Effect of Adding Potassium and Organic Fertilizers on the Soil NPK Content and the Productivity of maize (*Zea mays* L.)

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Abstract

The integrated use of organic and mineral fertilizers is a practical and good way to preserve and sustain soil fertility, which results in increased availability of nutrients in the soil and their absorption by plants, thus increasing crop productivity. Due to the fixation of potassium in the soil, it is necessary to work to increase the vitality of agricultural soil by adding fertilizers. Organic potassium is an important means of increasing the availability of macro- and micro-nutrients. Current research was carried out in a private farm in Deir Ezzor province during the summer season of 2022 with the aim of studying the effect of adding potassium, organic fertilizer, and their interaction, on the soil content of NPK and the productivity of maize (Gouta 82 variety). A factorial experiment was conducted according to a randomized complete block design (RCBD) with three replications. The experiment included two factors: the first was potassium fertilizer (potassium sulfate: 0, 100, 150, 200 kg K.ha^{-1}) and the second was organic fertilizer (sheep manure: 0, 15, 20, 25 tons.ha^{-1}). Results showed that the fourth level of potassium fertilizer was significantly superior in soil content of mineral nitrogen, available phosphorus, and exchangeable potassium. The values were (N: 8.27, P: 12.07, K: 267.81 mg.kg^{-1}), and the fourth level of organic fertilizer was significantly superior to the studied soil indicators (N: 8.97, P: 12.90, K: 262.79 mg.kg^{-1}), while the values decreased in the control. In the studied plant characteristics (plant height, leaf surface area, grain yield), there is a superiority of the fourth level of potassium and organic fertilizers separately. At the remaining levels and in the control, the values in potassium fertilizer were (180.98 cm, 6147.90 cm^2, 7.49 tons.ha^{-1}) respectively. In organic fertilizer, plant characteristics reached (183.49 cm, 6191.50 cm^2, 7.72 tons.ha^{-1}) at the fourth level. The interaction of the two fertilizers also had a positive effect on all soil indicators studied, as the interaction of the fourth level of potassium fertilizer with the fourth level of organic fertilizer achieved significant superiority over the rest of the interaction treatments and over the non-fertilized control (N: 9.60, P: 13.76, K: 288.27 mg. kg^{-1}). Likewise, with regard to plant characteristics, interfering the third levels (150 kg/ha) and fourth levels (200 kg/ha) of potassium fertilizer with the fourth level (25 tons/ha) of organic fertilizer achieved the best results (186.92 - 188.20 cm, 6296.15 - 6343.98 cm^2, 8.32- 8.36 tons.h^{-1}).

Keywords: Potassium fertilizer، organic fertilizer، NPK، maize، grain yield.

Introduction

Macronutrients play a very important role in plant nutrition and productivity, so the soil content of these elements in a state available to the plant is an essential factor in determining crop productivity (5). Adding optimal fertilizer amounts avoids environmental pollution caused by high fertilizer additions or incorrect fertilization (23). According to Aziz *et al*., (9) when organic and mineral fertilizers are combined, this gives a good result of increasing soil fertility. Using different sources of organic waste reduces the high cost of using mineral fertilizers and is therefore considered a good agricultural practice (18). Given the plant's high need for nutrients and its low need for organic fertilizers, which may not meet its need, farmers turn to adding various mineral fertilizers. One of the most important macronutrients for plants is potassium, which plays an important role in all stages of growth and the life cycle of the plant. Potassium is not included in any organic compound. It is found in plant tissues in the form of free K^+. However, all plants need it, including the type of plant, the stage of growth, and the quality of the grain. Or the fruits produced (3). Potassium has a positive role in increasing resistance to diseases and pests, as it works to form a thick cell wall in addition to its vital intervention in the activity of photosynthesis enzymes and the manufacture of proteins and carbohydrates (17). Brar *et al*., (12) found that nitrogen absorption improves with the addition of potassium, which leads to increased nitrogen utilization efficiency. It also helps the transfer of nitrate to the leaves from the roots in the form of KNO_3 (28, 30). The main role played by soil organic matter is to maintain soil fertility and production quantity. It directly prepares nutrients for plants and improves the physical and chemical properties of the soil as an indirect effect (26, 11) stated that the most important components of organic matter are carbon, oxygen, and hydrogen, in addition to a little sulfur, phosphorus, potassium, calcium, and magnesium. They have an important role in enriching the soil with nutrients (38). The importance of organic fertilizers is not only due to their environmental safety, but they also affect the structure and texture of the soil, the ability to retain water, and the exchange of cations, all of which improve soil fertility. Also, the fact that they contain vital micronutrients, essential macroelements, and microorganisms increases their importance. Mustatfa and Ahmed (33), Hu and Cao (22) found an increase in the amount of nitrogen, phosphorus, and potassium when adding animal manure to the soil, while this was not achieved when adding chemical fertilizer or not adding any fertilizer. Hopkins (21) confirmed that increasing organic fertilization leads to increased exchange of positive ions, which increases the percentage of potassium in the soil. This is due to the positive correlation between ready potassium and organic matter.

Maize (*Zea mays* L.) is an important cereal crop that occupies large areas around the world and is a field crop that responds greatly to the addition of nitrogen, phosphate and potassium fertilizers (1). Maize occupies first place in terms of the quantity of grains produced and used in human and animal nutrition. It also comes in second place in terms of cultivated area after wheat, in addition to its importance in various industrial fields, so it is considered a strategic crop. (34). Quality factors, the most important of which is grain weight, increase by adding potassium fertilizer (36).

The results of Al-Zaidi (7) showed that the interaction treatment of different levels of potassium and organic fertilizer gave the highest values with regard to the potassium content of the shoot and the plant traits studied in his study on maize crop. Al-Sammak (6) explained that using different levels of potassium sulfate on maize crop achieved a significant increase in both soluble and exchangeable potassium at different stages of plant growth and productivity. Eleduma *et al*., (16) indicated that adding organic fertilizers led to a significant increase in all growth and productivity traits of maize plants. Gomaa *et al.,* (19) explained that adding organic fertilizers (sheep waste) at several levels resulted in a significant increase in all growth and productivity traits of maize plants (cob length, number of rows in the cob, number of grains in a row, weight of 100 grains, grain yield, biological yield, harvest index, and protein content in grains). Akongwubel *et al*., (2) found an increase in the growth rate and yield of maize plants (plant height, number of leaves, dry weight of leaves and stem, and grain yield) in soil treated with organic fertilizers. In view of the role that potassium fertilizers play in increasing the productivity of the yellow maize crop, and because of the soil's suffering from potassium fixation despite its availability, as well as the importance of organic matter in making macro- and micro-nutrients available, as well as its low percentage in soils of dry and semi-arid climates for many reasons, our research came to achieve the following knowledge: The effect of adding potassium and organic fertilizers separately and their interaction in raising the soil content of NPK elements and in the growth and productivity of maize.

Materials and methods

The research was conducted on a private farm in Deir Ezzor province, where soil samples representing the research site were taken. After drying and cleaning the soil samples from root residues, they were ground and sieved using a sieve with a diameter of (2) mm. Physical and chemical analyses were performed, including mechanical analysis to determine soil texture (%) using the Hydrometer method, bulk density of the soil (g.cm^{-3}) using the density cylinder method, porosity, electrical conductivity (ECe) in deciSiemens/meter using an Electrical conductivity device, soil pH using a pH-meter, organic matter using the wet oxidation method, mineral nitrogen using the (Kjeldahl) method, available phosphorus using the Olsen method, and available potassium using a Flame photometer. Tables 1 and 2 illustrate the soil and organic fertilizer analyses.

Table 1. Some chemical and physical soil properties of the field before planting.

Parameters		Value	Unit
pH_{KCl}		7.9	-
Ece		0.63	dS/m
Organic matter		0.76	%
Mineral nitrogen	N	4.6	mg.kg^{-1}
Available phosphorus	P	6.9	mg.kg^{-1}
Dissolved potassium	K	12	mg.kg^{-1}
Mutual potassium	K	205	mg.kg^{-1}
	Sand	24.8	
Soil separates	Silt	35.52	
	Clay	39.68	
Soil texture		Clay silt	
True density		2.64	g.cm^{-3}
Bulk density		1.57	g.cm^{-3}
Porosity		40.53	%

Table 2. Characteristics of the organic fertilizer used in the research.

Parameters	Value
Organic materials	51.6 %
Organic carbon	30%
pH	7.25
EC	12.92 $dS.m^{-1}$
C/N	17.44
Total N	1.72%
%P	0.96%
%K	1.43%

A factorial experiment was conducted according to a randomized complete block design (RCBD) with three replicates and a rate of (36) plants per replicate, to study the effect of both the first factor, potassium fertilizer rates, and the second factor, organic fertilizer rates, and their interaction.

Four levels of potassium fertilizer were added, which are (K0:0- K1:100- K2:150- K3:200) kg $K.ha^{-1}$ in the form of potassium sulfate K_2SO_4 (50% K_2O) and were added to the soil before planting.

As for organic fertilizers (sheep manure), four levels (OM0:0- OM1:15- OM2:20- OM3:25) tons. ha^{-1} were mixed with the topsoil before planting for each experimental unit.

The land was plowed, smoothed, and divided into three sections, with each section divided into 16 experimental units. Each experimental unit contains three rows, with each row measuring 3 meters in length and spaced 70 cm apart. A distance of 1 meter was left between the experimental units, and 2 meters between the sections. The area of each experimental plot is 6.3 square meters, with dimensions of 3×2.1 meters. The experiment was then planted with maize (Gouta 82 variety) at a depth of 5 cm and spaced 25 cm between the rows. The planting was done on 21/6/2022, with three seeds placed in each row and later thinned to one plant after germination.

Phosphatic fertilizers were added at a rate of 170 kg of superphosphate 46% phosphorus per hectare before planting, and nitrogenous fertilizers at a rate of 120 kg N. ha^{-1} in the form of urea 46% were added in two doses: the first dose of 60 $kg.ha^{-1}$ before planting equivalent to 130 kg urea 46%, and the second dose of 60 kg N. ha^{-1} at the beginning of the male inflorescence formation stage, in accordance with the Ministry of Agriculture's recommendation based on soil analysis.

The results were statistically analyzed using the GenStat 12th program, and the ANOVA analysis of variance table was used by calculating the least significant difference (L.S.D) at the 5% and 1% significance levels for the laboratory results. Data related to soil and plants were studied (mineral nitrogen in the soil, available phosphorus in the soil, exchangeable potassium in the soil, average plant height, leaf area, and grain yield).

Results and discussion

1. Mineral nitrogen in soil

The data in table 3 indicates a significant increase in the average of the mineral nitrogen index in the soil at K3 compared to the other levels, reaching 8.27 $mg.kg^{-1}$, while it decreased in the control to 7.30 $mg.kg^{-1}$. This is consistent with the findings of (20) that increasing potassium fertilizer added to the soil causes an increase in the availability of nitrogen value in the soil, and the reason for this is competition between the potassium ion and the ammonium ion for the sites of the exchange complex, since their radii are close (K=1.33A, NH4=1.34A). High concentrations of potassium ions in soil cause the release of adsorbed ammonium on the internal surfaces of clay minerals. The results also show an increase in the mineral nitrogen index in the soil with increasing levels of organic fertilizer. OM3 achieved the highest value, with a significant difference compared to the rest of the treatments and the control, where its value reached (8.97 tons.kg^{-1}). The reason may be due to the role of microorganisms in decomposing and oxidizing organic fertilizer, which leads to the release of nitrogen and thus its increase. This result is consistent with Wen *et al*., (39) who demonstrated a significant increase in the soil content of mineral nitrogen when adding organic fertilizer. As for the combined effect of adding potassium and organic fertilizers, high levels of potassium fertilizer with high levels of organic fertilizer achieved a noticeable increase in the value of mineral nitrogen in the soil. Its highest value was reached when K3 was interspersed with OM3 which was (9.60 mg.kg^{-1}), while the value decreased significantly for the control to (5.79 mg.kg^{-1}).

Table 3. The effect of adding potassium and organic fertilizer on mineral nitrogen in the soil (mg.kg^{-1}) after harvest.

Potassium fertilizer kg.ha^{-1}	Organic fertilizer tons.ha^{-1}				Average (K)
	OM0	OM1	OM2	OM3	
K0	5.79	7.05	7.94	8.43	7.30d
K1	6.38	7.17	8.20	8.71	7.61c
K2	6.60	7.34	8.69	9.17	7.95b
K3	6.85	7.58	9.05	9.60	8.27a
Average (OM)	6.40d	7.28c	8.47b	8.97a	7.78
LSD1%K	0.27				
LSD1% OM	0.42				
LSD1% K×OM	0.38				

2. Available phosphorus in soil

From the data presented in Table 4, we conclude that there was a significant increase in the value of available phosphorus in the soil at K3 as it reached (12.07 mg.kg^{-1}), while the value of phosphorus in the control soil was (10.94 mg.kg^{-1}). followed by K2 which did not have any significant differences between it and K1. This may be due to a decrease in the pH of the soil due to the sulfur present in potassium sulfate, which increases the number of microorganisms, especially of the type *Thiobacillus Thioparus*, which helps in the release of hydrogen ions, which leads to a decrease in the pH of the soil, which helps in the release of phosphorus. This result is consistent with Jarallah and Abbas (27) who confirmed that adding sulfur fertilizers at all addition levels gave the highest values of phosphorus compared to the control treatment. The results also indicate an increase in the value of phosphorus in the soil with increasing levels of organic fertilizer. Each level was significantly higher than the lower level. The highest value was at OM3 (13.76 mg.kg^{-1}) and the lowest value was at the control (10.94 mg.kg^{-1}). The increase is explained by the presence of carbonic acid and other organic acids produced from the decomposition of organic fertilizer, which causes a decrease in the degree of soil interaction and thus the dissolution of some compounds containing phosphorus and their transfer to the soil solution, in addition to the clay colloids surrounding these compounds and their chelating behavior, which works to reduce phosphorus precipitation reactions, This is confirmed by the results of Muhawish and Hilal (32), where it was found that adding organic fertilizer led to an increase in the soil content of available phosphorus due to the decomposition of the organic fertilizer into organic and inorganic acids, which contributes to lowering the pH of the soil, which increases the dissolution of phosphorus compounds and thus increases the phosphorus in the soil. the soil. As for the combined effect of both potassium and organic fertilizers, the highest significant value for phosphorus was reached when K3 was intermingled with OM3 It reached (13.76 mg.kg^{-1}). While it was in the control (9.44 mg.kg^{-1}).

Table 4. The effect of adding potassium and organic fertilizer on available phosphorus in the soil (mg.kg^{-1}) after harvest.

Potassium fertilizer kg.ha^{-1}	Organic fertilizer tons.ha^{-1}				Average (K)
	OM0	OM1	OM2	OM3	
K0	9.44	10.82	11.32	12.21	10.94c
K1	10.01	10.90	11.85	12.63	11.34b
K2	10.26	11.05	12.11	13.02	11.61b
K3	10.67	11.17	12.68	13.76	12.07a
Average (OM)	10.09d	10.98c	11.99b	12.90a	11.49
LSD1%K	0.36				
LSD1% OM	0.73				
LSD1% K×OM	0.65				

3. Exchangeable potassium in soil

The results of Table 5 indicate a significant increase in the exchangeable potassium concentration in the soil at K3 reaching a value of (267.81 mg.kg^{-1}), followed by sequentially lower levels, while the value significantly decreased in the control to (213.56 mg.kg^{-1}). The increase is due to the addition of potassium fertilizer, which in turn led to an increase in the soil's exchangeable potassium content, and this is consistent with Ibrahim *et al*., (24) in their study of adding different levels of potassium fertilizer, where the results showed an increase in the potassium content of the soil, as a positive result of increasing the levels of potassium fertilization. Furthermore, the results indicate an increase in the exchangeable potassium value with increasing levels of organic fertilizer, with significant differences between all levels. The highest value (262.79 mg.kg^{-1}) was recorded at OM3 while the lowest value was observed in the control (224.89 mg.kg^{-1}). The increase in exchangeable potassium in the soil is explained by the organic acids resulting from the decomposition of organic fertilizer, which have the ability to dissolve some potassium-bearing compounds and minerals on the one hand, and the possibility of organic matter entering between the layers of clay on the other hand, in addition to the decrease in fertilizer loss due to the soil's organizing capacity and the release of potassium as a result of the formation of organic complexes with added potassium, which reduces fertilizer loss due to the regulating capacity of the soil and thus releases potassium into the soil solution. This result is consistent with his findings Bader *et al*., (10) showed that applying organic fertilizer to the soil increases potassium release and reduces potassium fixation in the soil. Regarding the combined application of potassium and organic fertilizers, the highest value was recorded when K3 intersected OM3 reaching (288.27 mg.kg^{-1}), while the value significantly decreased in the control to (183.26 mg.kg^{-1}).

Table 5. The effect of adding potassium and organic fertilizer on exchangeable potassium in the soil (mg.kg^{-1}) after harvest.

Potassium fertilizer kg.ha^{-1}	Organic fertilizer tons.ha^{-1}				Average (K)
	OM0	OM1	OM2	OM3	
K0	183.26	210.09	224.28	236.63	213.56d
K1	227.30	233.36	240.97	254.81	239.11c
K2	239.87	246.12	258.39	271.45	253.95b
K3	249.15	259.08	274.74	288.27	267.81a
Average (OM)	224.89d	237.16c	249.59b	262.79a	243.61
LSD1%K	10.86				
LSD1% OM	11.15				
LSD1% K×OM	7.32				

4. Average plant height

It is noted from Table 6 that the plants fertilized with potassium at K3 achieved a significant superiority in plant height over the rest of the treatments, as the height reached (180.98 cm), while the lowest value was reached in the control not fertilized with potassium, which was (169.37 cm). The results also show that with an increase in the rate of adding potassium fertilizer, an increase in height occurs, and the reason for this is the increase in the vascular bundles in the stem, which causes an increase in the elongation and hardness of the plant, and the reason for this increase is nutrition with potassium, in addition to the fact that potassium encourages the action of the hormones gibberellin and auxin, which encourage elongation. Plant, these results are consistent with the results of (31, 24). As for the organic fertilization treatments, the organically fertilized plants at OM3 were significantly superior to the rest of the treatments. The plant height reached (183.49 cm), while the plant height decreased significantly in the control. We also notice an increase in height with increasing fertilizer rates. This is explained by the fact that the nutrients released from the decomposition of organic matter improve the growth and development of the plant, in addition to the role that organic matter plays in improving the physical and chemical properties of the soil, which leads to an increase in plant height as a positive result, and this is consistent with the findings of (8, 29). As for the combined effect of adding potassium and organic fertilizers, K3 with OM3 achieved the highest plant height (188.20 cm), and there were no significant differences between it and the interaction of K2 with OM3, while the lowest value of height was reached in the control, which reached (160.55 cm), as the results show. That there is an increase in plant height accompanying an increase in the rates of the two fertilizers if they are added together.

Table 6. The effect of adding organic fertilizer and potassium on the average plant height (cm).

Potassium fertilizer kg.ha^{-1}	Organic fertilizer tons.ha^{-1}				Average (K)
	OM0	OM1	OM2	OM3	
K0	160.55	165.70	172.39	178.84	169.37d
K1	165.60	171.11	176.27	180.03	173.25c
K2	171.81	176.41	179.15	186.92	178.57b
K3	175.53	178.72	181.47	188.20	180.98a
Average (OM)	d168.37	c172.98	177.32b	183.49a	175.54
LSD5%K	2.15				
LSD5% OM	3.02				
LSD5% K×OM	2.90				

5. Surface area of leaf (cm^2)

The results of the statistical analysis in Table 7 indicate that there was a noticeable increase in the leaf surface area in the potassium fertilization treatments. The highest value of the leaf surface reached (6147.90 cm^2) at K3 with a noticeable significant difference compared to the rest of the treatments and the control that achieved The lowest value for a surface area of leaf (5783.62 cm^2). This may be due to the role of potassium in regulating the osmotic potential of the plant cell, which causes an increase in the turgor pressure of the cell and thus increases the leaf area. Thus, potassium contributes to increasing the division and elongation of leaf cells, and this is consistent with the findings of (15, 4). With regard to organic fertilization treatments, OM3 whose value reached (6191.50 cm2), was significantly superior to the rest of the treatments and to the control (5724.05 cm^2). The increase in leaf area is due to increasing levels of adding organic fertilizer to the role of the organic compounds present in the organic fertilizer in encouraging cell division and increasing their size, thus increasing the leaf area of the plant, in addition to the role of organic matter in providing the plant with sufficient quantities of nutrients and thus increasing its growth, which reflects positively on this. This trait is consistent with the findings of Budiastuti *et al.*, (13) who found that organic fertilizers gradually release nutrients into the soil solution which increases the leaf area due to the translocation of nutrients to the leaves. These results are also consistent with Iqbal and Iqbal (25), who found that adding organic fertilizer led to an increase in leaf area due to the presence of nutrients that help increase the size of leaf cells. The table also shows the positive effect of potassium and organic fertilizers, as the interaction of K2 and K3 of potassium fertilizer with OM3 of organic fertilizer achieved a significant increase in the leaf surface area (6296.15 - 6343.98 cm^2) compared with the rest of the interactions and with the control (5412.65 cm^2).

Table 7. Effect of adding potassium and organic fertilizer on leaf surface area (cm^2).

Potassium fertilizer kg.ha^{-1}	Organic fertilizer tons.ha^{-1}				Average (K)
	OM0	OM1	OM2	OM3	
K0	5412.65	5794.42	5914.91	6012.52	d5783.62
K1	5701.15	5802.48	6008.61	6113.36	5906.40c
K2	5824.84	6047.72	6104.72	6296.15	6068.35b
K3	5957.56	6091.91	6198.15	6343.98	6147.90a
Average (OM)	5724.05d	5934.13c	6056.59b	6191.50a	5976.571
LSD5%K	63.15				
LSD5% OM	82.46				
LSD5% K×OM	77.12				

6. Grain yield

It is clear from the data in Table 8 that there was a significant increase in the grain yield of maize upon K3 of potassium fertilizer (7.499 tons.ha^{-1}) compared to the rest of the treatments and to the control that recorded the lowest productivity (5.132 tons.ha^{-1}). As the results show, the more potassium the more grain yield due to the availability of a sufficient amount of potassium, which works to form a good plant cover that absorbs light effectively to increase the process of photosynthesis and increase growth characteristics such as plant height, number of leaves, increased leaf surface, increased grain weight, and increases the efficiency of transporting metabolic products to storage sites by increasing formation of ATP necessary to load metabolic products and reflects positively on plant production, and this agrees with (35, 37) As for organic fertilizer, OM3 recorded the highest value for grain yield (7.728 tons.ha^{-1}), followed by OM2, followed by OM1, with significant differences between all treatments and the control, in which productivity decreased to (4.784 tons.ha^{-1}). This may be attributed to the role of organic matter in improving the physical and chemical properties of the soil and thus increasing the availability of nutrients and thus their absorption by the plant and their transfer to storage places, which are the seeds. This result is consistent with the findings of Cokkizgin *et al*., (14) who confirmed that adding organic fertilizers increases the plant's supply of nutrients that play an important role in increasing grain yield. The results also indicate an increase in grain yield in all overlapping treatments compared to the control, which recorded the lowest value (3.220 tons.ha^{-1}). The highest value was reached when K3 was overlapping with OM3 (8.369 tons.ha^{-1}), and there was no Significant difference between it and the overlapping of K2 and OM3. (8.321 tons.ha^{-1}), followed by the rest of the interaction parameters.

Table 8. The effect of adding organic fertilizer and potassium on the grain yield of maize, tons.ha^{-1}.

Potassium fertilizer kg.ha^{-1}	Organic fertilizer tons.ha^{-1}				Average (K)
	OM0	OM1	OM2	OM3	
K0	3.22	4.75	5.97	6.57	5.13d
K1	3.99	5.98	6.02	7.64	5.91c
K2	5.62	6.62	7.87	8.32	7.10b
K3	6.29	7.31	8.01	8.36	7.49a
Average (OM)	4.78d	6.16c	6.97b	7.72a	6.41
LSD5%K	0.21				
LSD5% OM	0.37				
LSD5% K×OM	0.28				

Conclusion

Given the importance of the yellow corn crop and the role that potassium plays in increasing its productivity, and because the soil suffers from potassium fixation, it is necessary to add potassium fertilizers, and given the importance of organic matter as a means of increasing the availability of nutrients, including potassium, and its role in improving soil properties, it must be added to the soil. The experiment confirmed that all the studied characteristics of the soil and the yellow corn plant showed a significant increase when potassium and organic fertilizers were added to the soil. Adding both potassium and organic fertilizers at high levels had a positive effect on all studied soil and plant traits (mineral nitrogen, available phosphorus, replaced potassium, plant height, leaf surface area, and grain yield). Fertilizing potassium in K3 had the best results, as did OM3 separately. The interaction between potassium and organic fertilization treatments led to a significant superiority in the studied soil indicators (mineral nitrogen, available phosphorus, exchangeable potassium) at the level of K3 with OM3. The interaction between K2 and K3 potassium fertilization treatment and OM3 organic fertilization gave the best results for the studied plant traits (plant height, leaf area, grain yield).

Conflict of interest

The authors have no conflict of interest.

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