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Increasing Yield and Economic Value of Upland Rice Using Inorganic Fertilizer and Poultry Manure in Dryland

Sutardi [1], Miranti Dian Pertiwi [2,*], Raden Heru Praptana [1], Markus Anda [3], Heni Purwaningsih [4], Joko Triastono [5], Kristamtini [1], Untung Susanto [1], Setyorini Widyayanti [1], Mahargono Kabarsih [4], Dewi Sahara [5], Afrizal Malik [5], Renie Oelviani [5], Forita Dyah Arianti [2], Elisabeth Srihayu Harsanti [6], Anicetus Wihardjaka [1], Intan Gilang Cempaka [6], Damasus Riyanto [2] and Sugeng Widodo [5]

[1] Research Center for Food Crops, National Research and Innovation Agency, Jl. Raya Bogor-Jakarta, Cibinong Bogor 16911, Indonesia
[2] Research Center for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency Serpong, South Tanggerang 15314, Indonesia
[3] Research Center for Geospatial, National Research and Innovation Agency, Jl. Raya Bogor-Jakarta, Cibinong Bogor 16911, Indonesia
[4] Research Center for Food Technology and Processing, National Research and Innovation Agency, Jl. Jogja-Wonosari km. 31.5 Gading, Playen, Gunungkidul, Yogyakarta 55861, Indonesia
[5] Research Center for Behavioral and Circular Economics, National Research and Innovation Agency, Jl. Jend. Gatot Subroto No. 10, South Jakarta 12710, Indonesia
[6] Research Center for Horticultural and Estate Crops, National Research and Innovation Agency, Jl. Raya Jakarta-Bogor, Cibinong, Kabupaten Bogor 16915, Indonesia
* Correspondence: mdp.miranti@gmail.com

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Abstract: Rice production in the karst dryland is still low, due to soil characteristics that lack nutrient availability. Meanwhile, upland rice has received less attention, and it has not been used to its full potential. This study aimed to evaluate the effect of various combinations of inorganic fertilizers, poultry manure, and upland rice varieties on the production and economic value of karst dryland in Gunungkidul, Yogyakarta. This experiment was arranged in a factorial design, with inorganic fertilizers, poultry manure, and upland rice varieties set in a randomized block design with three replications. The first factor was a combination of inorganic and organic fertilizer rates: 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} organic, 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} organic, 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} organic. The second factor is the upland varieties of Inpago 8, Inpago 10, and Inpago 12 and lowland variety Inpari 42 Agritan GSR, as checked. Based on the study, we concluded that the combination of 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} poultry manure fertilizers with Inpago 8 resulted in an IDR profit of 23,586,000 ha^{-1}, and it is the most recommendable fertilizer and variety combination to be developed in the karst dryland, in consideration of land fertility and sustainability.

Keywords: fertilizer; karst; dryland; variety; poultry manure

1. Introduction

The serious threat for rice production in supporting global food security is climate change, owing to water scarcity. Therefore, an attempt should be made to overcome water scarcity in rice production by selecting rice cultivars that require less water and are suitable for the dry upland ecosystem. Indonesia has 95.81 million ha area of potential for agriculture, consisting of 70.59 million ha upland, 5.23 million ha lowland, and 19.99 swampy area [1]. Fulfilment of rice consumption as the staple food for many countries relies on the cultivation of rice under flood irrigation, which is vulnerable to the climate change associated with water scarcity. In addition, productive lands for agriculture decreased gradually, owing to land conversion for other development sectors. The alternative solution for facing the negative impact of climate change is to develop upland rice cultivars that are able to adapt to less water. The constraint for developing upland rice is low soil fertility and soil organic carbon. This constraint could be solved using inorganic fertilizers and organic manure/compost.

Dry upland soils in Gunungkidul, Yogyakata, Indonesia developed from karst have the potential to be used for rice cultivation, but they are constrained by the low availability of nutrients for plant growth and development [2]. The soil survey reports by the Research Center for Soil and Agroclimate [3] showed that the karst dryland in Gunungkidul contains 0.78% C-organic, 0.09% N, 27 mg 100 g^{-1} K_2O, 33 mg 100 g^{-1} P_2O_5 HCl 25%, 64 mg 100^{-1} P_2O_5 Olsen, and C/N 9. Nutrients and water availability are the main limiting factors for rice production in karsitic drylands [4,5]. Fertilizers play an important role in improving soil nutrition and crop yield [6]. However, excessive use of inorganic fertilizers can reduce soil quality, pollute the environment, increase production costs, and reduce farmers' profits. The combination of suitable rates of inorganic fertilizers and organic manure is continuously needed to increase land productivity [7].

Several studies have shown that the application of poultry manure (PM) can increase soil fertility [8], restore organic content to the soil, reduce production costs, and increase farmer profits [9]. The combination of 25% recommended dose of nitrogen (RDN) of PM and 75% RDN of chemical fertilizers can increase productivity, yield components, and growth characteristics [10]. Orluchukwu et al. [11] stated that the combination of PM and residual fungi substrate was suitable for upland rice and was more cost-effective than 15:15:15 NPK fertilization. Higher rice yields were obtained from a combination of PM and inorganic fertilizers than using only PM [12]. The organic fertilizer treatment of cow dung, PM, and water hyacinth gave higher yields than the control treatment [13]. However, organic fertilizer from PM has not been commonly used for rice cultivation in dryland, as is the case for vegetable commodities in upland dryland.

Rice production in karst dryland in Gunungkidul is still low, at <4.2 t ha^{-1}. The utilization of upland rice varieties, combined with the use of organic fertilizers, is one of the efforts to improve dryland productivity and increase rice yields in dryland [14]. Alavan et al. [15] reported that a 50:50 combination of organic and inorganic fertilizers yielded 10 t ha^{-1} on dryland rice varieties consisting of Cirata, Limboto, Situ Bagendit, and Situ Patenggang. The application of 50:50 combination of organic and inorganic fertilizers to Inpago 11 variety gave a yield of up to 6 t ha^{-1} [16]. This shows that the selection of varieties and the combined application of organic and inorganic fertilizers are prospective to increase rice yields, depending on land characteristics.

The development of high yielding and stable rice varieties on suboptimal land has been carried out through green super rice (GSR) technology [17,18]. The remaining challenge is to develop upland rice massively, in facing the negative impact of climate change associated with water scarcity to minimize the threat to food security. Several upland rice varieties have been developed and released specifically for dryland [19]. The released upland rice varieties, including Inpago 8, Inpago 10, and Inpago 12, have potential yields of 8.1, 7.3, and 10.2 t ha^{-1}, respectively. There is a crucial need to find technology and innovation to increase rice yields on the dry upland, such as in the karst dryland in Gunungkidul. Many farmers have tried to use cow dung and straw to increase soil fertility [20] because they are easy to access and cheap [21]. However, the application of the cow dung without composting could trigger the development of the *Phillophaga helleri* pest in the karst dryland of Gunungkidul (personal communication with farmers). According to local farmers, the use of poultry manure containing high rice husks can reduce pests in the soils; however, there is no data to confirm the information. Therefore, we hypothesized that the combined application of inorganic fertilizers and poultry manure could increase the yields of various upland rice cultivars on dryland soils developed from karst materials. The objective of the study was to evaluate the effect of various combinations of inorganic fertilizers and poultry manure on the production and economic value of several upland rice varieties grown on dryland.

2. Materials and Methods

2.1. Experimental Site

The field research was carried out in karst dryland in Trengguno Lor of Sidorejo Village, Ponjong District, Gunungkidul Regency, Yogyakarta Province, Indonesia (7°59′49″ S, 110°41′48″ E), with an elevation of 758.5 m above sea level (asl), from October 2019 to March 2020. Annual rainfall is the primary source of water for rice dryland farming. Ponjong has an average annual rainfall of 2040.81 mm. The wet season (monthly rainfall >100 mm) occurred in November to December 2019 and February to April 2020, while August to October 2019 and January 2020 were dry seasons (monthly rain-fall <60 mm) (Figure 1). The soil is classified as the Paliyan series of Typic Eutropepts, very fine, mixed minerals, isohipertermik, and a slope of 3–8%. The relief is plain to undulating, lime soil parent materials, very deep solum, good drainage, and medium permeability.

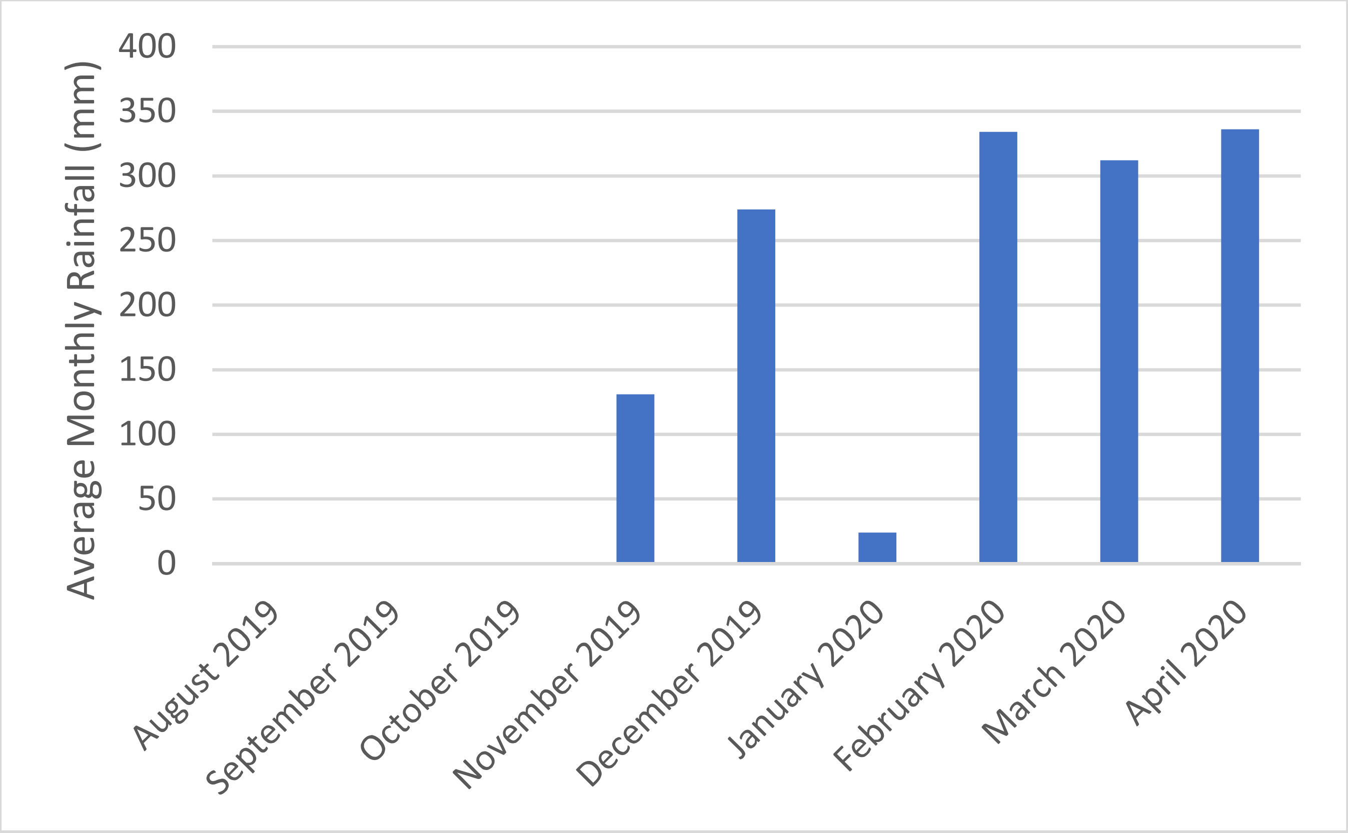
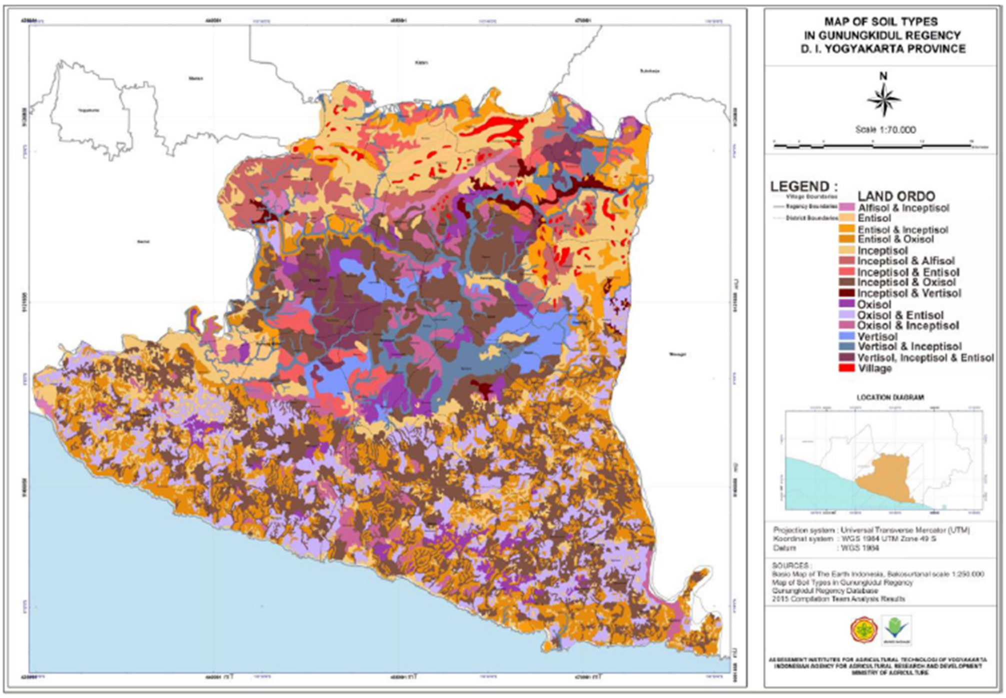


Figure 1. Average monthly rainfall in Gunungkidul, Yogyakarta, Indonesia, 2019–2020.

Gunungkidul is one of the specific karst areas on the southern coast of Java Island. The karst area is formed from the uplifting of coral reefs into limestone hills (Figure 2). Karst has hydrological characteristics and landforms caused by a combination of rocks that are easily soluble and have a well-developed secondary porosity. Karst aquifers are vulnerable to rapid reductions in groundwater availability, owing to prolonged dry seasons and reduced water catchment areas surrounding the aquifers. Hence, an attempt should be made to protect recharge areas.



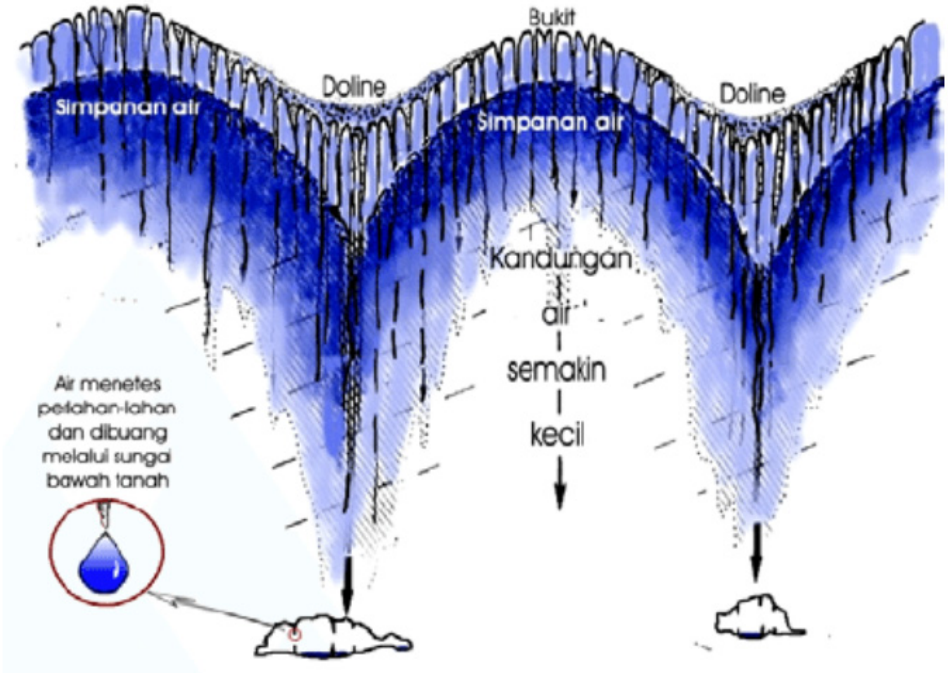


Figure 2. Karst characteristics in Gunungkidul, Yogyakarta, Indonesia. (Data from: Srihartanto and Widodo [22] and Adji, Tjahyo and Haryono, Eko [23]).

2.2. Description of Varieties

The upland rice varieties used were Inpago 8, Inpago 10, Inpago 12, and Inpari 42 Agritan GSR. Each of these varieties had a specific and different character. The maturation times for them were 119, 115, 111, and 112 days after sowing (DAS), respectively. The yields of the potential of the varieties were 8.1, 7.3, 10.2, and 10.58 t ha^{-1}, respectively. The plant height characters of them were 122, 104, 106, and 93 cm, respectively.

2.3. Experimental Treatments and Design

Factorial field experiment of 3 × 4 used inorganic fertilizer + PM and upland rice varieties and arranged them in a randomized complete block design with three replications. The first factor was three level combinations of inorganic fertilizer + PM designated as application packages, and the second factor was three upland rice varieties and one irrigated rice varieties. The treatments are listed in Table 1.

Table 1. Treatments of fertilizer dosage and varieties of the study in karst dryland, Gunungkidul, WS 2019/2020.

Fertilizer Dosage	Varieties
F1 (72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O kg ha^{-1} + 3 t ha^{-1} organic)	V1 (Inpago 8)
F2 (92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} organic)	V2 (Inpago 10)
F3 (112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} organic)	V3 (Inpago 12)
	V4 (Inpari 42 Agritan GSR)

Organic fertilizer was prepared from PM applied with bio-decomposer (Agrodeko) with the dose of 2 kg Agrodeko for 1 ton of manure, which was then added with urea 2.5 kg and 2.5 kg SP-36 kg, thoroughly and evenly mixed before covering with plastic for 21 days. Agrodeko is a bio-decomposer consortium from slotic microbe needed to decompose plant tissues. The quality of organic compost produced was evaluated based on SNI:19-7030-2004.

The PM contained nitrogen (N) 2.81%, phosphor (P) 1.08%, potassium (K) 1.01%, and C-organic 18.91%, while the heavy metals were below the threshold limit. Contents of C, N, P, and K in the PM were relatively high, indicating that the manure could release nutrients for rice and improve the physical properties of dry upland soils derived from karst.

2.4. Cultivation Practices

Soil tillage was conducted twice using mini tractor ploughing, followed by levelling. Next, a plotting space of 4 m × 5 m was made for each treatment. The full dose of composted poultry manure (100%) and 2/3 dose of inorganic fertilizers was applied before planting, while 1/3 dose of inorganic fertilizers were applied 45 days after planting (DAP). The base fertilizers were incorporated into the soil during tillage of the soil, then incubated for one week. The seeds were directly planted in rows using the "Atabela" machine (machine for direct planting). Two to three seeds were planted per hill in an upland row system (Largo) with spaces of 20 × 10 × 40 cm (row × planting point × stript between 2 rows), called "Jarwo 2:1 system", created by the vehicle. Using this system, the seed rate required was 25–29 kg ha^{-1}. The experiment was conducted during the wet season of 2019/2020, with planting time on 5 December 2019, and seed germination started on 15 December 2019.

The maintenance of plants was intensively achieved. The *Phillopaga helleri* were controlled manually by turning on the light in the evening. Fungicides and bactericides were applied at 65 and 70 DAP to control the blast and bacterial leaf blight diseases. Weeds were controlled manually when necessary.

2.5. Observed Parameter

2.5.1. Soil Sampling and Analysis

Soil sampling and analysis were carried out before and after the field experiment. The surface soil samples before planting were randomly selected from the experimental field at a depth of 0–30 cm. In addition, the collected soil samples were mixed thoroughly, and a representative of 1 kg was taken as a composite for analysis. The physical and chemical soil properties were analyzed in the Laboratory of Ecology and Plant Production, Faculty of Animal Husbandry and Agriculture, Diponegoro University, Semarang, Central Java Province, and Institute for Assessment of Agricultural Technology in Yogyakarta. Soil analysis before the trial shown in Table 2.

Table 2. Soil properties before the trial, Trenggono, Sidorejo Village, Ponjong District, Gunungkidul Regency, Yogyakarta Province, Indonesia, WS 2019/2020.

Parameter	Unit	Result	Criteria
Texture			
- Clay	%	83	Clay
- Sand	%	6	
- Dust	%	11	
- pH H_2O (1: 25)	-	5.7	Moderate Acid
pH KCl (1: 2.5)	-	4.9	Moderate Acid
C-organic	%	1.17	Low
N Kjeldahl	%	0.13	Very Low
C/N	%	9	Low
P_2O_5 HCl 25	mg 100 g^{-1}	47	High
P_2O_5 Olsen	mg 100 g^{-1}	25	Medium
K_2O	%	19	Low
Cation Exchange Capacity (CEC)	cmol kg^{-1}	16	Low
Ca	cmol kg^{-1}	54	High
Mg	cmol kg^{-1}	12.5	High
K	cmol kg^{-1}	1.8	Medium
Na	cmol kg^{-1}	0.4	Medium
Base saturation	%	92	Very High

Agronomic parameters included plant height, tiller number, panicle number per plant, panicle length, panicle weight per plant (at 18% moisture content), dry panicle weight per plant (at 14% moisture content), percentage of filled grain per plot, percentage of unfilled grain per plot, 1000 grain weight, harvest index (grain weight/total biomass), and grain yield. Plant height and tiller number were observed at 35, 65, and 112 DAP, as much as ten plant samples diagonally. Panicle number per plant, panicle length, panicle weight per plant (at 18% moisture content), dry panicle weight per plant (at 14% moisture content), percentage of filled grain per plot, percentage of unfilled grain per plot, 1000 grain weight, harvest index (grain weight/total biomass), and grain yield observed at harvest time as much as ten samples.

2.5.2. Economic Efficiency Assessment

Three criteria were used to determine economic profitability of the farming system, i.e., income, R/C, and BEP data. The observed input–output data included the quantity and cost of inputs for production, as well as the quantity and cost of rice production. Farmer income was calculated according to Bajracharya and Sapkota [24], Kharumnuid et al. [25], and Dube et al. [26], as follows:

$$\text{Net Income} = \text{Gross Income} - \text{Total Cost}.$$

$$\text{R/C} = \text{Gross Income}/\text{Total Cost}.$$

R/C was calculated using the formula of Bonabana et al. [27]; Muhammad and Hariyati [28]. A break-even point (BEP) is a point where the revenue is equal to the total cost, or the benefit is zero. There are two BEPs, i.e., for production (BEP-Y) and price (BEP-P). Production BEP is the minimum amount of output required to cover production costs. At the point of BEP, the farmer does not make a profit and does not incur a loss [29,30]. The formulas for both BEPs are follows:

$$\text{BEP-Y} = \text{Total Cost}/\text{Price of the Output}$$

$$\text{BEP-P} = \text{Total Cost}/\text{Total Production}$$

2.6. Data Analysis

Data analysis was executed by using S.A.S. versi 9.0. S.A.S. Institute Inc., Cary, NC, USA software. The variance was tested at $\alpha = 5\%$ and Duncan's multiple range test (DMRT) was conducted to compare means of traits with identified significant differences among the treatments. Cluster analysis was performed using R statistical program V 4.0.4.

3. Results

3.1. Karst Soils Characteristics

Soil analysis after the trial showed some changes, especially in soil pH, C-organic, N, P, and K content (Table 3). A significant interaction was shown by the application of inorganic fertilizer + PM with rice varieties on the chemical properties of soil on karst dryland, with p-value < 0.01 (Table 1). Soil chemical properties of V1, V2, and V3 were significantly higher than V4, except for the status of phosphorus availability in the soil. The pH changed from 5.7–4.9 (medium acidic) to neutral (6.06–7.10). N content was relatively stable at a low level (0.11–0.14% after harvesting). P_2O_5 content changed from very high (47 mg 100 mg^{-1}) to high (27–29 mg 100 mg^{-1}).

Table 3. Soil properties after trial at research site, Gunungkidul, Yogyakarta, WS 2019/2020.

Treatments Code	Soil pH	C-Organic (%)	N-Total (%)	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})
F1V1	6.36 bc	1.29 ab	0.23 bc	28.5 a	39.2 ab
F1V2	6.55 b	1.02 d	0.13 de	29.5 a	38.1 c
F1V3	7.10 a	1.39 a	0.24 b	30.5 a	37.4 cd
F1V4	6.55 b	1.22 cd	0.21 c	27.9 a	38.4 bc
F2V1	7.06 a	1.09 cd	0.33 a	29.9 a	39.5 a
F2V2	6.55 b	1.01d	0.31 a	29.7 a	36.8 de
F2V3	7.11 a	1.24 b	0.32 a	28.8 a	36.1 ef
F2V4	7.06 a	1.29 ab	0.23 bc	28.9 a	36.2 ef
F3V1	6.49 b	0.56 e	0.13 de	28.8 a	35.4 fg
F3V2	7.06 a	0.49 ef	0.14 d	28.1 a	30.4 h
F3V3	6.11 a	0.45 ef	0.12 de	27.9 a	35.1 g
F3V4	6.08 c	0.39 f	0.11 e	29.5 a	35.3 fg
"p" value for					
F	<0.0001	<0.0001	<0.0001	0.54	<0.0001
V	0.1607	0.0010	<0.0001	0.96	<0.0001
F × V	<0.0001	0.0010	<0.0001	0.661	<0.0001
CV	3.05	8.12	7.28	6.92	1.49

Note: Means in column followed by same letter are not significantly different, according to DMRT 5%; F1 = 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} PM, F2 = 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} PM, F3 = 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} PM, V1 = Inpago 8, V2 = Inpago 10, V3 = Inpago 12, V4 = Inpari 42 Agritan GSR.

Analysis showed that PM has relatively high N, P, K, and C-organic compounds, so that it is good to increase soil macronutrient availability. The PM also has high husk content and is good to remediate physical properties and fertility of the soil. It may, thus, increase the dryland rice yield.

3.2. Growth and Productivity

Rice cultivation in dryland areas is only once a year during the rainy season, followed by soybean/corn and a fallow period of waiting for the upcoming rainy season. At 35, 65, and 112 DAP, there were no significant interactions in plant heights between fertilization treatment and variety. There were no significant differences in plant height between the three fertilizer treatments in the fertilization treatment.

However, based on the varietal treatment, V1 showed the consistent plant height, compared to other varieties from the vegetative (35 DAP) to the generative (65 and 112 DAP) phase. Meanwhile, at 35 and 65 DAP, the plant heights of V2 and V3 were not significantly different, but at 112 DAP, V2 was significantly higher than V3. V4 had the lowest plant height growth in all growth phases (Table 4).

Table 4. Plant height of the treatments of the study in karst dryland, Gunungkidul, WS 2019/2020.

Treatment		35 DAP (cm)	65 DAP (cm)	112 DAP (Harvest Time) (cm)
Fertilizers	F1	43.77 a	88.77 a	108.77 a
	F2	39.79 a	84.79 a	104.79 a
	F3	43.40 a	88.40 a	108.40 a
Variety	V1	48.12 a	93.12 a	113.12 a
	V2	45.27 ab	90.27 ab	110.27 ab
	V3	40.49 bc	85.49 bc	105.49 bc
	V4	35.39 c	80.39 c	100.39 c
"*p*" value for:				
F		0.352 ns	0.352 ns	1.10 ns
V		0.007 **	0.007 **	5.32 ns
F × V		0.090 ns	0.090 ns	2.78 ns
CV		17.18	8.33	6.78

Note: Means in column followed by same letter are not significantly different, according to DMRT 5%; ns = not statistically significant; ** = statistically significant; F1 = 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} PM, F2 = 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} PM, F3 = 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} PM, V1 = Inpago 8, V2 = Inpago 10, V3 = Inpago 12, V4 = Inpari 42 Agritan GSR.

There was a significant interaction in the number of tillers formed between the combination treatment of fertilization and varieties in the vegetative phase (35 DAP) and the generative phase (65 and 112 DAP). The highest number of tillers was shown by the combination of fertilizer treatment of F1 with V1 and V4, at the vegetative phase (35 DAP) to the generative phase (65 and 112 DAP). In other treatments, the number of tillers was significantly lower than the two treatment combinations above (Table 5). This indicated that for the formation of tiller, V1, and V4 had the best response to the combination of F1.

Table 5. Tiller number per plant of the treatments of the study in karst dryland, WS 2019/2020.

Treatments	35 DAP	65 DAP	112 DAP (Harvest Time)
F1V1	20.00 a	18.00 a	13.00 a
F1V2	15.60 cde	13.60 cde	8.60 cde
F1V3	15.00 de	13.00 de	8.00 de
F1V4	19.50 a	17.50 a	12.50 a
F2V1	15.50 cde	13.50 cde	8.50 cde
F2V2	15.70 cde	13.70 cde	8.70 cde
F2V3	14.10 e	12.10 e	7.10 e
F2V4	16.50 bcd	14.50 bcd	9.50 bcd
F3V1	16.90 bc	14.90 bc	9.90 bc
F3V2	16.93 bc	14.93 bc	9.93 bc
F3V3	14.46 e	12.46 e	7.46 e
F3V4	17.46 b	15.46 b	10.46 b
"*p*" value for:			
F	<0.0001 **	<0.0001 **	<0.0001 **
V	<0.0001 **	<0.0001 **	<0.0001 **
F × V	0.001 **	0.001 **	0.001 **
CV	5.24	5.96	9.11

Note: Means in column followed by same letter are not significantly different, according to DMRT 5%; ** = statistically significant; F1 = 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} PM, F2 = 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} PM, F3 = 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} PM, V1 = Inpago 8, V2 = Inpago 10, V3 = Inpago 12, V4 = Inpari 42 Agritan GSR.

There was a significant interaction between the three combination treatments of fertilizers with four varieties tested on the parameters of the number of panicles per plant, percent filled grain, percent unfilled grain, and panicle dry weight per plant. The combination of fertilizer treatment of F1 that interacted with V1 and V4 Inpari 42 produced the highest panicles number, compared to the combination treatment.

Almost all treatments showed a similar percentage of filled grain, except for the combination of fertilizer treatments of F3 with V2, which produced the lowest percentage of filled grain, compared to other treatment combinations. The smallest percentage of unfilled grain produced by the combination of fertilizer treatment of F1 interacted with V1 and V3. For dry grain weight, the combination of fertilizer treatment of F3 with V1 and V2 showed the lowest dry grain weight, compared to other treatments (Table 6).

Table 6. Panicle number per plant, filled grain per panicle, unfilled grain per plant, and panicle dry weight per plant of the study in karst dryland, in Gunungkidul, WS 2019/2020.

Treatments Code	Panicle Number per Plant	Filled Grain per Panicle (%)	Unfilled Grain per Panicle (%)	Panicle Dry Weight per Plant (MC 14%)
F1V1	13.00 a	90.19 a	7.83 f	149.30 a
F1V2	8.60 cde	87.65 a	12.35 cde	150.40 a
F1V3	8.00 de	88.75 a	10.36 f	149.70 a
F1V4	12.50 a	87.73 a	13.14 cde	141.10 a
F2V1	8.50 cde	88.59 a	11.41 de	100.60 bcd
F2V2	8.70 cde	86.62 a	13.37 cd	134.20 a
F2V3	7.10 e	84.19 ab	12.93 cde	105.30 bc
F2V4	9.50 bcd	85.57 a	15.17 c	110.70 b
F3V1	9.90 bc	85.51 a	14.49 c	90.40 cd
F3V2	9.93 bc	65.53 c	34.91 a	86.90 d
F3V3	7.46 e	88.65 a	11.35 de	106.70 bc
F3V4	10.46 b	79.15 b	25.29 b	111.30 b
"*p*" value for:				
F	<0.0001 **	0.0021 **	<0.0001 **	0.464 ns
V	<0.0001 **	<0.0001 **	<0.0001 **	<0.0001 **
F × V	0.001 **	<0.0001 **	<0.0001 **	<0.0001 **
CV	9.11	4.06	9.99	7.45

Note: Means in column followed by same letter are not significantly different, according to DMRT 5%; ns = not statistically significant; ** = statistically significant; F1 = 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} PM, F2 = 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha−1 PM, F3 = 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} PM, V1 = Inpago 8, V2 = Inpago 10, V3 = Inpago 12, V4 = Inpari 42 Agritan GSR.

There was no significant interaction between the combination of fertilization and varieties on the parameters of 1000 grain weight, harvest index, yield, straw production, and total biomass (Table 7). The harvest index in the results of this study showed that all varieties and all fertilizer treatments resulted in almost the same biomass production and economic production. This means that the differences in the combinations of the fertilizer doses given did not result in the plants experiencing differences in growth and production.

From the results of this study, because there was no significant difference and interaction between the treatments given, it is necessary to conduct an economic analysis to determine which combination of fertilizers provides greater benefits for rice farming on the karst dryland in Gunungkidul.

Table 7. The average of 1000 grain weight, harvest index, yield, straw production, and total biomass of the study in karst dryland, in Gunungkidul, WS 2019/2020.

Treatment		**1000 Grain Weight (g)**	**Harvest Index**	**Yield(t ha^{-1})**	**Straw Production (t ha^{-1})**	**Total Biomass (Grain + Straw) t ha^{-1}**
Fertilizer	F1	17.00 a	0.64 a	8.57 a	3.07 a	11.64 a
	F2	17.83 a	0.62 a	8.53 a	3.22 a	11.76 a
	F3	17.83 a	0.65 a	8.73 a	3.02 a	11.75 a
Variety	V1	17.77 a	0.62 a	9.18 a	3.46 a	12.64 a
	V2	17.44 a	0.64 a	9.08 a	3.23 ab	12.30 a
	V3	17.94 a	0.64 a	8.38 a	2.99 ab	11.37 b
	V4	17.05 a	0.65 a	7.81 b	2.74 b	10.55 c
“*p*”-value	F	ns	0.9 ns	0.58 ns	0.570 ns	0.883 ns
	V	ns	0.89 ns	15.42 ns	0.027 ns	<0.0001 **
	F × V	ns	1.63 ns	0.29 ns	0.114 ns	0.351 ns
CV		8.49	9.56	5.65	15.54	5.74

Note: Means in column followed by same letter are not significantly different, according to DMRT 5%; ns = not statistically significant; ** = statistically significant; F1 = 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} PM, F2 = 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} PM, F3 = 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} PM, V1 = Inpago 8, V2 = Inpago 10, V3 = Inpago 12, V4 = Inpari 42 Agritan GSR.

3.3. Cluster Analysis

The treatment interaction dendrogram (horizontal) and the agronomic parameters can be seen via clustergram heatmap analysis (vertical). Two main groups were separated from the dendogram of treatment interactions. Cluster I comprised F3V3, F2V3, F2V4, F2V1, F3V4, F3V1, and F3V2, while cluster II comprised F1V2, F1V3, F1V1, F1V4, and F2V2, respectively.

The dendrogram of agronomic parameters (column) indicates into two groups (Figure 3). The harvest index, 1000 grain weight, panicle length, straw production, unfilled grain per panicle, total biomass, tiller number per plant on 112 DAP, panicle number per plant, and yield accumulated in cluster I. While, plant heights of 112 DAP, filled grain per panicle, and panicle dry weight per plant were clubbed into cluster II. Based on the pattern of color similarity between characters and their genotypes, this character grouping has been created.

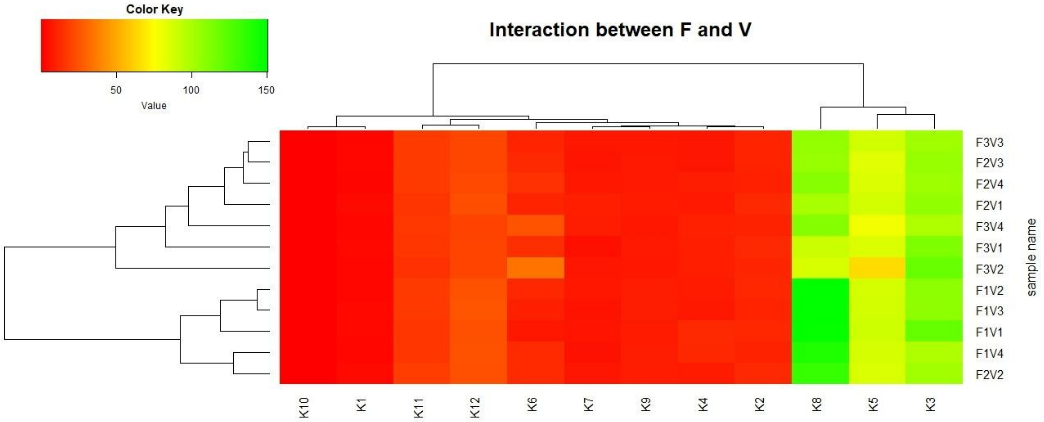


Figure 3. Grouping interaction FxV based on agronomic parameters. Note: K1 = Straw production (t ha^{-1}); K2 = Total biomass (grain + straw) t ha^{-1}; K3 = Plant height on 112 DAP (cm); K4 = Tiller number per plant on 112 DAP (pcs); K5 = Filled Grain per panicle (%); K6 = Unfilled grain per panicle (%); K7 = Panicle number per plant (pcs); K8 = Panicle dry weight per plant (MC 14%) (g); K9 = Yield (t ha^{-1}); K10 = Harvest Index; K11 = 1000 grain weight (g); K12 = Panicle length (cm); F1 = 72 N kg ha^{-1} + 26 P_2O_5 kg ha^{-1} + 25 K_2O ha^{-1} + 3 t ha^{-1} PM; F2 = 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 30 K_2O kg ha^{-1} + 2 t ha^{-1} PM; F3 = 112 N kg ha^{-1} + 46 P_2O_5 kg ha^{-1} + 35 K_2O kg ha^{-1} + 1 t ha^{-1} PM; V1 = Inpago 8; V2 = Inpago 10; V3 = Inpago 12; V4 = Inpari 42 Agritan GSR.

3.4. Yield Profitability (Economic Analysis)

The interaction data of organic fertilizer and variety treatments on yield parameters were used to determine the most economically feasible treatment. Economic analysis of this trial showed that production costs ranged from IDR 19,240,000 to 20,455,000 ha^{-1}. The highest cost occurred on F1, followed by F2 and F3. Different variety did not make any difference to the production cost. The highest proportion of production cost came from labor (43.43–46.79%), followed by seed, fertilizers, and pesticides purchasing (21.40–26.16%) and others such as rental cost, tax, etc. (27.06–28.77%) (Table 8).

Table 8. The production cost of the study in karst dryland, in Gunungkidul, WS 2019/2020.

Treatments Code	Yield (t ha^{-1})	Price (IDR kg^{-1})	Cost (IDR ha^{-1})	Revenue (IDR ha^{-1})	Profit (IDR ha^{-1})	RCR	BEP-Y (t ha^{-1})	BEP-P (IDR kg^{-1})
F1V1	8.90	4700	20,455,000	41,830,000	21,375,000	2.04	4352.13	2298.31
F1V2	9.13	4700	20,455,000	42,911,000	22,456,000	2.10	4352.13	2240.42
F1V3	8.40	4700	20,455,000	39,480,000	19,025,000	1.93	4352.13	2435.12
F1V4	7.83	4700	20,455,000	36,801,000	16,346,000	1.80	4352.13	2612.39
F2V1	9.23	4700	19,795,000	43,381,000	23,586,000	2.19	4211.70	2144.70
F2V2	8.93	4700	19,795,000	41,971,000	22,176,000	2.12	4211.70	2216.69
F2V3	8.20	4700	19,795,000	38,540,000	18,745,000	1.95	4211.70	2414.02
F2V4	7.77	4700	19,795,000	36,519,000	16,724,000	1.84	4211.70	2547.62
F3V1	9.40	4700	19,240,000	44,180,000	24,940,000	2.30	4093.62	2046.81
F3V2	9.17	4700	19,240,000	43,099,000	23,859,000	2.24	4093.62	2098.15
F3V3	8.53	4700	19,240,000	40,091,000	20,851,000	2.08	4093.62	2255.57
F3V4	7.83	4700	19,240,000	36,801,000	17,561,000	1.91	4093.62	2457.22

Note: The basis price of production consisted of: seeds (IDR 9000 kg^{-1}); Urea (IDR 1800 kg^{-1}); SP36 (IDR 2100 kg^{-1}); KCl (IDR 9500 kg^{-1}); poultry manure (IDR 750 kg^{-1}); biopesticides (IDR 130,000 1000 cc^{-1}); labor (IDR 60,000 man^{-1} days^{-1}); transportation (IDR 125 kg^{-1}); and tax (IDR 12,000 ha^{-1}).

The results of the economic analysis showed that the highest production cost was observed in F1 with the use of PM, as much as 3 t ha^{-1} of IDR 20,455,000 ha^{-1}, which was higher than the other two treatments. The high use of PM requires higher labor and transportation costs.

Rice straw produced by each treatment in this study ranged from 2.9 t ha^{-1} (F1V3) to 3.3 t ha^{-1} (F2V3) (Table 9). The highest straw production was obtained by F2V3, while the highest grain yield was obtained by F3V1. There may be interaction among the organic and inorganic fertilizers.

Table 9. Straw biomass and its economic value of the study in karst dryland, in Gunungkidul, WS 2019/2020.

Treatments Code	Straw Biomass (kg ha^{-1})	Straw Economic Value (IDR)	Total Revenue
			(Grain + Straw) (IDR ha^{-1})
F1V1	3000	3,000,000	24,375,000
F1V2	3100	3,100,000	25,556,000
F1V3	2900	2,900,000	21,925,000
F1V4	3005	3,005,000	19,351,000
F2V1	3200	3,200,000	26,786,000
F2V2	3100	3,100,000	25,276,000
F2V3	3300	3,300,000	22,045,000
F2V4	3220	3,220,000	19,944,000
F3V1	3022	3,022,000	27,962,000
F3V2	3001	3,001,000	26,860,000
F3V3	3011	3,011,000	23,862,000
F3V4	3033	3,033,000	20,594,000

Note: price in farmer level is IDR 1000 kg^{-1}.

BEP analysis showed that based on yield (BEP-Y) was between 4093.62–4352.13 kg ha^{-1} at the price of IDR 4700 kg^{-1}. Based on price, the BEP-P was between IDR 2,144,70–IDR 2612.39 kg^{-1} at grain yields ranging from 7.70–9.40 t ha^{-1} (Table 8). Yields increased from 44.42 to 56.45%, and the actual yields and prices will not generate revenue loss for the farmers (revenue less than the production cost).

4. Discussion

4.1. Karst Dryland Characteristicts

Karst has a high content of calcium and high available phosphorus. However, these soils are inherently low in N, K, and CEC. In these soils, P might readily react with Ca to sparingly form soluble calcium phosphates. As a result, a large proportion of applied P may become chemically bound, whereas only a small fraction of soil P remains in the soil solution and available for plant uptake [31]. The chemical properties of karst dryland soil that were applied by inorganic fertilizer + PM in the study area with specific V1, V2, and V3 were significantly higher than the lowland rice variety of V4. The V1, V2, and V3 have the specific character to adapt to dryland conditions during the plant growth phase, where the land may only be inundated for a short period. This means that the input of fresh organic matter in aerobic soil conditions accelerates the rate of mineralization of soil organic matter, which accelerates the release of nutrients, especially N, P, and K in the soil. According to Sultana et al. [32], the rate of mineralization of soil organic matter on aerobic soil conditions is faster than on anaerobic soils, so it will increase nutrient levels. The application of PM improves soil chemical properties, which was shown by the increase of soil reaction, organic carbon, total N, and available potassium in the soil after harvesting time. Thepsilvisut et al. [33] also reported that, after PM and inorganic fertilizer application, the soil pH increased from 4.10 to 4.20–7.10, and the soil E.C. was 0.03–0.08 dS m^{-1} at harvesting. They also reported that increasing P.M.s increased the soil's chemical properties, organic content, total N, available P, and available K at harvesting, compared to only inorganic fertilizers application.

PM has a high organic content (559.30 g kg−1) which slowly releases nutrients into plants to improve and increase the chemical and physical properties of the soil [34]. It is relevant to other previous studies, such as that of Schmidt and Knoblauch [35], who reported that PM contained 2.44% N, 0.67% P, 1.24% K, and C-organic 16.10% and was good for cabbage in Oxic Dystrudepts Lembantongoa. Moe et al. [36] also reported that chicken manure contained 4.87% N, 4.56% P, and 2.14% K, while Soe et al. [37] reported that highest P, K, Ca, and Mg contents in PM were 2.07%, 1.24%, 6.55%, and 0.70%, respectively. Poultry wasted manure is reported to contain high P [38]. According to Islam et al. [39], the application of an organic amendment, such as cow dung or poultry manure in mustard, significantly increased the pH and nutrient uptake of N, P, K, and S. Solid manure can raise soil pH, due to the presence of potassium, sodium, magnesium and calcium, calcium carbonates and bicarbonates, and organic anions, thus increasing the buffer and cation exchange capacities [40].

The reduction of the PM rate tends to decrease the chemical properties of karst dryland soil, namely a decrease of pH, organic C, and total N, as well as the availability of P and K in soil. PM with a relatively higher dose (3 t ha^{-1}) gave significantly better soil chemical properties than the lower dose of PM (1 t ha^{-1}). PM 3 t ha^{-1} was significant for the efficient use of inorganic fertilizers, which in turn increased nutrient uptake by rice plants. The rate of net mineralization of organic manure in soil is critical for supplementing some of the chemical fertilizers required throughout the plant growth phase [39]. Nutrient status and soil reaction after harvest time were not significant among the treatments, but there was a tendency for F1 and F2 treatments to show higher nutrient remains in the soil rather than F3 treatment. It indicates that the higher the PM dosage applied, will be better improve the soil properties.

4.2. Growth and Productivity

The treatment of different doses of organic–inorganic fertilizers and varieties in the dryland of the Gunungkidul karst region revealed that there were interactions between treatments on several growth parameters and production components. At 112 DAP, the maximum plant heights of V1, V2, V3, and V4 corresponded to 113.13 cm, 110, 28 cm, 105 cm, and 100 cm, respectively. According to the variety's description, their average plant heights were 122 cm, 104 cm, 106 cm, and 93 cm. The plant heights show that the plants' vegetative growths were average, meaning that different combinations of fertilizer doses did not generate plants to experience stress. Tiwari et al. [41] stated that plant height is affected by genotypes and environment. Another study by Puli et al. [42] reported that the increased availability of nutrients likely caused the regular increase in plant height, following organic and chemical fertilizers. These findings supported Bargaz et al. [43], in that plant height variations caused by feeding sources were once attributed to variations in the availability of essential nutrients.

Tillering is an important aspect of grain production and, thus, has a big impact on rice production. There was an interaction between the four rice varieties studied with different doses of organic–inorganic fertilizers in the formation of rice tillers. According to the data, the best interaction occurs in the F1V1 and F1V4 treatments, specifically between F1 fertilizer treatments and V1 and V4. Meanwhile, when the varieties interacted with other fertilizer combination treatments, the number of tillers was significantly lower than in F1V1 and F1V4. Fertilizer formula of F2 and F3 using lower doses of organic fertilizers and higher doses of inorganic fertilizers than F1. The differences in these formulas allegedly generated significant differences in the number of tillers formed by the four varieties. The high organic fertilizer content of F1 is thought to enhance the absorption of nutrients and water from the soil, resulting in a better tillering process than F2 and F3 treatments. Accordance to the research of Siavoshi et al. [44], different fertilizer mixtures boosted the number of tillers in rice plants. Micronutrients from organic sources, in particular, give plants a better-balanced diet and positively affect the number of tillers in plants [45].

The parameters of panicle number, percent of filled grain, percent of empty grain, and panicle dry weight show that different fertilizer combinations will give different responses to the same variety. In this case, it can be seen that when V1 interacted with fertilizer containing a high dose of PM (F1), the growth and yield components produced were higher than when V1 interacted with fertilizer containing a low dose of PM (F2 and F3). Meanwhile, the response was not as straightforward as in V1 for the three fertilizer combinations given to other varieties. It indicates the differences in the genetic abilities of the four varieties, and V1 responded better to the different combinations of fertilizers. The number of grains per panicle significantly increased when chemical and organic fertilizers were used [46,47].

In the parameters of economic yield (rice production), biological yield (biomass production), and harvest index, there were no interactions between the combination treatment of organic–inorganic fertilizers and varieties. The funding of this study was not in line with the study of Wang et al. [48], in which the varied fertilizers promoted tiller development and spikelet production, which increased yield. The results of this study showed the production of variety V1 was 9.18 t ha^{-1}, V2 was 9.88 t ha^{-1}, V3 8.38 t ha^{-1}, and V4 was 7.81 t ha^{-1}, respectively. The average productions from the variety descriptions were 8.1, 7.3, 10.2, and 10.58 t ha^{-1}, respectively. It indicates that the yield of V1 and V2 is higher than the average yield in the variety description. It occurred because organic and chemical fertilizers promoted growth, leading to higher harvests [49]. However, the rice productions of V3 and V4 were lower than their variety description.

4.3. Cluster Analysis

The heatmap's hue depicts how similar the agronomic elements of the FxV interaction are to one another. Based on the dendogram analysis of the interactions of FxV revealed that the best interactions of FxV were F1V2, F1V3, F1V1, F1V4, and F2V2 and were influenced by panicle dry weight per plant characters.

4.4. Yield Profitability (Economic Analysis)

The highest yield (9.40 t ha^{-1}) was obtained from F3V1, while the lowest yield (7.77 t ha^{-1}) was obtained from F2V4. It indicated a high yield from high inorganic fertilizers with low organic manure. The genetic potential and the dose of fertilizer applied affected the production of an upland rice variety. Genetically, Inpago 8 is an upland rice variety that has high yield potential (8.10 t ha^{-1}) [50]. Supported by high doses of chemical fertilizers, the F3V1 treatment gave the highest production, compared to other treatments. Redda et al. [51] reported that the increasing of inorganic fertilizers enhanced the rice yield. Herve et al. [52] reported the same case, i.e., that the highest yield in Nort West of Cameroon (5.82 t ha^{-1}) was obtained in the highest NPK application.

The grain price at harvesting time was IDR 4700 kg^{-1}, and the highest revenue obtained was IDR 24,940,000 in the treatment of F3V1. The lowest revenue was obtained in F1V4, i.e., IDR 13,346,000 with the yield of 7.83 t ha^{-1}. On the other hand, the lowest productivity was obtained in F2V4 (7.70 t ha^{-1}). Each treatment gave different revenues, but all treatments gave positive profits overall, as indicated by RCR value > 1. A previous study reported that upland rice farming in the Cross River State of Nigeria obtained an RCR of 3.06, while Ebonyi State of Nigeria had an RCR value of 1.13 and Libokemkem District, North Western Ethiopia, obtained an RCR value of 1.44 [30,53,54]. The variability of the RCR values indicates the variation of yields and outputs of the upland rice cultivation in the area.

Rice straw is a biological product that can have added value [55], but most rice straw is burned, as reported by Magahud et al. [56]. A previous study reported that straw production ranged from 0.76 to 1.77 t ha^{-1} [57]. Wei et al. [58] said that increasing rice yield affected the increase of straw biomass. Shrestha et al. [59] reported that the kind and dosage of organic fertilizer combined with inorganic fertilizers affected straw biomass production. In the trial area, it was used for animal feeding, which increased the farmers' incomes and benefits. The highest economic yields of the straw happened in F2V3 treatment (IDR 3,300,000 ha^{-1}), nevertheless the highest income from total of grain and straw economic value was identified in F3V1 treatment (IDR 27,962,000 ha^{-1}). It indicated that grain yield is still the main contribution to farmer benefit. Increasing grain yield will significantly increase farmer income and benefit.

The difference in profit between F3V1 (the highest profit) and F1V4 (the lowest profit) treatment is IDR 8,594,000 ha^{-1} (52.58%), whereas, when compared to F2V1 treatment, there is a profit difference of IDR 1,354,000 ha^{-1} (5.74%). So, the F2V1 treatment with a profit of IDR 23,586,000 ha^{-1} is recommended for soil management in karst dryland, with consideration of the sustainability of land fertility and productivity that is better than the F3V1 treatment.

Based on economic analysis (profit, RCR, and BEP), V1 showed the highest yield, compared to other varieties, with three levels of organic fertilization. This indicates that the V1 is the most adaptive variety in the study area. The highest profit occurred on F3V1 and lowest profit occurred on F1V4. The F2V1 treatment, with a profit of IDR 23,586,000 ha^{-1}, is an alternative treatment to be developed, with consideration of the sustainability of land fertility, which is better than the F3V1 treatment.

5. Conclusions

The findings of this study demonstrate that upland rice varieties can yield more than irrigated rice varieties, making them a novel invention that should be used to be applied to the development of rice in karst dryland areas in Gunungkidul Yogyakarta. The recommended fertilizer dosage is 92 N kg ha^{-1} + 36 P_2O_5 kg ha^{-1} + 32.5 K_2O kg ha^{-1} + 2 t ha^{-1} organic because it considers the balance between the doses of organic and inorganic fertilizers, so that, in addition to being able to supply plants with what they need to produce a lot, it will also improve the soil's fertility conditions. Economically, the combination of fertilizers and varieties provides a decent advantage for development because the RCR is 2.19, with a profit of IDR 23,586,000 ha^{-1}.

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