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Effects of vermicompost applications on chlorophyll content and flag leaf area in rice (*Oryza sativa* L.)

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Abstract: In this study, the effects of different vermicompost doses and applications on chlorophyll content and flag leaf development in three different rice cultivars (*Oryza sativa* L.) were investigated. The study used three different rice cultivars, two different vermicompost applications (foliar and soil), and four different fertilizer doses (0.7, 1.4, 2.1, and 2.8 liters per 100 liters). In this study, the time of measurement was considered as the fourth source of variation, and measurements were made at seven different times. Chlorophyll measurements were made at seven different times, every 10 days, starting from the first leaf formation. The first measurement was made at the beginning of the experiment, and subsequent measurements were made on days 16, 26, 36, 46, 57, and 67. After the plant had completed its development, the flag leaf length (in cm), flag leaf width (in cm), and flag leaf area (in cm^2) were also measured. The experiment was planned according to a factorial design on randomized plots with 3 replicates. The analysis results showed that the average flag leaf length was 11.92 ± 2.46 cm, the average flag leaf width was 0.95 ± 0.07 cm, and the average flag leaf area was 8.45 ± 1.83 cm^2. Chlorophyll content also varied considerably between measurements made on different days. The application method, time, and dose of vermicompost have been shown to have a significant impact on the amount of chlorophyll and flag leaf area in rice leaves.

ABOUT THE AUTHOR



Gözde Hafize Yildirim

Gözde Hafize Yıldırım In this study, the effects of different vermicompost doses and application methods on chlorophyll content and flag leaf development were investigated in three different rice cultivars. We examined how these factors affected the growth and vitality of rice plants, with a particular focus on flag leaves, which are the most important part of rice plants for grain yield. Soil application of vermicompost yielded the most favorable results. In addition, fertilizer application timing, specifically 16 days after the initial measurement, led to the highest chlorophyll levels. We also measured flag leaf sizes and observed variations among cultivars. For example, the Efe variety had the longest flag leaves. These findings show how different approaches to vermicompost application can affect rice plants, offering insights that can benefit both farmers and agricultural enthusiasts.

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Subjects: Agricultural Engineering; Crop Science; Agriculture and Food

Keywords: chlorophyll content; flag leaf; rice; *Oryza sativa* L

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important crops in the world for human nutrition and is a staple food for more than half of the world's population . Ninety percent of rice is produced and consumed in Asian countries. Turkey is also seeing an increase in rice production. In 2018, the cultivated area was 1,200 thousand hectares, the production amount was 940 thousand tons, and the average yield was 782 kg/hectare (TUİK, 2018). Rice has an important place in human nutrition as it is used in many dishes (Ayaşan et al., 2019). It contains nutrients such as iron, phosphorus, calcium minerals, vitamins B2, B1, carbohydrates, and protein (Şapaloğlu, 2015). It is also very important that such plants contain vital substances that meet the nutritional needs of the human population. Especially considering the share of cereal crops (e.g. wheat, rice, oats, corn, etc.) in human nutrition (FAO, 2018), the importance of these crop groups increases even more (Yazlık et al., 2020).

Human presence is an important element in agricultural ecosystems. The unscientific and imprudent use of chemical fertilizers leads to the degradation of the soil ecosystem, increased soil acidity, and heavy metal accumulation. Agricultural practices should be diversified and improved due to decreasing soil fertility and lowering groundwater levels (Singh et al., 2020). Organic agriculture (OA) is gaining popularity due to its health and environmental benefits, consumer demand, and government support. Organic agriculture is perceived as healthier than conventional agriculture, and farmers focus on producing high-quality natural products. OA practices promote biodiversity, reduce soil erosion, conserve water, and reduce pollution. Incorporating OA methods into land management practices can promote a sustainable bioeconomy and address equity concerns (Giampieri et al., 2022; Ondrasek et al., 2023; Smith-Spangler et al., 2012; Willer et al., 2022). Compost, vermicompost, and green manure are some of the important types of fertilizers used in organic farming. The use of vermicompost and other organic fertilizers is globally proposed as a way to offset natural and anthropogenic wastes. Vermicompost application changes the physicochemical properties of soil and microbial communities. It also affects the physiological and biochemical properties of plants. Photosynthesis is an important indicator of productivity and is essential for promoting plant growth and development (Liu et al., 2022). Another advantage of these fertilizers is that they are easily absorbed by plants (Jayakumar et al., 2011). The easy absorption of nutrient elements by plants will allow them to produce more nutrients and grow faster by taking advantage of other environmental factors (such as water and temperature) more efficiently during their growth period. Some organic and inorganic nutrients such as NPK (120-60-60), vermicompost, and green manure are observed to increase some yield elements and chlorophyll content in rice (Singh et al., 2015). The aim of this study was to determine the effects of vermicompost on chlorophyll content and flag leaf development in rice plants. It was also established to determine the effectiveness of different varieties, doses, and application methods.

2. Materials and methods

The experimental site for this study was located in the greenhouse area of the Ordu University Faculty of Agriculture Research and Application Land in 2021. Its exact geographical coordinates were 40.971247° latitude and 37.937063° longitude, with an elevation of 5.3 meters above sea level. Four different liquid fertilizer doses (0.7, 1.4, 2.1, and 2.8 liters per 100 liters of water), two different applications (foliar and soil applications), and three different rice varieties (*Oryza sativa* L.) were used in this study: Efe, Halilbey, and Baldo. The Efe variety used in the experiment is a high-yielding variety with a sturdy stem that is resistant to lodging. The leaves are semi-erect and green in color. The variety matures in 125–130 days. Halilbey matures in 130–135 days and also has high yield potential. The plant height is generally 95–100 cm. The leaves are broad and dark green. Baldo is an early-maturing variety with a high yield potential. Vermicomposts used in the experiment had the following

characteristics: 2–4% organic matter, 2–4% total (humic+fulvic) acid, 0.4–1.8% organic nitrogen, pH levels ranging from 6.5 to 7.7, and electrical conductivity (EC) values between 4 and 7. The experiment was planned according to a factorial design on randomized plots with three replicates. The main sources of variation within the study included the factors of variety, application method, dose, and measurement times. Throughout the study, measurements were carried out randomly on 10 plants selected from each pot, and subsequently, the mean values were calculated for analysis.

2.1. Cultivation method

The study was conducted in plastic pots with a diameter of 35 cm and a height of 30 cm. The pots were filled with a mixture of soil and sand in a 1:1 ratio. Each pot was manually sown with 30 seeds, calculated at 500 seeds per square meter. After the seeds germinated, the water amount was increased, and the water level was not lowered below 5 cm until approximately 10–15 days before harvest. The earthworm manure applied to the soil was applied once immediately after germination. The foliar application was started with a backpack sprayer with a fine nozzle after the first leaves formed. It continued every 10 days until the beginning of panicle formation. Chlorophyll measurements were also started with the chlorophyll meter SPAD on the days determined for all observations, along with the application of foliar fertilizers. Measurements were recorded every 10 days. The measurements were always taken from the youngest leaves. The last measurement was taken from the flag leaves. Standard fertilization was applied equally to all pots, calculated at 15 kg of pure nitrogen and 8 kg of pure phosphorus per hectare. The study was conducted in August, September, and October. During the study, the temperature in the greenhouse was recorded to fluctuate between 28 and 35 degrees Celsius during the day, and the humidity was recorded to fluctuate between 70 and 82 percent. These measurements were taken every 15 days and averaged. No lights or heaters were used.

2.2. Data analytics

Chlorophyll measurements were taken at seven different times (first measurement [when the first leaves were formed], 10 days after the first measurement [day 16], and then at ten-day intervals [day 16, day 26, day 36, day 46, day 57 and day 67]). Additionally, measurements for flag leaf length (cm), flag leaf width (cm), and flag leaf area (cm^2) were calculated.

2.3. Measurement of chlorophyll content (mSPU) with SPAD (Soil-Plant Analysis Development)

Measurements were conducted with the Minolta SPAD-502 m device, which provides a relative value ranging from 0 to 100. The total chlorophyll content was determined by recording SPAD readings on the leaves of 10 plants with a portable chlorophyll meter.

2.4. Flag leaf length and width (cm)

At the end of the experiment, the leaf length of 10 randomly selected plants was measured with a millimeter ruler.

2.5. Flag leaf area (cm^2)

Flag leaf area was calculated according to the following formula, as reported by Demir (1983).

$$FLA = \text{Flag Leaf Width XLength x}0.79$$

2.6. Statistical analysis

The data were analyzed using Minitab v14. Compliance with the normal distribution was examined through the Shapiro-Wilk test. The generalized linear models method was employed to compare chlorophyll content based on cultivar, application, dose, and time. Multiple comparisons were conducted using the Tukey HSD test. For leaf length, width, and area comparisons according to cultivar, application, and dose, a three-way ANOVA was performed, followed by multiple comparisons using the Tukey HSD test. The results of the analysis are presented as mean ± standard deviation. The significance level was set at $p < 0.050$.

3. Results and discussion

Two different foliar and soil applications and four different doses of vermicompost were applied on rice varieties and their effects on chlorophyll content and flag leaf development were investigated. The results obtained and the results of the statistical analyzes are given in Tables 1–8 and Figures 1–4 below

3.1. Chlorophyll amount

Vermicompost fertilizers increase chlorophyll levels in many plant species. Studies on rice and other plant species have shown that the chlorophyll content of plants [with vermicompost application] increased by a certain percentage compared to the control group (Gupta et al., 2011; Preeti Shrimal, 2017; Ruan et al., 2021; Sundari & Gandhi, 2013). In this study, the effects of vermicompost application on chlorophyll content of different rice varieties (Efe, Baldo, and Halilbey) were investigated. Vermicompost was applied at different doses (0.7, 1.4, 2.1, and 2.8 liters per 100 liters) and at different time intervals (16, 26, 36, 46, 57, and 67 days) by leaf and soil application methods. The results showed that there was a significant difference in chlorophyll content among rice varieties ($p < 0.001$). The average chlorophyll contents were 30.44 mSPU for the Efe variety, 32.36 mSPU for the Baldo variety, and 31.93 mSPU for the Halilbey variety. This difference was due to the lower chlorophyll content of the Efe variety than the other varieties. There was also a significant difference in chlorophyll content between application methods ($p = 0.011$). The average chlorophyll content for soil application was 31.84 mSPU, while the average chlorophyll content for leaf application was 31.31 mSPU. This difference was due to the higher chlorophyll content of soil application than leaf application. There was no significant difference in chlorophyll content between doses ($p = 0.078$). However, there was a significant difference in chlorophyll content between time intervals ($p < 0.001$). The highest chlorophyll content was obtained on the 16th day, while the lowest chlorophyll content was obtained at the first measurement. In the interaction between rice varieties and time intervals, the highest chlorophyll content was obtained from the Baldo × 16 interaction. In the interaction between application methods and doses, the highest chlorophyll content was obtained from the soil × 2.8 interaction. Similar studies have shown that vermicompost application can increase chlorophyll content in rice plants. Chiranjeeb et al. (2022) reported a chlorophyll value of 36.05 mSPU at the 8th week (56th day), which was higher than the control group. Didal et al. (2022) reported an increase of 32.9 to 35.4 mSPU, and Tari et al. (2009) reported values of 37.86–24. These results are consistent with our findings. Laila et al. (2022) reported values of 44.50–29.79 on the 30th day, 44.17–36.19 on the 50th day, 41.95–31.65 on the 70th day, and 40.55–25.90 on the 90th day, all in mSPU units. Sarker et al. (2022) reported a value of 42.12–34.01 mSPU, and Mehrabi and Sepaskhah (2022) reported a value of 50–36 mSPU. These values are higher than ours. Samant et al. (2022) reported a value of 22.61–18.59 mSPU, which is lower than ours. The amount of chlorophyll in plant leaves can vary depending on a number of factors, such as the environment in which the plant grows, cultural practices, light conditions, fertilization, or stress factors. The effects of these changing conditions on chlorophyll levels are very different. In this study, the effects of vermicompost applications on different rice varieties were investigated, and it was observed that chlorophyll efficiency was quite variable. It was found that this situation was greatly affected by the application method and dose.

3.2. Flag leaf length (cm)

It is known that vermicompost fertilizers of many different varieties have an effect on flag leaf length in both rice plants and other species (Alam et al., 2007; Ansari, 2008; Arancon et al., 2003; Edwards & Arancon, 2004) When we examined the results of the study, we found a significant difference between the average flag leaf length values of the varieties ($p < 0.001$). The mean of the Efe variety was 15.01 cm, the mean of the Halilbey variety was 10.43 cm, and the mean of the Baldo variety was 10.33 cm. There was no difference between the mean flag leaf length values according to the applications ($p = 0.500$). A statistically

Table 1. Mean squares and significance levels of cultivars, treatments, doses and interactions on chlorophyll content

	Sd	Sum of Squares	Mean Squares	F	p	Partial eta-squared
Cultivar	2	337.440	168.720	31.080	**<0.001**	0.156
Application	1	35.240	35.240	6.490	0.011	0.019
Dose	3	37.270	12.420	2.290	0.078	0.020
Time	6	6271.190	1045.200	192.520	**<0.001**	0.775
*Cultivar * Application*	2	6.960	3.480	0.640	0.528	0.004
*Cultivar *Dose*	6	39.860	6.640	1.220	0.294	0.021
*Cultivar *Time*	12	336.690	28.060	5.170	**<0.001**	0.156
*Application*Dose*	3	26.660	8.890	1.640	0.181	0.014
*Application*Time*	6	40.870	6.810	1.250	0.278	0.022
*Dose*Time*	18	67.910	3.770	0.690	0.816	0.036
*Cultivar *Application*Dose*	6	79.110	13.180	2.430	0.026	0.042
*Cultivar *Application*Time*	12	121.910	10.160	1.870	0.037	0.063
*Cultivar*Dose*Time*	36	174.040	4.830	0.890	0.653	0.087
*Application*Dose*Time*	18	89.650	4.980	0.920	0.558	0.047
*Cultivar*Application*Dose*Time*	36	148.150	4.120	0.760	0.843	0.075

SD:Degrees of freedom, F: Analysis of variance test statistic, R2 = %81.16, Adjusted R2 = %71.77.

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Table 2. Descriptive statistics and multiple comparison results of chlorophyll content

Application	Dose	Time	Cultivar			Total
			Efe	Halilbey	Baldo	
From Soil Application	0.7	1st measurement	26.91 ± 3.26	27.64 ± 2.11	26.80 ± 2.76	27.11 ± 2.41
		Day 16	33.85 ± 1.62	36.95 ± 0.53	36.83 ± 0.94	35.88 ± 1.80
		Day 26	31.95 ± 3.89	33.83 ± 0.98	33.40 ± 0.98	33.06 ± 2.23
		Day 36	26.15 ± 2.54	27.57 ± 0.56	27.65 ± 1.84	27.12 ± 1.75
		Day 46	32.22 ± 1.92	30.01 ± 2.71	32.79 ± 2.04	31.67 ± 2.33
		Day 57	33.38 ± 0.33	33.89 ± 3.16	32.69 ± 2.63	33.32 ± 2.13
		Day 67	33.67 ± 1.48	33.90 ± 1.73	34.95 ± 1.00	34.17 ± 1.38
		Total	31.16 ± 3.69^{BCDE}	31.97 ± 3.78^{ABCDE}	32.16 ± 3.82^{ABCD}	31.76 ± 3.73
	1.4	1st measurement	30.67 ± 4.85	26.02 ± 2.01	25.24 ± 1.94	27.31 ± 3.78
		Day 16	32.80 ± 2.06	36.51 ± 2.81	37.09 ± 2.00	35.47 ± 2.85
		Day 26	30.77 ± 2.91	32.83 ± 1.06	33.93 ± 1.63	32.51 ± 2.23
		Day 36	25.51 ± 1.96	26.53 ± 0.65	28.49 ± 1.78	26.84 ± 1.89
		Day 46	31.33 ± 3.21	31.08 ± 1.38	34.47 ± 1.85	32.29 ± 2.56
		Day 57	33.87 ± 2.14	35.90 ± 2.19	38.11 ± 3.25	35.96 ± 2.89
		Day 67	35.17 ± 0.62	34.41 ± 0.43	37.89 ± 1.99	35.82 ± 1.91
		Total	31.44 ± 3.77^{ABCDE}	31.90 ± 4.28^{ABCDE}	33.60 ± 5.03^{AB}	32.31 ± 4.42

(*Continued*)

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Table 2. (*Continued*)

Application	Dose	Time	Cultivar			Total
			Efe	Halilbey	Baldo	
	2.1	1st measurement	23.14 ± 6.38	26.65 ± 0.82	25.45 ± 1.03	25.08 ± 3.61
		Day 16	32.37 ± 1.69	36.25 ± 1.50	36.45 ± 2.03	35.02 ± 2.50
		Day 26	29.53 ± 0.98	35.34 ± 2.99	33.15 ± 3.55	32.67 ± 3.47
		Day 36	25.09 ± 2.01	28.88 ± 3.16	25.43 ± 1.10	26.47 ± 2.66
		Day 46	29.15 ± 2.87	31.41 ± 2.40	29.83 ± 2.61	30.13 ± 2.49
		Day 57	33.79 ± 2.63	31.25 ± 2.54	34.69 ± 3.67	33.24 ± 3.02
		Day 67	33.35 ± 4.07	36.23 ± 1.81	35.63 ± 2.27	35.07 ± 2.83
		Total	29.49 ± 4.82^{E}	32.29 ± 4.07^{ABCDE}	31.52 ± 4.90^{ABCDE}	31.10 ± 4.69
	2.8	1st measurement	25.61 ± 2.10	27.45 ± 0.69	27.99 ± 1.18	27.02 ± 1.65
		Day 16	33.74 ± 1.05	37.95 ± 1.31	37.36 ± 0.06	36.35 ± 2.15
		Day 26	31.33 ± 0.40	35.08 ± 1.14	35.80 ± 0.49	34.07 ± 2.18
		Day 36	25.04 ± 0.64	26.47 ± 1.34	28.59 ± 1.59	26.70 ± 1.89
		Day 46	30.05 ± 3.26	32.09 ± 4.86	32.32 ± 1.08	31.49 ± 3.17
		Day 57	34.35 ± 2.39	32.73 ± 0.90	38.01 ± 0.53	35.03 ± 2.68
		Day 67	33.94 ± 2.11	33.37 ± 3.39	36.80 ± 1.56	34.70 ± 2.67
		Total	30.58 ± 4.05^{CDE}	32.16 ± 4.35^{ABCD}	33.84 ± 4.09^{A}	32.19 ± 4.31
	Total	1st measurement	26.58 ± 4.74^{LM}	26.94 ± 1.48^{KLM}	26.37 ± 1.97^{LM}	26.63 ± 3.01
		Day 16	33.19 ± 1.55^{BCDEF}	36.92 ± 1.63^{A}	36.93 ± 1.33^{A}	35.68 ± 2.31
		Day 26	30.90 ± 2.31^{EFGHIJ}	34.27 ± 1.83^{ABCDEF}	34.07 ± 2.04^{ABCDEF}	33.08 ± 2.55
		Day 36	25.45 ± 1.70^{LM}	27.36 ± 1.82^{JKLM}	27.54 ± 1.91^{IJKLM}	26.78 ± 2.00
		Day 46	30.69 ± 2.73^{FGHIJ}	31.15 ± 2.76^{DEFGHI}	32.35 ± 2.42^{CDEFG}	31.40 ± 2.66
		Day 57	33.85 ± 1.81^{ABCDEF}	33.44 ± 2.68^{ABCDEF}	35.88 ± 3.38^{ABC}	34.39 ± 2.84
		Day 67	34.03 ± 2.19^{ABCDEF}	34.48 ± 2.13^{ABCDE}	36.32 ± 1.91^{AB}	34.94 ± 2.26
		Total	30.67 ± 4.10	32.08 ± 4.05	32.78 ± 4.52	31.84 ± 4.30

a-d:No difference between main effects with the same letter, A-M: No difference between interaction groups with the same letter, mean ± s. deviation.

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Table 3. Descriptive statistics and multiple comparison results of chlorophyll content

Application	Dose	Time	Cultivar			Total
			Efe	Halilbey	Baldo	
From Foliar Application	0.7	1st measurement	26.55 ± 2.21	25.57 ± 2.08	23.64 ± 1.57	25.25 ± 2.14
		Day 16	32.77 ± 4.30	36.63 ± 0.61	36.56 ± 3.06	35.32 ± 3.27
		Day 26	30.41 ± 0.79	33.36 ± 1.71	38.28 ± 2.36	34.02 ± 3.76
		Day 36	24.21 ± 0.93	24.94 ± 1.01	28.91 ± 2.15	26.02 ± 2.54
		Day 46	29.35 ± 3.68	30.06 ± 1.69	30.20 ± 1.38	29.87 ± 2.17
		Day 57	34.07 ± 0.98	33.33 ± 0.66	37.25 ± 6.92	34.88 ± 3.94
		Day 67	34.90 ± 0.95	35.07 ± 1.62	35.44 ± 1.65	35.13 ± 1.27
		Total	30.32 ± 4.25^{CDE}	31.28 ± 4.51^{ABC}	32.90 ± 5.83^{ABC}	31.50 ± 4.95
	1.4	1st measurement	25.08 ± 1.72	26.25 ± 0.50	24.93 ± 2.92	25.42 ± 1.82
		Day 16	32.50 ± 1.33	36.14 ± 2.42	36.11 ± 1.01	35.22 ± 2.24
		Day 26	31.43 ± 0.42	34.55 ± 1.34	34.05 ± 0.74	33.34 ± 1.65
		Day 36	25.71 ± 1.81	26.16 ± 3.49	26.93 ± 1.07	26.26 ± 2.11
		Day 46	28.42 ± 1.69	31.41 ± 4.77	27.85 ± 2.12	29.23 ± 3.20
		Day 57	34.89 ± 4.02	33.99 ± 1.74	34.73 ± 0.84	34.53 ± 2.27
		Day 67	34.94 ± 2.75	34.83 ± 3.37	33.25 ± 0.65	34.34 ± 2.35
		Total	30.32 ± 4.38^{CDE}	31.90 ± 4.60^{ABCDE}	31.12 ± 4.40^{BCDE}	31.13 ± 4.44

(*Continued*)

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Table 3. (*Continued*)

Application	Dose	Time	Cultivar			Total
			Efe	Halilbey	Baldo	
	2.1	1st measurement	24.66 ± 0.31	26.94 ± 4.07	27.40 ± 1.28	26.33 ± 2.49
		Day 16	32.31 ± 1.19	34.11 ± 3.29	36.49 ± 0.83	34.30 ± 2.55
		Day 26	30.48 ± 1.05	35.03 ± 1.76	35.55 ± 2.37	33.68 ± 2.88
		Day 36	23.36 ± 2.77	28.47 ± 3.10	28.58 ± 1.72	26.80 ± 3.43
		Day 46	27.50 ± 1.32	32.69 ± 1.12	27.46 ± 4.38	29.22 ± 3.51
		Day 57	33.91 ± 0.62	31.11 ± 4.53	35.91 ± 1.86	33.64 ± 3.23
		Day 67	34.97 ± 1.40	34.29 ± 3.49	32.84 ± 0.74	34.03 ± 2.13
		Total	29.60 ± 4.47^{DE}	31.80 ± 4.01^{ABCDE}	32.03 ± 4.33^{ABCDE}	31.15 ± 4.35
	2.8	1st measurement	28.62 ± 4.05	26.26 ± 2.06	25.79 ± 2.33	26.89 ± 2.87
		Day 16	32.72 ± 0.61	34.79 ± 0.32	36.18 ± 1.11	34.56 ± 1.64
		Day 26	29.91 ± 1.12	33.83 ± 1.79	35.38 ± 1.73	33.04 ± 2.80
		Day 36	24.08 ± 0.51	27.35 ± 3.96	26.80 ± 1.04	26.08 ± 2.56
		Day 46	29.10 ± 1.10	34.79 ± 3.56	30.83 ± 2.65	31.57 ± 3.41
		Day 57	36.36 ± 2.13	33.97 ± 2.46	33.74 ± 3.79	34.69 ± 2.80
		Day 67	32.88 ± 1.16	34.23 ± 1.11	33.01 ± 3.38	33.37 ± 1.98
		Total	30.52 ± 4.04^{CDE}	32.17 ± 4.08^{ABCD}	31.68 ± 4.38^{ABCDE}	31.46 ± 4.16
	Total	1st measurement	26.23 ± 2.65^{LM}	26.25 ± 2.21^{LM}	25.44 ± 2.31^{LM}	25.97 ± 2.36
		Day 16	32.58 ± 2.07^{BCDEFG}	35.42 ± 2.06^{ABC}	36.34 ± 1.51^{AB}	34.84 ± 2.43
		Day 26	30.56 ± 0.95^{FGHIJK}	34.19 ± 1.56^{ABCDEF}	35.81 ± 2.29^{ABC}	33.52 ± 2.77
		Day 36	24.34 ± 1.73^{M}	26.73 ± 2.98^{LM}	27.81 ± 1.66^{IJKLM}	26.29 ± 2.60
		Day 46	28.59 ± 2.02^{HIJKL}	32.24 ± 3.24^{CDEFGH}	29.08 ± 2.87^{GHIJKL}	29.97 ± 3.14
		Day 57	34.81 ± 2.24^{ABCD}	33.10 ± 2.64^{BCDEF}	35.41 ± 3.73^{ABC}	34.44 ± 3.02
		Day 67	34.42 ± 1.74^{ABCDE}	34.60 ± 2.26^{ABCDE}	33.63 ± 1.99^{ABCDEF}	34.22 ± 1.99
		Total	30.19 ± 4.22	31.79 ± 4.24	31.93 ± 4.73	31.31 ± 4.46

a-d:No difference between main effects with the same letter, A-M: No difference between interaction groups with the same letter, mean ± s. deviation.

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significant difference was found between the mean flag leaf lengths according to the dose (p = 0.005). The mean of the 0.7 dose was 11.73 cm, the mean of the 1.4 dose was 11.85 cm, the mean of the 2.1 dose was 11.44 cm, and the mean of the 2.8 dose was 12.68 cm. This difference is due to the difference between the 3rd dose and the 0.7 and 2.1 doses. There was no difference between the mean leaf length values according to the double and triple interactions of variety, application, and dose ($p > 0.050$). According to the varieties, the Efe variety gave the best result, but the Halilbey and Baldo varieties were in the same group as the second alternative. The best result was obtained from the 2.8% dose, while the 1.4% dose can also be given as an alternative. There is no linear increase in the amount of chlorophyll according to the increase of doses in this regard. The 3% dose is thought to be the best because it is generally more intense than the others. In similar studies, the following values were obtained: Panda et al. (2022); 43.87–22.97 (Zhu et al., 2022); 30.5 ± 0.2–18.4 ± 0.3; Tanaka et al. (2022); 33.9 ± 0.9–29.9 ± 0.9; Siavoshi et al. (2011); 29.48–28.17 cm; Haifaa and Moses (2022); 27.04–24.85; Mahesh et al. (2022); 32.38; Wang et al. (2022); 29.12 ± 5.48. These values were higher than ours. This is thought to be due to the different cultural practices and varieties used. There may be several reasons for the different results obtained in similar studies. First, cultural practices used in these studies may vary. This could lead to increased plant growth and longer flag leaves. The characteristics of the rice varieties used in the studies may also differ. Other factors, such as changing climatic conditions and the type of fertilizer used, may also have contributed to these differences.

3.3. Flag leaf width (cm)

A significant difference was found between the mean flag leaf width values according to the varieties ($p = 0.002$). The mean of the Efe variety was 0.92 cm, the mean of the Halilbey variety was 0.94 cm, and the mean of the Baldo variety was 0.98 cm. This difference is due to the difference between the Efe and Baldo varieties. There was no statistically significant difference between the mean flag leaf width values according to the applications ($p = 0.689$). There was no statistically significant difference between the mean flag leaf width values according to the dose ($p = 0.051$). There was no statistically significant difference between the mean flag leaf width values according to the double and triple interactions of cultivar, application, and dose (Tables 7 and 8). The best result in terms of flag leaf width development was obtained from the Baldo variety. However, in cases where Baldo is not available, Efe or Halilbey varieties can be recommended in second place. In similar studies, the results obtained are as follows; Haifaa and Moses (2022) 1.50–1.37; Abbasi et al. (2022) 2.6–1.25; Mahesh et al. (2022) 1.51; Panda et al. (2022); 2.98–0.8; Wang et al. (2022) 1.63 ± 0.12. It is observed that our findings are lower than these results. Flag leaf width is affected by genetic factors, environmental influences, cultural practices, as well as more specific factors (such as fertilization doses, irrigation amounts, the duration of time that plants utilize light, and temperature). Therefore, it is thought that these factors will lead to different results.

3.4. Flag leaf area (cm^2)

A significant difference was found between flag leaf area means according to varieties ($p <$ 0.001). The mean of the Efe variety was 10.36 cm^2, the mean of the Halilbey variety was 7.36 cm^2, and the mean of the Baldo variety was 7.61 cm^2. This difference is due to the difference between the Efe variety and the other varieties. No difference was found between flag leaf area means according to applications ($p = 0.650$). A statistically significant difference was found between flag leaf area means according to dose ($p < 0.006$) (Table 9). The mean of the 0.7 dose was 8.10 cm^2, the mean of the 1.4 dose was 8.65 cm^2, the mean of the 2.1 dose was 7.89 cm^2, and the mean of the 2.8 dose was 9.15 cm^2(Table 10). This difference is due to the difference between the 3rd dose and the 0.7 and 2.1 doses. No difference was found between flag leaf area means according to the interactions of variety, application, and dose ($p > 0.050$). The best flag leaf area was obtained from the Efe variety. The 2.8% dose gave the best flag leaf

Table 4. Descriptive statistics and multiple comparison results of chlorophyll content

Application	Dose	Time	Cultivar			Total
			Efe	Halilbey	Baldo	
Total	0.7	1st measurement	26.73 ± 2.50	26.60 ± 2.19	25.22 ± 2.65	26.18 ± 2.41
		Day 16	33.31 ± 2.97	36.79 ± 0.54	36.69 ± 2.03	35.60 ± 2.58
		Day 26	31.18 ± 2.65	33.59 ± 1.27	35.84 ± 3.12	33.54 ± 3.04
		Day 36	25.18 ± 2.01	26.26 ± 1.62	28.28 ± 1.92	26.57 ± 2.19
		Day 46	30.78 ± 3.06	30.03 ± 2.02	31.49 ± 2.11	30.77 ± 2.37
		Day 57	33.72 ± 0.76	33.61 ± 2.07	34.97 ± 5.30	34.10 ± 3.18
		Day 67	34.28 ± 1.30	34.48 ± 1.63	35.20 ± 1.25	34.65 ± 1.38
		Total	30.74 ± 3.95	31.62 ± 4.12	32.53 ± 4.88	31.63 ± 4.36
	1.4	1st measurement	27.88 ± 4.47	26.14 ± 1.31	25.09 ± 2.23	26.37 ± 3.04
		Day 16	32.68 ± 1.61	36.33 ± 2.36	36.60 ± 1.51	35.35 ± 2.50
		Day 26	31.10 ± 1.89	33.69 ± 1.43	33.99 ± 1.13	32.93 ± 1.95
		Day 36	25.61 ± 1.69	26.34 ± 2.25	27.71 ± 1.57	26.55 ± 1.97
		Day 46	29.88 ± 2.79	31.24 ± 3.14	31.16 ± 4.04	30.76 ± 3.23
		Day 57	34.38 ± 2.93	34.94 ± 2.06	36.42 ± 2.82	35.25 ± 2.63
		Day 67	35.05 ± 1.79	34.62 ± 2.16	35.57 ± 2.87	35.08 ± 2.21
		Total	30.90 ± 4.07	31.90 ± 4.39	32.36 ± 4.83	31.73 ± 4.45

(*Continued*)

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Table 4. (*Continued*)

Application	Dose	Time	Cultivar			Total
			Efe	Halilbey	Baldo	
	2.1	1st measurement	23.90 ± 4.13	26.80 ± 2.63	26.43 ± 1.49	25.71 ± 3.07
		Day 16	32.34 ± 1.31	35.18 ± 2.57	36.47 ± 1.39	34.66 ± 2.48
		Day 26	30.01 ± 1.05	35.18 ± 2.20	34.35 ± 3.00	33.18 ± 3.14
		Day 36	24.23 ± 2.36	28.67 ± 2.81	27.01 ± 2.15	26.64 ± 2.98
		Day 46	28.32 ± 2.19	32.05 ± 1.82	28.65 ± 3.48	29.67 ± 2.99
		Day 57	33.85 ± 1.71	31.18 ± 3.28	35.30 ± 2.69	33.44 ± 3.04
		Day 67	34.16 ± 2.87	35.26 ± 2.70	34.24 ± 2.15	34.55 ± 2.49
		Total	29.54 ± 4.59	32.04 ± 4.00	31.78 ± 4.58	31.12 ± 4.50
	2.8	1st measurement	27.12 ± 3.32	26.85 ± 1.52	26.89 ± 2.04	26.95 ± 2.27
		Day 16	33.23 ± 0.95	36.37 ± 1.93	36.77 ± 0.96	35.46 ± 2.07
		Day 26	30.62 ± 1.09	34.46 ± 1.50	35.59 ± 1.16	33.56 ± 2.49
		Day 36	24.56 ± 0.73	26.91 ± 2.69	27.70 ± 1.55	26.39 ± 2.21
		Day 46	29.58 ± 2.23	33.44 ± 4.09	31.57 ± 1.99	31.53 ± 3.19
		Day 57	35.36 ± 2.30	33.35 ± 1.79	35.88 ± 3.37	34.86 ± 2.66
		Day 67	33.41 ± 1.63	33.80 ± 2.30	34.90 ± 3.14	34.04 ± 2.38
		Total	30.55 ± 4.00	32.17 ± 4.16	32.76 ± 4.33	31.83 ± 4.24
	Total	1st measurement	26.40 ± 3.76^{IJ}	26.60 ± 1.87^{IJ}	25.91 ± 2.15^{IJ}	26.30 ± 2.70^{d}
		Day 16	32.90 ± 1.80^{DEF}	36.17 ± 1.97^{AB}	36.63 ± 1.42^{A}	35.27 ± 2.39^{a}
		Day 26	30.73 ± 1.74^{FG}	34.23 ± 1.66^{BCD}	34.94 ± 2.30^{ABCD}	33.30 ± 2.65^{b}
		Day 36	24.89 ± 1.77^{J}	27.05 ± 2.44^{IJ}	27.67 ± 1.75^{HI}	26.54 ± 2.32^{d}
		Day 46	29.64 ± 2.58^{GH}	31.69 ± 3.00^{EFG}	30.72 ± 3.09^{FG}	30.68 ± 2.98^{c}
		Day 57	34.33 ± 2.05^{ABCD}	33.27 ± 2.61^{CDE}	35.64 ± 3.49^{ABC}	34.41 ± 2.91^{ab}
		Day 67	34.23 ± 1.94^{BCD}	34.54 ± 2.15^{ABCD}	34.98 ± 2.35^{ABCD}	34.58 ± 2.15^{a}
		Total	30.43 ± 4.16^{b}	31.93 ± 4.14^{a}	32.36 ± 4.63^{a}	31.58 ± 4.39

a-d:No difference between main effects with the same letter, A-M: No difference between interaction groups with the same letter, mean ± s. deviation.

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Table 5. Comparison of leaf length by cultivar, treatment and dose

	Sd	Sum of Squares	Mean Squares	F	p	Kısmi eta kare
Cultivar	2	342.302	171.151	163.050	**<0.001**	0.872
Application	1	0.485	0.485	0.460	0.500	0.010
Dose	3	15.242	5.081	4.840	0.005	0.232
*Cultivar*Application*	2	5.101	2.551	2.430	0.099	0.092
*Cultivar*Dose*	6	7.856	1.309	1.250	0.299	0.135
*Application*Dose*	3	2.666	0.889	0.850	0.475	0.050
*Cultivar*Application*Dose*	6	5.475	0.912	0.870	0.524	0.098

SD:Degrees of freedom, F: Analysis of variance test statistic, R2=%88.27, Adjusted R2=%82.65.

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Table 6. Descriptive statistics and multiple comparison results of leaf length by cultivar, treatment and dose

Application	*Dose*	*Cultivar*			*Total*
		Efe	**Halilbey**	**Baldo**	
From Soil Application	0.7	14.64 ± 1.33	9.45 ± 0.58	10.49 ± 1.00	11.53 ± 2.54
	1.4	15.70 ± 1.96	10.81 ± 0.60	9.80 ± 0.82	12.10 ± 2.95
	2.1	14.44 ± 1.55	9.72 ± 1.02	9.63 ± 0.47	11.26 ± 2.56
	2.8	15.91 ± 2.01	9.94 ± 0.21	11.59 ± 0.60	12.48 ± 2.87
	Total	15.17 ± 1.63	9.98 ± 0.78	10.38 ± 1.03	11.84 ± 2.66
From Foliar Application	0.7	15.02 ± 0.13	10.30 ± 0.62	10.51 ± 0.26	11.94 ± 2.34
	1.4	14.99 ± 1.71	10.19 ± 0.45	9.62 ± 0.28	11.60 ± 2.71
	2.1	13.60 ± 0.24	11.09 ± 0.41	10.14 ± 1.68	11.61 ± 1.78
	2.8	15.77 ± 0.75	11.95 ± 0.80	10.90 ± 1.10	12.88 ± 2.35
	Total	14.85 ± 1.15	10.88 ± 0.90	10.29 ± 1.00	12.01 ± 2.28
Total	0.7	14.83 ± 0.87	9.87 ± 0.71	10.50 ± 0.65	11.73 ± 2.37^{b}
	1.4	15.34 ± 1.69	10.50 ± 0.58	9.71 ± 0.56	11.85 ± 2.76^{ab}
	2.1	14.02 ± 1.09	10.41 ± 1.02	9.89 ± 1.14	11.44 ± 2.15^{b}
	2.8	15.84 ± 1.36	10.95 ± 1.22	11.25 ± 0.88	12.68 ± 2.55^{a}
	Total	15.01 ± 1.39^{a}	10.43 ± 0.94^{b}	10.33 ± 0.99^{b}	11.92 ± 2.46

$^{a\text{-}b}$No difference between varieties/doses with the same letter.



Figure 1. Paddy pods from the experiment.

area. The results obtained by different researchers are as follows: Ansi et al. (2022): 30.84–27.90; Tanaka et al. (2022): 34.3 ± 0.9–31.4 ± 0.9; Haifaa and Moses (2022): 41.92–35.61; Mahesh et al. (2022): 35.14; Taha et al. (2022): 43.18–27.31 cm^2. Our findings were found to be lower than the results of the researchers. Flag leaf area is an important character in revealing the physiological

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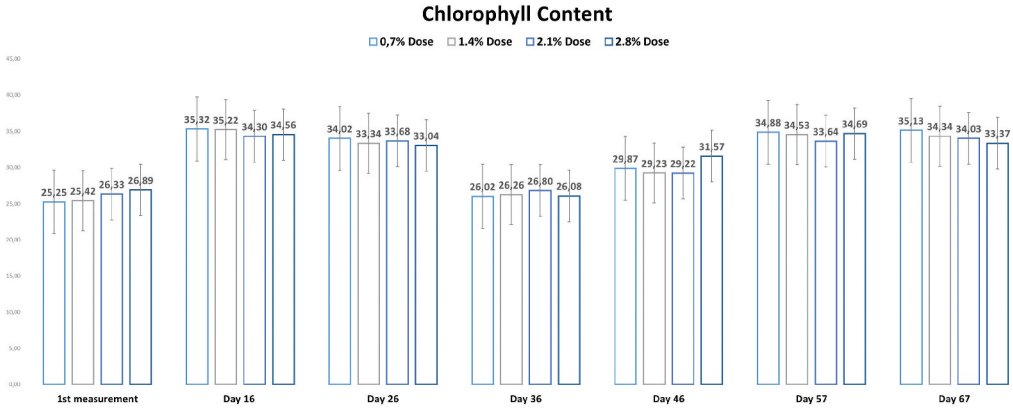


Figure 2. The effects of foliar vermicompost applications on the amount of chlorophyll.

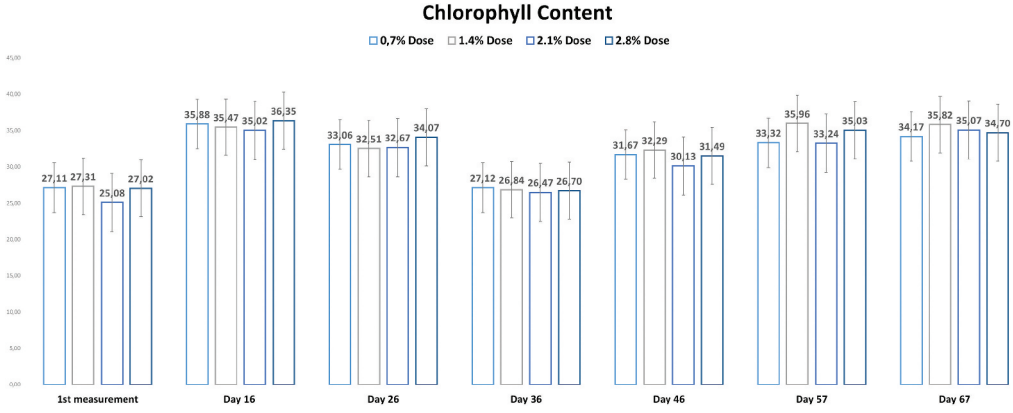


Figure 3. The effects of vermicompost applications applied from the soil on the amount of chlorophyll according to the days.

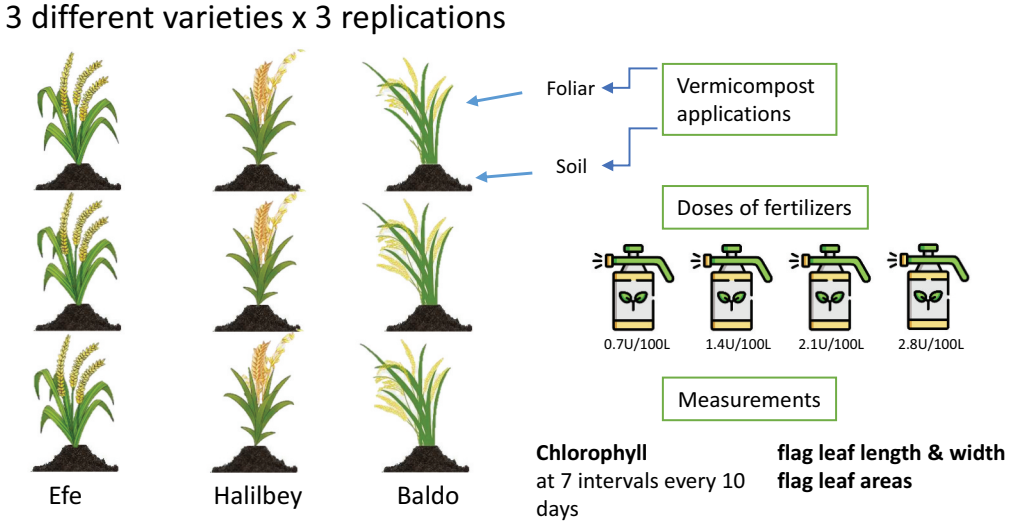


Figure 4. The application stages of the experiment.

and morphological characteristics of varieties. Therefore, varieties subjected to the same applications can give different results. This study was conducted in a climate that is lower than the optimum growing season of rice. Even though it was a study established under controlled greenhouse conditions, varieties may not be able to fully show their potential for flag leaf development according to the effectiveness of light. Therefore, the results may be different.

Table 7. Comparison of leaf width by cultivar, treatment and dose

	Sd	Sum of Squares	Mean Squares	F	p	Kısmi eta kare
Cultivar	2	0.048	0.024	7.040	**0.002**	0.227
Application	1	0.001	0.001	0.160	0.689	0.003
Dose	3	0.032	0.011	3.140	0.051	0.164
*Cultivar*Application*	2	0.015	0.007	2.180	0.124	0.083
*Cultivar*Dose*	6	0.039	0.007	1.910	0.098	0.193
*Application*Dose*	3	0.006	0.002	0.610	0.609	0.037
*Cultivar*Application*Dose*	6	0.015	0.002	0.730	0.630	0.083

SD: Degrees of freedom, F: Analysis of variance test statistic, R2=%48.77, Adjusted R2=%24.23.

Table 8. Descriptive statistics and multiple comparison results of leaf width by cultivar, treatment, and dose

Application	Dose	Cultivar			Total
		Efe	Halilbey	Baldo	
From Soil Application	0.7	0.90 ± 0.05	0.94 ± 0.05	0.92 ± 0.02	0.92 ± 0.04
	1.4	1.01 ± 0.11	0.92 ± 0.06	0.95 ± 0.02	0.96 ± 0.08
	2.1	0.88 ± 0.06	0.93 ± 0.04	0.93 ± 0.06	0.91 ± 0.05
	2.8	0.95 ± 0.03	0.93 ± 0.04	1.06 ± 0.07	0.98 ± 0.07
	Total	0.94 ± 0.08	0.93 ± 0.04	0.97 ± 0.07	0.94 ± 0.06
From Foliar Application	0.7	0.87 ± 0.09	0.93 ± 0.07	1.00 ± 0.05	0.93 ± 0.08
	1.4	0.97 ± 0.08	0.96 ± 0.05	1.00 ± 0.05	0.98 ± 0.05
	2.1	0.85 ± 0.03	0.95 ± 0.05	0.99 ± 0.08	0.93 ± 0.08
	2.8	0.90 ± 0.07	0.96 ± 0.08	0.99 ± 0.05	0.95 ± 0.07
	Total	0.90 ± 0.08	0.95 ± 0.05	0.99 ± 0.05	0.95 ± 0.07
Total	0.7	0.88 ± 0.06	0.93 ± 0.05	0.96 ± 0.05	0.93 ± 0.06
	1.4	0.99 ± 0.09	0.94 ± 0.05	0.98 ± 0.04	0.97 ± 0.06
	2.1	0.87 ± 0.04	0.94 ± 0.04	0.96 ± 0.07	0.92 ± 0.06
	2.8	0.93 ± 0.05	0.95 ± 0.06	1.02 ± 0.06	0.97 ± 0.07
	Total	0.92 ± 0.08[b]	0.94 ± 0.05[ab]	0.98 ± 0.06[a]	0.95 ± 0.07

[a-b]No difference between varieties/doses with the same letter.

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Table 9. Comparison of leaf area by cultivar, treatment and dose

	Sd	Sum of Squares	Mean Squares	F	p	Kısmi eta kare
Cultivar	2	132.564	66.282	53.520	**<0.001**	0.690
Application	1	0.258	0.258	0.210	0.650	0.004
Dose	3	17.552	5.851	4.720	**0.006**	0.228
*Cultivar*Application*	2	6.237	3.118	2.520	0.091	0.095
*Cultivar*Dose*	6	14.722	2.454	1.980	0.087	0.199
*Application*Dose*	3	1.334	0.445	0.360	0.783	0.022
*Cultivar*Application*Dose*	6	5.513	0.919	0.740	0.619	0.085

SD: Degrees of freedom, F: Analysis of variance test statistic, R2 = %74.98, Adjusted R2 = %63.00.

Table 10. Descriptive statistics and multiple comparison results of leaf area by cultivar, treatment and dose

Application	*Dose*	*Cultivar*			Total
		Efe	Halilbey	Baldo	
From Soil Application	0.7	9.82 ± 0.86	6.65 ± 0.69	7.28 ± 0.82	7.91 ± 1.61
	1.4	11.96 ± 2.68	7.41 ± 0.69	7.01 ± 0.68	8.79 ± 2.77
	2.1	9.57 ± 1.49	6.79 ± 0.85	6.73 ± 0.64	7.70 ± 1.68
	2.8	11.30 ± 1.67	6.94 ± 0.33	9.17 ± 0.40	9.14 ± 2.08
	Total	10.66 ± 1.85	6.95 ± 0.64	7.55 ± 1.15	8.39 ± 2.09
From Foliar Application	0.7	9.81 ± 0.91	7.17 ± 0.52	7.84 ± 0.29	8.28 ± 1.30
	1.4	10.99 ± 1.89	7.35 ± 0.68	7.18 ± 0.53	8.51 ± 2.13
	2.1	8.70 ± 0.31	7.93 ± 0.27	7.60 ± 1.83	8.07 ± 1.06
	2.8	10.73 ± 1.36	8.67 ± 1.25	8.09 ± 0.93	9.16 ± 1.58
	Total	10.06 ± 1.43	7.78 ± 0.90	7.68 ± 0.98	8.51 ± 1.56
Total	0.7	9.82 ± 0.79	6.91 ± 0.62	7.56 ± 0.63	8.10 ± 1.43^{b}
	1.4	11.47 ± 2.14	7.38 ± 0.61	7.09 ± 0.55	8.65 ± 2.40^{ab}
	2.1	9.14 ± 1.08	7.36 ± 0.84	7.16 ± 1.32	7.89 ± 1.38^{b}
	2.8	11.01 ± 1.40	7.81 ± 1.25	8.63 ± 0.87	9.15 ± 1.79^{a}
	Total	10.36 ± 1.65^{a}	7.36 ± 0.87^{b}	7.61 ± 1.04^{b}	8.45 ± 1.83

$^{a\text{-}b}$No difference between varieties/doses with the same letter.

4. Conclusions

In this study, the effectiveness of vermicompost fertilizer was investigated on three different rice varieties (Efe, Halilbey, Baldo), using two different application methods (foliar and soil) and four different fertilizer doses (0.7-1.4-2.1-3 liters of liquid fertilizer/100 liters of water). The effects of vermicompost fertilizer on the chlorophyll content, flag leaf width, length, and area of the varieties were determined. The results of the study showed that one of the main factors affecting the increase in photosynthesis based on chlorophyll content is the variety characteristics. Chlorophyll content was affected by vermicompost application and doses. On the other hand, flag leaf width, length, and area were not significantly affected by vermicompost fertilizer, as they are genetically controlled. However, it is recommended to expand studies on this topic with specific studies suitable for varieties.

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