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EFFECT OF BIOLOGICAL, ORGANIC, AND MINERAL FERTILIZERS ON THE GROWTH AND YIELD TRAITS OF RICE (*ORYZA SATIVA* L.)

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SUMMARY

The presented field experiment on rice (*Oryza sativa* L.) commenced in the summer of 2020 at the Rice Research Station in Al-Mishkhab, Iraq, aiming to estimate the genetic parameters of rice cultivars using bio-, organic, and mineral fertilizers. The experiment layout had a randomized complete block design (RCBD) with a split-plot arrangement and three replications. The main plots included fertilizer combinations, i.e., full dose of mineral fertilizer (T0), full dose of biological fertilizer (T1), full dose of organic fertilizer (T2), half of the mineral and biofertilizer (T3), half of the organic and biofertilizer (T4), and half of the organic and mineral fertilizer (T5). The subplots comprised six rice cultivars, i.e., Yasamin, Dijlah, Mishkhab-2, Brnamge-4, Amber-33, and Ghadeer. The results revealed, on average, the rice cultivar Amber-33 had the tallest plant height (107.32 cm) and minimum days to 50% flowering (103.73 days), and cultivar Dijlah had the highest average for panicle length, 1000-grain weight, and biological yield (28.12 cm, 23.05 g, and 12.29 t ha^{-1}, respectively). Cultivar Yasamin showed the maximum grain yield (4.50 t ha^{-1}) compared with other cultivars. For fertilizer treatments, half of the organic and mineral fertilizer (T5) had the utmost average of grain yield (4.05 t ha^{-1}), and half of the mineral and biofertilizer (T3) had the maximum plant height, panicle length, and biological yield (90.24 cm, 25.13 cm, and 13.58 t ha^{-1}, respectively).

Keywords: Rice (*O. sativa* L.) cultivars, biological fertilizers, mineral fertilizers, organic fertilizers, , growth and yield traits

Key findings: Rice (*O. sativa* L.) cultivars and fertilizer combinations revealed significant differences for all the traits. Cultivar Yasamin showed the highest average grain yield (4.50 t ha^{-1}). The solutions with half of the organic and mineral fertilizer (T5) and half of the mineral and biofertilizer (T3) excelled in most of the characteristics under study.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the valuable grain crops in Iraq due to its highest nutritional value and a source of energy, protein, and carbohydrates. The rice crop is a vital food source in most regions worldwide (Musa *et al.,* 2021). Rice ranks second after the wheat crop for economic importance and its role in food security in Iraq and the world, as half of the world's population depends on rice as a basic food source. It is also the primary source of energy, making it the staple of another 20% of the world's population. It is the most essential grain crop consumed directly or indirectly (Bin-Rahman and Zhang, 2023).

Rice growing includes more than 100 countries in the world, with global production reaching 742.54 million tons at a cultivated area of about 160.06 million hectares, and an average yield of 4.64 t ha^{-1} (FOA, 2021). In Iraq, during 2020, the local production was about 464,200 tons at a cultivated area of about 101,725 hectares, and an average yield of 4.56 t ha^{-1} (CSO, 2020).

Mineral fertilizers' use in growing strategic crops negatively affects the environment; hence, the trend to reduce adding these chemical fertilizers to the soil due to environmental damages has begun. Several technologies have demonstrated to reduce pollution by natural materials to increase production, such as, bio- and organic fertilizers. With the use of biofertilizers, especially microorganisms, fungi, and other biofertilizers, it can reduce applying chemical fertilizers to the soil, decreasing environmental pollution (Ajmal *et al.,* 2018; Abbas, 2024).

Integrated nutrient management (INM) can better contribute to meeting the growing demands for nutrients of crop plants in agriculture, especially in intensive and successive agriculture. It refers to the maintenance of soil fertility and plant nutrients supply at an optimum level for sustaining the desired productivity through optimizing the benefits from all possible sources of organic, inorganic, and biological components in an integrated manner. The INM is the best future strategy, which can also achieve higher levels of crop productivity in addition to improving soil properties and basic sources of production (Jat *et al.,* 2015; Abbas, 2023).

Biological fertilizers have a complementary role combined with chemical fertilizers because the first batch of chemical fertilizer may have an effective role in the early stages of plant growth and work to stimulate growth activities. Then, the biofertilizers supply the plant with the required nutritional elements in the various stages (Dadhich *et al.,* 2011). Abdulalkarem *et al.* (2015) also reported significant differences among the rice cultivars for yield characteristics, and the genotype IR-10198 showed the highest grain yield. Hasan *et al.* (2022) also declared the rice cultivars had significant differences for growth and yield-related traits. The presented study sought to determine the genetic potential of rice cultivars with bio-, organic, and mineral fertilizers, and their interactions.

MATERIALS AND METHODS

The rice field experiment of the study began during the summer of 2020 on the second half of June at the Rice Research Station, Al-Mishkhab, Iraq (lies below the longitude of 44 East and latitude 32 North). It aimed to estimate the genetic parameters of the rice cultivars under the integration of bio- and mineral fertilizers. The experiment layout in a randomized complete block design (RCBD) had a split plot arrangement, two factors, and three replications. Soil samples came from the experimental field at a depth of 0–30 cm, and incurred chemical and physical properties' analysis in the laboratory at the Department of Soil Research, Agricultural Research, Ministry of Agriculture, Iraq (Table 1). The main plots included several fertilizer combinations. These were full dose of mineral fertilizer (T0), full dose of biological fertilizer (T1), full dose of organic fertilizer (T2), half of the mineral and biofertilizer (T3), half of the organic and biofertilizer (T4), and half of the organic and mineral fertilizer (T5). The subplots included six rice cultivars—Yasamin, Dijlah, Mishkhab-2, Brnamge-4, Amber-33, and Ghadeer.

Table 1. Chemical and physical properties of the experimental field soil before planting.

Components	Values
Soil acidity (pH)	7.5
E.C (Ds m^{-1})	2.6
Nitrogen (mg kg^{-1})	42
Phosphorus (mg kg^{-1})	17.7
Potassium (mg kg^{-1})	203
Soil texture	Silty clay

Soil preparation operations included plowing, smoothing, and leveling. Afterward, dividing the soil into experimental units was according to the parameters, using the split plate arrangement. Each replicate comprised 36 experimental units, totaling 108 experimental units. Each experimental unit included six rows, 4 m long, and the distance between rows and plants was 25 cm. The recommended dose (160 kg ha^{-1}) of phosphatic fertilizer (P_2O_5) became the source of phosphorus, according to recommendation (160 kg ha^{-1}), urea fertilizer (46 N %) as source of nitrogen as per recommended dose (320 kg ha^{-1}) in two batches. The first application was at the branching stage and the second at the beginning of the flowering stage. The added biofertilizer was the Mycorrhiza bacteria full recommendation (10 g $plant^{-1}$), with the added organic fertilizer was in the form of palm frond compost at the full-recommended dose (20 t ha^{-1}). The manual method of transplanting ensued for rice genotypes planting. Rice crop harvesting took place on December 4, 2021.

Data recorded

The data on the vegetative growth characteristics recording transpired on 10 randomly selected plants in each experimental unit and then averaged, such as plant height (cm), days to 50% flowering, and panicle length (cm). The 1000-grain weight (g), biological yield (t ha^{-1}), and grain yield (t ha^{-1}) reached calculations at the end of the growing season. The harvest index (%) measurement used the following equation:

$$\text{Harvest index} = \text{Grain yield} / \text{Biological yield} \times 100$$

Statistical analysis

The analysis of all the recorded data based on various parameters employed the analysis of variance (ANOVA), as per the RCBD design (Al-Mohammadi and Al-Mohammadi, 2012). The least significant difference ($LSD_{0.05}$) test helped compare and further separate the means. The utilization of the computer software GenStat12 ran for all the statistical analyses.

RESULTS AND DISCUSSION

Plant height

The rice cultivars indicated significant differences for plant height (Table 2). Cultivar Amber-33 achieved the highest average (107.32 cm), while the cultivars Yasamin, Dijlah, Mishkhab-2, Brnamge-4, and Ghadeer showed average plant stature of 82.55, 91.77, 80.53, 77.22, and 87.81 cm, respectively. The superiority of the Amber-33 cultivar in plant height may be due to several factors, including genotypic, and the cultivar's better ability to adapt to environmental conditions of the existing surrounding. Such rice cultivars grow stronger and faster than other cultivars, with their performance reflected in growth traits (Mahato and Adhikari, 2017).

Fertilization treatments showed a significant effect on the plant height of the rice cultivars (Table 2). The fertilizer combination treatment half of the mineral and biofertilizer (T3) achieved the highest average for plant height (90.57 cm). However, it also had no significant difference from the treatment T5 (half of the organic and mineral fertilizer), which obtained the plant stature of 90.24 cm,

Table 2. Effect of cultivars, fertilizer combinations, and their interactions on plant height in rice.

Fertilizer combinations	Cultivars						Means (cm)
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	83.61	86.02	80.05	81.60	104.28	90.63	87.69
T1	80.34	94.66	78.64	74.30	100.91	85.04	85.64
T2	76.67	90.30	79.03	72.34	105.30	87.70	85.22
T3	87.00	89.67	80.00	80.67	113.50	92.58	90.57
T4	81.09	92.65	83.41	76.01	109.22	84.60	87.83
T5	86.60	97.33	82.07	78.40	110.74	86.35	90.24
Means (cm)	82.55	91.77	80.53	77.22	107.32	87.81	
$LSD_{0.05}$	Cultivars: 3.13, Fertilizer combinations: 2.86, Interactions: 6.98						

Table 3. Effect of cultivars, fertilizer combinations, and their interactions on the number of days from planting to 50% flowering in rice.

Fertilizer combinations	Cultivars						Means (days)
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	104.21	114.11	115.06	114.89	105.94	110.38	110.76
T1	110.03	111.30	111.58	111.13	105.20	111.80	110.17
T2	105.44	107.88	105.39	105.09	103.00	104.56	105.22
T3	109.60	112.02	112.66	110.36	102.04	109.43	109.35
T4	101.56	107.00	103.30	106.80	104.10	105.07	104.63
T5	104.00	108.13	111.05	108.01	102.12	106.09	106.56
Means (days)	105.80	110.07	109.84	109.38	103.73	107.88	
$LSD_{0.05}$	Cultivars: 1.24, Fertilizer combinations: 1.98, Interactions: 3.91						

compared with the treatment T0 (full mineral fertilizer), achieving the value of 87.69 cm.

Organic and biological fertilizers (T3 and T5) played an important role in improving growth traits, including plant height. These fertilizer combinations further improved soil properties enhancing the ability to retain more water and basic nutrients needed by crop plants for healthy growth. It added to its role in improving root growth, facilitating the process of absorbing more water and nutrients from the soil. Such fertilizer combinations are crucial in providing macronutrients to the plants, such as nitrogen, phosphorus, potassium, and other mineral elements. These elements can promote the growth, cell division and elongation, and thus, enhancing the growth variables in rice crop (Saha *et al.,* 2010).

The interaction effects between rice cultivars and fertilizer combinations revealed significant differences (Table 2). However, the highest value for plant height (113.50 cm) resulted in the interaction of cultivar Amber-33 and fertilizer combination T3 (half of the organic and mineral fertilizer), while the lowest value for the said trait (72.34 cm) occurred in the interaction of rice cultivar Brnamge-4 and fertilizer treatment T2 (full organic fertilizer).

Days to 50% flowering

The results exhibited significant differences among the rice cultivars for days to 50% flowering (Table 3). The minimum days to 50% flowering were visible in the rice cultivar Amber-33 (103.81 days), while the maximum number of days to 50% flowering appeared in the cultivar Dijlah (110.11 days). The superiority of the cultivar Amber-33 in achieving the minimum of 50% flowering may be due to genetic characteristics that cause it to begin the flowering process faster than other rice cultivars. Here, the importance of knowing the number of days from flowering to physiological maturity appears to know the extent of the balance between vegetative and reproductive growth. The dominance of the cultivar Amber-33 in the number of days required for 50% flowering is because of genetic characteristics that helped began the flowering process early compared with other rice cultivars. It may have such genes that affect the regulation of the flowering process and showed earlier flowering (Ashrafuzzaman *et al.,* 2009).

The results indicated significant differences among the fertilization combinations for days to 50% flowering (Table 3). The fertilizer treatment T4 achieved the lowest average number of days to 50% flowering (104.63 days). However, it was not significantly different from the two other fertilizer treatments (T2 and T5), which had the average number of days to flowering (105.22 and 106.56 days, respectively) compared with the chemical fertilizer treatment (T0 = 110.76 days). The reason may be due to the presence of organic fertilizer, which has a positive role of providing rich sources of many basic nutritional and small elements vital for plant growth. Organic fertilizers also enhance the readiness of these elements and increase the activity of microorganisms and root system, directly reflected with rice plants' growth (Myint *et al.,* 2010).

The findings also provided significant interaction effects between the rice cultivars and fertilizer treatments for days to 50% flowering (Table 3). The interaction with the best performance and early flowering emerged between the rice cultivar Yasamin and fertilizer treatment T4 (101.56 days). However, the highest and average days from planting to 50% flowering were evident in the interaction of cultivar Mishkhab-2 and fertilizer treatment T0 (115.06 days).

Panicle length

The outcomes revealed significant differences among the rice cultivars for panicle length (Table 4). Cultivar Dijlah achieved the maximum average of panicle length (28.12 cm), whereas Cultivar Brnamge-4 had the lowest average of panicle length (22.22 cm). The superiority of the cultivar Dijlah over other cultivars in panicle length may be due to several factors, including the cultivar's genotypic causing it to grow better than other cultivars. Similarly, the cultivar showed better adaptability to the prevailing environmental conditions, and therefore, makes it possible to excel in growth and development with other rice genotypes (Lestari *et al.,* 2015).

For panicle length, the fertilizer combinations also enunciated significant differences (Table 4). The fertilizer combination T3 (half of the mineral and biofertilizer) achieved the topmost average of panicle length (25.13 cm), which also had no significant difference from other fertilizer treatments (T1, T2, T4, and T5), amounting to 24.86, 24.77, 24.48, and 25.01 cm, respectively, compared with the chemical fertilization treatment (T0) with the lowest average (24.17 cm). It may be due to the effect of mycorrhizae, which contributed positively and has the ability to secrete and transport some compounds that contribute releasing nutrient elements and their transformation from the complex state to that for easy absorption by crop plants. These processes also improved their concentration in the soil, which were vital to stages of crop plants. The improvement in growth and development manifested in rice panicle growth (Kumar *et al.*2017).

Panicle length has recorded significant interaction effects between the rice cultivars and fertilizer treatments (Table 4). The enhanced panicle length (29.33 cm) appeared with the interaction of cultivar Dijlah and

Table 4. Effect of cultivars, fertilizer combinations, and their interactions on panicle length in rice.

Fertilizer combinations	Cultivars						Means (cm)
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	21.87	27.73	23.44	22.93	23.40	25.70	24.17
T1	21.53	28.57	24.13	22.07	26.93	25.93	24.86
T2	21.80	27.47	22.40	22.40	25.97	28.60	24.77
T3	22.07	29.33	23.87	22.80	25.00	27.73	25.13
T4	23.20	26.87	24.20	21.13	25.40	26.13	24.48
T5	24.33	28.80	23.00	22.00	24.03	27.93	25.01
Means (cm)	22.46	28.12	23.50	22.22	25.12	27.00	
$LSD_{0.05}$	Cultivars: 1.09, Fertilizer combinations: 0.85, Interactions: 2.56						

fertilizer treatment T3 (half of the mineral and biofertilizer), while the lowest panicle length (21.13 cm) resulted in the interaction of rice cultivar Brnamge-4 and fertilizer treatment T4 (half of the organic and biofertilizer).

1000-grain weight

The results indicated significant differences among the rice cultivars under study for 1000-grain weight (Table 5). Cultivar Dijlah exhibited the highest average of 1000-grain weight (23.05 g), with the lowest average for the said trait obtained in the cultivar Amber-33 (21.43 g). The superiority of the cultivar Dijlah in 1000-grain weight may be due to the genetic nature of the cultivar, manifesting in the nature of the composition of the genes responsible for this trait. It may also be because the cultivar Dijlah has well adaptability to existing environmental conditions, contributing to its growth and development with increased grain size and weight (Al-Salim, 2016).

Outcomes also showed a significant effect of the fertilization treatments (Table 5). The fertilizer treatment T4 achieved the maximum average for 1000-grain weight (23.04 g) compared with the chemical fertilization treatment/the control treatment (21.76 g). An explanation could be the positive effects of the microelements and biological fertilizers on the growth, productivity, and quality of rice plants (Gomaa *et al.,* 2015). Moreover, the readiness of nutrients caused by organic fertilizers increases the efficiency of plants to convert many net products of photosynthesis as possible into stored dry matter and transporting it to the grains, raising the rice's 1000-grain weight (Egbuchua and Enujeke, 2013).

The results showed significant interaction effects between the rice cultivars and fertilizer combinations (Table 5). The interaction between the cultivar Dijlah and fertilizer treatment T4 (half of the organic and biofertilizer) provided the supreme average for 1000-grain weight (24.76 g), while the minimum interaction effects (20.02 g) was apparent between the cultivar Ghadeer and fertilizer treatment T1 (full biofertilizer).

Biological yield

For biological yield, the rice cultivars specified noteworthy differences (Table 6). Cultivar Dijlah achieved the maximum biological yield (12.29 t ha^{-1}), and the cultivar Ghadeer emerging with the minimum average (10.97 t ha^{-1}). The superiority of the rice cultivar Dijlah over the rest of the cultivars in biological yield indicates its higher ability to assimilate more dry matter, and thus, reflecting in an increased biological yield. It may also refer to the excellent genetic characteristics of this rice cultivar by having more vegetative mass (Chowhan *et al.,* 2017).

The fertilization treatments also showed a significant effect on the rice cultivars' biological yield (Table 6). The fertilizer treatment T3 attained the highest average of biological yield (13.58 t ha^{-1}). However, it did not differ significantly from the average of the fertilizer treatment T5, which amounted to 13.57 t ha^{-1} compared with the chemical fertilizer (T0) and the control treatment (12.07 t ha^{-1}). The fertilizer combinations T1, T2, and T4 gave the average values of 9.22, 9.40, and 9.79 t ha^{-1}, respectively. Organic fertilizers are essential in increasing biological yields, as they contain natural organic materials, such as plant and animal waste and compost. These contain a variety of basic nutrients, such as nitrogen, phosphorus, potassium, microelements, and trace elements, which enhance plant growth and improve soil quality. Moreover, it can contribute to enhancing the efficiency of resource use, as reflected in an increased dry matter accumulation. The biofertilizers decompose organic material and release nutrients available to the plants, augmenting the root growth and efficiency of the plant's absorption of nutrients, and thus, increasing rice crop's biological yield (Farah *et al.,* 2014; Akhmad *et al*., 2024; Olzhabayeva *et al*., 2024).

The results further revealed a substantial interaction effects between the rice genotypes and fertilizer combinations. The interaction of cultivar Dijlah with fertilizer treatment T0 resulted with the utmost average biological yield (16.03 t ha^{-1}), while the interaction of rice cultivar Mishkhab-2 with

Table 5. Effect of cultivars, fertilizer combinations, and their interactions on the weight of 1000 grain in rice.

Fertilizer combinations	Cultivars						Means (g)
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	22.00	22.87	23.72	20.70	20.31	21.00	21.76
T1	22.60	21.49	22.19	22.08	22.00	20.02	21.73
T2	22.25	23.38	20.30	21.33	21.79	22.31	21.89
T3	22.69	22.50	21.99	21.09	22.14	20.87	21.88
T4	23.12	24.76	22.60	22.61	22.32	22.85	23.04
T5	23.00	23.34	22.42	21.80	20.06	22.91	22.25
Means (g)	22.61	23.05	22.20	21.60	21.43	21.51	
$LSD_{0.05}$	Cultivars: 0.345, Fertilizer combinations: 0.435, Interactions: 0.863						

Table 6. Effect of cultivars, fertilizer combinations, and their interactions on the biological yield in rice.

Fertilizer combinations	Cultivars						Means (t ha^{-1})
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	15.08	16.03	14.76	8.98	8.65	8.98	12.07
T1	10.25	8.42	11.22	8.20	8.39	8.89	9.22
T2	8.98	9.26	8.99	9.32	10.13	9.71	9.40
T3	14.89	14.25	13.74	12.44	12.10	14.04	13.58
T4	9.07	11.61	8.09	9.52	9.77	10.69	9.79
T5	13.95	14.18	12.34	12.63	12.85	10.87	13.57
Means (tons ha^{-1})	12.04	12.29	11.52	11.17	11.48	10.97	
$LSD_{0.05}$	Cultivars: 0.81, Fertilizer combinations: 1.17, Interactions: 2.10						

fertilizer treatment T4 was notably with the lowest average for the said trait (8.09 t ha^{-1}).

Grain yield (t ha^{-1})

The findings implied that rice cultivars have significant differences for grain yield (Table 7). Cultivar Yasamin reached the premier average grain yield (4.50 t ha^{-1}), whereas the cultivar Mishkhab-2 acquired the lowest average for the said trait (2.93 t ha^{-1}). The superiority of the cultivar Yasamin in grain yield may be due to its genotypic that makes it more capable of converting dry matter and moving it from the source to the sink, positively affecting the grain productivity. Cultivar Yasamin may have better adaptation to the environmental conditions, such as temperature, humidity, and soil type, benefitting from surrounding factors for increased grain productivity (Hussain *et al.,* 2014).

Furthermore, the fertilization combinations significantly influenced the grain yield (Table 7). Fertilizer treatment T5 (half of the organic and mineral fertilizer) achieved the highest average grain yield (4.05 t ha^{-1}) compared with the chemical fertilization treatment (T0), which gave 3.89 t ha^{-1}. Organic fertilization contributes considerably to improving the soil structure and aeration, which facilitates the plant roots' processes for growth and absorption. Therefore, the superiority of the fertilizer treatment T5 can contribute to organic fertilization for soil quality improvement by increasing the organic matter and basic nutrients, such as nitrogen, phosphorus, and potassium. These soil nutrients enhance plant growth and its ability to accumulate more dry matter, and thus, raising the grain productivity (Kakar *et al.,* 2020).

The results further revealed remarkable differences among the interactions between the rice cultivars and fertilizer treatments (Table 7). The maximum grain yield (5.18 t ha^{-1}) occurred with the interaction of cultivar Dijlah and fertilizer treatment T1, while the minimum average yield (1.88 t ha^{-1}) emerged with the interaction of cultivar Mishkhab-2 and fertilizer treatment T1.

Table 7. Effect of cultivars, fertilizer combinations, and their interactions on the grain yield in rice.

Fertilizer combinations	Cultivars						Means (t ha^{-1})
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	4.32	4.17	4.46	3.23	3.80	3.36	3.89
T1	4.69	5.18	1.88	2.38	2.28	2.51	3.15
T2	3.86	3.55	1.96	3.06	3.04	2.64	3.02
T3	4.42	3.47	3.42	4.40	3.32	2.86	3.65
T4	4.70	4.05	2.20	2.72	3.06	2.73	3.24
T5	4.98	4.74	3.65	3.37	3.45	4.12	4.05
Means (tons ha^{-1})	4.50	4.19	2.93	3.20	3.16	3.04	
$LSD_{0.05}$	Cultivars: 0.71, Fertilizer combinations: 0.92, Interactions: 1.10						

Table 8. Effect of cultivars, fertilizer combinations, and their interactions on the harvest index in rice.

Fertilizer combinations	Cultivars						Means (%)
	Yasamin	Dijlah	Mishkhab-2	Brnamge-4	Amber-33	Ghadeer	
T0	32.95	42.81	45.29	40.37	39.69	44.73	40.97
T1	44.84	54.04	41.91	45.77	34.65	37.72	43.15
T2	42.24	54.03	41.91	45.77	41.95	37.72	43.93
T3	44.47	47.04	45.13	49.33	38.51	44.19	44.77
T4	44.44	47.04	45.13	49.33	41.22	44.19	45.22
T5	36.94	51.42	48.54	42.63	44.98	40.72	44.20
Means (%)	44.76	48.79	46.63	43.58	40.16	42.88	
$LSD_{0.05}$	Cultivars: 1.29, Fertilizer combinations: 2.57, Interactions: 4.42						

Harvest index

For harvest index, the rice cultivars indicated significant differences (Table 8). Cultivar Dijlah gave the ultimate average of harvest index (48.79%), while the cultivar Amber-33 showed the lowest average of the said trait (40.16%). It may refer to the superiority of this cultivar in biological yield (Table 6), directly related to the harvest index. Similarly, it can be due to the genotypic of rice cultivars (Elkheir *et al.,* 2018). The results also expressed the prominent variances among the fertilization combinations for harvest index (Table 8). Fertilizer treatment T4 achieved the highest average of harvest index (45.22%), but had nonsignificant differences from other fertilizer combinations, T1, T2, T3, and T5, giving average values of 43.15%, 43.93%, 44.77%, and 44.20%, respectively, compared with the chemical fertilization treatment (T0), providing the lowest average (40.97%).

Harvest index has direct linkage to the grain and biological yields. Therefore, the superiority of the same treatment in biological yield may also authenticate its leading role in the harvest index (Gomaa *et al.,* 2015). The significant interaction effects were also evident between rice cultivars and fertilizer treatments (Table 8). Cultivar Dijlah in interaction with fertilizer treatment T1 revealed the topmost average (54.04%), while the lowest average interaction effect for harvest index (32.95%) appeared with the rice cultivar Yasamin and fertilizer treatment T0.

CONCLUSIONS

The results revealed that rice cultivars considerably responded to the fertilizer combinations, especially organic and biofertilizers added with mineral fertilizers. Therefore, this type of fertilization could be a favorable alternative for improving soil properties and increasing productivity sustainably, in addition to reducing environmental pollution caused by chemical fertilization.

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