Effect of Vermicompost and Foliar Magnesium Sulfate on Wheat Yield Sustainability

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Abstract

A factorial field experiment was conducted to study the effect of organic fertilizer application and foliar spraying with magnesium sulfate on the availability of some nutrients for soil sustainability and wheat productivity. The experiment was carried out in the experimental field of the College of Agriculture, University of Babylon, located between 32.8° N latitude and 44.23° E longitude, in a clay loam soil classified at the great group level as Typic Torrifluvent according to the USDA Soil Taxonomy (Soil Survey Staff, 2016).The experiment included two factors: The first factor was the application of vermicompost at three levels (0, 15, 30 tons ha^{-1}), denoted as (F0, F1, F2).

The second factor was magnesium sulfate at three levels (0, 1000, 2000 mg L^{-1}), denoted as (M0, M1, M2). The experiment was laid out in a randomized complete block design (RCBD) with 27 experimental units. Yield indicators were measured, including: thousand-grain weight, number of grains per spike, grain yield, biological yield, and harvest index. The results showed that the application of the second level of vermicompost (F2) recorded the following values: 42.01 g (thousand-grain weight), 37.99 grains $spike^{-1}$, 5.16 Mg ha^{-1} grain yield, 5.2516 Mg ha^{-1} biological yield, and 33.75% harvest index. As for the addition of magnesium sulfate, the values were: 40.99 g, 37.15 grains $spike^{-1}$, 4.93 Mg ha^{-1}, 14.79 Mg ha^{-1}, and 33.03%, respectively.

Keywords: Vermicompost, Productivity improvement, Soil fertility, Nutrients, *Sustainable agriculture*

Introduction

Vermicompost is considered one of the most important modern organic fertilizers used in sustainable agriculture. It is produced through the decomposition of organic matter by earthworms, particularly Eisenia fetida. Its significance lies in being rich in macro- and micronutrients, as well as bioactive substances such as amino acids and humic compounds, which improve soil quality and enhance plant growth in a natural and safe manner [12]. The use of vermicompost, along with foliar spraying of its liquid extract (Vermiwash), has led to a remarkable improvement in crop productivity and enhanced plant resistance to environmental stresses such as salinity and drought. This represents an important advancement toward promoting bio-farming techniques in home gardens and small farms [2].

A study by [4] indicated that magnesium application, whether through soil or foliar spraying, increases wheat grain yield and quality. Results showed that the interaction between both applications (soil and foliar) increased yield by up to 0.92 t ha^{-1}. Moreover, magnesium improved the distribution of dry matter in the plant during the grain-filling stage, which enhanced carbohydrate uptake and storage in grains.Magnesium application to wheat, either through soil or foliar spraying, also

ISSN 2072-3857

improved plant tolerance to high temperatures during the flowering stage. This resulted in increases in 100-grain weight, spike length, and biological yield by up to 45% compared to the control. Additionally, improvements in chlorophyll content and cell membrane stability were observed, indicating the role of magnesium in enhancing plant tolerance to heat stress [8].Wheat is one of the most important cereal crops cultivated for thousands of years, characterized by its adaptability to diverse climatic conditions, making it a cornerstone of global food security. It is widely used in the production of bread, pastries, and other food products, and is a rich source of protein and carbohydrates [5].

Materials and Methods

1. Soil Site and Classification

A factorial field experiment was conducted to study the effect of organic fertilizer application and foliar spraying with magnesium sulfate on the availability of some nutrients for soil sustainability and wheat productivity. The experiment was carried out in the experimental field of the College of Agriculture, University of Babylon, located between 32.8° N latitude and 44.23° E longitude. The soil texture was clay loam, classified at the great group level as Typic Torrifluvent according to the USDA Soil Taxonomy (Soil Survey Staff, 2016).

2. Soil Physical and Chemical Properties before Planting

Several soil samples were randomly collected from the experimental field before plowing at a depth of 0–30 cm. The samples were mixed to form a composite sample, air-dried, ground, and sieved through a 2 mm sieve, then stored in a polyethylene bag. Physical, chemical, and fertility characteristics of the soil before planting were analyzed as presented in Table 1.

3. Experimental Design and Treatments

The field experiment involved two factors:

- Factor 1: Organic fertilizer (vermicompost), mixed with soil before planting at three levels:
  F0: Control (no fertilizer)
  F1: 15 t ha^{-1}
  F2: 30 t ha^{-1}
- Factor 2: Magnesium sulfate foliar spraying at three concentrations:
  M0: Distilled water only
  M1: 1000 mg L^{-1}
  M2: 2000 mg L^{-1}

Table 1. Physical and Chemical Properties of the Field Soil Before Planting

Property	**Unit**	**Value**
Electrical conductivity (ECe)	dS m^{-1}	3.35
Soil reaction (pH)	–	7.35
Cation exchange capacity (CEC)	cmol(+) kg^{-1} soil	20.51
Organic matter	%	6.43
Carbonates	g kg^{-1} soil	225.30
Gypsum	%	4.31
Calcium (Ca^{2+})	mmol L^{-1}	9.25
Magnesium (Mg^{2+})		7.50
Sodium (Na^{+})		3.25
Potassium (K^{+})		0.75
Sulfates (SO_4^{2-})		13.00
Chlorides (Cl^{-})		9.30
Bicarbonates (HCO_3^{-})		3.15
Carbonates (CO_3^{2-})		Nil

ISSN 2072-3857

Nitrogen (N)	mg kg⁻¹ soil	29.50
Phosphorus (P)		13.25
Potassium (K)		181.43
Magnesium (Mg)		–
Sand	g kg⁻¹ soil	225
Silt		325
Clay		450
Texture	–	Clay loam
Bulk density	Mg m⁻³	1.34

Thus, the total number of treatments was 3 × 3 = 9, replicated three times, resulting in 27 experimental units. The experiment was laid out as a factorial trial in a Randomized Complete Block Design (RCBD).

Yield and Growth Indicators

- Thousand-grain weight (g):

The weight of 1000 grains was taken randomly from a harvested 1 m² area from each experimental unit, using a sensitive balance, and then returned to the yield.

- Grain yield (t ha⁻¹):

At maturity, 1 m² was harvested from each unit. The total yield was weighed, spikes were separated from straw, and grain yield was determined after threshing.

- Biological yield (grains + straw):

Calculated on the basis of Mg ha⁻¹ from the 1 m² harvested area from each unit (Donaldson, 1996).

- Harvest index (%):

Calculated according to Gonzalez et al. (2007) using the following equation:

Harvest Index (%) = (Grain yield / Total biological yield) × 100

Results and Discussion

Effect of Organic Fertilizer and Magnesium Sulfate Application and Their Interaction on Yield Traits and Components

1. Thousand-Grain Weight (g)

The statistical analysis (Table 1) indicated that all studied factors significantly affected the thousand-grain weight (g) of wheat. Application of organic fertilizer (Vermicompost) significantly increased this trait, with the highest value observed in treatment F2, which reached 42.01 g, compared to F1 and F0 (39.38 and 32.62 g, respectively), corresponding to an increase of 6.67% and 28.78%. Foliar application of magnesium sulfate also significantly enhanced the thousand-grain weight, with the highest value recorded in treatment M2 (40.99 g) compared to M1 and M0 (38.53 and 34.31 g), reflecting increases of 6.38% and 19.46%, respectively.

The interaction between organic fertilizer and magnesium sulfate application (F × M) also showed a significant effect on thousand-grain weight. The highest value was obtained in the F2M2 combined treatment (45.57 g), followed by F1M2 (43.40 g), while the lowest value was observed in the control treatment F0M0 (30.15 g).

ISSN 2072-3857

Table 1. Effect of Organic Fertilizer, Magnesium Sulfate, and Their Interaction on Thousand-Grain Weight (g)

Organic Fertilizer	Magnesium Sulfate Levels			Mean
	M0	M1	M2	
F0	30.15	33.71	34.00	32.62
F1	34.50	40.25	43.40	39.38
F2	38.30	42.17	45.57	42.01
Mean	34.13	38.53	40.99	-
L.S.D (0.05)	**Organic Fertilizer**	**Interaction**	**Levels of Magnesium Sulfate**	
	F	**F × M**	**M**	
	1.33	**2.38**	**1.33**	

2. Number of Grains per Spike

The analysis (Table 2) showed that all studied factors organic fertilizer (Vermicompost), magnesium sulfate foliar application, and their interaction significantly increased the number of grains per spike. Organic fertilizer significantly enhanced this trait, with the highest value in treatment F2 (37.99 grains/spike), compared to F1 and F0 (35.90 and 29.66 grains/spike), corresponding to increases of 5.73% and 28.08%. Magnesium sulfate application significantly improved this trait, with M2 producing 37.15 grains/spike compared to M1 and M0 (34.37 and 32.07 grains/spike).

The interaction between organic fertilizer and magnesium sulfate further enhanced grain number per spike, with the highest value in treatment F2M2 (40.55 grains/spike), followed by F1M2 (38.75 grains/spike), while the lowest value was observed in F0M0 (27.55 grains/spike).

Table 2. Effect of Organic Fertilizer, Magnesium Sulfate, and Their Interaction on Number of Grains per Spike

Organic Fertilizer	Magnesium Sulfate Levels			Mean
	M0	M1	M2	
F0	27.55	29.30	32.15	29.66
F1	33.05	36.00	38.75	35.93
F2	35.63	37.81	40.55	37.99
Mean	32.07	34.37	37.15	
L.S.D (0.05)	**Organic Fertilizer**	**Interaction**	**Levels of Magnesium Sulfate**	
	F	**F × M**	**M**	
	1.49	**3.35**	**1.49**	

3. Grain Yield (Mg ha^{-1})

The results (Table 3) revealed that organic fertilizer, magnesium sulfate application, and their interaction significantly increased wheat grain yield. Organic fertilizer (F2) increased yield to 4.58 Mg ha^{-1} compared to F1 and F0 (4.08 and 3.26 Mg ha^{-1}), representing increases of 12.66% and 58.28%. Foliar application of magnesium sulfate also significantly improved yield, with M2 achieving 4.93 Mg ha^{-1} compared to M1 and M0 (4.41 and 3.65 Mg

ISSN 2072-3857

ha^{-1}), corresponding to 11.79% and 35.06% increases.

The combined application (F × M) yielded the highest value under F2M2 (5.96 Mg ha^{-1}), followed by F1M2 (5.30 Mg ha^{-1}), while the control (F0M0) produced the lowest yield (3.00 Mg ha^{-1}), indicating a 98.66% increase.

Table 3. Effect of Organic Fertilizer, Magnesium Sulfate, and Their Interaction on Grain Yield (Mg ha^{-1})

Organic Fertilizer	**Magnesium Sulfate Levels**			**Mean**
	M0	M1	M2	
F0	3.00	3.25	3.55	3.26
F1	3.59	4.85	5.30	4.58
F2	4.37	5.15	5.96	5.16
Mean	3.65	4.41	4.93	
L.S.D (0.05)	**Organic Fertilizer**	**Interaction**	**Levels of Magnesium Sulfate**	
	F	**F × M**	**M**	
	0.42	**0.62**	**0.42**	

4. Biological Yield (Mg ha^{-1})

The statistical analysis (Table 4) showed significant increases in biological yield with all treatments. Organic fertilizer F2 produced the highest biological yield (15.25 Mg ha^{-1}) compared to F1 and F0 (15.06 and 12.94 Mg ha^{-1}), reflecting increases of 1.26% and 17.85%. Magnesium sulfate application significantly increased biological yield, with M2 reaching 14.79 Mg ha^{-1} compared to M1 and M0 (14.40 and 14.05 Mg ha^{-1}), with increases of 2.70% and 5.26%.

The interaction effect was significant, with F2M2 producing 15.61 Mg ha^{-1}, followed by F1M2 (15.43 Mg ha^{-1}), while the lowest value was observed in F0M0 (12.53 Mg ha^{-1}), indicating a 24.58% increase .

Table 4. Effect of Organic Fertilizer, Magnesium Sulfate, and Their Interaction on Biological Yield (Mg ha^{-1})

Organic Fertilizer	**Magnesium Sulfate Levels**			**Mean**
	M0	M1	M2	
F0	12.53	12.95	13.35	12.94
F1	14.75	15.00	15.43	15.06
F2	14.89	15.26	15.61	15.25
Mean	14.05	14.40	14.79	
L.S.D (0.05)	**Organic Fertilizer**	**Interaction**	**Levels of Magnesium Sulfate**	
	F	**F × M**	**M**	
	0.13	**0.57**	**0.13**	

5. Harvest Index (%)

The statistical analysis (Table 5) indicated that all treatments significantly increased the harvest index. Organic fertilizer F2 achieved the highest value (33.75%) compared to F1 and F0 (30.33 and 25.20%). Magnesium sulfate application also significantly enhanced this trait, with M2 reaching 33.03% compared to M1 and M0 (30.38 and 25.87%).

The combined treatment F2M2 achieved the highest harvest index (34.34%), while F0M0 had the lowest (23.94%).

Table 5. Effect of Organic Fertilizer, Magnesium Sulfate, and Their Interaction on Harvest Index (%)

Organic Fertilizer	Magnesium Sulfate Levels			Mean
	M0	M1	M2	
F0	23.94	25.09	26.59	25.20
F1	24.33	32.33	34.34	30.33
F2	29.34	33.74	38.18	33.75
Mean	25.87	30.38	33.03	
L.S.D (0.05)	**Organic Fertilizer**	**Interaction**	**Levels of Magnesium Sulfate**	
	F	**F × M**	**M**	
	1.72	**3.49**	**1.72**	

The data (Tables 1, 2 ,3,4,5) indicate that organic fertilizer (Vermicompost), magnesium sulfate, and their interaction significantly enhanced all measured yield components. The positive effect of Vermicompost is attributed to its ability to increase cell membrane permeability, enhancing nutrient translocation to grains and stimulating photosynthesis through enzyme activation. Improved soil structure and porosity also facilitated root penetration, nutrient uptake, and vegetative growth, leading to higher grain number per spike, thousand-grain weight, and grain and biological yield.

These findings are consistent with [7,9] who reported that Vermicompost provides macro- and micronutrients and growth-promoting substances (auxins, cytokinins), improving soil structure and nutrient availability, thereby enhancing grain quality. Beneficial microorganisms in Vermicompost also improve nitrogen fixation and phosphorus and potassium availability, positively influencing yield components [6.[

Magnesium sulfate application enhanced photosynthesis due to magnesium’s central role in chlorophyll formation and enzymatic activity related to protein synthesis and carbohydrate translocation, improving yield components [1,12. [

The synergistic interaction of Vermicompost and magnesium sulfate produced the highest improvements across all yield parameters, as organic fertilizer enhanced soil fertility and nutrient supply, while magnesium stimulated physiological processes in the plant. Additionally, magnesium sulfate reduced soil pH and increased nutrient availability, promoting cell elongation, vegetative growth, and root development, which collectively contributed to higher thousand-grain weight, grains per spike, grain yield, biological yield, and harvest index [3.[

ISSN 2072-3857

Conclusions

It can be concluded from the results that fertilization with vermicompost and foliar application of magnesium sulfate improves growth and yield traits, as evidenced by an increase in the number of grains per spike, grain yield, and biological yield. Additionally, the thousand-grain weight and harvest index improved due to enhanced nutrient uptake and improved soil fertility. These results demonstrate the effectiveness of these treatments in enhancing production efficiency under the studied environmental conditions.

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ISSN 2072-3857

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ISSN 2072-3857