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Article

Effect of Adding Levels of Palm Fronds Compost and Mineral Fertilizer on Fertile Soil Characteristics, Quality, and Productivity of Maize Yield (Zea Mays L.)

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Abstract
An experiment was carried out in one of the fields of the Soil Research Department - Agricultural Research Department/Ministry of Agriculture in the Abu Ghraib district at latitude 33° 17" 31 N and longitude 44° 03" 56 E and 35 m above sea level. This field study was conducted in the autumn season 2021-2022 for the cultivation of yellow maize (Maha cultivar) in sedimentary soil with silty clay loam texture, with a Split Plot Design. The treatments were distributed using the RCBD for three replicates with two factors. The first factor represents the main plots that include the addition of mineral fertilizer 120, 80, and 320 $kg.ha^{-1}$ for each of (N, P, and K), respectively, at three levels (0, 50, and 100%) of the fertilizer recommendation. On the other hand, the second factor was a subplot of organic fertilizer (palm frond compost) at three levels (0, 5, and 10) $\mu g.ha^{-1}$. Soil samples were taken to estimate the availability of nitrogen, phosphorous, and potassium, where the total yield and percentage of protein for yellow maize were estimated. The results showed that adding organic fertilizers (palm fronds) with the levels of mineral fertilizers increased the availability of nutrients and the yield of maize. Accordingly, the treatment O_2M_2 achieved the highest values of nutrient availability, quantity, and quality of yield, reaching (59.167, 33.407, and 257.967) $mg.kg^{-1}$ soil and (10,096) $\mu g.ha^{-1}$ and (9.435%) for each of nitrogen, phosphorous, potassium, yield, and protein percentage, respectively. Moreover, there were no significant differences between the treatments of O_1M_2 and O_2M_1 in the amount of yield and the percentage of protein, which gave the values of 8.403 and 8.134 $\mu g.ha^{-1,}$ respectively, and the protein percentage of 8.630 and 8.915% respectively. It can be concluded that organic fertilizers can be added to compensate for mineral fertilizers, reduce environmental pollution, and reduce the economic cost and soil preservation because organic fertilizers are considered safe and environmentally friendly.

Keywords: yellow maize, mineral fertilizer, palm fronds compost.

Introduction

The yellow corn crop (Zea mays L.) is one of the main important grain crops in global production in many countries, including Iraq, which ranks third in cultivated area after wheat and rice, where its productivity constantly evolves [1]. Organic fertilizers are an important factor in increasing vegetative growth, increasing production, and improving its quality. Given the low percentage of organic matter in soils with arid and semi-arid climates, such as Iraq, their addition is critical to raising the vitality of these soils and improving physical and chemical qualities and fertility. It is also considered a storehouse of nutrients necessary for plant growth, as it increases the availability of nutrients in the soil through its high content of organic acids that reduce the degree of soil reaction and the dissolution of some insoluble compounds [8, 10]. Maize plants are highly responsive to adding mineral fertilizers, as it is one of the crops that depletes a large amount of nutrients (soil-stressed crops). Generally, crops depend to a large extent on the absorption of nutrients from the soil, as these elements are necessary for plant growth and are absorbed by the root under the soil surface [7]. Therefore, the study aims to identify the effect of palm frond compost and mineral fertilizer and their interactions on nutrient availability in the soil and the quality and productivity of maize. Besides, reducing mineral fertilizers by adding organic fertilizers and preserving the health and environment of the soil since organic fertilizers are environmentally safe.

Materials and Methods

The experiment was conducted in the agricultural station in the Abu Ghraib area of the Soil Research Department / Agricultural Research Department / Ministry of Agriculture during the fall agricultural season (2020-2021). The study aims to investigate the effect of adding palm fronds and mineral compost on the yellow corn crop quality and productivity in calcareous soils of silty clay loam texture classified as Typic-Torrifluvent according to the modern American classification [15]. The experiment was carried out according to the Split Plots Design using the Randomized Complete Block Design(RCBD), with three replicates at a significant level (0.05) and by two factors, as the main factor included adding mineral fertilizer (N, P, K) with three levels. The first without addition symbolized by M_0, the second adding 50% (160 N $kg.ha^{-1}$ and 40 P $kg.ha^{-1}$ and 60 K $kg.ha^{-1}$) and symbolized by M_1, while the third adding 100% (320 N $kg.ha^{-1}$ and 80 P $kg.ha^{-1}$ and 120K $kg.ha^{-1}$) and symbolized by M_2 according to the fertilizer recommendation. The second factor, the Subplot, represents the organic fertilizer (palm frond compost) with three levels, the first without addition, symbolized by O_0, and the second adding 5 $\mu g.ha^{-1}$ symbolized by O_1, and the third adding 10 $\mu g.ha^{-1}$ symbolized by O_2 as shown in table (1).

Property	E.C. 1:5	pH 1:5	N total	P total	K total	C/N Ratio	O.M.
Value	2.4	6.7	0.7	0.3	0.2	18:1	53.6
Unit	DSM-1	-	%			-	%

Table (1) shows the specifications of the organic fertilizer (palm fronds compost).

The land was plowed, harrowed, and divided into experimental plots with dimensions of (2.5 x 4) meters, as the number of treatments was nine, with three replicates. Samples were taken from different field sites on 30/6/2021 at a depth of (0-30) cm. Then, the plant residues, stones, and pebbles were removed from the soil and mixed well to homogenize them, air-dried and crushed using a wooden mallet and passed through a sieve with holes 2 mm in diameter. A composite sample was taken to conduct specific chemical and physical analyses before planting, as shown in Table (2). All characteristics were estimated according to what was mentioned in [16,17], that mentioned in [5].

traits		Value	Unit
pH (1:1) degree of reaction		7.60	-
E.C. (1:1) Electrical conductivity		3.61	$Ds.m^{-1}$
CEC Cationic exchange capacity		22.1	$Cmol.kg^{-1}$
Organic matter		1.1	%
Dissolved positive ions	Ca^{+2}	10.2	Meq/L
	Mg^{+2}	6.25	Meq/L
	Na^{+}	13.4	Meq/L
	K^{+}	0.20	Meq/L
Dissolved negative ions	$HCO3^{-}$	3.00	Meq/L
	SO_4^{-2}	10.8	Meq/L
	Cl^{-}	21.5	Meq/L
	CO_3^{-}	Nil	-
Available nitrogen		37.0	$mg.kg^{-1}soil$
Available phosphorous		12.8	$mg.kg^{-1}soil$
Available potassium		238	$mg.kg^{-1}soil$
Carbonate minerals		210	$g.kg^{-1}soil$
Gypsum		60	$g.kg^{-1}soil$
Soil separates	Sand	204	$g.kg^{-1}soil$
	Silt	468	$g.kg^{-1}soil$
	Clay	328	$g.kg^{-1}soil$
Texture		Silty clay loam	
Bulk density		1.35	$Mg.m^{-3}$

Table (2) Chemical and physical properties of the soil before planting.

The seeds of yellow corn (Maha cultivar) obtained from the Agricultural Research Department were planted on 20/7/2021 for the fall season. Three seeds were placed in one hole, and the plants were thinned after 10 days of germination to one plant in one hole, where the number of plants in one furrow was 15 plants. The field was irrigated using tape drip tubes, while the mineral fertilizer was added in grooves at a distance of approximately 10 cm from the plant in three batches. The first was C.O. $(NH_2)_2$ at a rate of N 46%, triple superphosphate P_2O_5 at P 21%, and potassium sulfate K_2SO_4 at 42% K. Then, the organic fertilizer (palm frond compost) after planting was mixed with the soil inside the furrow. After the yellow corn crop matured, the ears dried up, and the plant reached the stage of full maturity, the harvesting was carried out on 1/12/2022. Five plants were randomly taken from the middle furrow for each treatment to calculate the maize yield. Simultaneously, samples were taken from the soil after harvesting to estimate some of the available nutrients in the soil.

Results

Effect of adding levels of palm frond compost and mineral fertilizer on the concentration of available nitrogen, phosphorous, and potassium in the soil after harvesting

Available nitrogen concentration in soil (mg $N.kg^{-1}$ soil)

The results of Table (3) showed significant differences in the treatment of organic fertilizer (palm fronds) in the nitrogen concentration after harvesting. This increase was accompanied by increased levels of organic fertilizer (palm fronds). The treatment of adding palm fronds compost O_1 and O_2 gave the highest available nitrogen in the soil, amounting to 38,092 and 44.868 mg $N.kg^{-1}$ soil, with an increase of 14.51% and 34.88%, respectively. In comparison, the O_0 treatment gave available nitrogen in the soil, which amounted to 33,263 mg $N.kg^{-1}$ soil. Furthermore, the results of Table (3) showed the superiority of the treatments M_1 and M_2, as they

gave the highest available nitrogen in the soil, which amounted to 37.711 and 52.876 mg $N.kg^{-1}$ soil, respectively, with an increase of 47.36 and 106.61%.
In contrast, the control treatment M gave available nitrogen in the soil, which amounted to 25,591 mg $N.kg^{-1}$ soil. As for the effect of the bilateral interaction between the level of organic (palm fronds) and mineral fertilization, the treatment O_2M_2 exceeded and gave the highest available nitrogen in the soil, amounting to 59.167 mg $N.kg^{-1}$ soil. The above interaction treatment increased 178.04% compared to the treatment O_0M_0, which gave available nitrogen in the soil amounted to 21.280 mg $N.kg^{-1}$ soil.

Organic fertilizer (O)	**Mineral Fertilizer (M)**			**Average (O)**	
	M_0	M_1	M_2		
O_0	21.280	30.788	47.723	33.263	
O_1	24.457	38.093	51.728	38.092	
O_2	31.037	44.402	59.167	44.868	
LSD 0.05	6.397			$LSD_{0.05}$	1.423
Average M	25.591	37.711	52.876		
$LSD_{0.05}$	1.423				

Table (3) Effect of adding levels of palm fronds compost and mineral fertilizer on nitrogen availability after harvesting (mg $N.kg^{-1}$ soil).

The concentration of available phosphorous in soil (mg $P.kg^{-1}$ soil)
Table (4) showed significant differences for the organic fertilization treatment (palm fronds) in the concentration of available phosphorous in the soil after harvesting. The treatments of adding organic fertilizers O_1 and O_2 gave the highest available phosphorous in the soil, amounting to 20,274 and 25.070 mg $P.kg^{-1}$ soil, with an increase of 22.54 and 51.53% for the two treatments, respectively. The treatment O_0 gave the lowest available phosphorous concentration in the 16.544 mg $P.kg^{-1}$ soil. On the other hand, Table (4) showed a significant difference in the treatments M_1 and M_2, as they gave the highest concentration of available phosphorous in the soil, amounting to 20,557 and 28,542 mg $P.kg^{-1}$ soil, respectively. These treatments recorded an increase of 60.73 and 123.17%, respectively, compared to the control treatment M_0, which gave available phosphorus in the soil amounted to 12.789 mg $P.kg^{-1}$ soil. The results in the same Table showed the effect of the bilateral interaction between organic and mineral fertilization levels.

Organic fertilizer (O)	**Mineral Fertilizer (M)**			**Average (O)**	
	M_0	M_1	M_2		
O_0	9.506	15.869	24.259	16.544	
O_1	12.447	20.417	27.961	20.274	
O_2	16.417	25.387	33.407	25.070	
LSD 0.05	2.626			$LSD_{0.05}$	0.542
Average M	12.789	20.557	28.542		
$LSD_{0.05}$	0.542				

Table 4. Effect of adding levels of palm frond compost and mineral fertilizer on phosphorous availability after harvesting (mg $P.kg^{-1}$ kg soil).

Significant differences were observed in the treatment O_2M_2, which gave the highest available phosphorous in the 33.407 mg $P.kg^{-1}$ soil. The interaction treatment increased by 251.43% compared to treatment O_0M_0, which gave an available phosphorous amount of 9.506 mg $P.kg^{-1}$ soil.

Available Potassium Concentration in soil (mg $K.kg^{-1}$ soil)

Table 5 showed significant differences in the treatment of organic fertilizer (palm fronds) in the available potassium concentration in the soil after harvesting. Accordingly, the treatment of adding organic fertilizer (palm fronds) O_1 and O_2 gave the highest available potassium in the soil, amounting to 227.240 and 241.021 mg $K.kg^{-1}$ soil, with an increase of 5.65% and 12.06%, respectively. In comparison, the treatment O_0, which gave available potassium in the soil, amounted to 215.070 mg $K.kg^{-1}$ soil. As for the effect of mineral fertilization levels on the concentration of available potassium in the soil, Table (5) shows the superiority of treatments M_1 and M_2. These treatments gave the highest available potassium in the soil, amounting to 229.038 and 243.938 mg $K.kg^{-1}$ soil, respectively, with an increase of 8.88 and 15.96%.

In comparison, the control treatment M_0 gave available potassium in the soil, which amounted to 210,354 mg $K.kg^{-1}$ soil. The same Table showed the effect of the bilateral interaction between the level of organic (palm fronds) and mineral fertilization. The treatment O_2M_2 gave the highest available potassium concentration in the soil, which amounted to 257.967 mg $K.kg^{-1}$ soil, with an increase of 29.77% compared to the treatment O_0M_0, which gave the lowest available potassium concentration in the soil, reached 198.783 mg $K.kg^{-1}$ soil.

Organic fertilizer (O)	**Mineral Fertilizer (M)**			**Average (O)**	
	M_0	M_1	M_2		
O_0	198.783	217.955	228.471	215.070	
O_1	210.720	225.624	245.377	227.240	
O_2	221.561	243.536	257.967	241.021	
LSD 0.05	12.076			$LSD_{0.05}$	1.936
Average M	210.354	229.038	243.938		
$LSD_{0.05}$	1.936				

Table 5. Effect of adding levels of palm frond compost and mineral fertilizer on potassium availability after harvesting (mg $K.kg^{-1}$ soil).

Effect of adding palm frond compost and mineral fertilizer on some yield characteristics

Total grain yield ($Mg.ha^{-1}$)

Table (6) shows the significant effect of organic and mineral fertilizers on the grain yield of maize. The effect of adding fertilizer levels of the organic fertilizer O_1 and O_2 was significant, as it gave the highest value of the yield of 7.402 and 8.561 $kg.ha^{-1}$, with an increase of 10.69 and 28.02%, respectively, compared with the comparison treatment O_0, which gave a value of 6.687 $Mg.ha^{-1}$. Moreover, the significant effect of mineral fertilizer with increasing levels of addition on grain yield at levels M_1 and M_2 gave the highest yield value of 7.433 and 8.700 $Mg.ha^{-1}$, with an increase of 14.03 and 33.47%, respectively, compared with the comparison treatment M_0, which amounted to 6.518 $Mg.ha^{-1}$. The bilateral interaction of organic and mineral fertilization had a significant effect in increasing the total grain yield of maize in the interaction treatment O_2M_2, where the highest value reached

10,096 $Mg.ha^{-1}$ with an increase of 74.85% compared to the treatment without the addition of O_0M_0, where its value reached 5.774 $Mg.ha^{-1}$.

Organic fertilizer (O)	Mineral Fertilizer (M)			Average (O)	
	M_0	M_1	M_2		
O_0	5.774	6.687	7.600	6.687	
O_1	6.327	7.477	8.403	7.402	
O_2	7.452	8.134	10.096	8.561	
LSD 0.05	0.829			$LSD_{0.05}$	0.115
Average M	6.518	7.433	8.700		
$LSD_{0.05}$	0.115				

Table 6. Effect of adding levels of palm frond compost and mineral fertilizer on the total grain yield of maize after harvesting ($Mg.ha^{-1}$).

Percentage of protein in grains %

Table 7 showed significant differences between the organic fertilization treatments (palm fronds) and the grain protein percentage after harvesting. The treatment of adding organic fertilizers O_1 and O_2 gave the highest protein percentage of 8.097 and 8.879% with an increase of 9.67 and 16.66 %, respectively, compared with the treatment O_0, which gave a protein content of 7.611%.

Organic fertilizer (O)	Mineral Fertilizer (M)			Average (O)	
	M_0	M_1	M_2		
O_0	7.197	7.447	8.190	7.611	
O_1	7.412	8.262	8.630	8.097	
O_2	8.286	8.915	9.435	8.879	
LSD 0.05	0.290			$LSD_{0.05}$	0.067
Average M	7.632	8.208	8.747		
$LSD_{0.05}$	0.067				

Table 7. Effect of adding levels of palm fronds compost and mineral fertilizer on yield characteristics (protein %).

Similarly, Table (6) showed differences in the treatments M_1 and M_2, as they gave the highest percentage of protein, amounting to 8.208 and 8.747%, respectively. These treatments recorded an increase of 6.65 and 14.60%, respectively, compared with the comparison treatment of M_0, which gave the protein percentage in the grains reached 7.632%. As for the effect of the bilateral interaction between the level of organic and mineral fertilization, significant differences and the highest percentage of protein in grains were found to treat O_2M_2. This percentage amounted to 9.435 %, with an increase of 31.09% compared to the comparison treatment O_0M_0, which amounted to 7.197%.

Discussion

The significant differences between study treatments may be due to the availability of nitrogen due to the bilateral interaction of organic fertilizers (palm fronds) and mineral fertilizers, which led to an increase in nitrogen availability in the soil. The increase is due to adding mineral fertilizers, urea, and potassium sulfate to the soil, in addition to their acidic effect, which led to a decrease in the pH reaction and an increase in the nitrogen availability in the soil, consistent with [3] findings. Besides, the presence of organic matter in the field, as shown in Table (2), led to increased nitrogen availability in the soil.

This effect is due to the availability of phosphorous due to the addition of mineral fertilizers and the decomposition of organic matter by microbial activity, which led to an increase in the availability of phosphorus in the soil. Likewise, adding organic matter to the soil leads to decreased phosphorus adsorption in the soil [19, 18].

The significant differences between the study treatments are due to the availability of potassium due to the addition of mineral and organic fertilizers (palm fronds) and the result of adding potassium sulfate fertilizer, which increased potassium availability in the soil. As well as, adding organic fertilizers to the soil affects the mineral part of the soil, such as dissolving some chemical compounds of nutrients. Then, converting them into a form available for absorption by the plant through the dissolving effect of organic acids increases the activity and effectiveness of microorganisms in the soil, which leads to the release of potassium from its minerals. In addition to the importance of organic fertilizer in improving soil construction and its ability to retain water, as well as increasing the availability of many nutrients necessary for plant growth [6] and among these, encouraging potassium in the exchange sites to participate in equilibrium reactions, which is the essential form of potassium in the soil [2].

Conversely, the yield characteristics differences are attributed to what is related to improving the nutritional status at the root environment through the availability of nutrients and improving soil structure. Besides increasing soil microorganisms, which improves growth characteristics reflected in the yield, these results present a good agreement with ([12, 13]) findings. The increase in grain yield is also attributed to the increase in the concentrations of N, P, and K available in the soil and absorbed into the plant to meet the plant's needs. Along with this, the influential physiological role of the leaves in the metabolism of NPK elements was absorbed through them in the upper parts, which in turn was positively reflected in the construction of a more significant dry matter in these locations, especially in the grain's dry weight. This is agreed with [11, 4]. The absence of significant differences between O_1M_2 and O_2M_1 gave values of 8.403 and 8.134 $Mg.ha^{-1}$, respectively. Thus, it can be concluded that adding organic fertilizer (palm fronds) of 5 $Mg.ha^{-1}$ with the recommendation of 100% of the mineral fertilizer did not show any difference in this characteristic compared to the addition treatment of 10 $Mg.ha^{-1}$ and 50% of the mineral fertilizer. These findings showed the possibility of reducing the use of mineral fertilizers and replacing them with organic fertilizers, consequently reducing environmental pollution and the economic cost[20].

The increase in the percentage of protein in grains is due to the role of added fertilizers in providing most nutrients, especially nitrogen, phosphorous, and potassium, which play a vital role in the synthesis and accumulation of protein in grains. This is reflected positively in the increase in the protein content in the grains, and these results agreed with [9,14]. Table 7 shows no significant difference between the treatment of O_1M_2 and O_1M_2, which gave the protein percentages of 8.630. and 8.915%, respectively. It can be concluded from this that when adding organic fertilizer at a level of 5 $Mg.ha^{-1}$ and 100% mineral fertilizer, no significant differences were observed in the percentage of protein in grains. Thus, this leads to the use of organic fertilizer that is safe and environmentally friendly[21].

Conclusions

The results showed that adding organic fertilizers (palm fronds) with the levels of mineral fertilizers increased the availability of nutrients and the yield of maize. Accordingly, the treatment O2M2 achieved the highest values of nutrient availability, quantity, and quality of yield, reaching (59.167, 33.407, and 257.967) mg.kg-1 soil and (10,096) µg.ha-1 and (9.435%) for each of nitrogen, phosphorous, potassium, yield, and protein percentage, respectively. Moreover, there were no significant differences between the treatments of O1M2 and O2M1 in the amount of yield and the percentage of protein, which gave the values of 8.403 and 8.134 µg.ha-1, respectively, and the protein percentage of 8.630 and 8.915% respectively. It can be concluded that organic fertilizers can be added to compensate for mineral fertilizers, reduce environmental pollution, and reduce the economic cost and soil preservation because organic fertilizers are considered safe and environmentally friendly.

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