limit set by USEPA.

Toxic Heavy Metal Content of Soil Sample from Buguias, Benguet

The toxic heavy metal content of soil collected from Buguias, Benguet for dry season sampling is shown in Table 8. Result shows that the soils planted with potato and cabbage are found to have mercury content of 0.024 ppm and 0.021 ppm respectively which are below the maximum residual limit set by USEPA.

Table 6.Chemical properties of agricultural soils in Buguias, Benguet-Dry Season Sampling

Sampling Area	Soil pH	Organic Matter Content (%)	Available phosphorus Content (ppm)	Exchangeable potassium Content (ppm)
Loo (Potato)	5.87	4.58	71.07	199.33
Loo (Potato)	6.67	4.36	74.04	200.00
Loo (Potato)	6.07	4.49	66.64	200.00
Loo (Chinese Cabbage)	5.11	4.67	67.38	86.67
Loo (Chinese Cabbage)	5.06	4.42	80.61	187.00
Loo (Chinese Cabbage)	5.72	4.52	120.52	200
Loo (Cabbage)	6.43	4.44	87.90	200.00
Loo (Cabbage)	6.02	3.99	107.34	120
Loo (Cabbage)	6.2	3.76	107.9	200
Loo (Garden pea)	6.02	3.73	124.35	200
Loo (Garden pea)	6.07	4.33	111.88	132
Loo (Garden pea)	5.59	3.24	117.17	120
Loo (Broccoli)	5.96	4.52	74.77	130.67
Baculongan Sur (Chinese Cabbage)	5.63	3.82	87.77	166.33
Baculongan Sur (Chinese Cabbage)	5.29	3.45	94.88	200
Baculongan Sur (Chinese Cabbage)	5.35	3.79	108.54	200
Baculongan Sur (Garden pea)	5.38	3.31	75.90	149.00
Baculongan Sur (Garden pea)	4.87	3.66	108.56	200
Baculongan Sur (Garden pea)	5.90	3.98	88.52	200
Baculongan Sur (Cabbage)	5.30	3.83	90.15	131.67
Baculongan Sur (Cabbage)	5.33	2.53	96.07	127.33
Baculongan Sur (Cabbage)	5.78	3.14	110.96	200
Baculongan Sur (Broccoli)	5.51	4.19	98.78	146.67
Baculongan Sur (Broccoli)	5.98	4.47	96.26	200
Baculongan Sur (Broccoli)	5.42	3.60	90.85	200
Bangao (Carrot)	5.85	3.17	74.36	180.67
Bangao (Carrot)	5.58	3.20	78.40	175.60
Bangao (Carrot)	5.90	3.21	72.26	168.67
Bangao (Potato)	5.27	2.55	83.21	184.33
Bangao (Potato)	5.30	3.20	80.78	200
Bangao (Potato)	5.26	2.98	82.26	200
Bangao (Garden pea)	5.74	2.99	73.30	156.33
Bangao (Garden pea)	5.12	4.57	73.94	182
Bangao (Garden pea)	5.56	4.30	65.06	196
Bangao (cabbage)	5.46	2.89	81.26	183.67
Bangao (cabbage)	5.33	4.42	76.91	200
Bangao (cabbage)	5.79	4.33	84.36	200

Table 7. Pesticide residue of soils in cabbage and potato plant of Buguias, Benguet

Sampling Area	Pesticide Analyzed (ppm)		Maximum Residual Limit (ppm)
Loo (Cabbage)-soil	Cyhalothrin	0.10	N/A[1]
	Chlorpyrifos	0.09	0.03
Loo (Cabbage)-plant	Chlorpyrifos	0.04	0.05
Loo (Potato)-soil	Chlorpyrifos	0.54	0.03
	Cypermethrin	0.10	0.05
Loo (Potato)-plant			LOQ[2]

[1]— No Available Data
[2]— Limit of Quantification for Organophosphates, Organochlorines and Pyrethroids is 0.01 ppm
[3]— Calculated from the calibration curve of mercury (r=0.9974)
[4]— Calculated from the calibration curve of lead (r=0.9999)
[5] — Below detection limit

Table 8. Pesticide residue of soils in cabbage and potato plant of Buguias, Benguet

Sampling Area	Toxic Heavy Metals Analyzed (ppm)		Maximum Residual Limit (ppm)
Loo (Cabbage)-soil	mercury	0.02133	0.60
	lead	<5.005	350.00
Loo (Cabbage)-plant			N/A[1]
Loo (Potato)-soil	mercury	0.02433	0.60
	lead	<5.005	350.00
Loo (Potato)-plant			N/A[1]

[1]—No Available Data
[2]—Limit of Quantification for Organophosphates, Organochlorines and Pyrethroids is 0.01 ppm
[3]—Calculated from the calibration curve of mercury (r=0.9974)
[4]—Calculated from the calibration curve of lead (r=0.9999)
[5]—Below detection limit

Soil Properties of Agricultural Farms in High Mountain Zone in Atok, Benguet (Wet Season Sampling)

Bulk density of soils. Most of the agricultural soils sampled in Atok, Benguet for wet season sampling have bulk density values lower than 1.33 g/cm[3] (Table 9). The lowest bulk density was obtained in a farm from Paoay, Atok, Benguet planted with carnation. In crop production, lower bulk densities are preferred because there is a balance of the solid and liquid spaces where water and air moves freely. Root growth is also favored due to spaces provided in between soil aggregate.

Porosity of soils. The porosity of agricultural soils in Atok, Benguet for wet season sampling ranges from 44.49% to 58.22% (Table 9). The result indicates that majority of the soil samples have 50% and above porosity. Porosity of 50% and above is favorable for plant growth in terms of root growth and development. This value indicates good air circulation and water percolation that favors good root penetration.

Soil pH. Table 10 shows the pH of agricultural soils in Atok, Benguet for wet season sampling ranging from 4.46 (very strongly acidic) to

Table 9.Physical properties of agricultural soils in Atok, Benguet-Wet Season Sampling

Sampling Area	Bulk density (g/cm3)	Porosity (%)
Paoay (Potato)	1.16	51.67
Paoay (Potato)	1.17	48.95
Paoay (Potato)	1.13	44.49
Paoay (Cabbage)	1.18	50.00
Paoay (Carrot)	1.10	51.67
Paoay (Chinese Cabbage)	1.31	44.67
Paoay (Carnation)	1.18	50.00
Paoay (Carnation)	1.07	44.58
Paoay (Carnation)	1.14	56.44
Paoay (Alstroemella)	1.37	56.15
Paoay (Alstroemella)	1.24	58.22
Paoay (Alstroemella)	1.18	50.00

Table 10.Chemical properties of agricultural soils in Atok, Benguet-Wet Season Sampling

Sampling Area	Soil pH	Organic Matter Content (%)	Available phosphorus Content (ppm)	Exchangeable potassium Content (ppm)
Paoay (Potato)	4.46	3.67	72.84	175.67
Paoay (Potato)	6.63	4.61	98.06	89.00
Paoay (Potato)	6.33	3.92	126.45	74.00
Paoay (Cabbage)	5.18	4.07	77.09	125.00
Paoay (Carrot)	5.28	2.98	68.95	125.00
Paoay (Chinese Cabbage)	5.25	3.74	69.11	145.67
Paoay (Carnation)	6.02	4.17	183.85	104.00
Paoay (Carnation)	5.99	4.57	103.37	200.00
Paoay (Carnation)	5.88	4.05	103.32	196.00
Paoay (Alstroemella)	5.89	4.03	165.11	39.00
Paoay (Alstroemella)	6.10	5.21	174.87	57
Paoay (Alstroemella)	5.92	4.50	172.48	36

6.63 (slightly acidic). Result shows that most agricultural soils in Atok, Benguet are suitable for vegetables and cut flowers. Brady and Weil (2008) stated that generally the pH values suitable for vegetable crops are within the range of 5.5 to 7.0.

It was noted that soils in Paoay, Atok and planted with potato had the lowest pH value of 4.46. This is considered very strongly acidic. This result confirms the findings of Panas (1996), Faroden (1998), and Miguel (1996) that the soil pH of most Benguet soils are acidic due to the effects of continues application of NH4-containing fertilizers applied by farmers coupled by heavy rainfall in the province during rainy months.

Organic matter content of soil. The organic matter content of the different agricultural soils in Atok, Benguet for wet season sampling ranges from 2.98% to 4.61% (Table 10). The result indicates that the values are marginal or moderately favorable thus the needs to apply organic fertilizer since these areas are continuously cultivated. The organic matter content of the soil can be improved with the application of organic fertilizer and compost (Schinister, 1991).

According to BSWM (n.d.) soil's organic matter content of more than 4.5% is considered adequate, 2.1% to 4.5% as marginal and less than 2% is deficient.

Available phosphorus content of soil. The available phosphorus content obtained from different agricultural soils in Atok for wet season sampling ranges from 68.95 ppm to 183.85 ppm (Table 10). These values are considered adequate based on the soil fertility rating by BSWM (n,d). Further, PCARRD (1982) also reported that phosphorus content in soil at 30-40 ppm is considered sufficient for most crops.

Exchangeable potassium content of soil. Table 10 shows the exchangeable potassium content of the different agricultural soils in Atok, Benguet for wet season sampling. The result shows that most of the agricultural soils sampled in Atok have moderate to adequate amounts of potassium. BSWM (n.d) reported that more than 150 ppm exchangeable potassium in soil is considered adequate, 76 ppm to 150 ppm as moderate, and less than 75 ppm as deficient.

Soil Properties of Agricultural Farms in High Mountain Zone in Atok, Benguet (Dry Season Sampling)

Bulk density of soils. Most of the agricultural soils sampled in Atok, Benguet for dry season sampling have bulk density values lower than 1.33g/cm$_3$ (Table 11). One farm however, has a bulk density of 1.71 g/cm$_3$. A soil with a bulk density above 1.33 g/cm$_3$ is considered compacted. This condition requires the application of organic matter to promote better soil aggregation and aeration in order to provide favorable environment for plant roots. Lower bulk densities are preferred for crop production because there is a balance of the solid and liquid spaces where water and air moves freely. Root growth is also favored due to spaces provided in between soil aggregate.

Porosity of soils. The porosity of agricultural soils in Atok, Benguet for dry season sampling ranges from 20.33% to 51.67% as shown in Table 11. The result shows that majority of the soils have porosity of more than 50%. One soil sample collected from Cattubo, Atok however, has a porosity of 20.33%. Porosity of 50% and above is favorable for plant growth in terms of root growth and development and water and nutrient retention. Brady (1996) stated that soils having 25% to 30% pore space are compacted and have poor soil aggregation and inadequate aeration that provide resistant to root penetration.

Soil pH. The pH of agricultural soils in Atok, Benguet for dry season sampling has pH values ranging from 5.31 to 5.46 both considered as strongly acidic (Table 12). The result indicates that pH values are below the pH requirements of vegetable crops thus, the application lime to increase pH that promotes nutrient availability in the soil is needed.

Brady and Weil (2008) stated that generally pH values ranging from 5.5 to 7.5 are the most common for agricultural land, whereas; for vegetable crops, pH values ranging from 5.5 to 7.0 is the most suitable.

Organic matter content of soil. The organic matter content of the different agricultural soils in Atok, Benguet for dry season sampling ranges from 3.94% to 4.65% (Table 12). The result indicates that the values are moderately available thus, the need to apply organic fertilizer since these areas are continuously cultivated. The soil organic matter content of more than 4.5% are classified as adequate, 2% to 4.5% are moderate or marginal and less than 2% are deficient (BSWM, n.d.).

Available phosphorus content of soil. The available phosphorus content of the different agricultural soils in Atok for dry season sampling ranges from 66.51 ppm to 78.26 ppm (Table 12). The result indicates that based on the soil fertility rating by BSWM (n.d.) these values are considered adequate. A value of 30-40 ppm available phosphorus is considered sufficient for most crops (PCARRD, 1982). According to BSWM (n.d.) more than 20 ppm available phosphorus is considered adequate, 6 ppm - 20 ppm is moderate and less than 6 ppm is deficient.

Exchangeable potassium content of soil. Table 12 shows the exchangeable potassium content of

Table 11.Physical properties of agricultural soils in Atok,Benguet-Dry Season Sampling

Sampling Area	Bulk density (g/cm_3)	Porosity (%)
Cattubo (Carrot)	1.05	51.67
Cattubo (Cabbage)	1.07	51.67
Cattubo (Astromella)	1.71	20.33
Cattubo (Potato)	1.06	50.67

Table 12.Chemical properties of agricultural soils in Atok,Benguet-Dry Season Sampling

Sampling Area	Soil pH	Organic Matter Content (%)	Available phosphorus Content (ppm)	Exchangeable potassium Content (ppm)
Cattubo (Carrot)	5.31	4.65	66.51	144.33
Cattubo (Cabbage)	5.32	4.06	67.55	146.00
Cattubo (Astromella)	5.46	4.53	78.26	108.33
Cattubo (Potato)	5.40	3.94	71.32	169.00

the different agricultural soils in Atok, Benguet for dry season sampling. The result shows that all of the agricultural soils sampled in Atok have moderate or marginal amount of exchangeable potassium. Exchangeable potassium content of more than 150 ppm in soil is considered adequate, 76 ppm to 150 ppm as moderate and less than 75 ppm as deficient.

Pesticide Residue of Soils in Cabbage and Potato Plant of Atok, Benguet

Table 13 shows the pesticide residues of soils,cabbage and potato plants from Atok, Benguet for the dry season sampling. The table shows that soils planted with cabbage were positive with Dieldrin, Endosulfansulfate (both organochlorines) and Cypermethrin with values of 0.03 ppm, 0.01ppm and 0.01ppm, respectively. On the other hand, soils planted with potato have Chlorothalonil (organochlorine), and Cypermethrin and Deltamethrin (both pyerethroids) with values of 0.47 ppm, 0.13 ppm and 0.01 ppm respectively. Values of chlorothalonil and cypermethrin exceeded the maximum residual limits set by USEPA.

Pesticides differ based on their active ingredient. They are classified as organochlorines, organophosphates and pyrethroids. Organochlorines are pesticides of chlorinated hydrocarbon group that generally have oral toxicity and long residual action. They are among the most persistent pesticides due to their low biodegradability and these were highly toxic to humans and mammals, the reason why these were banned or strictly restricted in many countries. On the other hand, organophosphates show a diversity of biological activity and persistence. They are severe poisons, which kill by inhibiting the action of certain enzymes in the nervous system. Likewise, pyrethroids have synthetic structure resembling the natural pyrethrins, with which they share the biological activity against insects (Edwards, 1986).

Toxic Heavy Metal Content of Soil Sample from Atok, Benguet

Table 14 shows the toxic heavy metal contents of the soil samples collected from Atok, Benguet for the dry season sampling. The results revealed that soils planted with potato and cabbage were both found to have mercury contents of 0.025 ppm which are below the maximum residual limit. On the other hand, the lead contents of the soils planted with potato and cabbage found out below the detection limit set by USEPA.

Table 13.Pesticide Residue of Soils in Cabbage and Potato Plant of Atok, Benguet

Sampling Area	Pesticide Analyzed	(ppm)	Porosity (%)
Cattubo (Cabbage)-soil	Dieldrin	0.03	N/A[1]
	Endosulfansulfate	0.01	N/A[1]
	Cypermethrin	0.01	0.05
Cattubo (Cabbage)-plant		LOQ[2]	
Cattubo (Potato)-soil	Chlorothalonil	0.47	0.04
	Cypermethrin	0.13	0.05
	Deltamethrin	0.01	N/A[1]
Cattubo (Potato)-plant		LOQ[2]	

[1]— No Available Data
[2]— Limit of Quantification for Organophosphates, Organochlorines and Pyrethroids is 0.01

ppm Table 14.Toxic Heavy Metal of Soils in Cabbage and Potato Plant of Atok, Benguet

Sampling Area	Toxic Heavy Metals Analyzed	(ppm)	Maximum Residual Limit (ppm)
Cattubo (Cabbage)-soil	mercury	0.0253[3]	0.60
	lead	<5.00[5]	350.00
Cattubo (Cabbage)-plant		N/A[1]	
Cattubo (Potato)-soil	mercury	0.0253[3]	0.60
	lead	<5.00[5]	350.00
Cattubo (Potato)-plant		N/A[1]	

[1]— No Available Data
[2]— Limit of Quantification for Organophosphates, Organochlorines and Pyrethroids is 0.01 ppm
[3]— Calculated from the calibration curve of mercury (r=0.9974)
[4]— Calculated from the calibration curve of lead (r=0.9999)
[5]— Below detection limit

CONCLUSIONS

Based on the findings, the following conclusions were drawn;

1. Majority of the agricultural soils from the two agro-ecological zones have moderately favorable soil properties for crop production as shown in the values of bulk density, particle density, porosity, soil pH, organic matter, nitrogen, phosphorus, potassium and cation exchange capacity. For the soil texture majority of the agricultural soils belong to the coarse textured soils;

2. Pesticide residues in soils and plants were found in the two agro-ecological zones but most of the values are within the maximum allowable maximum concentrations; and

3. Toxic heavy metals in soils were also found in the two agro-ecological zones and all of the values are within the maximum residual limit.

RECOMMENDATIONS

On the basis of the conclusions drawn, the following recommendations are made:

1. Agricultural soils in the two agro-ecological zonesshouldbemaintainedorimprovedtoguarantee favorable soil properties for crop production especially in the long period of cultivation through the application of organic fertilizers and to control the use of inorganic fertilizers.

2. Application of pesticides should be reduced to minimize contamination of soils and crops.

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