ISSN: 1412-4718, eISSN: 2581-138x

Safrudin A · Dewi R · Dulbari

Comparative study of rice morphological and physiological characteristics grown under organic and inorganic farming

Abstract. Organic farming practices have shown a potential to improve rice yields, aside from the popular conventional ones. This study aimed to comparatively analyze the morpho-physiological characteristics of rice plants grown under organic and inorganic farming. This research was conducted at the Polinela Organic Farm experimental station (5°21'10"S 105°13'43"E, 114 m sea above level), from February to April 2023 using a completely randomized design. The results showed that rice grown organically exhibited a notably higher chlorophyll index and actual water use efficiency compared to those grown inorganically. Conversely, inorganic farming resulted in a greater number of tillers than organic farming. However, there were no significant differences between the two systems regarding CO_2 efficiency and plant height. An interesting fact is the improved water use efficiency by organic farming helps rice plants to achieve similar growth performance while requiring less water.

Keywords: Chlorophyll index · Conventional farming · CO_2 efficiency · Morpho-physiological characteristics

Submitted: 11 June 2024, Accepted: 14 November 2024, Published: 15 December 2024
DOI: https://doi.org/10.24198/kultivasi.v23i3.55286

Safrudin A[1] · Dewi R[2*] · Dulbari[2]
[1]Graduate Students in Applied Master Study Program of Food Security, Politeknik Negeri Lampung. Jalan Soekarno Hatta No.10, RajabasaBandar Lampung 35141, Indonesia.
[2]Lecture in Applied Masters Study Program of Applied Master of Food Security, Politeknik Negeri Lampung. Jalan Soekarno Hatta No.10 Rajabasa, Bandar Lampung 35141, Indonesia.
*Correspondence: dulbari@polinela.ac.id

Safrudin A, Dewi R, Dulbari. 2024. Comparative study of rice morphological and physiological characteristics grown under organic and inorganic farming, Jurnal Kultivasi, 23(3): 273-278.

Jurnal Kultivasi Vol. 23 (3) December 2024
ISSN: 1412-4718, eISSN: 2581-138x

Introduction

Rice is a staple food globally, meeting over 21% of human caloric needs and accounting for 76% of caloric intake in Southeast Asia. The cultivation practices for rice significantly influence the crop's quality, safety, and nutritional value. However, the sustainability of these practices is increasingly questioned as organic farming methods are proposed as environmentally friendly alternatives (Mohidem *et al.*, 2022). The critical challenge in rice production lies in balancing productivity with environmental sustainability. While organic farming is touted for its potential to improve soil health, its impact on rice's physiological characteristics, particularly water efficiency and plant health during crucial growth stages, still needs to be explored. This study aims to address this gap by examining how different cultivation methods, mainly organic and conventional practices, affect the morpho-physiological characteristics of rice plants (Chiou *et al.*, 2023). Organic rice cultivation emerges as a potential solution, offering enhanced soil physical properties and improved water use efficiency (WUE) through practices like cover crop planting. This method aligns with sustainable agriculture principles, providing an environmentally friendly alternative for food production (Wacławowicz & Giemza, 2023). However, while organic cultivation may not significantly boost productivity, its profound impact on the natural environment is noteworthy.

As the global population expands and fertile land resources decrease, the strain on food security intensifies. The choice of rice variety directly influences its quality and yield, which is a critical consideration in addressing these challenges (Long *et al.*, 2023). The physical quality of rice plants during the vegetative phase is essential, influencing WUE and productive tiller count (Venkatesan *et al.*, 2023). Challenges persist in managing limited water resources, with disputes over distribution complicating sustainable water management. Organic cultivation patterns and strategic irrigation arrangements demonstrate the potential to optimize rice productivity by enhancing photosynthesis rates during the critical stages of the growth period (Liu *et al.*, 2023). The resultant neglect of water distribution infrastructure is a debatable issue, affecting the technical aspects of plant cultivation, especially during the vegetative phase (Wudil *et al.*, 2023). Despite these challenges, more research is still needed to focus on the morpho-physiological characteristics of the vegetative phase in rice varieties geared towards efficient water use. Consequently, this study aims to undertake a comparative analysis of the morpho-physiological traits of rice plants, considering their cultivation locations and the impact of enhanced WUE achieved through organic farming practices. Improving WUE is expected to lead to better growth and yield outcomes by optimizing water utilization, which influences key morpho-physiological traits such as plant height, number of tillers, and chlorophyll content.

Materials and Methods

This research was conducted at Polinela Organic Farm experimental garden, Politeknik Negeri Lampung, Bandar Lampung, Lampung, Indonesia (5°21'10"S 105°13'43"E, 114 m sea above level), from February to April 2023. A population of 72 rice plants was grown in a tropical greenhouse using organic and inorganic methods. Straws from previous rice plants were allowed to decompose in the soil for four weeks before being utilized in the organic cultivation method. The straw was treated with natural decomposition agents before being incorporated into the soil to accelerate the decomposition process. In the inorganic cultivation method, rigorous soil preparation was undertaken to ensure the absence of any pre-decomposed organic compounds. This process involved thoroughly cleaning and preparing land to remove residual organic matter before applying chemical fertilizers.

The vegetative phase observation focused on two distinct cultivation methods: organic and inorganic. Straws from previous rice plants were employed in the organic method by immersing them in the soil to decompose. Meanwhile, inorganic cultivation employed chemical fertilizers (Dose per plant: 4 g N, 3 g SP36, and 2 g KCl), manual weeding, and pest and disease control when necessary.

Procedure. The research was conducted using a Completely Randomized Design (CRD) with one factor, consisting of two treatment levels: organic and inorganic cultivation. The experiment had eight replications, resulting in 16 experimental units. Each replication consisted of nine pots with rice plants, resulting in 72 rice plants overall. The criterion for selection included the absence of pest and disease attacks, ensuring the chosen rice plants exhibited normal and healthy growth. Utilizing a completely randomized design, the selection aimed to maintain an unbiased representation across both cultivation methods. This study selected rice plants 45 days after planting, typically reaching a height of approximately ±70 cm with 12-17 tillers, based on a standardized sampling method. The experimental plots were divided into six sections, with 2-3 plants being randomly selected from each section. Only plants that were free from pests and diseases were included in the sample to ensure the accuracy of the observed morphological and physiological characteristics (Yassi *et al.*, 2023).

Observation variables were measured in this research. Plant height was measured from the plant stem's base to the flag leaf's tip using a ruler expressed in cm units. The number of tillers is calculated by counting the number of stems in one clump of rice plants. Meanwhile, Soil Plant Analysis Development (SPAD) was administered to measure the chlorophyll content (Zhang et al., 2023). Furthermore, physiological characteristics of rice were observed using a portable photosynthesis system Li-6800XT (Jia et al., 2023), Licor Inc., Lincoln, NE, USA on a sunny day at 9:00 am (Yang et al., 2022), 16 March 2023 with three replications (triplo) that were carried out automatically by the Li-6800XT. The actual water use efficiency (WUE) was measured using a Licor photosynthesis system, which calculates WUE as the ratio of the net photosynthesis rate (A) to the transpiration rate (E). The system expresses WUE in μmol CO_2 mmol H_2O^{-1}, allowing for precise quantification of the plant's water use efficiency under different environmental conditions. Carbon dioxide use efficiency (CO_2) was also determined using the same Licor system. The measurement involves analyzing the CO_2 concentration in the air entering and exiting the leaf chamber and calculating the difference to determine the net CO_2 assimilation. The system reports CO_2 use efficiency as CO_2 mmol H_2O^{-1}, reflecting the plant's ability to utilize available carbon dioxide efficiently. The Licor system uses an infrared gas analyzer (IRGA) to measure the concentration of CO_2 in the air stream. The CO_2 concentration is measured before and after the air passes over the leaf surface, and the difference is used to calculate the rate of photosynthesis. This precise measurement allows for an accurate assessment of both WUE and CO_2 use efficiency.

Data analysis. The collected data was then subjected to a least significant difference (LSD) test at α 5% using the Statistical Tool for Agricultural Research (STAR) version 2.0.1. (IRRI, Los Banos Philippines, 2013).

Results and Discussion

Comparative analysis of rice morphological characteristics**.** Plant height is a crucial growth parameter in rice plants as it dictates traits influencing yield and rice grain production (Wu et al., 2022). The characteristics of rice plants, particularly their height, are influenced by genetically controlled elements, predominantly determined by the genetic composition of the genotype, which is dependent on factors such as the number of internodes and internode length. (Jahan, 2020). In turn, the number of tillers per plant governs the count of panicles, a pivotal component of grain yield. The capacity of tiller production often determines the potential yield of rice cultivation. Higher tiller counts in rice plants may lead to disparities in assimilate and nutrient mobilization between tillers, resulting in variations in grain development and yield (Berahim *et al.*, 2021). The chlorophyll index plays a vital role in assessing plant N status. Over the past two decades, SPAD-measured rice N status has been widely used to ascertain N requirements at different growth stages and optimize grain yield and N use efficiency (Rueda *et al.*, 2016).

Statistical analysis in this study indicates that organically cultivated rice exhibits a significantly higher chlorophyll index than its inorganically cultivated counterpart as the plants mature. The SPAD values were recorded at 41.97 units for organic rice and 40.62 units for inorganic rice, respectively (Figure 1). The organic plant attains a height of 83.23 cm, while the inorganic counterpart reaches 81.31 cm (Figure 2). The number of inorganic tillers is 15.17, whereas the organic variant has 12.72 tillers (Figure 3). SPAD values, plant height, and the number of tillers increased significantly by 3.22%, 2.31%, and 16.12%, respectively, upon entering the vegetative phase. The observed differences in plant height, number of tillers, and SPAD values between the organic and inorganic rice plants can be attributed to the distinct cultivation methods and their impact on plant physiology.

Jurnal Kultivasi Vol. 23 (3) December 2024
ISSN: 1412-4718, eISSN: 2581-138x

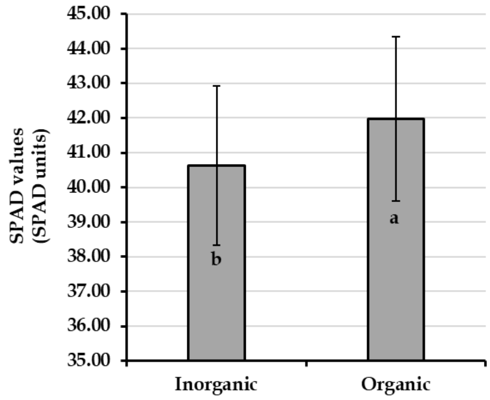

Figure 1. Comparative analysis of rice leaf SPAD values grown under inorganic and organic farming. Different letters within the rectangular bars indicate significant differences based on the LSD test at α 5%; error bars represent the standard deviation.

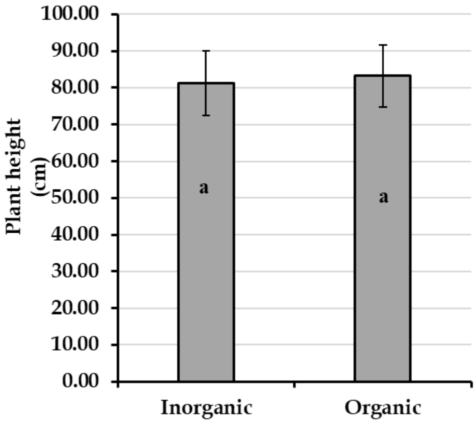

Figure 2. Comparative analysis of rice plant height grown under inorganic and organic farming. Different letters within the rectangular bars indicate significant differences based on the LSD test at α 5%; error bars represent the standard deviation.

Comparative analysis of physiological characteristics of rice. This research underscores the impact of organic and inorganic cultivation methods on water use efficiency within each planting approach. Notably, organic rice plant's WUE exhibited a substantial improvement, registering an increase of 9.12%—from 1591.82 to 1751.50 µmol CO_2 mmol H_2O^{-1} (Figure 4). It is essential to recognize that in a purely hydrological context, WUE has been defined as the ratio of the volume of water used productively (Stanhill, 1986). Agronomic practices associated with organic methods enhance grain yield and contribute to an overall increase in WUE (Mallareddy *et al.*, 2023). Previous studies have emphasized the pivotal role of nitrogen in augmenting agricultural yields, with its utilization and absorption contingent on water availability. Applying organic fertilizer is essential for increasing yield and WUE (Liu *et al.*, 2023).

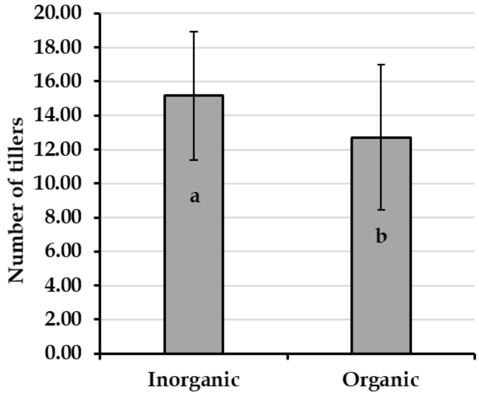

Figure 3. Comparative analysis of a number of tillers in rice plant grown under inorganic and organic farming. Different letters within the rectangular bars indicate significant differences based on the LSD test at α 5%; error bars represent the standard deviation.

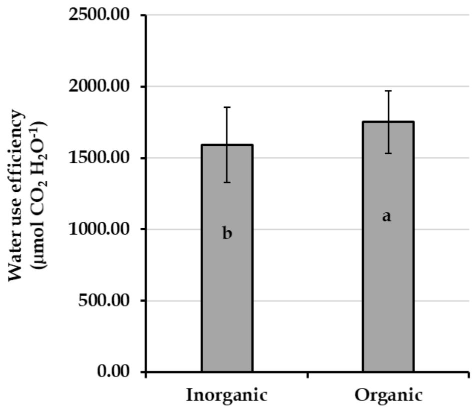

Figure 4. Comparative analysis of the actual water use efficiency of rice plants grown under inorganic and organic farming. Different letters within the rectangular bars indicate significant differences based on the LSD test at α 5%; error bars represent the standard deviation.

A prior investigation identified the critical challenge of managing nutrient availability while improving WUE in rice cultivation under limited water conditions (Ma *et al.*, 2024). Furthermore, it is imperative to anticipate the response of diverse crops' WUE to environmental factors and escalating atmospheric CO_2 levels (Bhattacharya, 2019). Several studies have demonstrated that elevated CO_2 levels not only lead to increased plant biomass but also positively influence water and nitrogen use efficiency (Ullah *et al.*, 2019). In the context of organic rice cultivation, it is noteworthy that irrigation practices contribute to a 56% reduction in runoff, consequently augmenting water storage in the soil compared to inorganic methods (de Avila *et al.*, 2015). In this research, inorganic rice cultivation showed comparable efficiency in using carbon dioxide to the organic method, with both methods obtaining similar values of 0.022 and 0.020 µmol CO_2 mmol H_2O^{-1} (Figure 5). The plant responded to atmospheric CO_2 by increasing its photosynthesis rate, which supported the growth and yield of crops (Priyadarsini *et al.*, 2024).

Neither inorganic nor organic cultivation showed a significant effect on CO_2 efficiency. The level of CO_2 in rice has been simulated in climate change studies using a "current/high CO_2" approach, where crop models are put at current CO_2 (usually 0.05–0,10 µmol CO_2 mmol H_2O^{-1}) and under the high CO_2 concentration scenario (Neeharika *et al.*, 2024). The reduction in nutrient uptake can be attributed to diminished plant transpiration under conditions of CO_2 efficiency, altering the nutrient uptake from the soil, typically translocated via water (Balbinot *et al.*, 2021). Remarkably, plants cultivated in organic conditions acquired higher levels of CO_2 during specific planting phases, thereby potentially mitigating the adverse impact of increased CO_2 concentrations in a single planting cycle on the nutrient content within the plant's growing environment (Lv *et al.*, 2022).

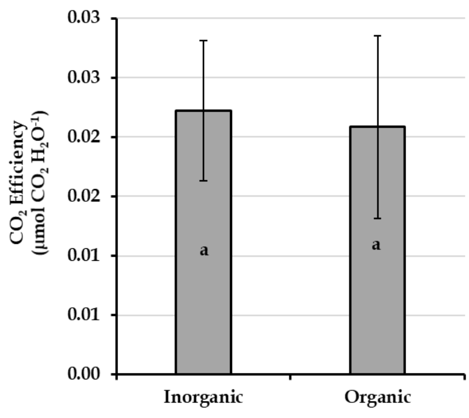

Figure 5. Comparative analysis of the efficiency of actual carbon dioxide in rice plants grown under inorganic and organic farming. Different letters within the rectangular bars indicate significant differences based on the LSD test at α 5%; error bars represent the standard deviation.

Conclusion

This research presents a comparative analysis of morpho-physiological characteristics as affected by organic and inorganic farming methods in 45-day-old greenhouse-grown plants. Rice grown under organic farming has a significantly higher chlorophyll index and actual WUE of rather than those under inorganic farming. While inorganic farming has a higher tiller number than organic ones. Both farming systems have insignificant differences in the variable of CO_2 efficiency and plant height.

Acknowledgments

The Polinela Organic Farming team from Politeknik Negeri Lampung, Bandar Lampung, Indonesia, acknowledges the contributions of Moh. Haris Imron S. Jaya and Aris Marwanto for their assistance in conducting the experiments. The authors express their gratitude to everyone who participated in data collection and research activities.

References

Abbas T, Rizwan M, Ali S, Adrees M, Mahmood A, Zia-ur-Rehman M, Ibrahim M, Arshad M, Qayyum MF. 2018. Biochar application increased the growth and yield and reduced cadmium in drought-stressed wheat grown in an aged contaminated soil. Ecotoxicology and Environmental Safety, 148: 825–833.

Balbinot A, da Rosa Feijó A, Fipke MV, Rockenbach D, Massey JH, Camargo ER, Mesko MF, Scagliioni PT, de Avila LA. 2021. Impact of irrigation methods on rice yield, water use efficiency, and arsenic and cadmium accumulation in grain. Agriculture, 11(8): 705.

Berahim Z, Dorairaj D, Omar MH, Saud HM, Ismail MR. 2021. Spermine mediated improvements on stomatal features, growth, grain filling and yield of rice under differing water availability. Scientific Reports, 11(1): 10669.

Bhattacharya A. 2019. Global climate change and its impact on agriculture. Academic Press.

Chiou Y, Wu P, Liou J, Huang T. 2023. What is the willingness to pay for a basket of agricultural goods? Multi-features of organic, animal welfare-based, and natural products with no additives. Foods, 12(6): 1176.

de Avila LA, Martini LFD, Mezzomo RF, Refatti JP, Campos R, Cezimbra DM, Machado SLO, Massey JH, Carlesso R, Marchesan E. 2015. Rice water use efficiency and yield under continuous and intermittent irrigation. Agronomy Journal, 107(2): 442–448.

Jia Q, Liu Z, Guo C, Wang Y, Yang J, Yu Q, Wang J, Zheng F, Lu X. 2023. Relationship between photosynthetic CO2 assimilation and chlorophyll fluorescence for winter wheat under water stress. Plants, 12(19): 3365.

Liu K, Shi Y, Yu Z, Zhang Z, Zhang Y. 2023. Improving photosynthesis and grain yield in wheat through ridge–furrow ratio optimization. Agronomy, 13(9): 2222.

Long C, Wen Z, Deng Y, Hu T, Liu J, Zhu X. 2023. Locality preserved selective projection learning for rice variety identification based on leaf hyperspectral characteristics. Computers and Electronics in Agriculture, 205: 107601.

Lv C, Huang Y, Yang K, Yang J, Cao P, Hu Z, Sun W, Yu L. 2022. Multiyear CO2 elevation improves PSII efficiency in a japonica rice cultivar. Crop Science, 62(1): 346–357.

Ma L, Wang S, Ni C, Wang W, Kang S, Li Z, Wright AL, Jiang X. 2024. Measurement and modelling of soil water dynamics under ridge tillage in paddy field. Soil and Tillage Research, 244: 105579.

Mallareddy M, Thirumalaikumar R, Balasubramanian P, Naseeruddin R, Nithya N, Mariadoss A, Eazhilkrishna N, Choudhary AK, Deiveegan M, Subramanian E, Padmaja B, Vijayakumar S. 2023. Maximizing water use efficiency in rice farming: A comprehensive review of innovative irrigation management technologies. Water (Switzerland), 15(10): 1790.

Neeharika TSVR, Anjaneyulu B, Rani KNP, Sandeepa K, Satyannarayana S. 2024. Mathematical modelling for sustainable extraction of oil from rice bran, safflower seeds and flaxseeds employing supercritical carbon dioxide at pilot scale: An insight to comprehensive physico-chemical analysis. Separation and Purification Technology, 342: 124990.

Priyadarsini P, Pal M, Pandey R, Gopalakrishnan S, Sehgal VK, Chinnusamy V, Taria S, Kumar P, Padaria J, Lal MK. 2024. Photosynthesis and radiation use efficiency at anthesis in relation to biomass accumulation and yield in Basmati rice (Oryza sativa L.). Plant Physiology Reports, 29(2): 239–248.

Ruan S, Luo H, Wu F, He L, Lai R, Tang X. 2023. Organic cultivation induced regulation in yield formation, grain quality attributes, and volatile organic compounds of fragrant rice. Food Chemistry, 405: 134988.

Rueda D, Valencia G, Soria N, Rueda BB, Manjunatha B, Kundapur RR, Selvanayagam M. 2016. Effect of Azospirillum spp. and Azotobacter spp. on the growth and yield of strawberry (Fragaria vesca) in hydroponic system under different nitrogen levels. Journal of Appl. Pharmaceutical Sci, , 6(1): 048–054.

Stanhill G. 1986. Water use efficiency. Advances in Agronomy. Vol. 39. Academic Press.

Ullah H, Santiago-Arenas R, Ferdous Z, Attia A, Datta A. 2019. Improving water use efficiency, nitrogen use efficiency, and radiation use efficiency in field crops under drought stress: A review. Advances in Agron., 156: 109–157.

Venkatesan S, Udhaya Nandhini D, Senthilraja K, Prabha B, Jidhu Vaishnavi S, Eevera T, Sivakumar SS. 2023. Traditional cultivars influence on physical and engineering properties of rice from the Cauvery Deltaic region of Tamil Nadu. Applied Sci., 13(9): 5705.

Wacławowicz R, Giemza M, Pytlarz E, Wenda-Piesik A. 2023. The impact of cultivation systems on weed suppression and the canopy architecture of spring barley. Agriculture, 13(9): 1747.

Wu DH, Chen CT, Yang MD, Wu YC, Lin CY, Lai MH, Yang CY. 2022. Controlling the lodging risk of rice based on a plant height dynamic model. Botanical Studies, 63(1): 25.

Wudil AH, Ali A, Usman M, Radulescu M, Sass R, Prus P, Musa S. 2023. Effects of inequality of access to irrigation and water productivity on paddy yield in Nigeria. Agron., 13(9): 2195.

Yang H, Yang Q, Kang Y, Zhang M, Zhan X, Cao L, Zhang Y. 2022. Finding stable QTL for plant height in super hybrid rice. Agric., 12(2): 165.

Yassi A, Farid M, Anshori MF, Muchtar H, Syamsuddin R, Adnan A. 2023. The integrated minapadi (rice-fish) farming system: Compost and local liquid organic fertilizer based on multiple evaluation criteria. Agron., 13(4): 978.

Zhang L, Hashimoto N, Saito Y, Obara K, Ishibashi T, Ito R, Homma K. 2023. Validation of relation between SPAD and rice grain protein content in farmer fields in the coastal area of Sendai, Japan. AgriEngineering, 5(1): 369–379.