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Research Article
Physiological Characters of the Local and Improved Cultivars of Rice under Organic Culture

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Abstract
Background and Objective: Local and improved varieties of rice have different physiological characteristics under organic cultivation. The purpose of this study was to determine the physiological characteristics of local and improved cultivars grown under organic cultivation of rice. **Methodology:** The design used was completely randomized factorial with 2 factors and 3 replications. The first factor was the kind of cultivation, i.e. organic cultivation and conventional cultivation and the second factor was the kind of cultivars of rice comprising: 5 different cultivars which consisted of Mentikwangi, Pandanwangi and Cianjur as local cultivars and IR64 and Cisedane as improved cultivars. The research was conducted at the greenhouse of the experiment station of Faculty of Agriculture, Gadjah Mada University in Yogyakarta Indonesia situated at 113 m above sea level. Data were analyzed by one way analysis of variance of CRD and SAS. **Results:** The results indicated that physical and chemical properties of soil under organic and conventional system were good, except total nitrogen (N) was low. N weight of leaf of cv Cianjur, the greenness of leaves and stomatal conductivity of rice organically grown were lower than those of conventional cultivation, however the CO_2 of leaf cells and the rate of photosynthesis were not different. There were no differences between the greenness of leaves, the CO_2 of leaf cells, the rate of photosynthesis of the local varieties compared to those of in the improved varieties. The stomatal conductivity of cv. Mentikwangi a local variety was greater than other varieties. **Conclusion:** The results of study showed that there is a change of physiological characters of rice varieties when cultivated organically. Not much difference is observed in physiological characters between local and improved varieties.

Key words: Greenness of leaves, organic cultivation, rate of photosynthesis, stomatal conductivity, photosynthesis

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Productivity of rice was increased after application of the green revolution[1], with the usage of large quantities of chemical fertilizers, chemical pesticides and herbicides[2].

The abundance use of chemical fertilizers and chemical pesticides caused excessive deterioration of soil properties[1], accelerated soil erosion, decreased land quality, contaminated underground water[3] and ultimately reduced the productivity of the land[3,4]. Salem[5] reported that the continuous using of chemical fertilizers and chemical pesticides were emergence a serious environmental threat to plants, soil, water, animals and humans.

Facing the threat of ecological damage, as well as human casualties due to chemical pollution has encouraged the emergence of today's farming culture that is an environmentally safe alternative, i.e to organic farming. Organic farming focuses on the integration between agriculture and animal husbandry in ensuring optimum nutrient cycling. Organic farming is an agricultural system that aims to keep the harmony with natural systems by utilizing and developing as much as possible the natural processes in farm management[6]. Organic farming systems in Indonesia are regulated by the Indonesian National Standard. The application of organic cultivation in Indonesia on rice usually uses local cultivars such as Mentikwangi and Pandanwangi and the use of improved cultivars is rarely done. Local and improved cultivars of rice have varied physiological characteristics[7]. Both types of rice organically grown could have different responses. The purpose of this study was to determine the physiological characteristics of local and improved rice cultivars grown under organic cultivation.

MATERIALS AND METHODS

An experimental research was conducted at the greenhouse of the experiment station of Faculty of Agriculture, Gadjah Mada University in Yogyakarta Indonesia situated at 113 m above sea level. Inceptisol soil for organic and conventional cultivation was taken from each different rice fields. Composite soil samples were taken which then representing the fields.

The design used was a 2×5 factorial arranged in a Completely Randomized Design (CRD) with 3 replications. The first factor was the kind of cultivations, i.e. organic cultivation and conventional cultivation and the second factor was the kind of cultivar consisted of Mentikwangi, Pandanwangi and Cianjur as local cultivars and IR64 and Cisedane as improved cultivars.

Soil samples were taken from a depth of 0-20 cm at certain selected points in field that has been organically and conventionally cultivated for 8 years or more. The soil samples were dried, then composited, crushed and screened and analyzed for soil chemical properties. The screened soil was put into pots (12 kg/pot), then watered up to 2 weeks before planting. Five cultivars of rice seeds were soaked overnight before sowing day and they were germinated in a plastic tub 30×40 cm in size. Seedling of the 5 cultivars aged of 21 days were transplanted into a pot/bucket, containing two plants.

Amount 15 ton ha^{-1} or 75 g/pot organic fertilizer was applied for organic cultivation and doses of 250-100-75 kg ha^{-1} N-P_2O_5-K_2O (urea, SP36, KCl) for conventional cultivation. The organic fertilizer was mixed with the soil then put into the pots. Inorganic fertilizers were applied in three steps, each 1/3 dose at 1, 5 and 7 weeks. Irrigation was done by inundation up to the full panicle phase. Two weeks before harvest, the water was drained. The seeds were harvested when the seed coats at the top of the panicle were clean and hard and 80% of the seeds coat had turned into golden brown[8].

Physiological variables observed were N content of leaf, the greenness of leaves, CO_2 of leaf cells, stomatal conductivity and the rate of photosynthesis.

Statistical analysis: Data were analyzed by one way analysis of variance of CRD. Duncan's new multiple range test at 5% significance level was done when the data were significantly different. Data were also analyzed using SAS version 9.1 program.

RESULTS AND DISCUSSION

Characteristics soil for planting media: Soil for planting media largely determines plant growth. Physical and chemical properties of cow manure, organic and conventional soils were analyzed. Cow manure showed low content of N, P and K. The pH was high and C/N ratio was low (Table 1). Cow

Table 1: Cow manure contents

pH H_2O	Moisture content (%)	C (%)	Organic matter (%)	Total N (%)	Total P (%)	Total K (%)	C/N
7.60	54.11	24.72	50.11	1.81	0.23	0.17	13.68

Table 2: Physical and chemical properties of soil under organic and conventional system before experiment

Soil properties	Cultivation system	
	Organic	Conventional
pH H_2O	6.253	6.453
C (%)	4.163	3.637
Organic matter (%)	7.170	6.280
Total N (%)	0.183	0.157
Available P (ppm)	34.640	8.280
Available K (mE/100g)	0.600	0.820
Cation exchange capacity (mE/100g)	23.733	26.267
Soil moisture content (%)	5.250	4.993
Bulk density (g cm^{-3})	2.093	2.103
N por (%)	45.553	42.867
Clay (%)	24.443	22.970
Dust (%)	40.320	44.230
Silt (%)	36.007	32.800

Table 3: Physical and chemical properties of soil under organic and conventional system after experiment

Soil properties	Cultivation system	
	Organic	Conventional
Total N (%)	0.13	0.12
Available P (ppm)	42.43	18.53
Available K (mE/100g)	0.73	0.96
Cation exchange capacity (mE/100g)	22.53	29.31
Organic matter (%)	2.96	2.58
pH H_2O	6.71	6.86

Table 4: N weight of leaf (μg g^{-1}) of organically and conventionally cultivated rice

Cultivar	N weight of leaf		Mean
	Organic cultivation	Conventional cultivation	
IR64	40.43[de]	66.56[a-d]	53.44
Cianjur	31.71[e]	61.95[a-d]	46.83
Pandanwangi	50.44[c-e]	73.25[a-c]	61.85
Mentikwangi	57.14[b-e]	53.37[b-e]	55.26
Cisedane	78.80[ab]	84.97[a]	81.89
Mean	51.68	68.02	(+)

Values followed by the same letter indicated not significantly different according to DMRT 5%

manure as soil conditioner increased CEC, facilitate gas exchange, stabilize soil structure, increase soil permeability and help manage soil reaction in uniform conditions. Organic matter as soil conditioner was able to increase the water holding capacity of soil that could provide opportunities to extent the availability of water[9].

Organic and conventional soil composition constituent fractions each soil texture was included in the loam texture. The composition of the fractions making up the soil texture affects the ability of soil to pass water or power permeability of soil. Macronutrient of organic and conventional soil was good, except total N was low (Table 2).

Levels of available P, available K and pH of soil both in organic and conventional cultivation were increased after harvest. Total N and organic matter content were decreased. Available P content in organic cultivation before experiment was high and after the experiment was very high. This was due to the release of P from cow manure of organic cultivation. This was due to the decomposition of organic matter which release organic acids such as humic acids and fulvic acid, some polyelectrolytes, that can bind Al and Fe so that P becomes available. Cation exchange capacity (CEC) of organic cultivation decreased after harvest (Table 3). Organic matter was contributed as very large negative charge through the surface area of its kind that was so high that organic matter was expected to increase the CEC of the soil. The CEC of the soil under organic cultivation was lower than that of conventional cultivation, this was due to the slow decomposition of organic matter in lowland of rice. The process of decomposition of organic matter in anaerobic conditions (flooded) was slower than the soil in aerobic conditions (not flooded). Anaerobic bacteria involved were less efficient than aerobic microflora that was of more diverse kind[10].

N weight of leaf: N weight of leaf was multiplication of nitrogen (N) content of leaf by dry weight of leaf[11]. Tayefe *et al.*[12] stated different N weight of leaf on different varieties. Peng *et al.*[13] added N weight of leaf and were affected by plant genotype, stage of growth and leaf position.

There were interactions between cultivars and methods of cultivation to the N weight of leaf. N weight of leaf in cv. Cianjur under organic cultivation was lower than that of conventional cultivation and the other varieties tend to be smaller too. (Table 4). This was due to nutrient levels (i.e. nitrogen) of organic cultivation that was smaller than those of conventional cultivation. N weight of leaf influenced by fertilizer applied, the organic fertilizer in organic cultivations had nutrient levels lower than chemical fertilizer in conventional cultivation thus causing N weight of leaves smaller than organic cultivation.

Greenness of leaves: Greenness of leaves is a value representing the chlorophyll content of leaves and has linear correlation with the nitrogen concentration[14] and can be used to monitor the N status of rice[15-18].

There was no interaction between cultivars and the methods of cultivation on greenness of leaves but it was affected by methods of cultivations (Table 5). The leaves in organic cultivation were less green than those in conventional cultivation, because the level of N in the organic cultivation was smaller than those in conventional cultivation. Greenness of leaves was manifestation on chlorophyll of leaves and N was forming chlorophyll element.

Table 5: Greenness of leaves and stomatal conductivity of organically and conventionally cultivated rice

Treatment	Greenness of leaves (SPAD Unit)	Stomatal conductivity (mol H_2O m^{-2} sec^{-1})
Cultivation		
Organic	31.72^{y}	0.122^{y}
Conventional	37.14^{x}	0.132^{x}
Cultivar		
IR64	36.06^{a}	0.123^{b}
Cianjur	37.01^{a}	0.125^{b}
Pandanwangi	30.30^{b}	0.124^{b}
Mentikwangi	33.97^{ab}	0.141^{a}
Cisedane	34.80^{ab}	0.123^{b}

Values in the same column followed by the same letters indicated that not significantly different according to DMRT 5%

Table 6: CO_2 content of leaf cells and rate of photosynthesis of organically and conventionally cultivated rice

Treatment	CO_2 content of leaf cells (µmol CO_2 mol^{-1})	Rate of photosynthesis (µmol CO_2 m^{-2} sec^{-1})
Cultivation		
Organic	309.40	242.6
Conventional	282.63	280.2
Cultivar		
IR64	310.00	257.8
Cianjur	276.33	288.9
Pandanwangi	289.00	251.5
Mentikwangi	325.00	245.6
Cisedane	278.67	263.3

Values in the same column followed by the same letters indicated that not significantly different according to DMRT 5%

Yoshida[19] reported that the critical value of greenness of leaves with SPAD 502 in rice is 36 and below the critical value the plant has undergone a shortage of N in its growth. There was a strong linear relationship between SPAD values and leaves with total nitrogen concentration which than varies with cultivar[20,21].

There was no significant difference among cultivars on their greenness of leaves (Table 5). However greenness of leaves IR64 and Cianjur varieties were greater and significantly different than Pandanwangi variety, but not significantly different with Mentikwangi and Cisedane varieties. Greenness of leaves was more influenced by environmental factors i.e. nitrogen. However IR64 and Cianjur had leaves greenness value over critical limit value indicated the two cultivars did not undergo shortage of nitrogen. Cianjur cultivar produced greenness of leaves at the highest value.

Stomatal conductivity: Stomatal conductivity was a measure of the ability of the leaf to release water and absorb CO_2 through the stomata[22]. The amount of water released during transpiration determined by the conductivity of stomata. The greater value of conductivity, the greater water can be transpired by the leaves if other factors are in normal circumstances. Stomatal conductivity and transpiration were closely correlated with leaf photosynthesis in rice[23-25]. Stomatal conductivity of rice was affected by cultivars. There was no interaction between cultivars and cultivations (Table 5).

The stomatal conductivity of cv. Mentikwangi was the highest and significantly different. The value of stomatal conductivity was determined by the anatomical features such as size, structure, arrangement and stomatal density of the plant itself which was strongly influenced by species, cultivars and even the individual plant[2]. Stomatal conductivity in organic cultivation did not differ as compared to that of conventional cultivation, because stomatal conductivity was influenced by genetic factors of variety than external factors. This caused the rate of transpiration in organic cultivation to be lower than that of conventional cultivation.

Carbon dioxides content of leaf cells: Carbon dioxide (CO_2) is the main raw compound of plant photosynthesis. Sustainability of CO_2 fixation by photosynthesis process was highly dependent availability of CO_2 in the leaf cells[26]. The results showed that the method of cultivation, cultivars and interactions did not affect the CO_2 content in the leaf cells of rice (Table 6). Carbon dioxide of leaf cells in organic cultivation did not differ as compared to that of conventional cultivation. It was indicated that the different nutrient content between organic cultivation and conventional cultivation did not lead to different fixation of CO_2 from the air so that the CO_2 of leaf cell was also not different. Rice is a C3 plant which was very responsive to CO[2 27,28.]

The kinds of cultivars tested showed no difference in the fixation of CO_2 in leaf cells. This was due to stomatal conductivity between different varieties except for cv. Mentikwangi. Stomatal conductivity was one of the things that affect CO_2 levels of leaf cells. There were other things that affect CO_2 levels of leaf cells i.e stomata openings, external CO_2 levels and CO_2 utilization by cells. Increased levels of external CO_2 around the leaf could result in CO_2 ratio of external to internal CO_2 and becomes higher that will affect the process of diffusion of CO_2 into the leaf mesophyll faster. This resulted in leaf internal CO_2 levels and also increased in turn with the increasing CO_2 levels externally[29].

Rate of photosynthesis: Photosynthesis was a process of the capturing light energy, converted into chemical energy and the product was stored as carbohydrates. Photosynthesis was effect by N content of leaf, greenness of leaves, CO_2 content of leaf cells and stomatal conductivity.

Methods of cultivation, cultivars and their interactions did not affect the rate of photosynthesis (Table 6). Rate of photosynthesis influenced by CO_2 leaves cells. Non significant CO_2 leaves cell caused non significant rate of photosynthesis. CO_2 was raw material for photosynthesis. Rice plant is C3 plants where the rate of photosynthesis was influenced by amount internal CO_2 of leaf. Photosynthetic rate of C3 plants group was strongly influenced by activity of rubisco enzyme. One of the factors that influence activity of rubisco was the ratio between CO_2 with O_2 in the mesophyll[26]. Gardner *et al.*[30], stating that photosynthesis was affected by availability of water, temperature, age of leaves, translocation of carbohydrates and the availability of CO_2. Organic cultivation tended to reduce the rate of photosynthesis. It was related to the greenness of leaves, stomatal conductivity in organic cultivation. Yoshida[19], showed the net rate of photosynthesis of rice ranges from 400-500 mg CO_2 m^{-2} sec^{-1} at full light. Rate of photosynthesis of the present research was lower because this research was conducted in tropical region with respiration rate higher than in sub tropical region.

CONCLUSION

Physical and chemical properties of soil under organic and conventional system are good, except total N was low. N weight of leaf of cv Cianjur, the greenness of leaves and stomatal conductivity of rice organically grown were lower than those of conventional cultivation, however the CO_2 of leaf cells and the rate of photosynthesis were not different. There were no differences between the greenness of leaves, the CO_2 of leaf cells, the rate of photosynthesis of the local varieties compared to those of in the improved varieties. The stomatal conductivity of cv. Mentikwangi a local variety was greater than other varieties.

SIGNIFICANCE STATEMENTS

This study determined for the first time the physiological characteristics of local and improved cultivars grown under organic cultivation of rice. This study was important because there is no research that compares the physiological character of local and improved varieties of rice under organic cultivation. This study will help the researcher to determine the rice varieties to be planted organically.

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