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Assessment of pests, natural enemies and soil microorganisms in lowland rice field under organic and inorganic production systems

W.B. DELA PEÑA♥, B.C. RATILLA
Department of Agronomy, College of Agriculture and Food Science, Visayas State University. Visca, Baybay City, Leyte 6521, Philippines.
Tel./fax.: +63-53-565-0600, ♥email: wencesrey.delapena@vsu.edu.ph

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Abstract. *Dela Peña WB, Ratilla BC. 2022. Assessment of pests, natural enemies and soil microorganisms in lowland rice fields under organic and inorganic production systems. Asian J Agric 6: 40-46.* Farmers readily use synthetic pesticides over organic and natural pest management strategies in controlling pests that may disrupt the ecological balance. This study assessed the population of insect pests, natural enemies, and soil microorganisms associated with lowland rice PSB Rc18 grown under different production systems. A lowland area at the Department of Agronomy, Visayas State University, Visca, Baybay City, Leyte, Philippines, was used to produce organic rice for four consecutive croppings. Results revealed that organic farmers' practice in Leyte (T2) showed a higher population of natural enemies, especially mirid bugs, fewer brown planthoppers, and green leafhoppers at 14-44 DAT and the number of folded leaves observed. However, conventional farmers' practices in Leyte (T3) had the highest incidence and severity of bacterial blight and rice blasts. On the other hand, bacterial and fungal microorganisms were found to be associated with the soil samples. Furthermore, the fungal population increased in both organic production systems compared to the conventional production system. Hence, organic production systems increased the number of beneficial insects and soil microbes' populations that may, directly and indirectly, affect pests and diseases in lowland rice.

Keywords: Lowland rice, microbial population, natural enemies, organic production system

INTRODUCTION

Lowland rice fields are considered a unique and varied ecosystem. It is characterized by rapid physical, chemical, and biological changes and has a large diversity of floral, faunal, and microbial species. Most of these species are beneficial, such as predators, parasitoids, and soil microorganisms (MEA 2005; Acosta et al. 2016). On the other hand, it is also home to several insect pests and diseases. Accordingly, about 44 diseases causing microorganisms (Hollier 1994) and about 187 species of insect pests (Yunus and Ho 1980) in rice are known to cause greater economic losses. It is estimated that the global losses in rice due to weeds, animal pests, and diseases reach 10.2%, 15.1%, and 12.2%, respectively, of the total rice production per year (Oerke 2006).

Studies have shown that organic crops are more resistant to pest attacks due to their thicker cell wall and lower free amino acid levels than conventional rice (Ramesh et al. 2005). Also, the presence of natural enemies is enhanced under organic systems, thus reducing the pest population (Hesler et al. 1993; Drinkwater et al. 1995). In addition, some insect species (lady beetles, ground beetle, crickets, long-horned grasshopper, water bugs, and damselfly) and spiders often control insect pests and maintain a balance insect population (Shepard et al. 1987. For instance, the hymenopteran parasitoids, *Telenomus dignus*, *Tetrastichus schoenobii*, and *Trichogramma japonicum* parasitize 75.29 to 97.56% of stem borer eggs (Rama et al. 2013). Jayakumar and Sankari (2010) also reported five spiders, namely: *Lycosa pseudoannulata*, *Callitrichia formosana*, *Tetragnatha javanas*, *Argiope catenulata*, and unidentified *Plexippus* species, that successfully reduced six different insect pests, such as *Nephotettix virescens*, *Scirpophaga incertulas*, *Cofana spectra*, *Cnaphalocrosis medinalis*, *Nilaparvata lugens*, and *Leptocorisa acuta*.

However, the production practices affect the ecological balance of different organisms within the rice ecosystem. With the extent to achieve the targeted potential yield of modern varieties nowadays, intensive crop management practices were introduced (Byerlee 1994). The higher application of synthetic fertilizers and periodic pesticide spraying resulted in environmental toxicity, pollution, eutrophication, soil acidity, and ecological imbalance (Vimpany and Kelly, 2004). Continuous application of synthetic insecticides also caused a resurgence of pests (Wu et al. 2001; Dutcher 2007; Matsumura and Morimura 2010) due to resistance build-up against insecticides and reduction in natural enemy populations, disrupting the natural balance of insect pests and their natural enemies (Hardin et al. 1995). Furthermore, applying a large amount of chemical fertilizer and pesticide in the agricultural soil reportedly resulted in increased heavy metals like Cadmium (Cd), Lead (Pb), and Arsenic (As) that pose negative effects on the soil fauna (Atafar et al. 2010). Liu et al. (2011) reported a significant reduction in microbial diversity and population in paddy soil due to the intensive application of inorganic inputs.

Organic farming is one of the possible solutions that could address the problems mentioned above while also addressing food and resource sustainability, health, and environmental issues. It reduces the use of agrochemicals, thereby enhancing productivity without destroying the ecosystem balance and harming farmers, consumers, and the environment, hence observed in this study.

MATERIALS AND METHODS

This study focused only on evaluating the effects of different production systems on pests, natural enemies, and soil microorganisms in the lowland rice field. A total 782 m^2 lowland experimental area at the Department of Agronomy devoted to various production systems for four consecutive croppings with similar treatment applications was used. In addition, a Randomized Complete Block Design (RCBD) with three treatments and four replications separated by a 2 m alleyway used by the previous croppings was retained. Each treatment plot measured 5 m x 6 m with 750 hills of lowland rice spaced at 20 cm x 20 cm.

The following treatments were as follows: (i) T1= Best bet organic production system (green manuring + green leaf manuring + vermicast + vermitea + fermented plant juice (FPJ) + fermented fruit juice + organic insecticide (rumphii "*panyawan*" based extract). (ii) T2= Organic farmers' practice in Leyte (vermicast + FPJ + vermitea + fermented fruit juice + organic insecticides (rumphii "panyawan" based extract). (iii) T3= Conventional farmers' practice in Leyte (urea + complete + Karate a.i. lambda-cyhalothrin + Lannate a.i. methomyl)

Field management and treatment application

A month after harvesting the previous cropping, mungbean (*Vigna radiata* L.) seeds were broadcasted at 30 kg/ha to the best bet organic production system (T1) plots without tilling the soil. When the mungbean reaches the flowering stage, it is plowed and mixed in the soil combined with the kakawate [*Gliricidia sepium* (Jacq.) Kunth] leaves at a rate of 2 kg m^{-2} and allowed to decompose for three weeks before transplanting. Plowing was done twice weekly without disturbing the previous croppings' layout. In addition, dikes and canals around the experimental plot were cleaned, fixed, and repaired.

Three sets of PSB Rc 18 seeds were soaked and incubated separately, and the seeds for T1 were coated with microbial slurry (20% solution of MykoPlus). Pre-germinated seeds for T1 and T2 were sown evenly in a prepared wet bed applied with vermicompost at a rate of 0.5 kg m^{-2}, while T3 seeds were sown in a seedbed applied with complete fertilizer at a rate of 30 g m^{-2}. After sowing, these seedlings were reared and transplanted 21 days after sowing to their respective treatment plots. Seedlings were transplanted at a 20 x 20 cm planting distance. Seedlings planted in T_1 were dipped in the microbial slurry before planting. Replanting was done on the missing hills five days after transplanting (DAT) to maintain the plant population.

FPJ, fruit juice, and vermitea were applied as foliar sprays for T1 and T2. For T1, vermitea and 10% solution of FPJ were sprayed alternately at weekly intervals two weeks after transplanting up to the flowering stage. T2 was applied with a mixture of FPJ and vermitea spray at weekly intervals starting two weeks after transplanting up to the flowering stage at a rate of 30 mL of each foliar supplement per liter of water. At the panicle initiation stage, fermented fruit juice was sprayed at weekly intervals for T1 and T2 at 30 mL per liter of water up to two weeks before the harvesting date. Spraying of foliar fertilizers was done at 4 p.m. when sunlight was not so intense. For T3, synthetic fertilizer at a rate of 109.04 -17.5-17.5 kg N, P_2O_5, K_2O ha^{-1}.

Weeds were controlled manually throughout the experiment, and proper water management was employed. For the pests and diseases, T1 and T2 were sprayed with organic-based insecticides (*Tinospora rumphii*-based extract), while T3 was applied with chemical insecticide lambda-cyhalothrin during the vegetative and methomyl insecticide during the heading stage. Moreover, to prevent contamination of spray mists of chemical pesticides to organic treatments, a plastic enclosure was provided during spraying around the conventional treatment plots.

Statistical analysis

Analysis of variance on data gathered was done using the Statistical Analysis Software (SAS) Version 9.2 developed by SAS Institute. In addition, a comparison of means was made using Tukey's Honestly Significant Difference (HSD) test.

Data gathered

Disease incidence of major rice diseases

Disease incidence was determined at 30, 60, and 90 days after transplanting by counting the number of infected hills within the harvestable area. That was calculated using the formula:

$$\text{Disease incidence (\%)} = \frac{\text{no. of infected hills}}{\text{total no of hills}} \times 100$$

Disease severity of the observed diseases

Rice blast. The severity of blast infection was determined by visual observation of the ten sample plants randomly selected within the harvestable area in each treatment plot using the following rating scale (IRRI 1996).

Bacterial leaf blight. This blight was obtained by measuring the length of the lesion from the 3rd fully expanded leaf of the infected plants.

Table 1. Rice blast scale rating by IRRI (1996)

Rating	Description
0	no infection
1	less than 1% area affected
3	1-5% area affected
5	6-15% area affected
7	26-50% area affected
9	51-100% area affected

The population of insect pests and beneficial insects

This population was determined by sweeping each treatment plot using a swept net. Swept insects were identified and counted with the aid of a hand lens. Sampling was done at 14, 44, and 74 DAT.

Insect damage

This damage was assessed by counting the number of folded/rolled leaves, dead hearts, whiteheads, and other insect damage observed within the harvestable area of each treatment plot throughout the production period.

Grain yield

After cleaning, this yield was determined by weighing the grains from the harvestable area (12 m2) of each treatment plot. In addition, the number of hills harvested in each plot was counted. Moisture content (MC) was determined before weighing using a grain moisture tester. Grain yield was adjusted to 14% MC using the formula:

$$\text{Adjusted Grain Yield at 14\% MC} = \frac{100\% - \text{MC (\%) of grains at harvest}}{100\% - \text{Desired MC (14\%)}} \times \text{Grain yield at harvest (kg)}$$

The weight per plot will be converted to tons per hectare using the formula:

$$\text{Grain yield (t ha}^{-1}) = \frac{\text{Plot yield (kg)}}{\text{Harvestable area (20 m}^2)} \times \frac{10{,}000\ \text{m}^2\ \text{ha}^{-1}}{1{,}000\ \text{kg t}^{-1}}$$

Soil microbial analysis

Soil samples from each treatment plot at a depth of 20 cm were collected using a soil auger. Freshly collected samples were submitted to Plant Disease Diagnostic Laboratory, Visayas State University, Visca, Baybay, Leyte, for microbial identification and colony count at mL^{-1}.

RESULTS AND DISCUSSION

Incidence and severity of rice diseases

The incidence and severity of the major rice diseases throughout the production period are presented in Table 2. Variance analysis showed that tungro disease occurrence was significantly higher in T2, while T1 and T3 are comparable. The higher incidence of tungro in T2 could be due to the lower amount of nutrients applied compared to the other treatments involved in the study. According to Rillon et al. (1998), rice plants treated with additional N fertilizer during the production period showed significantly lower symptoms. They concluded that the application of N enabled the plants to recover from RTSV and RTBV disease, thereby reducing the disease infection.

Lower incidence and severity of bacterial blight and rice blast diseases were observed in T1 and T2 compared to T3. These results could be due to the higher nitrogen applied in the conventional production system, which favored the disease infection spread. Long et al. (2000) reported that applying nitrogen at a higher rate significantly increases blast incidence and total lesion regardless of cultivar. Kurschner (1992) also mentioned that increasing Nitrogen application increases leaf blast due to increases in tissue susceptibility and canopy density. Moreover, Chaudhary et al. (2009) reported that nitrogen application also affects bacterial leaf blight incidence and severity. They found that different N doses caused 6.67 to 55.11% bacterial leaf blight incidence under research field conditions and 7.12 to 62.00% under farmers' field conditions.

The population of insect pests and beneficial insects

The population of five dominant insects throughout the production period: black bug, brown planthopper (BPH), green leafhopper (GLH), grasshopper, and rice bug in the field is presented in Figure 1. The mean number of BPH and GLH showed the lowest in plants under T2 at 14, and 44 DAT, compared to T1.T3 had the highest, which eventually reduced to 74 DAT regardless of treatments. As expected, the mean number of rice bugs greatly increased at 74 DAT when rice had already reached the milking stage. However, a higher number of rice bugs were observed at T_3 while the least in T_1. On the other hand, only fewer grasshoppers and black bugs were observed throughout the production period.

The more GLH and BPH in T_3 is likely due to the higher fertilization. Higher N's application increases BPH's feeding and oviposition (Wang and Wu 1991) and GLH (Karnataka 2011). The increase in the amino acid content of rice sap and more succulent plants due to high nitrogen fertilization could also improve the nutritional conditions for sap-sucking insects, thus increasing their population (Balasubramanian et al. 1983). On the other hand, the reduction of BPH and GLH in T_2 could also be related to the higher population of mirid bugs, as indicated in Figure 2. Manti (1990) reported that a mirid bug is a predatory insect of hoppers' egg that consumes up to 61.23-143.68 eggs in the total lifetime of a single matured mirid bug.

Table 2. Incidence and severity of rice diseases of lowland rice PSB Rc18 as affected by different production systems

Treatments	Tungro incidence	Rice blast		Bacterial blight	
		Incidence	Severity	Incidence	Severity
T1	4.17[b]	2.58[b]	0.27[b]	2.50[b]	18.67[ab]
T2	7.83[a]	2.42[b]	0.15[b]	3.67[b]	11.60[b]
T3	5.42[b]	9.17[a]	1.08[a]	18.25[a]	26.17[a]
Mean	5.80	4.72	0.50	8.14	18.81
CV %	11.61	27.85	22.85	21.25	21.50

Note: Means within each column followed by a common letter and those without designation are not significantly different based on HSD and ANOVA, respectively. Legend: T1: Best bet organic production system, T2: Organic farmers' practice in Leyte, T3: Conventional farmers' practice in Leyte

Moreover, the population of five dominant beneficial insects, namely: damselfly, long-horned grasshopper, lynx spider, mirid bug, and wasp at 14, 44, and 74 DAT, is presented in Figure 2. Results showed that more long-horned grasshoppers and damselfly were noted in T3 at 14 DAT of rice, which subsequently reduced as the crop matured at the succeeding sampling periods. On the other hand, the mirid bug was higher in T2 at 14 and 44 DAT, eventually reducing at 74 DAT.

The Lynx spider population was also higher in both organic production systems (T1 and T2) than in T3 in all sampling periods. On the other hand, higher wasps were observed in T2 at 44 DAT compared to the other production systems. However, no wasp was observed at 14 DAT and fewer at 74 DAT. The reduction of beneficial insects at a later stage (74 DAT) was due to the spraying of organic insecticides (rumphii "panyawan" based extract) in T1 and T2 and chemical insecticide in T3, which either deter or kill the beneficial insects.

The total population of insect pests and beneficial insects at 14, 44, and 74 DAT is presented in Figure 3. The graph shows that the mean number of beneficial insects was higher at 14 and 44 DAT and eventually reduced at 74 DAT. However, the mean number of insect pests increased at 74 DAT while the number of beneficial insects reduced.

The fewer insect pests at an earlier sampling period were possibly due to the reasonable number of beneficial insects and lesser infestation during earlier days of crop establishment. On the other hand, the reduction of beneficial insects in the later sampling period was perhaps due to the spraying of organic insecticide in organic treatments T1 and T2 and chemical insecticide in T3. Therefore, the later increase in insect pests population was mainly attributed to the increased number of rice bugs during the milking stage and the reduction of beneficial insects due to spraying.

Yield and insect damage

Table 3 shows rice yield and insect damage as affected by the different organic production systems throughout the production period. Analysis of variance revealed that there was no significant difference in the number of dead hearts and whiteheads. However, a higher number of folded leaves were observed in T3, which was 93.30% higher than in T2, followed by T1 with 37.50 folded leaves. This result may be attributed to the higher N concentration in conventional farmers' practices in Leyte, which conforms to the findings of Singh and Shahi (1984). They noted an increasing damage rate at increasing N application. For example, at 30 kg nitrogen/ha, the leaf folder damage rate reached 11.03%, while at 60 and 150 kg N/ha, leaf damage increased to 15.33% and 15.06-16%, respectively.

A significantly higher percentage of unfilled spikelets was observed in T1 and T3, while the lowest was in T2. On the other hand, no significant difference was observed in grain yield, indicating a comparable grain yield of rice between organic and inorganic production systems. The higher number of unfilled spikelets is mainly due to the higher number of black bugs and rice bugs in T1 and T3.

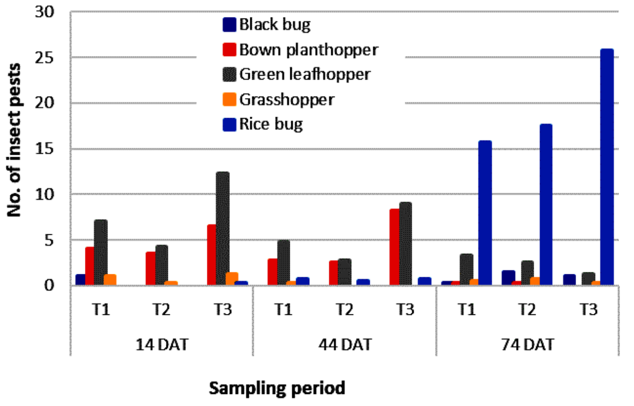

Figure 1. Population assessment of insect pests at 14, 44, and 47 DAT as affected by different production systems

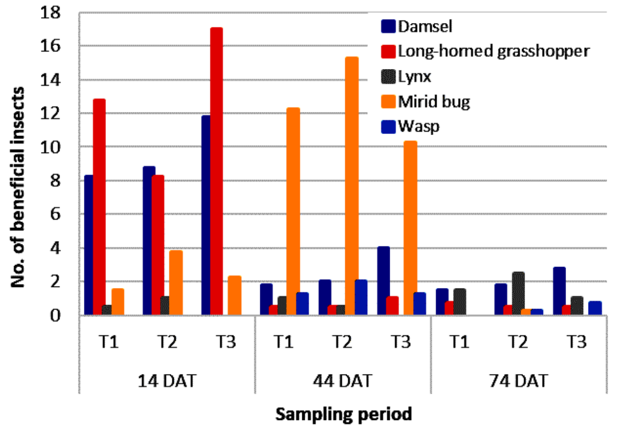

Figure 2. Population assessment of beneficial insects at 14, 44, and 74 DAT as affected by different production systems

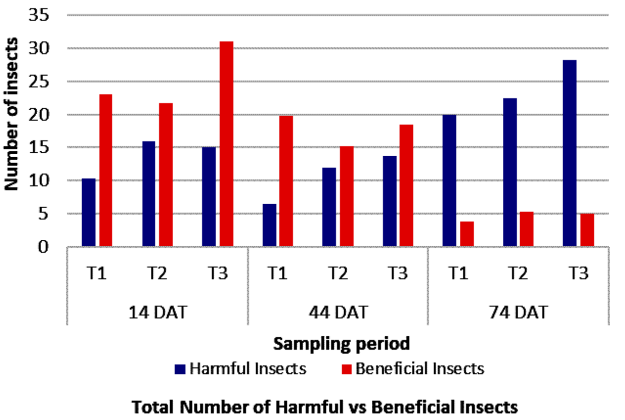

Figure 3. Population assessment of insect pests versus beneficial insects at 14, 44, and 47 DAT as affected by different production systems

Soil microbial analysis

Table 4 presents the microbial counts (cfu mL^{-1}), while Figures 4 and 5 show the bacterial cells and fungi associated with the sample. Initial and final microbial analysis indicated bacterial and fungal microorganisms were associated with the soil samples. Regardless of the treatment, bacterial and fungal colony count mL^{-1} increased at the final analysis relative to the initial count. However, colony-forming unit mL^{-1} of fungi in T1 and T2 showed a reasonably higher increase in count than in T3. The microorganism species associated with T1 were *Bacillus, Chromobacterium, Coccobacillus,* and *Aspergillus*. In T2, *Chromobacterium, Bacillus, Coccobacillus, Aspergillus,* and *Trichoderma* were observed, while T3 observed *Chromobacterium, Bacillus, Coccobacillus, Aspergillus*, and *Fusarium.* These are saprophytic soil-inhabiting microorganisms which are the major decomposers of organic matter (Gomes et al. 2014; Sudrajat et al. 2019). The higher increase of microorganisms in both organic production systems compared to conventional farmers' practices in Leyte could be attributed to the application of organic fertilizer. Bot and Benites (2005) reported that most fungi, bacteria, and actinomycetes rely on organic materials for their carbon and energy needs.

Table 3. Insect damage of lowland rice PSB Rc18 as affected by different production systems

Treatments	Insect damage		Percentage unfilled spikelet panicle^{-1}	Grain yield (t ha^{-1})
	Folded leaves	Dead hearts and whiteheads		
T1	37.50^b	44.00	45.04^a	3.03
T2	4.50^c	69.25	30.43^b	3.26
T3	67.25^a	42.75	50.15^a	3.08
Mean	46.33	52.01	41.87	3.12
CV %	29.75	28.19	13.45	12.75

Note: Means within each column followed by a common letter and those without designation are not significantly different from each other based on HSD and ANOVA, respectively

Table 4. Microbial counts (cfu mL^{-1}) of microorganisms associated with soil samples from different production systems using potato dextrose agar (PDA) and nutrient agar (NA)

Treatment	Microorganism (cfu/mL)			
	Bacteria		Molds/fungi	
	Initial	Final	Initial	Final
T1	1.17x 105	2.33 x 105	3.00 x 102	4.03 x 103
T2	2.60 x 105	4.63 x 105	1.33 x 102	3.00 x 103
T3	2.47 x 105	4.66 x 105	2.00 x 102	1.47 x 103

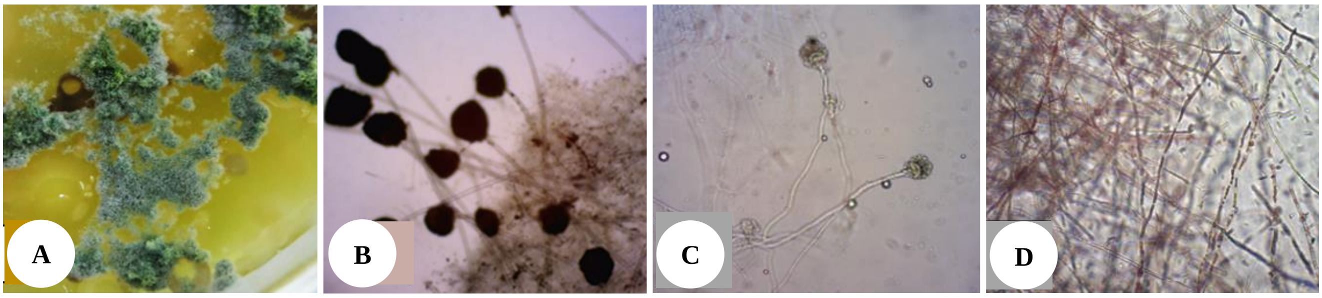

Figure 4. Molds/fungal isolates found associated with soil samples. A. *Trichoderma sp*.; B. *Aspergillus niger*; C. *Aspergillus* sp.; D. *Fusarium* sp.

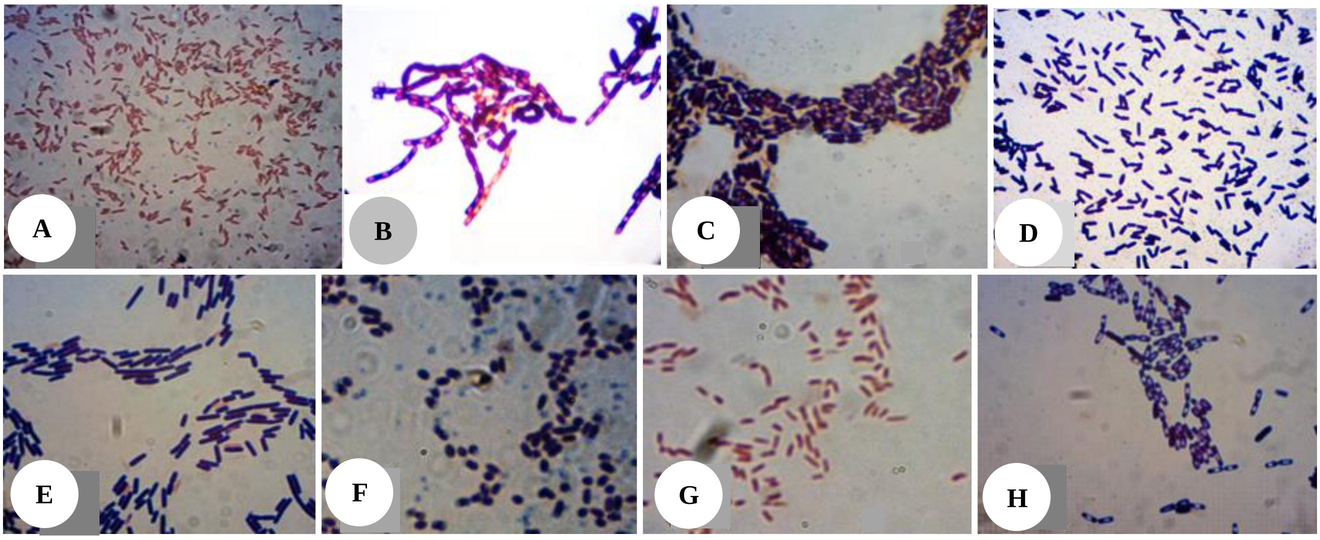

Figure 5. Cells of the bacteria isolate; A. *Chromobacterium* sp.; B. *Bacillus* sp.; C. Flat, a slimy, dirty white colony with irregular margin and Gram-positive rod-shaped endospore-forming *Bacillus* sp.; D. Semi-dry flat, dirty white colony with highly lobate margin, Gram-positive, short rod-shaped, *Bacillus* sp.; E. Dirty white, filamentous and flat colony, Gram-positive rod-shaped *Bacillus* sp.; F. *Cocobacillus* sp.; G. Slimy dirty white lobate colony, Gram-negative rod-shaped *Bacillus* sp.; H. Dirty white, flat, irregular colony, Gram-positive rod-shaped endospore-forming bacterium *Bacillus* sp.

In conclusion, lower incidence and severity of rice blast and bacterial blight but higher tungro virus incidence was observed in rice grown in organic farmer's practice in Leyte compared to the conventional practice. Conventional farmers' practices in Leyte had a slightly higher number of harmful insects such as brown planthopper, green leafhopper, and rice bug. In contrast, organic farming practices in Leyte had the highest number of beneficial insects, like the mirid bug as a predatory insect. The number of folded leaves observed was lowest in organic farmers' practice in Leyte while highest in conventional farmers' practice. The different production systems did not significantly affect the number of dead hearts, whiteheads, and grain yield, but lower unfilled grains were observed in organic farmers' practices in Leyte. The population and diversity of microorganisms are higher in organic farmers' practices in Leyte.

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