BIBILIOGRAPHY

VALENTINO L. MACANES. November 2006. Assessment on the Occurrence and Severity of Diseases Infecting Arabica Coffee (*Coffea arabica* L.) in Benguet Province. Benguet State University, La Trinidad, Benguet.

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ABSTRACT

The study was conducted to identify and document the different plant diseases closely associated with two Arabica coffee varieties namely Typica (*Coffea Arabica* var. Arabica) and Red Bourbon (*Coffea arabica* var. bourbon) widely cultivated on Benguet Province; assess the occurrence and severity of these plant diseases and to correlate the effects of the environment particularly elevation, relative humidity and temperature on the severity of the diseases.

The results of the study found four plant diseases closely associated with Arabica coffee varieties Typica and Red Bourbon. These are coffee rust (*Hemeleia vastatrix* B. and Br.), sooty mold (*Capnodium sp*.), Brown-eye leaf spot or berry rot (*Cercospora coffeicola*) and leaf blight, also called stem/twig blight or berry rot (*Colletotrichum coffeanum*). Coffee rust and sooty mold were observed to severely infect Typica. On the other hand, Red Bourbon was highly infected with brown-eye leaf spot and leaf blight. Coffee rust and sooty mold were seen to give minimal infection to this variety.

Results of the study also revealed that the degree of severity of the identified coffee diseases varied from the different municipalities. These municipalities were

clustered into four groups using the Complete Linkage Method of statistical analysis of which the degree of disease severity was determined ranging from severe, moderately sever and slightly infected.

Finally, the study discovered that the existing elevation, relative humidity and temperature in the different municipalities had no significant correlation on the severity of coffee rust and sooty mold to Arabica coffee var. Typica. Likewise, these environmental conditions had no significant correlation to the severity of sooty mold, brown-eye leafspot and leaf blight to Arabica coffee var. Red Bourbon. However, relative humidity had a positive significant correlation to the severity of coffee rust to Red Bourbon. Favorable atmospheric moisture during warm season increases the uredospore germination, spread and severity of this disease.
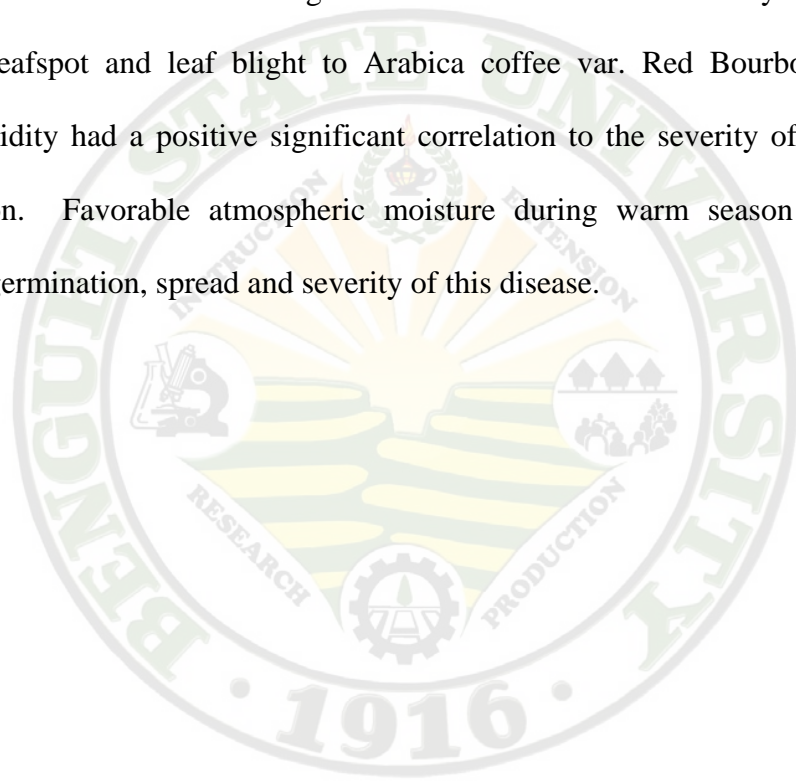
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INTRODUCTION

Background of the Study

The most well-known story of the discovery of the coffee plant is that concerning Kaldi, a goatherd tending his flock in the hills around a monastery on the banks of the Red Sea in the Middle East. He noticed that his goats, after chewing berries from the bushes growing there started to prance about excitedly. A monk from the monastery observed their behaviour, took some of the berries then back to the monastery, roasted and brewed them and tried out the beverage on his brethren. As a result they were kept more alert during their long prayers at night (Smith as cited by Willson and Clifford, 1985).

The wild coffee plant (*Coffea arabica*) is indigenous to Ethiopia, where it was discovered in about AD850 growing under forest trees. It was cultivated in the Arabian colony of Anan. If then spread to Mecca, from whence it was taken home by pilgrims to other parts of the world. Coffee was introduce to the Philippines in 1740 by the Franciscan friars.

Today, Coffee is the second universal drink next to water and is also the second most traded commodity next to oil (ICOCA, 2000).

Presently, there are four commercial coffee varieties traded worldwide. These are Arabica coffee (*Coffea arabica*), Robusta coffee (*Coffea robusta* or *Coffea canephora*), Excelsa coffee (*Coffea excelsa*) and Liberica coffee

(*Coffea liberica*). Of these varieties, Arabica coffee is of the highest market value having the best cup quality with excellent flavor and aroma. It is commonly used by coffee processors for flavoring the other coffee varieties.

Aside from its commercial value, Arabica coffee has medicinal values. An article published by the Philippine Daily Inquirer in November 2005 stated that a Japanese Medical Research Team discovered that drinking two cups of coffee a day lowers high blood pressure. The Philippine Council for Agricultural Research and Resources Development (1976) found that coffee stimulates respiration, gastric and renal activities and digestion. It also serves as a palliative in spasmodic asthma, whooping cough, hysterical affections and as a remedy for diarrhea, typhoid fever and vomiting after surgical operations. In addition, it was reported in the Reader's Digest (March 2002) that coffee prevents Parkinson's disease.

In the Philippines, Arabica coffee is found to grow favorably in the cool areas of the Cordillera Administrative Region (CAR) particularly in Benguet and Mountain Province. The Coffee Foundation Institute of the Philippines recognized that green beans of Arabica coffee from these areas have excellent crop quality and comparable to the world class coffee of South America (Bagao, 2000). Presently, Arabica coffee is listed as one of the top five high value crops in the region with Benguet Province as the forefront for the production of this valuable crop.

The green bean yield, however, of Arabica coffee in Benguet is very low. The Department of Agriculture-CAR survey report in 2002 found that an average of only 300 kilograms green beans is produced per hectare. This is far below the yield of 2-3 tons green beans per hectare by the Arabica coffee-exporting countries of South America. Thus, local production could not match domestic demand which is continuously increasing at 2.25% or 1.65 metric tons green beans per year (Mojica, 2000). The DA-CAR report further stated that one foremost cause for low production is the occurrence of plant diseases which infect the crop.

Initial surveys conducted by Macanes and Basalong (2001) in some Arabica coffee-producing areas in the Cordilleras particularly in Benguet and Mountain Province revealed that the rust fungi, *Hemeliea vastatrix* B. and Br. Is the most common disease affecting the coffee plants. However, there is a need for more comprehensive identification and severity studies of all the other economically important Arabica coffee diseases, hence this study.

Objectives of the Study

This study was conducted to:

1. Collect, identify and document the different plant diseases associated with two Arabica coffee varieties namely Typica (*Coffea Arabica* var. arabica) and Red Bourbon (*Coffea Arabica* var. bourbon) grown in Benguet Province from July to October 2006.

2. Assess the occurrence of the different coffee diseases in the different locations.

3. Assess the severity of the diseases observed in the different municipalities, and

4. Correlate the effects of the environment particularly elevation, relative humidity and temperature on the severity of the identified diseases.

Importance of the Study

Arabica coffee which is known locally as "native coffee" or "Benguet coffee" is now widely promoted by experts as alternative source of income for the costly and declining vegetable industry of Benguet Province. In addition, this crop is vigorously promoted by both government and non-government agencies as a primary Agroforestry crop in the province to check the over-exploitation of the forest covers. Furthermore, the demand for Arabica coffee in the country has increased. The Philippine Daily Inquirer in its July 2004 issue stated that domestic consumption of coffee per year is 55,000 metric tons compared to a production of 35,000 metric tons. Thus, there is a shortage of 20,000 metric tons per year.

The recent report of Ananayo (2006) revealed that there is increase in land area for the production of Arabica coffee in the Cordillera Administrative Region from 6,192 hectares in 2001 to 6,452 hectares in 2002 particularly in Benguet Province. This is due to the demand of this coffee variety by both

local and international coffee shops which continue to proliferate in the country.

This study is conducted to generate data to contribute for the formulation of an integrated management strategy for the prevention and control of Arabica coffee diseases in Benguet considering the scenario of increasing land area for Arabica coffee production. Although there are several publications of diseases affecting coffee these are mostly generalized and not specific to Arabica coffee. Furthermore, the conditions described are far different from those prevailing in Benguet Province.

Time and Place of Study

The study was conducted in the major Arabica coffee-growing areas of Benguet Province namely: Caliking, Atok; Ampusongan, Bakun; Poblacion, Buguias; Lomon, Kapangan; Sagpat, Kibungan; BSU-Agroforestry Project, Puguis, La Trinidad; Banangan, Sablan and Old Poblacion, Tublay. The study was done from July to October 2006.

REVIEW OF LITERATURE

Overview and Opportunities for Arabica
Coffee Production

The recent inclusion of Arabica coffee as one the priority commodities of the Department of Agriculture-Cordillera Administrative Region under the High Value Crops Program is a welcome move. This is in-line with the Agriculture and Fisheries Modernization Act's objective of enhancing profits and income in agriculture, particularly that of the small farmers by promoting high value crops, value-added processing and agribusiness activities (CIARC-DA-CAR, 2001).

Highland Agricultural Research Center (1987), emphasized that coffee production, particularly of the Arabica variety, is being eyed as a source of additional income for Benguet and the rest of the mountain provinces.

The local demand for coffee, particularly the Arabica type, has dramatically increased from 2.25% per annum in the early 1990's to 3.0% per annum in the late 1990's. This is because of the needs of local coffee shops looking for gourmet coffee (Torrejon, 2000).

The gist of all the papers presented during the First National Coffee Congress held in Baguio City in December 2000 stated that high quality green coffee beans will always find their way to the local and international markets more so if it is the Arabica coffee which is highly demanded by the gourmet and specialty coffee shops (DA-CAR, 2000).

Importance of Plant Disease Identification

Manion (1991) stated that plant disease involves disturbance in the normal physiologic functioning of a plant, has many causes, and exhibits an array of appearances. He also stated that the plant pathologist can often readily recognize the presence of a specific pathogen based on symptoms alone. The symptoms of plant diseases are expressions of disturbed or abnormal physiology of the host plant.

The identity of plant disease causal agents may be established for some classes of organisms on the basis of morphology but this approach may not give sufficient information on its own. However, with more sophisticated molecular techniques now available, race identification without resorting to inoculation experiments which are time-consuming has become a possibility. Meanwhile, the survey of plant disease and its effects on crop yield, quality and value are crucial both for the establishment of priorities for control and for evaluation of any control measures that may be instituted (Strange, 1993).

Agrios (1997) emphasized that when a pathogen is found on diseased plants, the pathogen is identified by reference to special manuals. If the pathogen is known to cause such a disease and the diagnostician is confident that no other causal agents are involved, the disease diagnosis is considered completed. If however, the pathogen found seems to be the cause of the

disease but no previous reports exist to support this, then the Koch's rules or postulates are applied.

Diseases of Coffee

Wellman (1961) stated that the classic coffee rust variously called leaf disease, orange rust, common rust and orient rust is by far the most important, the most dangerous and the most feared coffee disease in the world.

In the Philippines, a severe epidemic of coffee rust started in Batangas in 1965. Five years later, the coffee rust disease had all but ruined the coffee industry in the province. Today, it still breaks out occasionally in some places causing severe damage to coffee plantations (Anonymous, 1967).

Ocfemia (1954) said that Arabica coffee in Guinobatan, Albay and its vicinity were heavily infected with the rust fungus. He also mentioned that coffee rust commonly infects the Arabica coffee variety and is the most serious coffee disease in the world.

The study of Nicanor (2003) at the Benguet State University Agroforestry Project in La Trinidad, Benguet found five fungal diseases associated with Arabica coffee. These were coffee rust, leaf spot, Berry blotch, *Fusarium sp*. and *Pestalotia sp*.

Basalong (2006) reported that coffee rust is the most common disease affecting Arabica coffee in the different cropping systems at the Benguet State University, La Trinidad, Benguet.

MATERIALS AND METHODS

<u>Disease Collection Areas</u>

The collections of diseased Arabica coffee plants or plant parts were done in most of the major Arabica growing areas in the municipalities of Benguet (Figure 1). These were the following:

<u>Barangay</u>	<u>Municipality</u>
Caliking	Atok
Poblacion	Bakun
Poblacion	Buguias
Lomon	Kapangan
Sagpat	Kibungan
BSU Agroforestry Project Puguis	La Trinidad
Bangangan	Sablan
Poblacion	Tublay

These places were some of the important areas in the region identified by the Regional Coffee Task Force of the DA-CAR in 2000 as major Arabica coffee centers. They were previously visited by the researcher during his lectures and trainings to farmers on Arabica coffee production management.
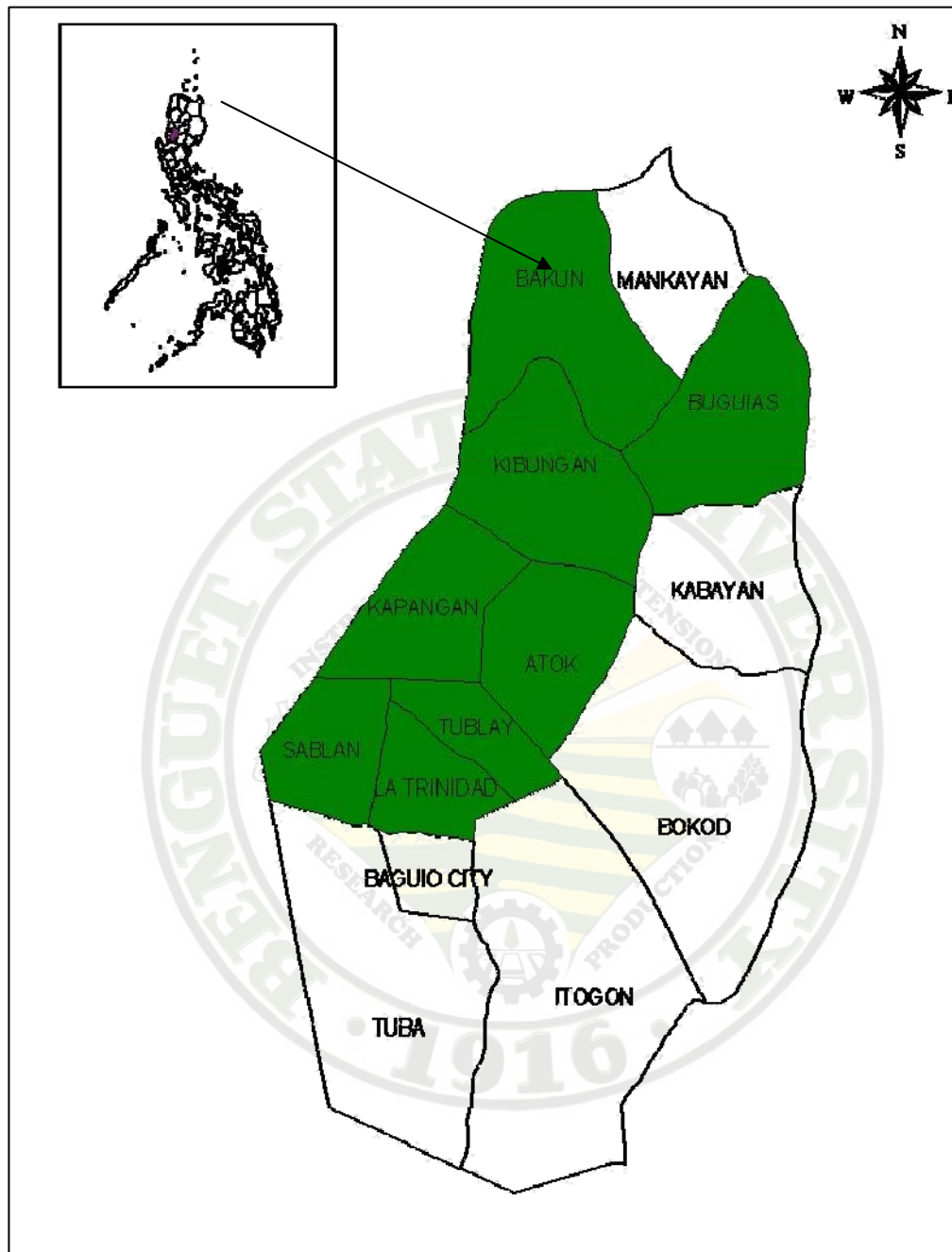
Figure 1. Map of Benguet province showing the different sample municipalities

Data Gathering

Actual farm visits for the identified areas for disease-collection were done. The farmers were consulted and so with the local government units concerned.

The average temperature and relative humidity of the sample sites were taken using the thermometer and hygrometer, respectively. Likewise, the elevation readings of the sample areas were done using the Bushnell Digital Altimeter.

Collection of Samples

Collections of disease samples were done in all the identified sampling sites. Focus was done on *Coffea Arabica* var. *arabica* (Typica) and *Coffea Arabica* var. *bourbon* (Red Bourdon). These Arabica coffee varieties were commonly grown in all the study areas.

Suspected diseased leaves, berries, twigs and branches were collected from representative Arabica coffee trees. These were put in individual plastic bags, sealed and properly labeled. Afterwards, these were brought to the Crop Protection Laboratory of the Benguet State University, La Trinidad, Benguet for disease diagnosis.

Data Gathered

The data gathered were:

1. Disease identification. Samples of the disease infected coffee plant parts were prepared and mounted under the microscope for examination and identification. Identification was done based on symptoms and reproductive structures of the causal micro-organism. Further verification was done by comparing the symptoms with existing reference books and manuals for coffee diseases.

2. Percent disease severity on leaves (%). The percentage of disease severity on the coffee leaves were visually assessed for each Arabica coffee varieties of Typica and Red bourbon. Assessments were done from 10 sample leaves taken at random from every tree of the 10 sample trees of the respective Arabica coffee varieties. The following 9-point field scale as suggested by Subba Rao, *et al.* (1991) as cited by the UNDP-ESCAP (1999) was modified and used for all the leaf diseases:

Percent Leaf Infection	Description
0%	No disease observed on leaves
1-25%	Slight disease incidence
26-50%	Moderate disease incidence
51-75%	Less severe disease incidence
76-100%	Severe disease incidence

3. <u>Percent disease severity on the whole tree (%)</u>. Disease infection on the whole coffee tree was visually assessed for disease severity. 10 sample trees for each of the Typica and Red Bourbon Arabica coffee varieties were used. The following 9-point field scale of Suba Rao, *et al.* (1999) was modified and utilized:

<u>Percent Plant Infection</u>	<u>Description</u>
0%	No disease observed
1-5%	Lesions sparsely distributed on lower leaves.
6-10%	Many lesions on lower leaves, necrosis evident, very few lesions present on middle leaves.
11-20%	Numerous lesions present on lower and middle leaves, severe necrosis on lower leaves.
21-30%	Severe necrosis of lower and middle leaves. Lesions may be present on top leaves but less severe.
31-40%	Extensive damage to lower leaves. Lesions densely present on top leaves.
41-60%	Severe damage on lower and middle leaves, lesions densely distributed on top leaves.
61-80%	100% damage to lower and middle leaves, lesions present on top leaves with severe necrosis.
81-100%	Almost all leaves withering, bare stems present.

4. <u>Environmental conditions prevailing in the area</u>. The environmental conditions for disease development particularly the elevation, relative humidity and temperature were taken in the different sample sites.

<u>Data Analysis</u>

The study basically employed descriptive statistics involving percentage, mean correlation and cluster analysis using the complete linkage method.
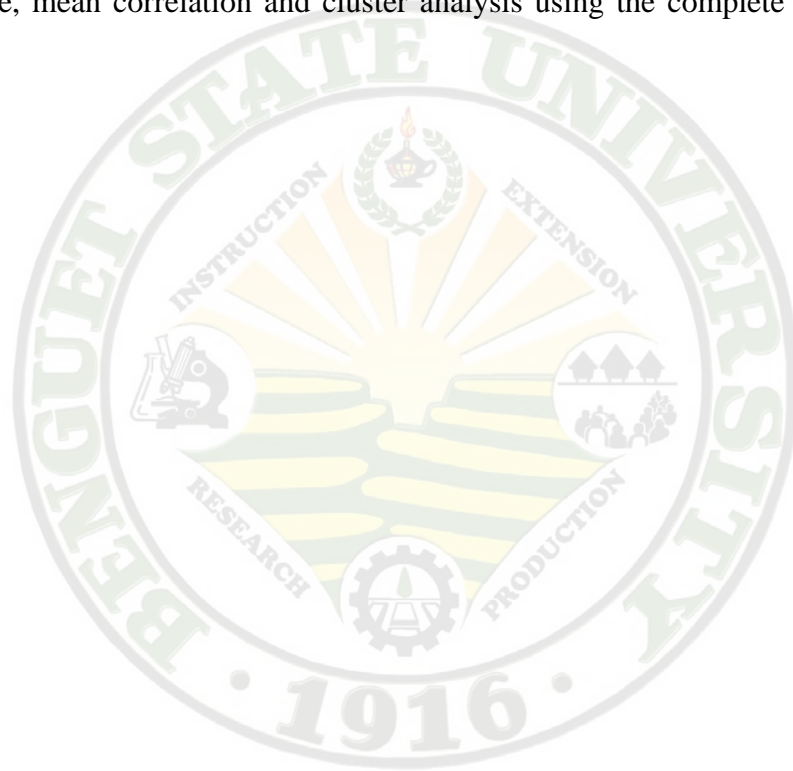
RESULTS AND DISCUSSION

<u>Pathogens Associated to the Two Arabica Coffee
Varieties in the Eight Growing Areas
of Benguet</u>

The study found that there were four (4) fungal pathogens generally associated with the Arabica coffee grown in all the selected sample sites of Benguet Province namely: Atok, Bakun, Buguias, Kapangan, Kibungan, La Trinidad, Sablan and Tublay. These pathogens were *Hemeleia vastatrix* B. and Br. (coffee rust), *Capnodium sp.* (sooty mold), *Cercospora coffeicola* (brown-eye leaf spot or berry blotch) and *Colletotrichum coffeanum* (leaf blight, stem/twig blight or berry rot).

The study further found that coffee rust infection was confined to the leaves while sooty mold affected the leaves, berries, shoots, stems and twigs. On the other hand, brown-eye leaf spot and leaf blight primarily attacked the leaves but could infect the berries, stems and twigs.

Table 1. Symptoms of the fungal diseases exhibited by the infected
　　　　Arabica coffee (*Coffea arabica* L.)

DISEASE	LEAF	STEM/TWIG	BERRY
Coffee Rust (*Hemileia vastatrix*)	Bright orange powdery mass under the leaves. Yellow-orange color on leaf surface. Lesions have dark-brown color when mature.	Dieback	Small-sized mature berries. Pre-mature ripening
Sooty mold (*Capnodium sp.*)	Black mold covers the upper and lower leaf surface hindering light penetration for photosynthesis. Presence of mealy bugs and scale insects on shoots. Ants are all over the plant.	Black mold covers stem and twigs and shoots.	Black mold covers ripe or un-ripe berries.
Brown-eye leafspot of berry blotch (*Cercospora coffeicola*)	Circular spots on leaf surface with distinct reddish to purple borders. Center of spot soon becomes gray and drops out leaving a hole ("shoot hole").	Dieback.	Irregular browning of mature berries. Berry pulp appears to be burned.

Table 1. *Continued . . .*

DISEASE	LEAF	STEM/TWIG	BERRY
Leaf blight stem blight or berry rot (Colletotrichum coffeanum)	Infected leaf have large, irregular spots arising from the leaf margin. The spots have light brown or reddish brown color. Advance leaf infection have large, gray center on leaf surface.	Dieback.	Berry pulp have circular, watery, dark sunken lesions.

Plate 1. Uredospores of *Hemeliea vastatrix* (coffee rust) at 400x magnification

Plate 2. Arabica coffee leaf infected with coffee rust (*Hemeleia vastatrix*)

Plate 3. Structure of sooty mold (*Capnodium sp.*) at 400x magnification

Plate 4. Arabica coffee tree infected mainly with sooty mold

Plate 5. Conidiogenous cells of *Cercospora coffeicola* at 400x
magnification

Plate 6. Brown-eye leafspot caused by *Cercospora coffeicola*
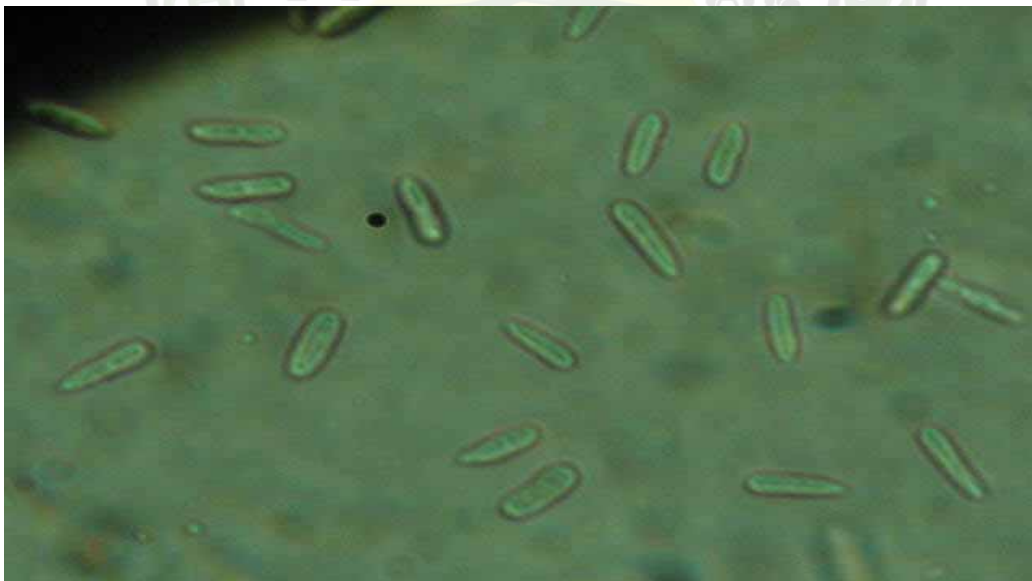
Plate 7. *Colletotrichum coffeanum* conidia from leaf blight at 400x
magnification

Plate 8. Arabica coffee berries infected with *Colletotrichum coffeanum* (leaf blight)

Caliking, Atok

The Arabica coffee var. Typica cultivated in this area was mostly infected with coffee rust and sooty mold. On the other hand, var. Red Bourbon was infected with coffee rust, brown-eye leaf spot and leaf blight. Coffee rust infection to this variety was slight.

Ampusongan, Bakun

The disease observed associated with Arabica coffee variety Typica in this site were coffee rust and sooty mold. The Red Bourbon variety was attacked by coffee rust, brown-eye leaf spot and leaf blight. Coffee rust infection to this variety was minimal.

Plate 9. Arabica coffee leaf blight in Atok

Plate 10. Initial infection of Arabica coffee leaf blight in Bakun

Poblacion, Buguias

Coffee rust and sooty mold were the diseases found infecting Arabica coffee var. Typica grown in this locality. Meanwhile, variety Red Bourbon was infected with coffee rust, brown-eye leaf spot and leaf blight. Coffee rust attacked to this variety was slight.

Lomon, Kapangan

The Arabica coffee var. Typica raised in this barangay was found affected with coffee rust and sooty mold. On the other hand, variety Red Bourbon was less infected with coffee rust. Brown-eye leaf spot and leaf blight were found to attack this coffee variety.

Sagpat, Kibungan

Coffee rust and sooty mold were the diseases found associated to the Arabica coffee var. Typica grown in this locality. Meanwhile, variety Red Bourbon was infected with brown-eye leaf spot and leaf blight.

BSU-IHFSA, Puguis, La Trinidad

The Arabica coffee var. Typica cultivated in this locality was mainly infected with coffee rust and sooty mold. Meanwhile, the Red Bourbon coffee variety was infected with brown-eye leaf spot and leaf

Plate 11. Initial infection of brown-eye leaf spot (*Cercospora coffeicola*) in
Buguias

Plate 12. Arabica coffee berries infected with *Colletotrichum coffeanum*
in Kapangan

Plate 13. Initial infection of coffee rust in leaves of Arabica coffee in Kibungan

Plate 14. Leaf blight infection of Arabica coffee in BSU-IHFSA, La Trinidad

blight. In addition, there was a minimal infection of sooty mold to this variety.

Banangan, Sablan

Coffee rust and sooty mold were found attacking the Arabica coffee var. Typica planted in this place. On the other hand, the Red Bourbon variety was infected with sooty mold, brown-eye leaf spot and leaf blight.

Poblacion, Tublay

The diseases identified infecting the Arabica coffee var. Typica in this locality were coffee rust and sooty mold. For the var. Red Bourbon, the identified diseases were sooty mold, brown-eye leaf spot and leaf blight.

Plate 15. Arabica coffee leaves attacked by coffee rust in Sablan

Plate 16. Damage of leaf blight in Arabica coffee in Tublay

<u>Assessment of Leaf Severity of the Diseases Associated
with Two Arabica Coffee Varieties Grown
in Eight Municipalities of Benguet</u>

<u>Arabica Coffee Var. Typica</u>

Table 2 shows the average percentage leaf severity of the coffee rust and sooty mold diseases associated with Arabica coffee variety Typica grown in the selected sampling areas of Benguet.

<u>Coffee rust</u>. Results as shown in Table 2 revealed that there was a severe coffee rust infection in the leaves of the variety Typica planted in Kapangan, La Trinidad and Sablan. Average leaf severity in these places

ranged from 77-90%. Meanwhile, there was a less severe coffee rust incidence of 74% in the leaf infection of the variety Typica grown in Tublay.

On the other hand, a moderate coffee rust infection of 47.5% was observed in the leaves of variety Typica cultivated in Kibungan.

Table 2. Mean percent severity of diseased leaves affecting Arabica coffee var. Typica in eight growing areas of Benguet

DISEASE	MUNICIPALITY							
	Atok	Bakun	Buguias	Kapa-ngan	Kibu-ngan	La Trinidad	Sablan	Tublay
Coffee rust (%)	9.00	14.00	18.00	77.50	47.50	90.00	90.00	74.00
Sooty mold (%)	17.00	24.00	68.50	80.00	10.00	15.50	78.00	83.00

Finally, a slight coffee rust incidence ranging from 9-18% were observed in variety Typica plants grown in Atok, Bakun and Buguias.

Sooty mold. Table 2 further shows that severe sooty mold leaf incidence was observed in Arabica coffee variety Typica planted in Sablan, Kapangan and Tublay. Leaf severity in these areas ranged from 78-83%. On the other hand, less severe sooty mold incidence of

68.5% were noted in the Typica trees grown in Buguias. Meanwhile, slight sooty mold infection were observed in the leaves of the Typica coffee trees cultivated in Kibungan (10%), La Trinidad (15.5%), Atok (17%) and Bakun (24%).

Arabica Coffee Variety Red Bourbon

Table 3 reveals the mean leaf severity percentage of the diseases associated with Arabica coffee variety Red Bourbon cultivated in the eight growing areas of Benguet.

Coffee rust. Table 3 shows that there was a very slight coffee rust infection ranging from 0.2-0.7% in the leaves of Arabica coffee var. Red Bourbon grown in Atok, Bakun and Buguias. The Red Bourbon coffee trees cultivated in the other sampling municipalities exhibited no coffee rust leaf infection of zero percent. This confirms with the recommendation of the Coffee Technoguide for the Highlands published in 1987 by the Highland Agricultural Research Center

Table 3. Mean percent severity of diseased leaves affecting Arabica coffee Red Bourbon in eight growing areas of Benguet

DISEASE	MUNICIPALITY							
	Atok	Bakun	Buguias	Kapa-ngan	Kibu-Ngan	La Trinidad	Sablan	Tublay
Coffee rust (%)	0.2	0.3	0.7	0.6	0	0	0	0
Sooty mold (%)	0	0	0	0	0	15.2	3.6	15.2
Brown-eye leaf spot	8.0	3.5	5.0	6.0	5.1	16.5	8.5	7.0
Leaf blight	11.5	9.0	7.5	14.0	4.0	7.0	9.0	8.5

(HARC), Benguet State University, La Trinidad, Benguet that Red Bourbon is a resistant Arabica coffee to coffee rust.

Sooty mold. Table 3 further shows that slight sooty mold incidence were encountered in variety Red Bourbon trees grown in Sablan, La Trinidad and Tublay. Leaf severity ranged from 3.6% to 15.2%.

All the other areas showed no sooty mold leaf infection.

Brown-eye Leaf spot. As shown in Table 3, there was a slight incidence of brown-eye leaf spot infecting the leaves of variety Red Bourbon cultivated in all the eight sampling municipalities of Benguet Province. Leaf infection percentage ranged from 3.5%-16.5%.

Leaf blight. Table 3 further reveals that there was also a slight incidence of leaf blight in the leaves of variety Red Bourbon in all the selected municipalities. Leaf infection incidence ranged from 4%-14%.

<u>Assessment of Whole Plant Severity of the Diseases
Associated with Two Arabica Coffee Varieties
in the Eight Municipalities of Benguet</u>

Arabica Coffee Var. Typica

Table 4 shows the average whole plant infection percentage of coffee rust and sooty mold to Arabica coffee variety Typica in the eight growing areas of Benguet Province.

Coffee rust. Results showed that Typica Arabica coffee grown in Tublay, Kibungan, Sablan and BSU-IHFSA, La Trinidad had 100% coffee rust damage to the lower and middle leaves. It was also found that lesions were present on top leaves with severe necrosis. Whole plant infection ranged from

65%-76%. On the other hand, there was extensive damage of this disease to coffee trees grown in Kapangan. Lesions were also densely present on top leaves. Whole plant disease infection rating was 38.50%.

Meanwhile, the Typica trees in Bakun and Buguias were observed to have many rust lesions on the lower leaves with evident necrosis. Very few lesions were also present in the middle leaves. The

Table 4. Mean whole plant disease severity affecting Arabica coffee
          Var. Typica Bourbon in eight growing areas of Benguet

DISEASE	MUNICIPALITY							
	Atok	Bakun	Buguias	Kapa-ngan	Kibu-ngan	La Trinidad	Sablan	Tublay
Coffee rust (%)	9.0	15.0	18.5	38.5	72.0	76.0	74.0	65.0
Sooty mold (%)	10.0	19.5	19.5	54.0	6.50	1.70	68.0	77.0

average whole plant infection of this disease in Bakun was 15% while Buguias had 18.5%. Finally, the coffee trees in Atok were found to have many lesions on the lower leaves with evident necrosis. However,

there were very few lesions present on the middle leaves. The infection percentage was 9%.

Sooty mold. Arabica coffee var. Typica trees grown in Tublay and Sablan gave 77% and 68% whole plant infection to sooty mold, respectively. There was 100% damage to the upper and middle leaves. The molds covered

the leaves, berries, branches and twigs of the whole plant. The fungi was also present on the lower leaves. Meanwhile, the coffee trees in Kapangan and Buguias exhibited severe damage to sooty mold on the upper and middle leaves. The sooty mold infection was densely distributed in the lower leaves. Whole plant infection rating was 54% and 51.5%, respectively.

On the other hand, Typica coffee trees cultivated in Atok had 10% while Bakun 19.5% mean whole plant infection. The disease was present in the upper and middle leaves. Severe infection was also found in the upper leaves.

Finally, the coffee trees grown in BSU-IHFSA, La Trinidad had the lowest whole plant incidence of sooty mold with 1.7%. The mold fungi was sparsely distributed in the upper leaves.

Arabica Coffee Var. Red Bourbon

Table 5 shows the mean whole plant infection percentage of coffee rust, sooty mold, brown-eye leaf spot and leaf blight to Arabica coffee variety Red Bourbon.

Coffee rust. Infection of this disease to Arabica coffee variety Red Bourbon was observed in the municipalities of Atok, Bakun, Buguias and Kapangan but was very minimal. Whole plant infection ranged from 0.4 – 0.7%.

Sooty mold. The Arabica coffee var. Red Bourbon grown in Tublay gave the highest mean whole plant infection of 21.2% for sooty mold. It was observed that this disease exhibited numerous black mold covers on the upper and middle leaves. Furthermore, the fungi was present on the lower leaves but was less severe.

Table 5. Mean whole plant disease severity affecting Arabica coffee Red
         Bourbon in eight growing areas of Benguet

| | MUNICIPALITY | | | | | | | |
DISEASE	Atok	Bakun	Buguias	Kapa-ngan	Kibu-ngan	La Trinidad	Sablan	Tublay
Coffee rust (%)	0.6	0.4	0.7	0.6	0	0	0	0
Sooty mold(%)	0	0	0	0	0	5.2	21.2	21.2
Brown-eye leaf spot (%)	22.5	1.5	5.0	10.0	10.0	18.0	0.5	0.5
Leaf blight (%)	11.5	10.0	5.0	6.0	0.50	9.5	12.5	12.5

This disease was also noticed infecting the Red Bourbon Arabica coffee trees in Sablan and La Trinidad. However, the overall whole plant infection was very minimal at 2.1% and 5.2%, respectively.

Brown-eye leaf spot. The highest percentage whole plant infection of 22.5% of brown-eye leaf spot was obtained from the Red Bourbon Arabica coffee grown in Atok. There was severe necrosis on the lower and middle leaves while lesions were present on top leaves although less severe. On the other hand, the Red Bourbon coffee trees cultivated in BSA-IHFSA, La Trinidad gave 18% mean whole plant infection. There were numerous lesions present on the lower and middle leaves with severe necrosis observed on the lower leaves. Meanwhile, the coffee trees grown in Tublay, Kibungan and Kapangan exhibited a respective 6.5% and 10% average whole plant infection

for this disease. There were lesions present in the lower leaves with evident necrosis. However, very few lesions were present on the middle leaves.

Finally, the Arabica coffee variety Red Bourbon raised in Sablan, Buguias and Bakun had the lowest average whole plant infection for brown-eye leaf spot. The disease infection for these areas ranged from 0.5% to 1.5%

Leaf blight. The Arabica coffee var. Red Bourbon cultivated in Tublay and Atok were observed to have the highest average whole plant infection for leaf blight of 12.5% and 11.5%, respectively. It was observed that numerous blight lesions were present in the lower and middle leaves with severe necrosis on the lower leaves. On the other hand, Red Bourbon coffee plants grown in Bakun had 1.0% whole plant infection while BSU-IHFSA, La Trinidad gave 9.5% whole plant infection. The coffee trees assessed in these places had many blight lesions in the lower leaves with evident necrosis. Furthermore, there were few lesions present in the middle leaves. Meanwhile, low whole plant infection for this disease was taken from the Red Bourbon trees planted in Kapangan with 6%, Sablan 5.5% and Buguias 10%. The coffee trees were observed to have many lesions in the lower leaves with evident necrosis but very few lesions were present in the middle leaves.

The least percentage of whole plant infection for leaf blight were exhibited by Red Bourbon coffee trees planted in Kibungan with 0.5%. It was noticed that there were very few lesions were present and sparsely distributed in the lower leaves of the coffee plant.

Correlation Between Plant Disease Severity to Elevation, Relative Humidity
and Temperature Existing in the Eight
Arabica Coffee Growing Areas

Table 6 shows the elevation, relative humidity and temperature of the eight Arabica sample municipalities cultivating Arabica coffee.

Statistical analysis was done to determine the correlation of the whole coffee plant infection to the elevation, relative humidity and temperature.

Correlation of Arabica Coffee Var. Typica

Table 7 and Table 8 revealed that elevation, relative humidity and temperature of the study areas had no significant effect on the severity of coffee rust and sooty mold to Arabica coffee strain Typica. This could confirm the findings of Van der Vossen as cited by Clifford and Willson (1985) that besides the environment, breeding and selection contribute to the susceptibility or resistance of a certain plant to certain diseases.

Table 6. Elevation, relative humidity and temperature prevailing in the different study areas

MUNICIPALITY/ BARANGAY	ELEVATION (Meters above sea level)	RELATIVE HUMIDITY (%)	TEMPERATURE (^{O}C)
Atok (Caliking)	1,650	69	24
Bakun (Ampusongan)	1,230	58	24

Buguias (Poblacion)			
	1.350	77	25
Kapangan (Lomon)	930	68	26
Kibungan (Sagpat)	1,355	62	24
La Trinidad (BSU-IHFSA)	1,380	62	24
Sablan (Banangan)	1,110	58	27
Tublay (Poblacion)	1,175	55	24

Table 7. Correlation between whole plant infection of Arabica coffee var. Typica to coffee rust on elevation, relative humidity and temperature

VARIABLE	PARAMETER		STATISTICAL SIGNIFICANCE
	Correlation Coefficient	Probability	
Elevation	-0.303	0.463	ns
Relative Humidity	-0.565	0.141	ns
Temperature	0.176	0.677	ns

ns = not significant

Table 8. Correlation between whole plant infection of Arabica coffee var. Typica to sooty mold on elevation, relative humidity and temperature

VARIABLE	PARAMETER		STATISTICAL SIGNIFICANCE
	Correlation Coefficient	Probability	
Elevation	-0.655	0.078	Ns
Relative Humidity	-0.125	0.767	Ns

Temperature	0.604	0.113	Ns

ns = not significant

Correlation of Arabica Coffee Var. Red Bourbon

Elevation, relative humidity and temperature of the disease collection sites had no significant effect to the severity of sooty mold, brown-eye leaf spot and leaf blight to Arabica coffee var. Red Bourbon. This is shown by Table 10, Table 11 and Table 12. However, Table 9 reveals that relative humidity had positive significant correlation on the severity of coffee rust to this Arabica coffee variety. High atmospheric moisture increases coffee rust infection. This upholds the discovery of Walter as cited by Clifford and Willson (1985) that spores of coffee rust dispersed by wind coupled with favorable atmospheric moisture is suitable for spore germination of this disease. He further stated that rainfall increases the spread and development of this disease in warm,

Table 9.   Correlation between plant infection of Arabica coffee var. Red Bourbon to coffee rust on elevation, relative humidity and temperature

VARIABLE	PARAMETER		STATISTICAL SIGNIFICANCE
	Correlation Coefficient	Probability	
Elevation	0.122	0.774	ns
Relative Humidity	0.801	0.017	s[*]
Temperature	0.067	0.874	ns

ns = not significant
[*]s = significant

Table 10. Correlation between plant infection of Arabica coffee var. Red Bourbon to sooty mold on elevation, relative humidity and temperature

VARIABLE	PARAMETER		STATISTICAL SIGNIFICANCE
	Correlation Coefficient	Probability	
Elevation	-0.167	0.692	ns
Relative Humidity	-0.542	0.165	ns
Temperature	0.251	0.549	ns

ns = not significant

Table 11.   Correlation between plant infection of Arabica coffee var. Red Bourbon to brown-eye leaf spot on elevation, relative humidity and temperature

| VARIABLE | PARAMETER | | STATISTICAL SIGNIFICANCE |
	Correlation Coefficient	Probability	
Elevation	0.628	0.096	ns
Relative Humidity	0.258	0.537	ns
Temperature	-0.325	0.432	ns

ns = not significant

Table 12.   Correlation between plant infection of Arabica coffee var. Red Bourbon to leaf blight on elevation, relative humidity and temperature

| VARIABLE | PARAMETER | | STATISTICAL SIGNIFICANCE |
	Correlation Coefficient	Probability	
Elevation	0.199	0.637	ns
Relative Humidity	-0.276	0.509	ns
Temperature	-0.363	0.377	ns

ns = not significant

dry season. He emphasized that irrigation of coffee should be regulated during warm temperatures.

Cluster Analysis of Plant Disease Severity of the Two Arabica Coffee Varieties Grown in the Different Municipalities of Benguet Used as Sample Areas

Cluster analysis was done to observe the data patterns of the municipalities having similar plant disease severity to the two Arabica coffee varieties Typica and Red Bourbon. The disease severity percentage was based on the whole plant infection observed in the different municipalities of Benguet that were used in this study.

Cluster Classification of Plant Disease Severity to Arabica Coffee var. Typica

Statistical analysis using the Complete Linkage Method grouped the municipalities that have similar disease severity of coffee rust and sooty mold to Arabica coffee variety Typica. Results revealed four clusters (Figure 2). These were cluster 1: Atok, Bakun and Buguias; Cluster 2: Kibungan and La Trinidad; Cluster 3: Kapangan; and cluster 4: Sablan and Tublay.

Biplot

The Biplot (Figure 3) graphically shows that the Typica coffee trees grown in Kibungan and La Trinidad (Cluster 2) were severely

Figure 2.   Dendrogram of Complete Linkage Method showing the cluster of municipalities of Benguet that have similar disease severity of coffee rust and sooty mold on Arabica coffee var. Typica

Figure 3. Biplot of coffee rust and sooty mold severity to Arabica coffee
var. Typica grown in the different municipalities of Benguet

infected with coffee rust. On the other hand, severe infection of sooty mold were observed in coffee trees planted in Sablan and Tublay (Cluster 4); and Kapangan (Cluster 3). The areas of Atok, Bakun and Buguias (Cluster 1 were less infected with rust and sooty mold

Coffee Rust Severity

Analysis by the Bonferroni one-way cluster shows significant differences of the four clustered municipalities to coffee rust disease severity (Table 13). The Typica coffee cultivated in Cluster 2: Kibungan and La Trinidad were severely infected with coffee rust followed by the coffee plants grown in Cluster 4: Sablan and Tublay. On the other

hand, the Typica coffee in Cluster 3: Kapangan, had moderate disease severity while those raised in Cluster 1: Atok, Bakun and Buguias were

Table 13. Bonferroni tabulate of coffee rust disease severity on Arabica
coffee var. Typica

CLUSTER/ MUNICIPALITY	MEAN PERCENT SEVERITY
1 = Atok, Bakun, Buguias	14.17[c]
2 = Kibungan, La Trinidad	74.0[a]
3 = Kapangan	38.5[c]
4 = Sablan, Tublay	69.5[b]

Means with common letters are not significantly different.

slightly infected. However, There were no significant differences of coffee rust severity between Cluster 1 and Cluster 3.

Sooty Mold Severity

Table 14 shows significant differences among clusters to sooty mold infection according to the Bonferroni one-way cluster analysis. The Typica coffee grown in Cluster 4 (Sablan and Tublay) were highly infected with sooty mold while those planted in Cluster 3 (Kapangan) were moderately attacked. On the other hand, the Typica raised in Cluster 1 (Atok, Bakun and Buguias) were slightly infected. Less infection was observed in Typica cultivated in Cluster 2 (Kibungan and La Trinidad). However, there were no significant differences to sooty mold infection of the Typica coffee grown in Cluster 1 and Cluster 2.

Table 14. Bonferroni tabulate of sooty mold disease severity on Arabica coffee var. Typica

CLUSTER/ MUNICIPALITY	MEAN PERCENT SEVERITY
1 = Atok, Bakun, Buguias	16.33^c
2 = Kibungan, La Trinidad	4.10^c
3 = Kapangan	54.0^b
4 = Sablan, Tublay	72.5^a

Means with common letters are not significantly different.

Cluster Classification of Plant Disease
Severity to Arabica Coffee
Variety Red Bourbon

The Complete Linkage Method gave four clusters of the municipalities of Benguet used in this study that have similar severity infection of coffee rust, sooty mold, brown-eye leaf spot and leaf blight to Arabica coffee var. Red Bourbon (Figure 4).   Cluster 1 composed of Atok and La Trinidad while Cluster 2 consisted of Bakun. Cluster 3 consisted of Buguias, Kapangan and Kibungan while Cluster 4 were Sablan and Tublay.

Biplot

The Biplot (Figure 5) reveals the severity of the plant diseases associated with Arabica coffee var. Red Bourbon grown in the different municipalities.

The Red Bourbon coffee planted in Sablan and Tublay (Cluster 4) were severely infected with sooty mold and leaf blight while those planted in Atok and La Trinidad (Cluster 1) were susceptible to brown-eye leaf spot. The Red Bourbon coffee grown in the other sample areas (Cluster 2 and Cluster 3) had minimal infection to coffee rust, sooty mold, brown-eye leaf spot and leaf blight as further shown by the Biplot.
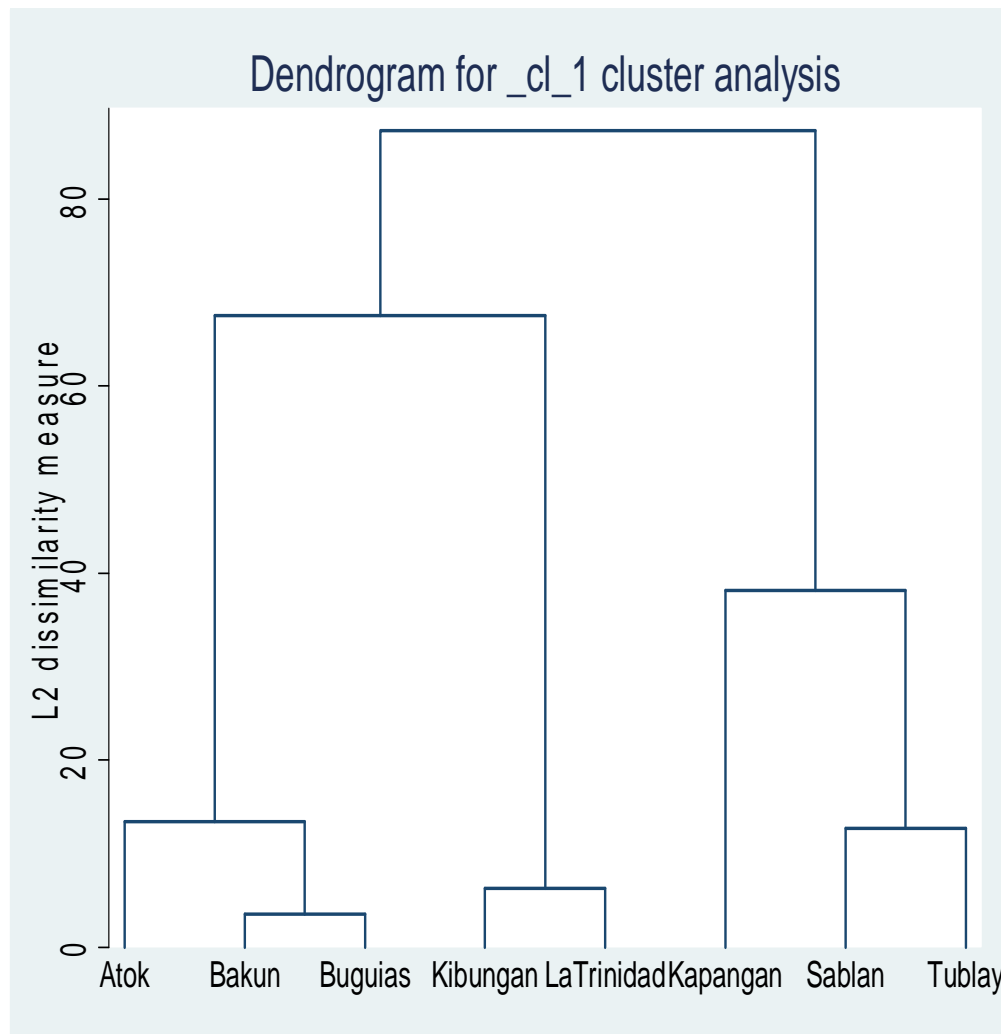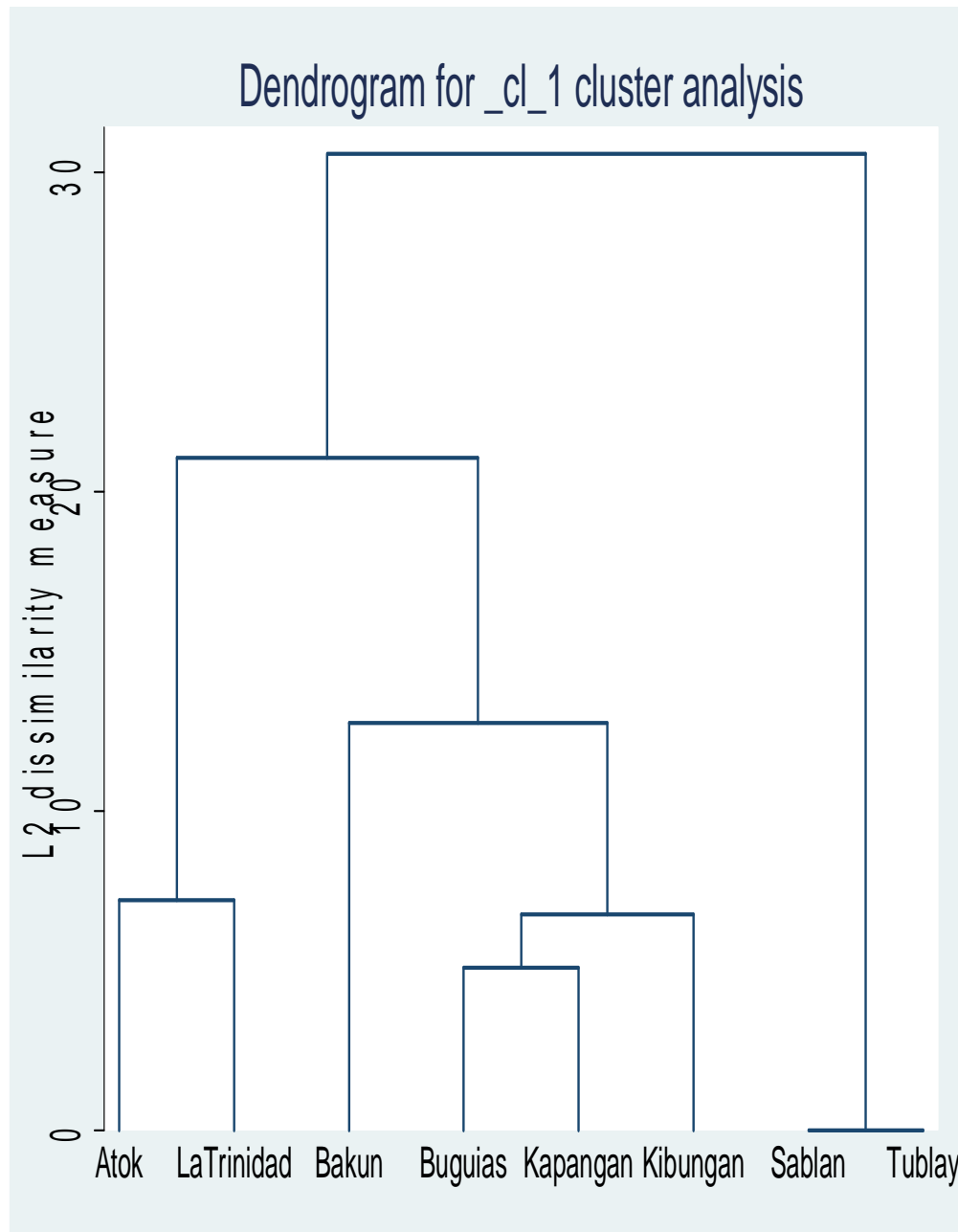
Figure 4.   Dendrogram of Complete Linkage Method of the clustered municipalities of Benguet that have similar disease severity to coffee rust sooty mold, brown-eye leaf spot and leaf blight to Arabica coffee var. Red Bourbon
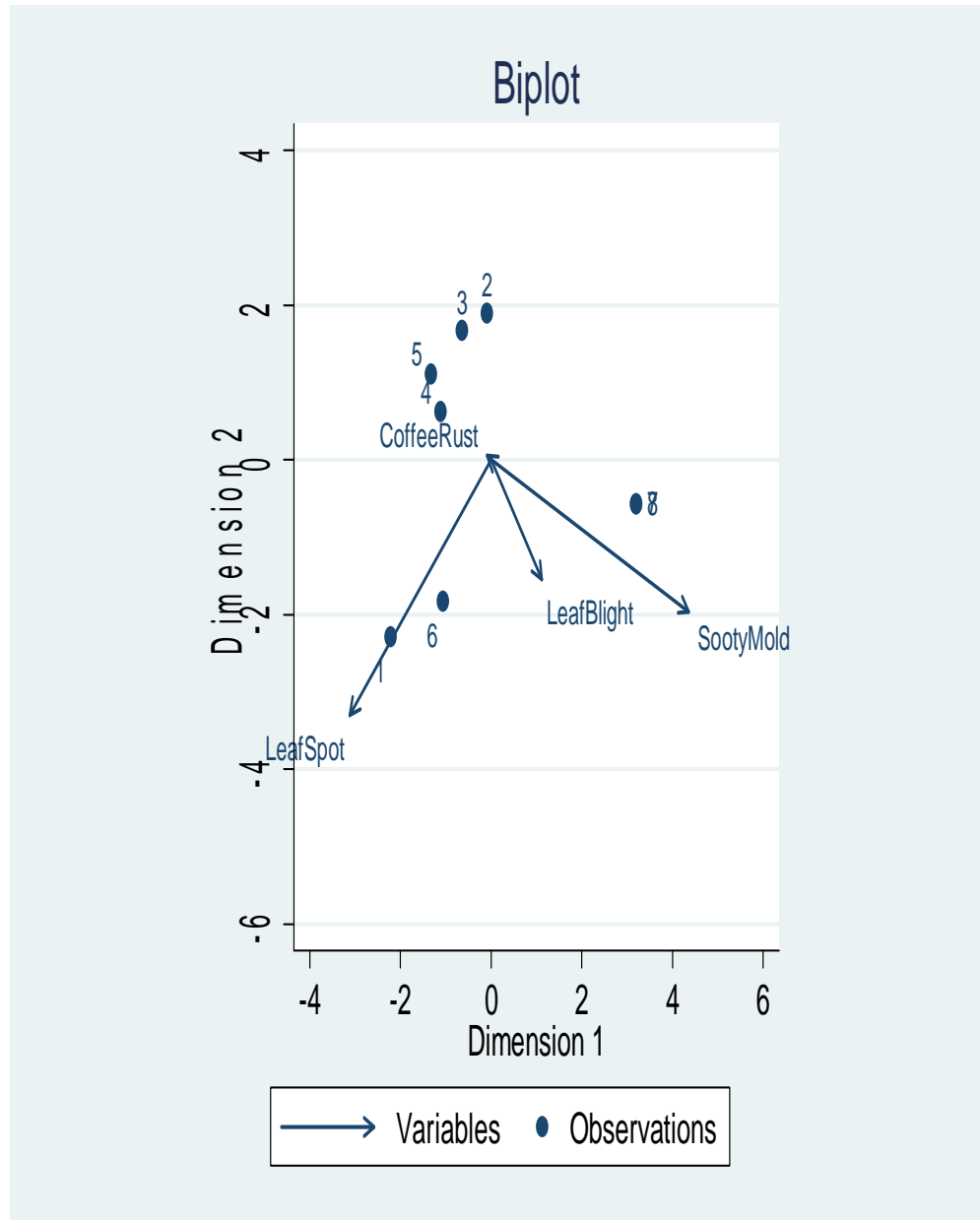
Figure 5.   Biplot of the plant diseases severity to Arabica coffee var. Red Bourbon cultivated in the different municipalities of Benguet

Coffee Rust Severity

The Bonferroni one-way cluster analysis showed no significant differences on the severity of coffee rust infection on the Red Bourbon coffee grown in the different cluster municipalities of Benguet. The areas have zero to very slight coffee rust infection.

Sooty Mold Severity

Statistical analysis found that there was a significant difference of sooty mold infection to Red Bourbon coffee cultivated on the different municipal cluster (Table 16). Cluster 4 (Sablan and Tublay) gave the highest severe infection to sooty mold disease compared to the other areas. The coffee trees of one municipality (La Trinidad) in Cluster 1 had slight infection but the severity were not significantly different to

Table 15. Bonferroni tabulate of coffee rust disease severity on Arabica coffee var. Red Bourbon

CLUSTER/ MUNICIPALITY	MEAN PERCENT SEVERITY
1 = Atok, Bakun, Buguias	0.30
2 = Kibungan, La Trinidad	0.40
3 = Kapangan	0.43
4 = Sablan, Tublay	0

Means with common letters are not significantly different.

Table 16. Bonferroni tabulate of sooty mold disease severity on
Arabica coffee var. Red Bourbon

CLUSTER/ MUNICIPALITY	MEAN PERCENT SEVERITY
1 = Atok, Bakun, Buguias	2.59^b
2 = Kibungan, La Trinidad	0^b
3 = Kapangan	0^b
4 = Sablan, Tublay	21.2^a

Means with common letters are not significantly different.

those exhibited by Red Bourbon coffee grown in Atok (Cluster 1), Bakun
(Cluster 2), Buguias, Kapangan and Kibungan (Cluster 3).

Brown-eye Leaf Spot Severity

Comparison of brown-eye leaf spot severity (Table 17) to Red bourbon
coffee among the different clusters found significant differences. Leaf spot
severely infected the Red Bourbon coffee planted in Cluster 1 (Atok and La
Trinidad) while moderate infection were observed in Cluster 3 (Buguias,
Kapangan, Kibungan). Slight infection was seen on coffee trees found in
Cluster 2 (Bakun) and Cluster 4 (Sablan and Tublay). However, further
analysis revealed no significant differences of brown-eye leaf spot infection to
the Red Bourbon trees grown in Cluster 2, Cluster 3 and Cluster 4.

Table 17. Bonferroni tabulate of brown-eye leaf spot severity on
Arabica coffee var. Red Bourbon

CLUSTER/ MUNICIPALITY	MEAN PERCENT SEVERITY
1 = Atok, Bakun, Buguias	20.25[a]
2 = Kibungan, La Trinidad	1.50[b]
3 = Kapangan	8.33[b]
4 = Sablan, Tublay	0.50[b]

Means with common letters are not significantly different.

Leaf Blight Severity

Statistical analysis on the severity of leaf blight disease to Arabica coffee variety Red Bourbon gave significant differences among the cluster municipalities (Table 18). The Red Bourbon planted in Cluster 4 (Sablan and Tublay) were highly infected with leaf blight. This was followed by the coffee trees grown in Cluster 1 (Atok and La Trinidad) and Cluster 2 (Bakun). However, no significant differences in the severity between these two clusters. On the other hand, the Red Bourbon coffee plants found in Cluster 3 (Buguias, Kapangan and Kibungan) were slightly infected by leaf blight.

Table 18. Bonferroni tabulate of leaf blight severity on Arabica coffee var. Red Bourbon

CLUSTER/ MUNICIPALITY	MEAN PERCENT SEVERITY
1 = Atok, Bakun, Buguias	10.50^{ab}
2 = Kibungan, La Trinidad	10.00^{ab}
3 = Kapangan	3.83^{b}
4 = Sablan, Tublay	12.50^{a}

Means with common letters are not significantly different.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The study was conducted in eight major Arabica coffee-growing municipalities of Benguet namely: Atok, Bakun, Buguias, Kapangan, Kibungan, La Trinidad, Sablan and Tublay. The study was conducted from July to October, 2006. The laboratory part was done at the Crop Protection Laboratory of the Benguet State University, La Trinidad, Benguet.

The study had the following objectives:

1. Collect, identify and document the different plant diseases associated with two Arabica coffee varieties namely Typica and Red Bourbon grown in Benguet Province.

2. Assess the incidence of the different coffee diseases, and,

3. Assess the severity of the diseases observed in the provinces, and

4. Correlate the effects of the environment particularly elevation, relative humidity and temperature to the coffee plant infection.

The study found that there were four diseases infecting the two Arabica coffee varieties Typica and Red Bourbon planted in these municipalities. These diseases were coffee rust (*Hemeliea vastatrix* B. and Br.), sooty mold (*Capnodium sp.*), brown-eye leaf spot or berry blotch (*Cercospora coffeicola*), leaf blight or berry rot (*Colletotrichum coffeanum*).

The study further revealed that the most prevalent disease associated with Arabica coffee variety Typica were coffee rust and sooty mold. On the other hand, the Arabica coffee variety Red Bourbon were dominantly affected by brown-eye leaf spot and leaf blight. These diseases were found in all the municipalities where the study was conducted. These diseases were observed infecting the leaves, berries, stems and twigs. Sooty mold and coffee rust were also seen to attack this coffee variety but infection was minimal.

The research also discovered that the degree of percent leaf infection to these diseases did not necessarily indicate the degree of whole plant infection. In addition, the disease occurrence and severity to the coffee plants varied from the different municipalities of collection and these places could be clustered into four groups using the Complete Linkage Method of statistical analysis. Plant disease severity was classified into severe, moderately sever and slightly infected.

Finally, the study found that the elevation, relative humidity and temperature in the municipalities concerned had no significant effect on the infection of these diseases to Arabica coffee variety Typica and variety Red Bourbon. However, it was observed that relative humidity had a positive significant correlation to coffee rust infection on Red Bourbon. The germination of the uredospores of this disease was favored by atmospheric moisture existing in the locality.

Conclusions

The findings of this study revealed that Arabica coffee var. Typica was susceptible to the diseases, coffee rust and sooty mold but was not affected by brown-eye leaf spot and leaf blight. On the other hand, Arabica coffee var. Red Bourbon was favored by brown-eye leaf spot and leaf blight diseases. However, slight infection to coffee rust and sooty mold were observed in this strain.

Finally, elevation, relative humidity and temperature existing in the different study areas had no significant effect on the development of these diseases to Typica. On the other hand, relative humidity significantly affected the infection of coffee rust to Red Bourbon.

Recommendations

Based on the informations obtained by this study, the following are recommended:

1. A year-round similar research should be done to capture the over-all disease assessment in Benguet Province. Included in the data to be collected will be rainfall, wind direction and speed, seed source and soil pH.

2. For purposes of field diagnosis, symptomatology can be used as basis for management since the symptoms of the Arabica coffee diseases had been confirmed in this study. However, further laboratory examinations and

tests should be done to the primary causal pathogen of the disease considering the disease complex in the field.

3. There is an urgent need for collection, breeding or selection on field trials of other Arabica coffee varieties resistant or tolerant to the identified plant diseases. Collection of other Arabica coffee varieties could be done locally or internationally.

4. This researcher has always emphasized during his lectures, trainings and seminars on Arabica coffee production and post-production, coupled by his long experience working on Arabica coffee that the following crop protection strategies could be adopted: 1) seed selection and use of disease-free planting materials; 2) rejuvenation of more than 10 years old coffee trees which are susceptible to pests and diseases; 3) proper cultural methods like correct planting distance and hole preparation, brush weeding, prompt pruning of infected coffee trees or tree parts, fertilization and irrigation; 4) planting of Arabica coffee to higher elevations at 1,000 – 1,800 meters above sea level with temperatures of 17°C - 24°C. This was found unfavorable for coffee rust disease; 5) practice of Agroforestry to promote biodiversity which increases natural enemies of pests and diseases; and 6) certification of accreditation of Arabica coffee nurseries by the Bureau of Plant Industry. Recommending pesticide application to prevent or control Arabica coffee diseases to local farmers is very expensive and not environment-friendly considering also the trend to organic farming.

5. Concerned agencies both government and non-government should continue to provide needed support to Arabica coffee farmers. These are in terms of technology development for Arabica coffee crop protection; seminars, trainings and lectures in integrated pest management; provision of disease-free planting materials and other necessary assistance to local farmers.

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APPENDICES

APPENDIX TABLE 1. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Caliking, Atok, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	5	10	5	10	10	10	15	10	10	5	90	9.0
Whole Plant	5	5	5	10	10	10	10	10	10	15	90	9.0
Sooty Mold												
Leaf	0	0	50	0	10	10	0	0	10	0	170	17.0
Whole Plant	0	0	25	0	25	0	0	0	50	0	100	10.0

Elevation : 1,650 meters above sea level
Relative Humidity : 69%
Temperature : 24°C

APPENDIX TABLE 2. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon in Caliking, Atok, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	0	0	1	0	0	1	1	0	0	0	2.00	0.20
Whole Plant	0	0	1	0	0	1	5	0	0	0	6.00	0.60
Sooty Mold												
Leaf	5	5	5	10	5	10	10	10	10	10	8.00	8.00
Whole Plant	25	20	10	25	25	25	25	25	25	20	2.25	22.50
Leaf Blight												
Leaf	5	20	20	5	5	10	10	10	10	20	11.50	11.50
Whole Plant	10	20	10	10	10	10	10	25	10	10	11.50	11.50

Elevation   : 1,650 meters above sea level
Relative Humidity   : 69%
Temperature   : 24°C

APPENDIX TABLE 3. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Ampusongan, Bakun, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	50	10	25	10	5	5	5	10	10	10	140	14.0
Whole Plant	25	10	25	10	5	5	5	20	25	20	150	15.0
Sooty Mold												
Leaf	50	50	25	5	5	5	25	50	25	5	240	24.0
Whole Plant	50	25	10	5	5	10	10	25	50	5	195	19.5

Elevation   : 1,230 meters above sea level
Relative Humidity   : 58%
Temperature   : 24°C

APPENDIX TABLE 4. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon in Ampusongan, Bakun, Benguet

DISEASE SEVERITY	TREE SAMPLE										TOTAL	MEAN
(%)	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	0	0	1	1	0	0	0	0	0	1	3.0	0.30
Whole Plant	0	1	1	1	0	0	0	0	0	1	4.0	0.40
Sooty Mold												
Leaf	5	5	5	5	5	0	5	0	5	0	35.0	3.50
Whole Plant	5	1	1	1	5	0	1	0	1	0	15.0	1.50
Leaf Blight												
Leaf	5	10	10	10	5	30	5	5	5	5	90.0	9.00
Whole Plant	10	10	10	10	10	10	10	10	10	10	10.0	10.0

Elevation   : 1,230 meters above sea level
Relative Humidity : 58%
Temperature   : 24°C

APPENDIX TABLE 5. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Poblacion, Buguias, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	10	20	10	35	10	20	35	10	10	20	180	18.00
Whole Plant	20	20	20	20	10	20	25	10	20	20	185	18.50
Sooty Mold												
Leaf	100	100	50	10	50	100	100	100	25	50	685	68.50
Whole Plant	50	50	50	5	50	50	80	80	50	50	515	51.50

Elevation   : 1,350 meters above sea level
Relative Humidity   : 77%
Temperature   : 25°C

APPENDIX TABLE 6. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon grown in Poblacion, Buguias, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	1	1	0	1	1	0	0	1	1	1	7.0	0.70
Whole Plant	1	1	0	1	1	0	0	1	1	1	7.0	0.70
Sooty Mold												
Leaf	5	5	5	5	5	5	5	5	5	5	15.0	1.50
Whole Plant	5	5	5	5	5	5	5	5	5	5	50.0	5.00
Leaf Blight												
Leaf	5	10	10	10	5	5	5	10	10	10	75.0	7.50
Whole Plant	5	5	5	5	5	5	5	5	5	5	50.0	5.00

Elevation   : 1,350 meters above sea level
Relative Humidity : 77%
Temperature   : 25°C

APPENDIX TABLE 7. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Lomon, Kapangan, Benguet

DISEASE SEVERITY	TREE SAMPLE										TOTAL	MEAN
(%)	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	50	50	100	50	100	75	100	50	100	100	77.5	77.5
Whole Plant	25	50	25	15	20	25	50	75	50	50	38.5	38.5
Sooty Mold												
Leaf	100	100	100	100	75	100	80	25	50	100	800.0	54.0
Whole Plant	80	80	50	50	80	50	25	25	50	50	540.0	54.0

Elevation   : 930 meters above sea level
Relative Humidity   : 68%
Temperature   : 26°C

APPENDIX TABLE 8. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon grown in Lomon, Kapangan, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	1	0	0	1	1	0	1	0	1	1	6.0	0.60
Whole Plant	1	0	0	1	1	0	1	0	1	1	6.0	0.60
Sooty Mold												
Leaf	5	5	10	5	5	5	5	10	5	5	60.0	6.00
Whole Plant	10	10	10	10	10	10	10	10	10	10	100.0	10.00
Leaf Blight												
Leaf	5	5	20	10	5	10	20	20	20	25	140.0	14.00
Whole Plant	5	5	5	5	5	10	5	5	10	5	10.0	1.00

Elevation   : 930 meters above sea level
Relative Humidity   : 68%
Temperature   : 26°C

APPENDIX TABLE 9. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Sagpat, Kibungan, Benguet

DISEASE SEVERITY	TREE SAMPLE										TOTAL	MEAN
(%)	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	75	50	75	20	50	50	75	20	10	50	475.0	47.50
Whole Plant	50	80	80	50	75	75	75	80	75	80	720.0	72.00
Sooty Mold												
Leaf	25	10	10	0	0	25	10	0	10	10	100.0	10.00
Whole Plant	10	10	10	0	0	10	10	0	10	5	65.0	6.50

Elevation   : 1,355 meters above sea level
Relative Humidity   : 62%
Temperature   : 24°C

APPENDIX TABLE 10. Leaf and whole plant severity percentages of diseases observed in Arabica coffee Var. Red Bourbon grown in Sagpat, Kibungan, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	0	0	0	0	0	0	0	0	0	0	0	0
Whole Plant	0	0	0	0	0	0	0	0	0	0	0	0
Sooty Mold												
Leaf	5	5	5	5	1	5	5	5	5	5	51.00	5.10
Whole Plant	10	10	10	10	10	10	10	10	10	10	100.0	10.0
Leaf Blight												
Leaf	5	5	0	5	0	0	0	20	5	5	5.00	0.50
Whole Plant	1	1	0	1	0	0	0	1	1	1	1.50	0.50

Elevation   : 1,355meters above sea level
Relative Humidity   : 62%
Temperature   : 24°C

APPENDIX TABLE 11.   Leaf and whole plant severity percentages of diseases observed in Arabica coffee Var. Typica grown in BSU-IHFSA, Puguis, La Trinidad, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	100	100	100	75	100	75	100	100	50	100	900	90.0
Whole Plant	80	80	80	80	80	75	75	80	50	80	760	76.0
Sooty Mold												
Leaf	50	50	0	0	1	50	0	0	1	0	13.2	13.2
Whole Plant	5	5	0	0	1	5	0	0	1	0	17.0	1.70

Elevation   : 1,380 meters above sea level
Relative Humidity   : 62%
Temperature   : 24°C

APPENDIX TABLE 12. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon grown in BSU-IHFSA, Puguis, La Trinidad, Benguet

DISEASE SEVERITY	TREE SAMPLE										TOTAL	MEAN
(%)	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	0	0	0	0	0	0	0	0	0	0	0	0
Whole Plant	0	0	0	0	0	0	0	0	0	0	0	0
Brown Eye Leafspot												
Leaf	25	10	25	10	5	5	10	25	25	25	165	1605
Whole Plant	25	25	25	25	25	10	5	5	5	25	180	18.0
Leaf Blight												
Leaf	25	5	5	10	5	2	5	10	10	10	70	7.0
Whole Plant	25	10	10	5	10	10	10	10	10	10	95	9.5
Sooty Mold												
Leaf	5	0	50	0	0	0	0	0	0	1	152	15.2
Whole Plant	10	0	25	0	0	0	0	0	0	1	52	5.2

Elevation : 1,380meters above sea level
Relative Humidity : 62%
Temperature : 24°C

APPENDIX TABLE 13. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Banangan, Sablan, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	100	100	75	100	75	50	100	100	100	100	900	90.0
Whole Plant	80	80	80	80	80	80	50	80	50	80	740	74.0
Sooty Mold												
Leaf	100	100	100	75	85	100	50	50	75	50	785	78.5
Whole Plant	80	80	80	80	50	50	80	80	50	80	680	68.0

Elevation   : 1,380 meters above sea level
Relative Humidity   : 62%
Temperature   : 24°C

APPENDIX TABLE 14. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon grown in Banangan, Sablan, Benguet

DISEASESEVERITY	TREE SAMPLE										TOTAL	MEAN
(%)	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	0	0	0	0	0	0	0	0	0	0	0	0
Whole Plant	0	0	0	0	0	0	0	0	0	0	0	0
Brown Eye Leafspot												
Leaf	10	10	10	10	10	10	10	5	5	5	85	8.5
Whole Plant	5	5	5	5	5	5	5	5	5	5	50	5.0
Leaf Blight												
Leaf	10	10	10	10	10	10	10	5	10	5	90	9.0
Whole Plant	5	5	5	5	10	5	5	5	5	5	55	5.5
Sooty Mold												
Leaf	25	0	0	0	0	1	10	0	0	0	36	3.6
Whole Plant	10	0	0	0	0	1	10	0	0	0	21	2.1

Elevation   : 1,110meters above sea level
Relative Humidity : 58%
Temperature   : 27°C

APPENDIX TABLE 15. Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Typica grown in Poblacion, Tublay, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	100	50	50	100	85	100	100	85	50	75	745	74.5
Whole Plant	80	80	80	80	80	80	80	80	50	50	650	65.0
Sooty Mold												
Leaf	100	50	100	100	100	50	80	50	100	100	830	83.0
Whole Plant	80	80	80	80	80	80	80	50	80	80	770	77.0

Elevation   : 1,175 meters above sea level
Relative Humidity : 55%
Temperature   : 24°C

APPENDIX TABLE 16.   Leaf and whole plant severity percentages of diseases observed in Arabica coffee var. Red Bourbon grown in Poblacion, Tublay, Benguet

DISEASE SEVERITY (%)	TREE SAMPLE										TOTAL	MEAN
	1	2	3	4	5	6	7	8	9	10		
Coffee Rust												
Leaf	0	0	0	0	0	0	0	0	0	0	0	0
Whole Plant	0	0	0	0	0	0	0	0	0	0	0	0
Brown Eye Leafspot												
Leaf	5	5	5	5	5	10	10	5	10	5	70	7.00
Whole Plant	5	10	10	5	5	10	5	5	5	5	65	6.50
Leaf Blight												
Leaf	10	10	10	10	10	10	5	5	10	10	85	8.50
Whole Plant	15	20	10	10	10	10	10	20	10	10	125	12.50
Sooty Mold												
Leaf	80	50	0	0	0	1	50	0	0	0	152	15.20
Whole Plant	80	80	0	0	0	1	50	0	0	0	212	21.20

Elevation   : 1,175meters above sea level
Relative Humidity : 55%
Temperature   : 24°C

APPENDIX TABLE 17.   Biplot of coffee rust and sooty mold severity to

Arabica coffee var. Typica grown in the eight municipalities of Benguet

MUNICIPALITY	DIM 1	DIM 2
Atok	-4.40	-1.54
Bakun	-3.22	-1.78
Buguias	-2.97	-1.46
Kapangan	1.19	-2.51
Kibungan	-0.14	4.49
La Trinidad	0.23	5.25
Sablan	4.85	-0.44
Tublay	4.91	-2.00
DISEASE	DIM 1	DIM 2
Coffee rust	6.3133	5.9949
Sooty mold	6.9183	-5.4706

APPENDIX TABLE 18. One-way coffee rust severity cluster, Bonferroni tabulate for Arabica coffee var. Typica

CLUSTER	MEAN	STANDARD DEVIATION	FREQUENCY
1=Atok, Bakun, Buguias	14.16	4.80	3
2 = Kibungan, La Trinidad	74.0	2.83	2
3 = Kapangan	38.5	0	1
4 = Sablan, Tublay	69.50	6.36	2

ANOVA TABLE

SOURCE OF VARIANCE	SS	Df	MS	F	Prob F
Between groups	5.768.83	3	1922.94	81.25	0.0005
Within groups	94.66	4	23.66		
TOTAL	5863.5	7	837.64		

APPENDIX TABLE 19. One-way sooty mold severity cluster, Bonferroni tabulate for Arabica coffee var. Typica

CLUSTER	MEAN	STANDARD DEVIATION	FREQUENCY
1=Atok, Bakun, Buguias	16.33	5.48	3
2 = Kibungan, La Trinidad	4.10	3.39	2
3 = Kapangan	54.00	0	1
4 = Sablan, Tublay	72.50	6.36	2

ANOVA TABLE

SOURCE OF VARIANCE	SS	Df	MS	F	Prob F
Between groups	6057.65	3	2019.22	71.99	0.0006
Within groups		4	28.0466		
TOTAL	112.19	7			

APPENDIX TABLE 20. Manova of coffee rust and sooty mold severity
cluster for Arabica coffee var. Red Bourbon

CLUSTER	STAT	F (df1)	F (df2)	F	Prob>F
1 = Atok, Bakun, Buguias	0.0003	6.0	6.0	55.07	0.0001
2 = Kibungan, La Trinidad	1.9627	6.0	8.0	70.16	0.0000
3 = Kapangan	115.2659	6.0	4.0	38.42	0.0017
4 = Sablan, Tublay	74.7834	3.0	4.0	99.71	0.0003
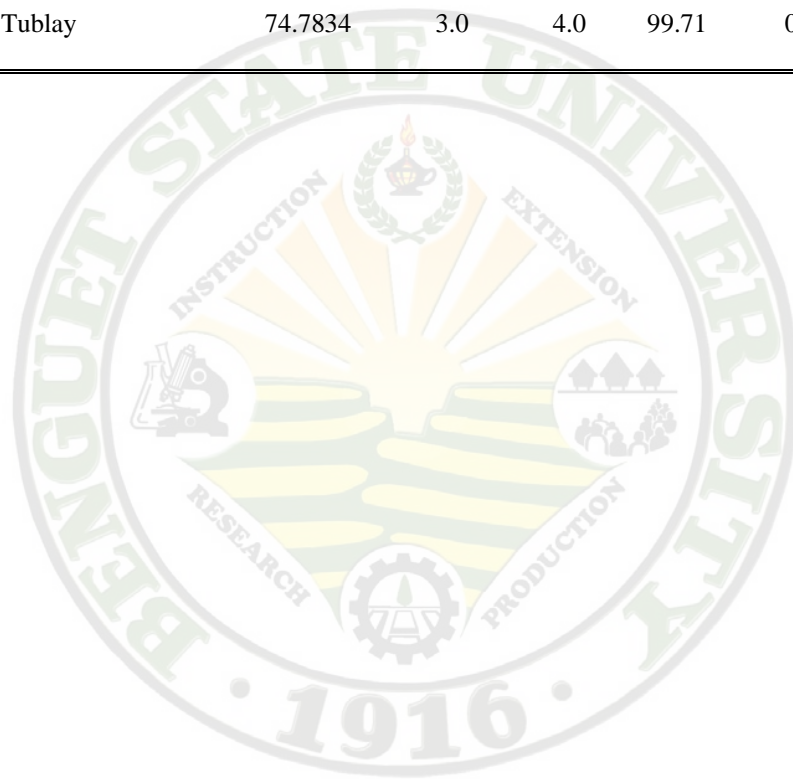
APPENDIX TABLE 21. Biplot of plant diseases severity to Arabica coffee var. Red Bourbon cultivated in the different municipalities of Benguet

MUNICIPALITY	DIM 1	DIM 2
Atok	-2.21	-2.29
Bakun	-0.08	1.88
Buguias	-0.63	1.66
Kapangan	-1.11	0.61
Kibungan	-1.32	1.11
La Trinidad	-1.06	-1.84
Sablan	3.21	-0.57
Tublay	3.21	-0.57
DISEASE	DIM 1	DIM 2
Coffee rust	-0.08	0.0531
Sooty mold	4.36	-1.96
Leaf spot	-3.11	-3.31
Leaf blight	3.20	-1.55

APPENDIX TABLE 22.   One-way coffee rust severity cluster, Bonferroni tabulate for Arabica coffee var. Red Bourbon

CLUSTER	MEAN	STANDARD DEVIATION	FREQUENCY
1 = Atok, Bakun, Buguias	.300	.424	2
2 = Kibungan, La Trinidad	.400	0	1
3 = Kapangan	.433	.378	3
4 = Sablan, Tublay	0	0	2

ANOVA TABLE

SOURCE OF VARIANCE	SS	Df	MS	F	Prob F
Between groups	.242	3	.806	0.69	0.6032
Within groups	.466	4	.116		
TOTAL	.287	7	.101		

APPENDIX TABLE 23. One-way sooty mold severity cluster, Bonferroni tabulate for Arabica coffee var. Red Bourbon

CLUSTER	MEAN	STANDARD DEVIATION	FREQUENCY
1 = Atok, Bakun, Buguias	2.59	3.68	2
2 = Kibungan, La Trinidad	0	0	1
3 = Kapangan	0	0	3
4 = Sablan, Tublay	21.20	0	2

ANOVA TABLE

SOURCE OF VARIANCE	SS	Df	MS	F	Prob F
Between groups	629.18	3	209.73	62.05	0.0008
Within groups	13.52	4	3.38		
TOTAL	642.70	7	91.81		

APPENDIX TABLE 24. One-way severity cluster, Bonferroni tabulate for Arabica coffee var. Red Bourbon

CLUSTER	MEAN	STANDARD DEVIATION	FREQUENCY
1 = Atok, Bakun, Buguias	20.25	3.18	2
2 = Kibungan, La Trinidad	1.50	0	1
3 = Kapangan	8.33	2.88	3
4 = Sablan, Tublay	.50	0	2

ANOVA TABLE

SOURCE OF VARIANCE	SS	Df	MS	F	Prob F
Between groups	453.21	3	151.06	22.55	0.0057
Within groups	26.79	4	6.69		
TOTAL	480	7	68.57		

APPENDIX TABLE 25. One-way leaf blight severity cluster, Bonferroni tabulate for Arabica coffee var. Red Bourbon

CLUSTER	MEAN	STANDARD DEVIATION	FREQUENCY
1 = Atok, Bakun, Buguias	10.5	1.41	2
2 = Kibungan, La Trinidad	10	0	1
3 = Kapangan	3.83	2.93	3
4 = Sablan, Tublay	12.5	0	2
TOTAL	8.44	4.25	8

ANOVA TABLE

SOURCE OF VARIANCE	SS	Df	MS	F	Prob F
Between groups	107.55	3	35.85	7.48	0.0407
Within groups	19.16	4	4.79		
TOTAL	126.72	7	18.10		

APPENDIX TABLE 26. Manova of sooty mold, leaf spot, leaf blight severity
cluster for Arabica coffee var. Red Bourbon

CLUSTER	STAT	F (df1)	F (df2)	F	Prob>F
1 = Atok, Bakun, Buguias	0.0002	9.0	5.0	17.22	0.0029
2 = Kibungan, La Trinidad	2.5757	9.0	12.0	8.09	0.0007
3 = Kapangan	110.1852	9.0	2.0	8.16	0.1139
4 = Sablan, Tublay	91.8935	3.0	4.0	122.47	0.0002