Number and Activity of Microorganisms in Organic and Conventional Soil in Subak Blongyang Tabanan, Bali, Indonesia

Rio Jonathan Avianto[1], Ni Luh Kartini[1*], Ni Nengah Soniari[1]

[1]Agrotechnology, Agriculture Faculty, Udayana University, Denpasar 80235, Bali, Indonesia

**Correspondence*: luhkartini@unud.ac.id

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Abstract: Microorganisms are most broadly used as an indicator of soil fertility and quality. Organic farming is an agricultural technique that does not use synthetic pesticides or fertilizers, believed to be a solution to the negative impacts of conventional farming systems. This study aimed to compare soil microbial numbers and activities in organic and conventional paddy fields and determine their influencing factors in *Subak* Blongyang, Tabanan, Indonesia. The research methods comprised literature study, field survey, soil sampling, and soil analysis in the laboratory, with soil respiration as a measure of microbial activity. Afterward, the data derived were tabulated and analyzed descriptively. Results show that the total microorganisms (19.16×10^6 cfu/g) and soil respiration (8.58 mgC-CO_2/kg/day) in organic paddy fields were higher than in samples collected from conventional paddy fields (2.46×10^6 cfu/g; 5.82 mgC-CO_2/kg/day). Similarly, the laboratory tests of various supporting variables indicate that soils in the former were always more favorable for microbial growth and activities than the latter, as seen from total-N, organic-C, organic matter, C/N ratio, and soil pH.

Keywords: conventional farming, microbial activity, organic farming, paddy field soil, total microorganisms.

1. Introduction

Soil is one of the main natural resources that is very influential for the life of living things. Soil is home to millions of organisms from a large number of species. Soil resources are soil biological reservoirs that play an important role in improving soil quality. Soil quality is the ability of the soil to function in land use or ecosystems to support biological productivity, maintain environmental quality and improve plant, animal and human health (Soil Science Society of America, 1994).

Microorganisms are an important aspect which is an indicator of soil fertility and soil quality (Atmaja, 2017). Microorganisms use O2 and emit CO2 which is used as the basis for measuring soil respiration. The rate of respiration is affected by the large population of microorganisms in the soil that emit CO2 and the amount of O2 needed by these microorganisms. Measurement of soil respiration reflects more the metabolic activity of microorganisms than the number, type, or development of soil microorganisms (Anas, 1989).

The total number of microorganisms present in the soil is used as a soil fertility index. Fertile soil will contain a large number of microorganisms. The total number of microorganisms can be influenced by various factors, including chemical and physical aspects in the soil. The number of microorganisms can also be affected and affect Nitrogen levels in the soil and soil pH. Nitrogen, Carbon and soil microorganisms are interrelated and influence each other in the soil. Soil respiration is one indicator of microbial activity in the soil. Soil respiration is a way to determine microbial activity, characterized by the higher the soil respiration, the higher the microbial activity (Fitriana *et al*.,2022). Determination of soil respiration is based on determining the amount of CO2 produced by soil microbes and the amount of O2 used by soil microbes.

Subak Blongyang is the widest subak in Tabanan district, stretching from the foot of Mount Batu Karu to the beach. Subak Blongyang located in Megati Kaja is included in group 1 or subak Aseman 1, covering an area of 37 hectares with 46 farmers. To the west it is bordered by Jelijih Village, to the east by Gunung Salak Village and to the south by the Denpsar-Gilimanuk highway. Irrigation water for the needs of Subak Blongyang is relatively insufficient, because only the upstream part can grow two rice crops, and the rest is only one rice crop. This is caused by a number of causes, including: frequent rice cultivation experiences crop failure, increasing fertilizer prices are often not balanced with yield values, low productivity of rice plants, and increasing taxes, and others (Sunarta *et al*., 2016).

Organic farming is an agricultural technique that does not use chemicals (non-synthetic), but uses organic materials. Organic farming according to IFOAM is an integrated production management system that avoids the use of artificial fertilizers, pesticides and genetic engineering products, reduces air, soil and water pollution. Organic farming is a solution to the negative impacts of conventional farming systems. The application of organic farming systems is able improve soil biological characteristics by increasing soil respiration, total soil microorganisms (Margolang *et al*.,2014). Conventional farming systems use a lot of chemical residues and are not suitable for ensuring long-term environmental sustainability. Organic farming systems play a role in improving soil biological properties as a source of energy and food for soil micro and meso fauna which will increase the number and activity of soil organisms, increase nutrient availability, increase soil nutrient cycles, and form soil macro and micro pores by microorganisms. One of the efforts to increase land productivity and avoid land conversion is agricultural innovation by implementing organic farming systems. This will improve soil quality and land productivity, as well as increase product selling power and prices so as to improve the welfare of local farmers. The research was conducted to determine the differences in the number and activity of microorganisms and the effect of pH, total-N, organic-C, organic substance, and C/N ratio on the number and activity of microorganisms in organic and conventional paddy soil in Subak Blongyang, Tabanan.

2. Methodology

2.1 Location

This research was conducted from January to April 2023 in Subak Blongyang in Jelijih Tegeh Banjar, Megati Village, Selemadeg Timur District, Tabanan. They were later brought to the Soil Laboratory, Faculty of Agriculture, Udayana University, for further analyses of selected variables, including total microorganisms, soil respiration, soil pH, organic carbon (C-organic), and total nitrogen.

2.2 Materials

The tools used in the field included hoes/shovels, plastic, and cooling boxes. To determine the variables in the laboratory, the materials used were nutrient agar, NaCl, KOH, distilled water (Aqua Dest), phenolphthalein (PP) indicator, methyl orange, 0.1N HCl, 30% sodium hydroxide, 1% boric acid, selenium reagent mixture, concentrated sulfuric acid, nitrogen indicator, ferro sulfate, Diphenylamine (DPA), phosphoric acid, potassium bichromate, 30% sodium hydroxide. The laboratory equipment consisted of Petri dishes, test tubes, pipettes, autoclaves, Erlenmeyer flasks, jars, plastic film bottles, tapes/duct tapes, buret, stoves, scales, Kjeldahl flasks, distillation apparatus. During the analyses, acids were prepared or added in a fume hood.

2.3 Study design

It was comprised of five stages: literature study, (preliminary) field survey, soil sampling, laboratory analysis, and data tabulation and analysis. The preliminary survey determined sampling points for data collection and gathered information on soil treatment in each paddy field in the subak. Soil samples were collected in the morning to prevent damage or deterioration. Twenty samples were obtained: ten from paddy fields with organic farming systems and ten from conventional systems.

3. Results

3.1 Total Nitrogen, Organic Carbon, and C/N Ratio of Soils in Organic and Conventional Paddy Farming

Table 1 shows the total nitrogen, organic carbon (C-organic), and C/N ratio of twenty soil samples from organically and conventionally cultivated paddy fields. The total nitrogen varied from 0.18 to 0.29% in fields with organic farming systems and 0.16 to 0.24% in conventional systems. The C-organic was identified in the range of 3.39–4.68% for organic and 2.97–4.63% for conventional farming. C-organic is a component of soil organic matter that measures the presence of organic matter in the soil (Nopsagiarti et al., 2020). The C/N ratios between the two types of paddy fields were also different, namely 16.13–19.36 for the organic system and 16.91–21.43 for the conventional one. However, the latter had a higher mean C/N ratio (18.95) than the former (17.73).

Table 1. Total Nitrogen, Organic Carbon, and C/N Ratio of Soils in Organic and Conventional Paddy Farming Systems

Num.	Total Nitrogen (N-total) (%)		Organic Carbon (C-Organic) (%)		C/N Ratio	
	Organic Soil	Conventional Soil	Organic Soil	Conventional Soil	Organic Soil	Conventional Soil
1	0,27	0,20	4,36	3,84	16,14	19.20
2	0,22	0,17	4,26	3,41	19,36	20,05
3	0,22	0,16	3,84	2,98	17,45	18,62
4	0,21	0,20	3,85	3,42	18,33	17,10
5	0,23	0,16	3,84	3,43	16,69	21,43
6	0,21	0,19	3,81	3,83	18,14	20,15
7	0,20	0,24	3,82	4,06	19,10	16,91
8	0,18	0,17	3,39	2,97	18,83	17,47
9	0,25	0,17	4,29	2,99	17,16	17,58
10	0,29	0,22	4,68	4,63	16,13	21,04
Avg.	0,23	0,19	4,01	3,56	17,73	18,95

3.2 Organic Matter and Soil pH Classification of Soils in Organic and Conventional Paddy Farming Systems

Table 2 compares the organic matter contents and soil pH levels between paddy fields with organic and conventional farming systems. The organic matter was found between 5.85% and 8.07% in soil samples from organic paddy fields, with an average of 6.92% (high). This range and mean values were generally higher than the conventional ones, 5.13–7.98% (medium to high) with an average of 6.14%. Organic matter is the primary energy source of biological processes in the soil that also regulates its physical and chemical functions as two determinants of ecological resilience. Accordingly, it affects soil physical, biological, and chemical properties and total microorganisms in the soil. The higher the soil organic matter, the larger the soil microorganism populations (Wicaksono et al., 2015). Furthermore, the organic paddy fields had a pH of 6.12–6.73, indicating neutral (N) soils, while the conventional paddy fields had a pH of 6.07-6.55, suggesting a slightly acid (SA) condition.

Table 2. Organic Matter and Soil pH Classification of Soils in Organic and Conventional Paddy Farming Systems

Sample	Organic Matter (%)				pH			
	Organic	Class	Conventional	Class	Organic	Class	Conventional	Class
1	7.52	H	6.63	H	6.71	N	6.24	AM
2	7.35	H	5.88	H	6.12	SA	6.37	SA
3	6.62	H	5.14	H	6.55	N	6.55	N
4	6.63	H	5.91	H	6.54	N	6.31	SA
5	6.62	H	5.91	H	6.32	SA	6.33	SA
6	6.57	H	6.60	H	6.61	N	6.07	SA
7	6.59	H	7.01	H	6.66	N	6.15	SA
8	5.85	H	5.13	M	6.73	N	6.43	SA
9	7.40	H	5.16	M	6.61	N	6.08	SA
10	8.07	H	7.98	H	6.58	N	5.96	SA
Avg.	6.92	H	6.14	H	6.54	N	6.25	SA

3.3 Organic Matter and Soil pH Classification of Soils in Organic and Conventional Paddy Farming Systems

Table 3 shows the total microorganisms and soil respiration rates of the soil samples. Paddy fields with organic farming systems contained total microorganisms in the range of 0.61x106 to 22.27x106 cfu/g or substantially higher than those with conventional farming. 0.27x106– 7.40x106 cfu/g. Similarly, the former also had higher soil respiration rates, 7.50–10.20 mgC-CO2/kg/day, than the latter, 2.7–7.5 mgC-CO2/kg/day.

Table 3. Total Microorganism and Soil Respiration Rates of Soils in Organic and Conventional Paddy Farming Systems

Sample	Total Microorganism ($x10^6$ cfu/g)		Soil Respiration (mgC-CO_2 /kg/day)	
	Organic	Conventional	Organic	Conventional
1	53.00	0.63	9.30	6.00
2	6.30	0.72	7.50	6.30
3	6.50	7.40	8.10	7.50
4	7.00	0.64	8.10	6.60
5	6.60	7.40	8.10	7.20
6	8.10	0.40	10.20	6.60
7	6.70	0.29	7.80	2.70
8	58.00	0.38	10.20	5.40
9	33.00	0.27	9.00	2.70
10	6.40	6.50	7.50	7.20
Avg.	19.16	2.46	8.58	5.82

From the three tables presented above, it can be inferred that organic farming creates paddy field soils with higher total nitrogen (0.23%) than conventional farming (0.19%). With higher nitrogen contents, the soils will have lower C/N ratios, as seen in Table 1. Nitrogen uptake depends on several factors: respiration, soil compaction, nutrient concentration, root density and distribution, soil pH, and plant absorption (Sutanto, 2002). This is evident in the directly proportional relationship between total nitrogen, soil pH, and respiration rate. Soils in organic paddy fields varied from 6.12 to 6.73, within the normal range. Hasibuan (2015) stated that soil pH creates environmental conditions that control the growth of soil microorganisms. At this normal pH range, organically cultivated soils have higher total nitrogen, 0.18–0.29% (medium), and respiration rate, 7.50–10.20 mgC-CO2/kg/day, or more favorable conditions for rice growth than conventionally treated soils. This applies to all soil samples, except for sample number 7. Nevertheless, the mean total nitrogen is substantially higher in soil samples collected from organic than in conventional paddy fields.

4. Discussion

The C/N ratio indicates the balance between organic carbon and total nitrogen in agricultural soils. High C/N ratios represent a lack of nitrogen for protein synthesis, leading to the slow decomposition of organic matter by soil microbes (Widyorini, 2016). On the contrary, low C/N ratios mean high ammonia (NH3) presence. Ammonia-oxidizing bacteria (AOB) oxidize NH3 into nitrites and nitrates, which plants easily absorb. High C-organic results in a high C/N ratio, while high total nitrogen produces a low C/N ratio that enhances the loss of nitrogen due to leaching. This research found that conventional farming practices created soils with higher C/N ratios than the organic ones, except for samples 4, 7, and 8. On average, the latter has significantly lower C/N ratios and, thus, more favorable conditions for microbial activities than the former.

Total microorganisms are generally higher in organic paddy fields (19.16x106 cfu/g) than their conventional counterparts (2.46x106 cfu/g). Paul and Clark (1989) explained that soil microorganisms are essential for soil ecosystems because they affect nutrient availability and cycling and the stability of soil structure. Total microorganisms represent a small fraction of total carbon and nitrogen but have a relatively strong effect. In other words, microbial numbers and activities are key factors in controlling the amount of mineralized C and N. Results of C-organic, organic matter, and total nitrogen analyses confirm this causal relationship as they are directly proportional to total microorganisms.

Furthermore, total microbes are positively correlated with soil respiration; the greater the total microbes, the higher the soil respiration rate (Fitriana *et al*., 2022). Soils from organic paddy fields contain higher total microorganisms and mean respiration rates (8.58 mgC-CO2/kg/day) than conventional paddy field soils (5.82 mgC-CO2/kg/day). Some influencing factors include C-organic content, organic matter, total nitrogen, C/N ratio, and soil pH. These variables have been tested in this research, and the analysis results support the conclusion that soils in organic paddy fields have better soil microbial number and activity than conventional paddy fields. C-organic, total nitrogen, and organic matter support and sustain the life of microorganisms and thus directly increase their presence in the soil (directly proportional relationship). Organic paddy field soils have a low C/N ratio due to high C-organic and total nitrogen, suggesting a stable or balanced chemical condition favorable to microorganisms. Also, the pH levels indicate neutral soils suitable for microbial activities. Overall, the results of the current study correspond with Mayasari (2018) and Purniasari (2019), which also found higher organic matter in organically treated land. With this high availability of food sources, more microorganisms can grow and perform their functions in maintaining soil quality.

5. Conclusions

Microbial numbers and activities (the latter are represented by soil respiration) in *Subak* Blongyang are higher in soils from organic paddy fields than their conventional counterparts. Total microorganisms and soil respiration rates have been found at 6.30–58.00x10^6 cfu/g and 7.50–10.20 mgC-CO_2/kg/day in organic paddy fields and 0.27–7.40x10^6 cfu/g and 2.70–7.50 mgC-CO_2 /kg/day at conventional paddy fields. C-organic, total nitrogen, organic matter, and soil pH are also higher in the former than in the latter, suggesting directly proportional relationships with microbial numbers and activities. Low C/N ratios have also been linked to organic instead of conventional farming systems.

Author Contributions

Contributions: Conceptualization, R.J.A. and N.L.K.; methodology, R.J.A.; N.L.K. and N.N.S.; software, R.J.A. and N.L.K.; validation, R.J.A. and N.L.K.; formal analysis, R.J.A. and N.L.K.; investigation, N.L.K.; resources, R.J.A; data curation, R.J.A.; writing—original draft preparation, R.J.A.; N.L.K. and N.N.S.; writing—review and editing, R.J.A.; N.L.K. and N.N.S.; visualization, R.J.A..; supervision, N.L.K.; project administration, R.J.A.; N.L.K. and N.N.S; funding acquisition, N.L.K. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare there no conflict of interest

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