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ROLE OF ORGANIC MATTER AND MINERAL FERTILIZATION IN THE RETENTION OF POTASSIUM AND GROWTH OF YELLOW MAIZE

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SUMMARY

A biological experiment proceeded on yellow corn (*Zea mays* L.) in plastic pots during the agricultural season on August 4, 2021, which included adding organic matter (0% and 5%) and bentonite mineral (0%, 10%, and 20%) of soil weight and potassium (0, 50, and 100 kg ha^{-1}) as potassium sulfate. After 90 days of planting, the amount of soluble and exchangeable potassium measured revealed results that adding organic matter with bentonite minerals increased soluble potassium by 38.46%. Meanwhile, exchangeable potassium decreased by 1.61% and dry matter increased by 6.5%. As for adding bentonite, the 20% level was the most effective compared with 0% and 10%, in reducing soluble potassium by 25% and 50%. It also increased exchangeable potassium by 1.62% and 2.45% and dry weight of the plant by 95.04% and 48.32%. As for the effect of the added potassium levels, the results showed 100 kg ha^{-1} was superior to 50 and 0 kg ha^{-1} in soluble potassium (92.86% and 440%, respectively). The drained potassium was the highest at the level of 100 and 50 kg ha^{-1} (5.88% and 5.04%) in the direction of the contact line, and 100 kg ha^{-1} was superior to 100 and 50 kg ha^{-1} in the dry weight of the plant (9.85% and 4.80%). The results of the double and triple interaction showed significant differences.

Keywords: Yellow maize (*Z. mays* L.), organic matter, bentonite, potassium fertilizer, growth traits

Key findings: The addition of organic matter and bentonite to sandy soils can improve potassium availability and reduce the values of exchangeable potassium, aside from improving the yellow maize corn (*Z. mays* L.) growth.

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INTRODUCTION

The yellow corn crop (Z. mays L.), which belongs to the Poaceae family (Stuessy, 2009), is one of the most valued crops of great economic importance, as it has a high production capacity. It is one of the most efficient grain crops in exploiting production sources of water, light, and nutrients (Awika, 2011). It is a C4-quaternary plant with a high yield index (Taiz and Zeiger, 2002). Each part of the yellow corn plant has a contribution in several fields. Its seeds are ingredients in the manufacture of flour and starch, and the vegetative part and seeds serve as fodder, as well as contribute to the manufacture of many medical drugs (Delcour and Hoseney, 2010).

Sandy soils are often poor in their content of nutrients due to their exposure to soil losses through leaching caused by high porosity. Many efforts attempted to reduce the effect of this loss through the use of some natural materials, such as, organic materials and clay minerals (Al-Bassam and Dawood, 2009). One critical factor affecting the potassium element's readiness is the clay mineral's quantity and quality, with many studies conducted in Iraq to verify its impact on the stabilization process, making many converters to reduce that process by adding organic matter (Abdali, 2013). Studies conducted by some researchers also indicate the use of clay minerals, including bentonite being the best mineral improvers for different soils, especially coarse textures, due to its great role in preserving soil nutrients (Ibrahim and Al-Badri, 2020; Al-Hayani et al., 2022).

The addition of organic matter to the soil has an essential role in increasing the available potassium and improving the chemical, physical, and biological properties of the soil and organic acids. Such acids include humic, fulvic, and humane results of decomposing organic matter. This works to reduce the degree of soil interaction and then increases potassium readiness through its ability to dissolve some minerals containing potassium, increasing its availability and release to the soil solution from one side. Conversely, it tends to form chelating compounds with the positive ions of the elements.

Moreover, study findings of Al-Zubaidi (2010), Hoshan (2016), and Issa (2022) indicated adding organic fertilizers significantly influenced an increase in the available potassium concentration in the soil. This resulted from the replacement of the hydrogen ion H^{+1} emerging from the dissolution of organic acids. It is a consequence of the organic fertilizer decomposing in place of the potassium ion K^{+1} on the exchange surfaces of the soil. Afterward, it combines with the potassium contained in the organic fertilizer making the organic fertilizer dissolve some compounds and minerals further carried by the action of organic acids. This process produces the bentonite, a natural clay mineral with the structure [AI, Mg 6 (Si40O10) 3 (OH) 6H].

Potassium is an essential and necessary nutrient in plants, and it has attracted the attention of many researchers and those interested in soil chemistry, fertility, nutrition, physiology, and biochemistry of plants. It stimulates many processes, such as, the enzymatic reactions and the regulation of the guard cells' work around the stomata, the regulation of the process of respiration, and transpiration through the mechanism of opening and closing those stomata (Krauss, 2009). This research sought to determine the effect of adding organic matter and bentonite mineral on the available of potassium in sandy soils.

MATERIALS AND METHODS

The biological experiment began in plastic pots with a capacity of 25 kg in the canopy of the Department of Soil Sciences and Water Resources, College of Agricultural Engineering Sciences. Samples came from the banks of the Tigris River at the University of Baghdad, near the current Deanship of the College of Agriculture. After bringing the soil from the field, it underwent the following procedure. Air dried and sifted using a sieve with a diameter of 4 mm and placed in plastic pots after mixing it with bentonite mineral and organic matter (cow waste) for the final weight of the soil in the pot to reach 20 kg of soil pot^{-1}. Afterward, conducted physical and chemical analysis of the soil, organic matter, and mineral (Richards, 1954; Jackson, 1958; Page et al., 1982). Tables 1, 2, and 3 showed the chemical and physical properties of the soil, organic matter (cow waste), and the mineral bentonite.

The experimental design utilized a randomized complete block design (RCBD) with split-plot arrangement. The study included 90 experimental units (5 × 3 × 3 × 2), resulting from the overlapping of two levels of organic matter addition (0% and 5%) labeled as O_0 and O_1, and three levels of bentonite mineral (0%, 10%, and 20%) tagged as M_0, M_1, and M_2 of the soil weight, and three levels of potassium (0, 50, and 100 kg ha^{-1}), with corresponding symbols, K_0, K_1, and K_2, as potassium sulfate fertilizer. The added nitrogen and phosphorus had the level of 200 and 100 kg ha^{-1}, respectively, in the form of urea fertilizer. Its addition comprised two batches, the first at planting and the second 45 days after adding the first batch. Triple superphosphate fertilization occurred once at planting. Sowing yellow maize seeds at five seeds per pot commenced on August 4, 2021. After the first week of germination, reducing the plants to three plants lasted for 90 days. Meanwhile, maintaining the moisture content of the soil in the pot proceeded at 80% limits of field capacity throughout the growth period and according to the gravimetric method. At the end of the experiment, the estimation of soluble and exchangeable potassium and some plant growth characteristics continued.

Statistical analysis

Statistical analysis of the parameters of the biological experiment ensued using the Genstat V12.1 software, with significant differences' comparison by the LSD for a significance level of 0.05 according to SAS (2018).

Table 1. Some chemical and physical properties of the soil sample under study.

Adjective	The value	Unit
Reaction number (pH)	7.4	
Electrical conductivity (ECe)	2.26	dS m^{-1}
Cation exchange capacity (CEC)	11.03	Cmol+kg^{-1}
Organic matter (OM)	6.9	gm kg^{-1}
Carbonate minerals	246	
Dissolved ions (1:1)		
$CO3^{-2}$	0.00	mol l^{-1}
$HCO3^{-1}$	4.10	
$SO4^{-2}$	4.03	
Cl^{-1}	11.60	
Ca^{+2}	6.25	
Mg^{+2}	3.5	
Na^{+1}	3.25	
Potassium Forms		C.mol K kg^{-1}
Soluble	0.011	
exchangeable	0.131	
non-exchangeable	1.67	
Mineral	12.55	
Total	14.36	
available Nitrogen	14	mg kg^{-1}
available Phosphorus	4.1	
Soil separates		
Sand	856	gm kg^{-1}
Silt	82	
Clay	62	
Soil texture	Sandy	

Table 2. Some chemical properties of the organic matter.

Studied trait	Compost	Measuring unit
Electrical conductivity EC (1:5)	10.56	dS m^{-1}
The reaction number pH (1:5)	6.8	
Moisture content	10.26	%
Nitrogen	2.97	%
Phosphorus	1.097	%
Potassium	1.32	%
Organic carbon	48	%
C\N ratio	16.16	%

Table 3. Some properties of the mineral bentonite.

Studied trait	Bentonite mineral	Measuring unit	Studied trait	Bentonite mineral	Measuring unit
pH reaction number	7.5	-	Ga	0.00197	%
Electrical conductivity EC	1	dS.m^{-1}	Ge	<0.00005	
Organic matter	0.00	gm kg^{-1}	As2O3	0.00218	
Items content			Se	0.00026	
SiO2	49.59	%	Br	0.00105	
Al2O3	12.56		Rb2O	0.00275	
MgO	3.025		SrO	0.02865	
Fe2O3	5.498		Y	0.00191	
CaO	9.049		ZrO2	0.01927	
Na2O	2.013		Nb2O5	0.00519	
K2O	0.4186		Mo	0.00166	
SO3	4.625		Ag	<0.00020	
Cl	0.5604		Cd	0.00021	
TiO2	0.9793		SnO2	<0.00039	
V2O5	0.0498		Sb2O5	<0.00040	
Cr2O3	0.02028		Te	<0.00030	
MnO	0.01317		I	0.00096	
CoO	<0.00083		Cs	<0.00040	
NiO	0.00918		Ba	0.00271	
CuO	0.00197		La	<0.00020	
ZnO	0.03282		Ce	<0.00020	
Ta2O5	0.00776		Hf	<0.00010	
WO3	0.00056		Hg	<0.00010	
U	0.00060		Pbo	0.00137	
Th	0.00071		Bi	<0.00010	

RESULTS AND DISCUSSION

Fertilization effect on the soluble potassium

The results showed the effect of adding organic matter, bentonite mineral, and extra potassium on the concentration of soluble potassium in the soil after 90 days (Table 4). Potassium came from the organic matter after exposure to adsorption on its surfaces due to the weak bonding strength between potassium and the decomposition products of the organic matter, represented by carboxylic and phenolic aggregates. In addition, liberating the content of the organic matter of potassium can be available for the plant these wastes decomposed (Table 2). As for the effect of the levels of added bentonite mineral, results showed a decrease in the levels of soluble potassium as the added levels of the mineral increase. The level of M_2 exceeded the M_1 and M_0 levels of addition in reducing the concentration of soluble potassium by 25% and 50%, respectively. This is due to the exposure of soluble potassium to adsorption on the surfaces of the added bentonite mineral.

Consequently, the amount of dissolved bentonite mineral in the soil decreases, as confirmed by Al-Bassam and Dawood (2009). As for the effect of the levels of added potassium on the amount of soluble potassium, the outcomes revealed an increase in the concentration of soluble potassium as the additive level rises. Furthermore, Al-Amiri (2005) and Al-Tamimi (2017) reported increasing levels of potassium fertilizer contributed to raising the concentration of soluble potassium in the soil.

On the effect of the bilateral interaction between levels of organic matter and mineral levels on the dissolved potassium concentration, results gave significant differences between the treatments (Table 4). For the effect of the tripartite interaction between the organic matter, the added mineral, and potassium levels, the outcomes indicated considerable variations. The highest value of soluble potassium was 0.043 cmol kg^{-1} in the treatment K_2; M_0; O_1 and the lowest value in treatment K_0; M_2; O_0 at 0.001 cmol kg^{-1}. Hence, it is clear that the addition of the organic matter and the added metal contributed to maintaining the balance concentration of soluble potassium in the medium through the adsorption process. This obtained potassium on the surfaces of the mineral or organic matter, and, then supplying the plant with it over time.

Fertilization effect on the exchange potassium concentration

The results provided the effect of adding organic matter, bentonite mineral, and potassium levels on the amount of exchanged potassium (Table 5). The findings showed the presence of the organic matter reduced the exchange of potassium by 1.61% compared with its absence in the plant and its low concentration in the center of the soil balance. This was consistent with the study of Havlin et al. (2005), stating increasing the chemical readiness of any element differently, soluble and exchanged, can contribute to boosting the vital readiness of that element by the plant. In addition to the role of organic matter in increasing the rate of plant growth, it also enhanced the amount of the element absorbed by the plant and its decrease in the soil, as confirmed by Abdul Rasoul (2007).

Table 4. Soluble potassium concentration (Cmol kg^{-1} soil).

The average -O	O*M	K_2	K_1	K_0	M	O
	0.017	0.012	0.017	0.003	M_0	
0.013	0.013	0.022	0.015	0.002	M_1	O_0
	0.007	0.031	0.010	0.001	M_2	
	0.023	0.043	0.017	0.010	M_0	
0.018	0.018	0.032	0.013	0.009	M_1	O_1
	0.013	0.021	0.012	0.007	M_2	
LSD: O = 0.001*	LSD: O*M= 0.007*	LSD: O*M*K = 0.009*			Values LSD	
---					K x O	
LSD: O*K = 0.007*		0.022	0.014	0.002	O_0	
		0.032	0.014	0.009	O_1	
the average M					K x M	
0.020		0.037	0.017	0.007	M_0	
0.0155		0.027	0.014	0.006	M_1	
0.0105		0.0165	0.011	0.004	M_2	
LSD: M = 0.002*		LSD: M*K = 0.0088			Values LSD	
---		0.027	0.014	0.005	---	the average K
		LSD: K = 0.002*			Values LSD	

Table 5. Exchange potassium concentration (Cmol kg^{-1} soil).

The average -O	O*M	K_2	K_1	K_0	M	O
0.124	0.123	0.127	0.125	0.117	M_0	O_0
	0.124	0.128	0.126	0.118	M_1	
	0.126	0.129	0.129	0.120	M_2	
0.122	0.120	0.121	0.121	0.118	M_0	O_1
	0.121	0.123	0.123	0.118	M_1	
	0.124	0.127	0.125	0.121	M_2	
LSD: O = 0.002 *	LSD: O*M=0.004*	LSD: O*M*K = 0.006 *			Values LSD	
---					K x O	
LSD: O*K = 0.004 *		0.128	0.127	0.118	O_0	
		0.124	0.123	0.119	O_1	
the average M					K x M	
0.122		0.124	0.123	0.117	M_0	
0.123		0.126	0.125	0.118	M_1	
0.125		0.128	0.127	0.121	M_2	
LSD: M = 0.002		LSD: M*K = 0.004 *			Values LSD	
---		0.126	0.125	0.119	---	the average K
		LSD: K = 0.002 *			Values LSD	

Regarding the effect of the added bentonite levels on the exchange potassium concentration, the results revealed substantial differences between the treatments, with the M_2 level surpassing the M_1 and M_0 levels, with a ratio of 1.62% and 2.45%, respectively. The reason for this is the bentonite mineral absorbing a massive amount of the added potassium due to the negative charge's density increase and the strength of the bond as the added levels rise in the mineral. Then, boosting the amount of liberation from it occurs in the extraction process. These results received confirmation from Yssaad and Belkhodja (2007) and Satje and Nelson (2009) in the role of bentonite mineral in preserving soil nutrients and the exchangeable form.

On the added potassium levels' effect on the exchange potassium concentration, the results showed the levels K_2 and K_1 were significantly superior to the K_0 level, with a percentage of 5.88% and 5.04%. This points to the role of the added potassium in the retention of exchange potassium. This was in agreement with past studies reporting the addition of potassium fertilizer contributed to maintaining the level of available potassium in the soil (Al-Abdali, 2013; Al-Bandawy, 2017).

As for the effect of the binary interaction between organic matter and bentonite mineral, organic matter and potassium levels, and bentonite mineral and potassium levels, findings displayed noteworthy differences between the treatments. As for the triple interaction between the organic matter, bentonite mineral, and potassium levels on the exchange potassium concentration, the results indicated remarkable variations between the treatments. The maximum value reached 0.129 cmol kg^{-1} soil in the K_2; M_1; O_0 and $K_{1;}$ M_1; O_0 treatments. The minimum value was 0.112 cmol kg^{-1} soil in K_0; M_0; O_0 treatment.

Fertilization effect on the plant's dry weight

The effect of the organic matter, bentonite mineral, and potassium fertilizer levels on the dry weight values appear in Table 6. The results implied the organic matter played a significant role in increasing the average dry weight of the plant. The treatments wherein adding the organic matter significantly outperformed those untreated by a percentage of 6.5%. This is due to the role of organic matter in improving the chemical properties of the soil and increasing the soil nutrient content, which reflects positively on plant growth and increases the percentage of vegetative growth (Al-Hilfy and Al-Temimi, 2017; Ali and Shaker, 2018).

Table 6. The amount of dry weight (g plant^{-1}).

The average -O	O*M	K_2	K_1	K_0	M	O
155.48	142.88	145.100	142.960	140.510	M_0	O_0
	158.15	165.720	157.310	151.410	M_1	
	165.43	176.710	164.270	155.300	M_2	
165.59	153.46	160.310	152.710	147.370	M_0	O_1
	169.62	176.310	170.180	162.360	M_1	
	173.71	184.700	175.120	161.320	M_2	
LSD: O = 3.47 *	LSD: O*M = 7.596*	LSD: O*M*K = 10.517*			Values LSD	
---					K x O	
LSD: O*K = 7.596*		162.510	154.85	149.073	O_0	
		173.773	166.003	157.017	O_1	
the average M					K x M	
148.16		152.705	147.835	143.940	M_0	
163.88		171.015	163.745	156.885	M_1	
169.570		180.705	169.695	158.310	M_2	
LSD: M = 4.25*		LSD: M*K = 8.608*			Values LSD	
---		168.14	160.43	153.05	---	the average K
		LSD: K = 4.25*			Values LSD	

On the effect of the added bentonite mineral levels, outcomes signified the M_2 level was remarkably superior to the M_0 and M_1 levels, with a percentage of 95.04% and 48.32%, respectively. This agrees with the findings by Al-Bassam and Dawood (2009). As for the effect of the potassium fertilizer levels, the results showed the potassium had a significant influence on increasing the amount of dry weight. The K_2 level was significantly superior to the K_0 and K_1 levels by 9.85% and 4.80%, respectively, and it is due to the role of the potassium additive. Increasing the percentage of the vegetative total reflects positively on the dry weight of the plant, and this is consistent with those indicated by Al-Bandawy (2017) and Muhammad (2019).

Regarding the binary interaction between the added organic and mineral matter levels, as well as, the added fertilizer, mineral and organic matter, and fertilizer in the plant's dry weight, the outcomes indicated significant differences between the organic matter and the added fertilizer levels. This was due to the effect of each level on the other existing level by increasing the efficiency of the influence on the dry weight values (Blebish and Al-Anbari, 2024; Fatima and Al-Yasari, 2024). As for the triple interaction between the organic matter, bentonite mineral, and potassium fertilizer levels on dry weight values, the results revealed notable disparities between the treatments, as it showed the lowest value for the treatment (K_0; M_0; O_0), at 140.510 g plant^{-1}. Meanwhile, the maximum value emerged for the treatment K_2; M_2; O_1, with 184,700 g plant^{-1}.

CONCLUSIONS

The investigative study showed the addition of organic matter and bentonite to sandy soils can improve potassium availability and reduce the values of exchangeable potassium, aside from improving yellow maize growth. The best levels for bentonite addition were 20% to enhance exchange potassium concentration. Furthermore, for the levels of potassium addition, the results showed the 100 kg ha^{-1} was superior to other levels in the dissolved potassium values and mutual potassium values, additionally enriching the yellow maize dry weight. Overall, to improve potassium availability and enhance yellow maize growth in sandy soils, organic matter and bentonite minerals can be effective with 5% and 20% of soil weight for each, respectively. Therefore, it is necessary to add the bentonites to sandy soils to increase potassium availability.

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