



Effect of Organic Manures and Chemical Fertilizers on Soil Properties and Crop Yield in a Wheat–Maize Cropping Sequence

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted at Sids Agricultural Research Station, ARC, Beni Suef Governorate, Egypt (29° 24' N latitude, 31° 04' E longitude and 30.4 m above mean sea level), during two winter seasons (wheat, 2021/2022 and 2022/2023) and two summer seasons (maize, 2022 and 2023) to evaluate the effect of organic manures, FYM or compost or its residual effect in combined with N, P and K fertilizers on soil properties and wheat or maize as second crop productivity. The experiment consist of fifteen treatments for wheat viz., T1= absolute control, T2= 50 % RRF, T3= 100 % RRF, T4= 28 t ha⁻¹ FYM, T5= 28 t ha⁻¹ FYM+50 % RRF, T6= 28 t ha⁻¹

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FYM+100 % RRF, T7= 56 t ha⁻¹ FYM, T8= 56 t ha⁻¹ FYM+50 % RRF, T9= 56 t ha⁻¹ FYM+100 % RRF, T10= 17 t ha⁻¹ compost, T11= 17 t ha⁻¹ compost+50 % RRF, T12= 17 t ha⁻¹ compost+100 % RRF, T13= 34 t ha⁻¹ compost, T14=34 t ha⁻¹ compost+50 % RRF and T15=34 t ha⁻¹ compost+100 % RRF. However, the maize as second crop after wheat not supplied with organic manure, only received inorganic fertilizers as wheat. According to the results, 56 t ha⁻¹ FYM or 34 t ha⁻¹ compost or its residual effect in combined with 100% RRF is the best treatments for improving soil properties (pH, EC and organic matter) and fertility (available N, P and K) as well as wheat and maize yields and its components and nutrient status (N, P and K concentration and uptake). 34 t ha⁻¹ compost gave wheat or maize yield somewhat nearly to 100% RRF, consequently the possibility to save about 50% of the inorganic fertilizers by using high level of compost. In general, compost surpassed FYM in its effect.

Keywords: *FYM; compost; wheat; maize; yield; nutrient status.*

1. INTRODUCTION

Wheat-maize cropping system is one of the most agricultural management systems in Egypt, which consider the first among the other systems. Panwar et al., (2019) cleared that both wheat and maize are heavy nutrients demand. The use of high yielding and nutrient responsive varieties of wheat or maize, beside faulty agricultural practice by farmers led to over exploitation of natural resources like soil fertility, causing adverse impact on soil health and crop production (Susmit et al., 2024).

Inorganic fertilizers have the advanced of rapidly source of soil fertilizer due to it contain rapidly soluble nutrients for plants. Therefore, farmers have placed a strong emphasis for using inorganic fertilizer forms to maximizing their crop production. Chemical fertilizers being water-soluble in case of most essential nutrients needed for plant growth. Han et al., (2016) mentioned that chemical fertilizers enhanced crop productivity due to its quick and efficient action as well as it requires in small amounts.

Organic manure are natural materials prepared from animal or/and plant sources like green manure, crop residues, livestock, compost, households and others. These materials serve as valuable reservoirs of water and nutrients in soil. Also, organic manures have a positive effect on soil properties, in turn promote the microorganisms activity and plant growth (Titirmare et al., 2024).

The use of chemical or organic fertilizers alone as both advanced and disadvantaged effects on plant growth and soil properties. The use of organic manures alone as nutrient sources are indigenous for increasing plant growth beside improving the soil properties. However, the use

of chemical fertilizers in combination with organic ones improved both crop production and soil health (Sharma et al., 2020). Consequently, a well-balanced approach for contributing use of inorganic and organic fertilizers will be used for highly effective strategy for both crop production and soil properties and its fertility (Hati et al., 2014).

Therefore, concerning the damage of both soil health and crop productivity owing to prolonged excessive use of inorganic fertilizers in wheat-maize system, the present research was performed to investigate the beneficial effects of the use of chemical fertilizers and organic manure alone or in combination on the productivity and soil properties in the wheat-maize system.

2. MATERIALS AND METHODS

The present study was administrated at Sids Agricultural Research Station, ARC, Beni Suef Governorate, Egypt (29° 24' N latitude, 31° 04' E longitude and 30.4 m above mean sea level), during two winter seasons (wheat, 2021/2022 and 2022/2023) and two summer seasons (maize, 2022 and 2023) to evaluate the impact of using inorganic, organic fertilizers and their combination on productivity of the two crops and the physicochemical characteristics in the post-harvest soil for wheat and maize. The experimental site was prepared and divided into 52 plots (3.5x3=10.5 m² = 1/950 ha) where it prepared manually for wheat and the followed maize treatments on the same plots, Complete randomized blocks in four replications for the two studied crops were used. The treatments for wheat : T1= absolute control, T2= 50 % RRF, T3= 100 % RRF, T4= 28 t ha⁻¹ FYM, T5= 28 t ha⁻¹ FYM+50 % RRF, T6= 28 t ha⁻¹ FYM+100 % RRF, T7= 56 t ha⁻¹ FYM, T8= 56 t ha⁻¹

FYM+50 % RRF, T9= 56 t ha⁻¹ FYM+100 % RRF, T10= 17 t ha⁻¹ compost, T11= 17 t ha⁻¹ compost+50 % RRF, T12= 17 t ha⁻¹ compost+100 % RRF, T13= 34 t ha⁻¹ compost, T14=34 t ha⁻¹ compost+50 % RRF and T15=34 t ha⁻¹ compost+100 % RRF,. The recommended rate of NPK fertilizers for wheat and maize were 200/54/57 and 286/71/114 kg N/ P₂O₅/ K₂O/ ha, respectively. Whereas, the treatments of maize did not supply with organic manures, but only received inorganic fertilizers as wheat.

Wheat (*Triticum aestivum* L, Sids 12) was sown on 17th and 15th November in both seasons, respectively, while maize (*Zea mays* L, Single cross 10) as second crop was planted in the same previous wheat plots (five ridges, 3.5 m long, 60 cm apart and 25 cm spaced between hills, prepared manually) on 15th and 19th May for the two seasons, respectively. Phosphorus was added as mono-calcium phosphate (15.5 % P₂O₅) before planting, during land preparation. Nitrogen and potassium were added as ammonium nitrate (33.5 % N) and potassium sulphate (48 % K₂O), respectively in two equal doses, the first after one month from sowing and

the second after one month later. Organic manures, whether farmyard manure or compost (prepared from maize straw) were, added before planting, during land preparation. All recommended agriculture practices for wheat or maize were done as in district.

2.1 Soil Analysis

Surface soil sample was taken before wheat planting to determine some soil characteristics before beginning of the experiment and listed in Table 1.

Also, soil samples were taken from each experimental plots after wheat and maize harvest to determine some soil physical properties such as pH, EC and soil organic matter as well as some soil chemical properties, i.e., soil available N, P and K (according to A.O.A.C, 2012).

Organic manure analysis: chemical composition of FYM or compost were determined in 1:10 water: manure extraction according to A.O.A.C, (2012) and listed in Table 2.

Table 1. Some soil properties before the start of the experiment

Soil properties	First season	Second season
Physical properties:		
Particle size distribution		
Clay %	51.16	53.37
Silt %	30.37	28.14
Sand %	18.47	18.49
Texture grade	Clay	Clay
Chemical properties:		
pH (1:2.5 soil-water suspension)	8.2	8.1
EC, dSm ⁻¹ (soil paste)	1.37	1.30
Organic matter (%)	2.01	1.87
CaCO ₃ (%)	1.95	1.79
Available N (Ugg ⁻¹)	27.8	25.8
Available P (Ugg ⁻¹)	12.3	11.0
Available K (Ugg ⁻¹)	189.5	196.5

Table 2. Some chemical composition of FYM and compost

Chemical composition	FYM		Compost	
	First season	Second season	First season	Second season
pH (1:10 water: manure extraction)	7.51	7.83	7.11	7.25
EC, dSm ⁻¹ (1:10 water: compost extraction)	6.19	6.03	5.96	6.10
Organic matter (%)	23.11	22.53	19.24	18.61
Organic carbon	13.40	13.07	11.16	10.79
C/N ratio	1:17	1:19	1:11	1:10
Total N (%)	0.72	0.69	1.03	1.12
Total P (%)	0.29	0.27	0.65	0.61
Total K (%)	0.50	0.53	1.19	1.20

At harvest grain and straw yields of each plot for wheat and maize were measured and converted to ton per hektar. Also, samples from grain and straw for each crop were taken to determine N, P and K concentration and converted to uptake (according to A.O.A.C, 2012).

The data were statistically analysis according to Snedecor and Cochran (1980). The difference between treatments were done using the least significant differences (L.S.D at 5%).

3. RESULTS

3.1 Soil Properties after Harvest

The statistical analysis carried out on some soil properties, i.e., pH, EC, O.M and soil available N, P and K after wheat plant harvested (Fig. 1) show that these soil characteristics were improved due to organic manures application in both seasons when compared with its initial values before beginning of the experiment, except soil salinity which increased by organic manures addition. It is notably that compost surpassed FYM on its effect on improving soil properties. Also, it can be notice that the positive effect of the two organic sources increase as its level increased. On the other hand, inorganic fertilizers were positively increased soil available N, P and K, while soil reaction, salinity and soil organic matter did not affect.

Concerning the response of soil properties after maize harvested to the residual effect of organic manure and inorganic fertilizers, the data in Fig. 2 clearly reveal that the studied soil properties were significantly improved due to the residual effect of organic manures addition before wheat. The improvement in soil properties after maize harvested caused by the residual effect of

organic manure had similar trends as the effect of manures after wheat, but in lower degree. It is obvious to notice that compost surpassed FYM in its residual effect on soil properties. Furthermore, increasing manure levels resulted in higher residual effect on soil properties. In addition, soil pH, EC and organic matter did not affect by inorganic fertilizers, while soil available N, P and K were positively affected by inorganic fertilizers.

3.2 Yield and Yield Components

The yield components of wheat (number of spikes/m², number of grains/spike and 1000-grain weight) and yield parameters (grain, straw and biological yields) were positively affected by organic manures or inorganic fertilizers, individually or in combination (Table 3). In absence of inorganic fertilizers, addition of 28 or 56 t ha⁻¹ FYM as well as 17 or 34 t ha⁻¹ compost increased grain yield by about 93.0, 126.6, 124.6, and 161.8 % when compared with absolute control in the first season, respectively. Similar trends were obtained in the second season and other parameters. Also, these parameters were positively responded to inorganic fertilization. Without organic manures added full recommended N, P and K fertilizers rate increased wheat grain yield by about 170.1 and 156.5 % over absolute control in both seasons respectively. Similar trends were obtained for straw and biological yields. Noteworthy that compost have most pronounced effect on wheat yields and its components than FYM. Also, increasing organic or inorganic fertilizers levels were increased yields and its components of wheat plant. In general, the highest yields and its components were obtained under organic manures when combined with 100 % RRF.

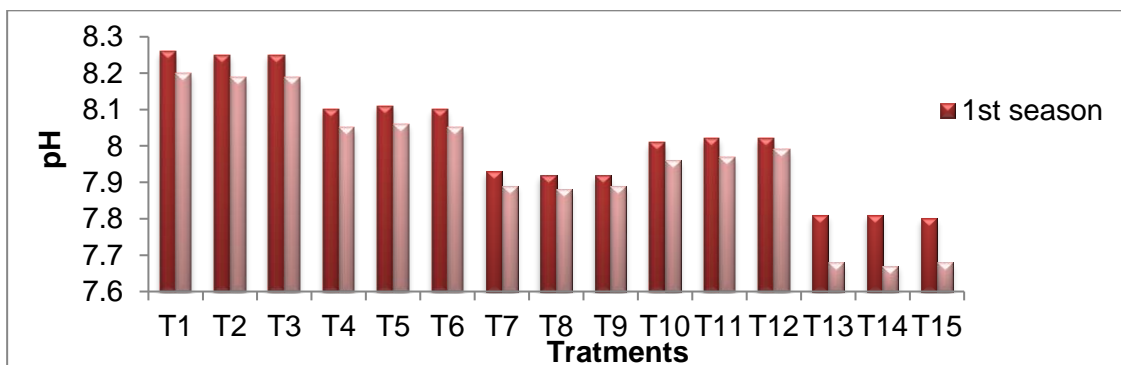


Fig. (1a)

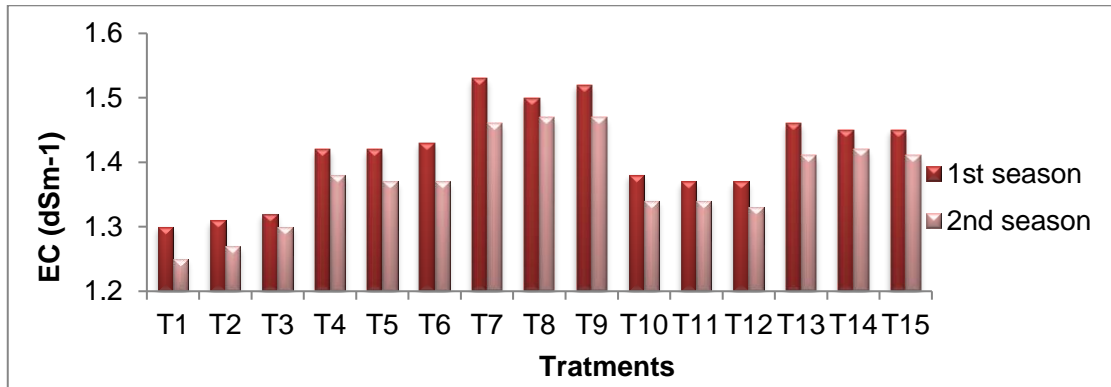


Fig. (1b)

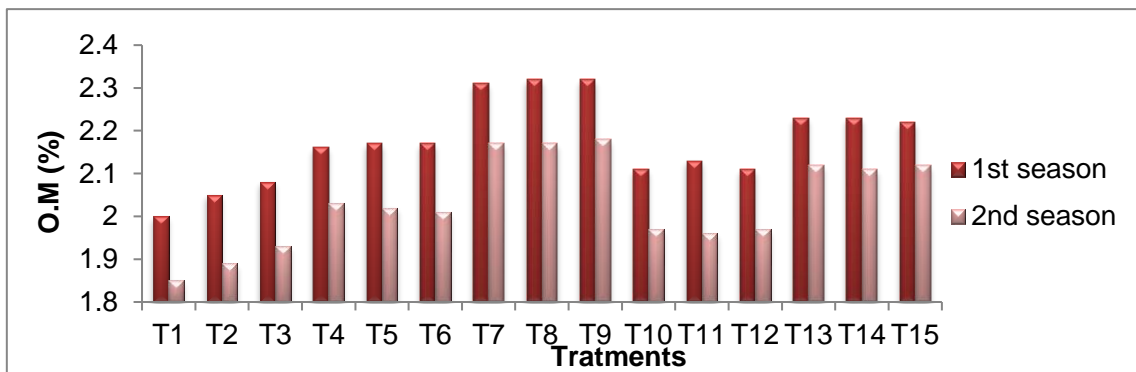


Fig. (1c)

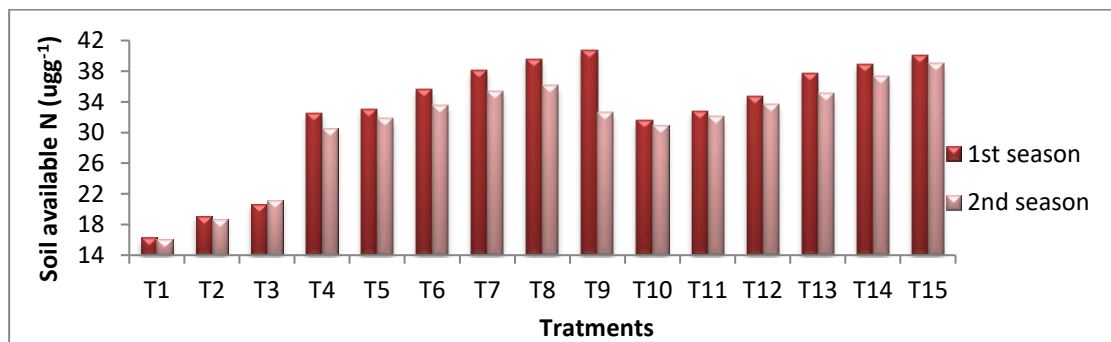


Fig. (1d)

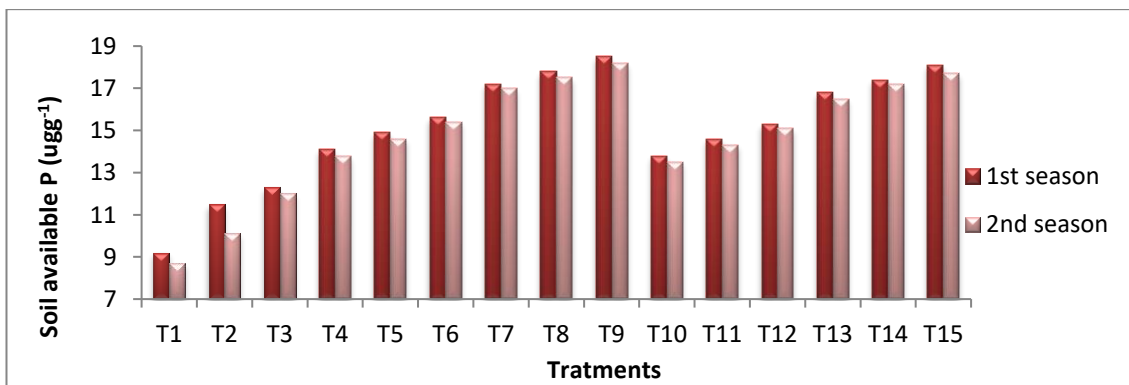


Fig. (1e)

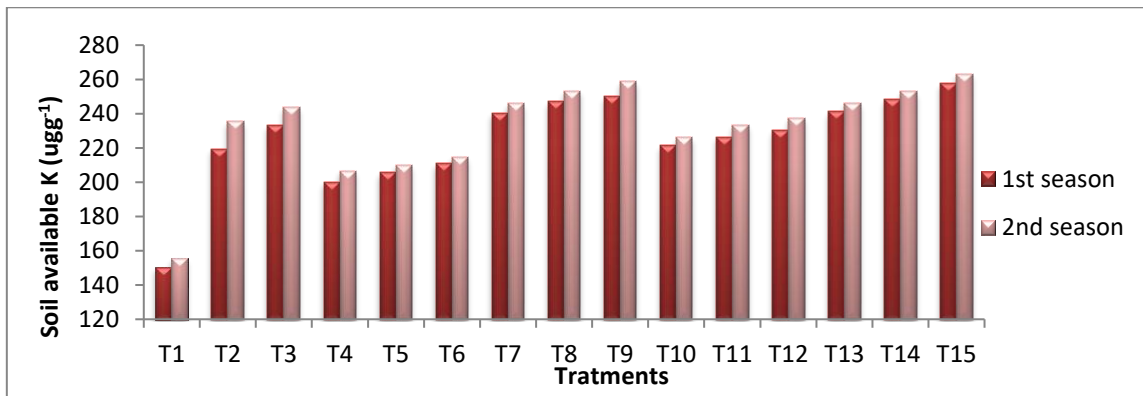


Fig. (1f)

Figs. 1 (a, b, c, d, e and f). Effects of the residual effect of organic manures and inorganic fertilizers on some soil properties after wheat harvest

The data in Table 4 show that the abovementioned parameters for maize were significantly affected by inorganic fertilizers alone or in presence of the residual effect of two studied organic manures. In absence of the residual effect of organic manures, the relative increasing in number of rows/ears, number of grains/rows, 100-grain weight, grain yield, straw yield and biological yield due to added 100% RRF reached to 62.0, 57.6, 128.5, 129.9, 421.0, 189.4 and 310.5 % over the absolute control, respectively in the first season. similar trends were obtained in the second season. Put the residual effect of organic manure in consideration, the results clearly show that the residual effect of the initial application of compost or FYM had a synergistic effect on the positive effect of inorganic fertilizers on these parameters. Number of rows/ear (14.9), number of grains/ear (34.7), 100-grain weight (33.1 g), grain yield (6.88 t ha⁻¹), straw yield (3.54 t ha⁻¹) and biological yield (10.42 t ha⁻¹) were significantly higher in the treatment of 100 RRF under the residual effect of applied 34 t ha⁻¹ compost before wheat planting. The results of the residual effect of FYM in combination with inorganic fertilizers were found to be at par with the residual effect of compost when mixture with inorganic fertilizer but at somewhat lower degree.

3.3 Nutrient Status

The data of the wheat N, P and K concentration in grains and straw as well as N, P and K uptake in grains and /or straw as affected by organic and inorganic fertilizers are presented in Tables 5, 7 and 8. Regard less the residual effects of manure, the results reveal that the plants grown with 100 % recommended rate accumulated

significantly higher N, P and K than 50 % RRF and absolute control. The relative increasing of total N, P and K uptake due to 100 % RRF were 244.68, 229.61 and 212.01 over no inorganic fertilizers application, respectively in the first season. Same trends were obtained in the second season also, significantly higher N, P and K concentration and uptake was observed due to organic manures application whether FYM or compost. Increasing manures level led to increase of nutrient accumulation in grains and straw. It is worthy to notice that compost surpassed FYM in its effect on nutrient accumulation in wheat plants. Moreover, combined organic manure with inorganic fertilizers encouraged the plants to adsorb nutrients from the soil. The highest values of N, P and K were obtained under fertilized wheat plants with 34 t ha⁻¹ compost plus 100 % RRF in both seasons. On the other hand, absolute control exhibited the lowest nutrient content values.

The effect of the inorganic fertilizers and / or the residual effect of the applied FYM or compost before wheat sowing on maize nutrient concentration and uptake of maize are shown in Table 6, 9 and 10. In absence of the residual effect of manures, the data indicate that added inorganic fertilizers alone positively affected maize nutrient content and uptake in grain and straw. Fertilized maize plants with 100 % RRF increased total N, P and K by about 426.64, 616.58, and 910.98 when compared with absolute control in the first season, respectively. Similar trends were obtained in the second season. Also, the residual effect of organic manures has a positive effect on N, P and K concentration and uptake, where

added FYM or compost without inorganic fertilizers positively increased the nutrient status of maize when compared with the absolute control. The relative increasing in total N, P and K due to the residual effect of added the highest level of FYM or compost over absolute control were 217.35, 287.44, and 532.21; and 253.15, 368.84, and 604.47 respectively in the first season. The corresponding increasing in the second season were 205.54, 300.54, and 247.07, 397.03 and 604.73 in the abovementioned order. Combined organic manure gave the highest nutrient accumulated in maize plants than organic or inorganic application alone. The highest values of N, P and K concentration and uptake in grains or straw were achieved under the treatment of 34 t ha⁻¹ compost + 100 % RRF, while the plants without organic or inorganic fertilized possessed the lowest values.

4. DISCUSSION

4.1 Soil Properties

Undoubtedly, use of inorganic fertilizers under intensive cultivation enhanced crop production, unfortunately it disturbed the agro-ecosystems and polluted water quality and soil to great extent. Therefore, to enhance crop production without or minimum damaging the nature, it must be using better management practices in which judicious use of inorganic fertilizers in combined with some organic manures. In this study individual and integrative effect of chemical N, P and K fertilizers and FYM or compost manures on wheat production and post-harvest soil properties. Also, this study concerned to evaluate the residual effect of the two manures added before wheat planting on soil after harvest the successive maize crop.

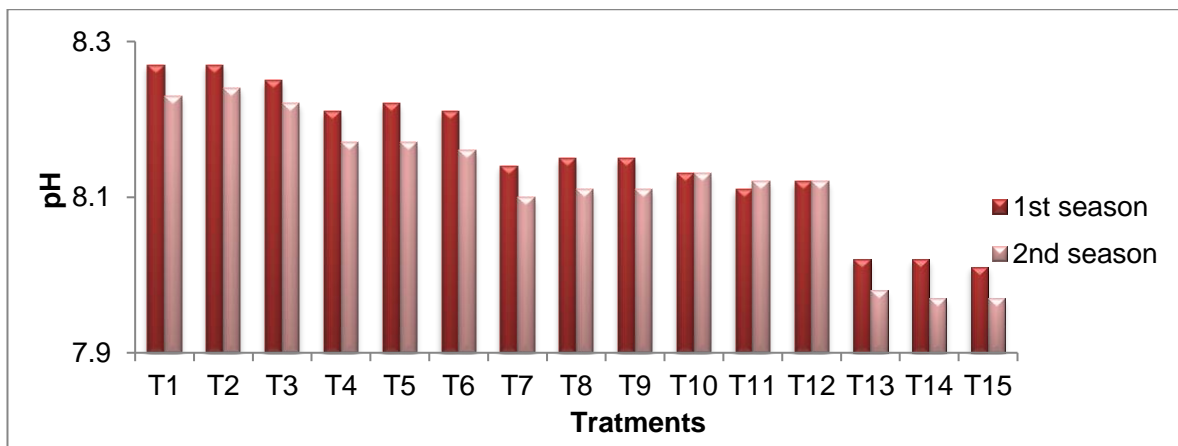


Fig. (2a)

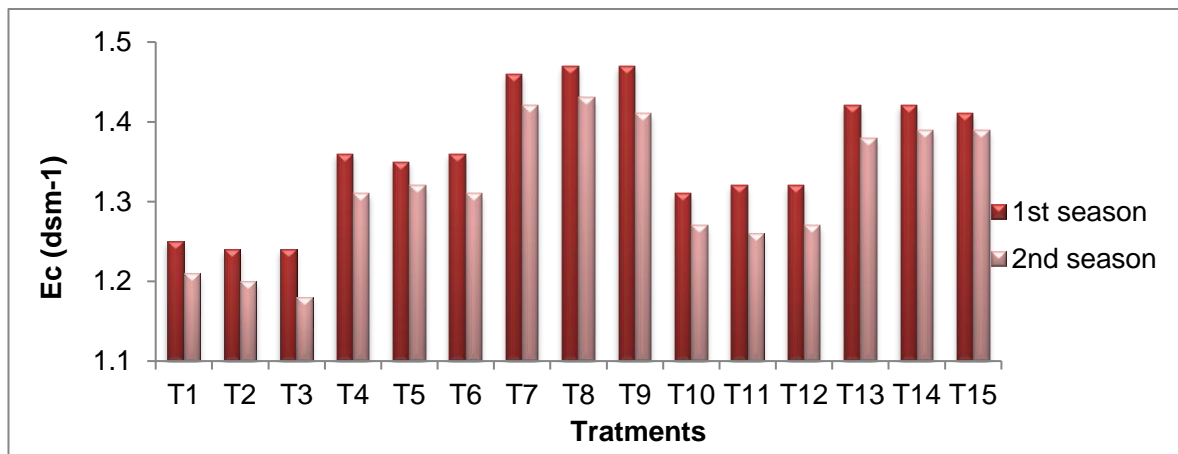


Fig. (2b)

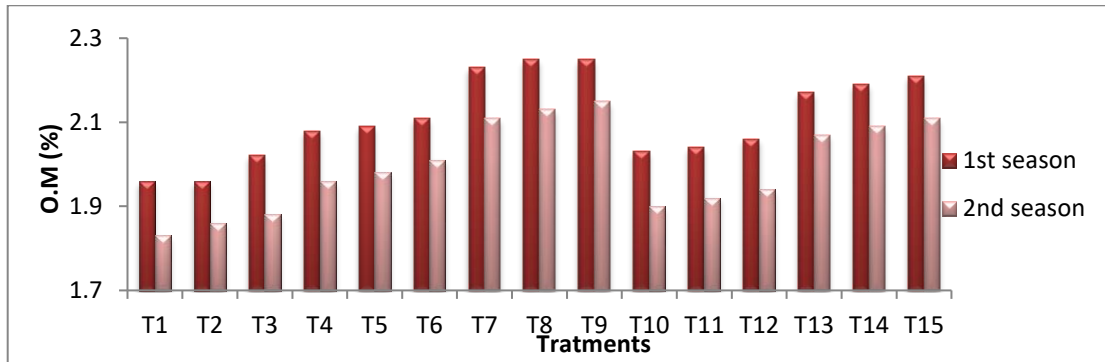


Fig. (2c)

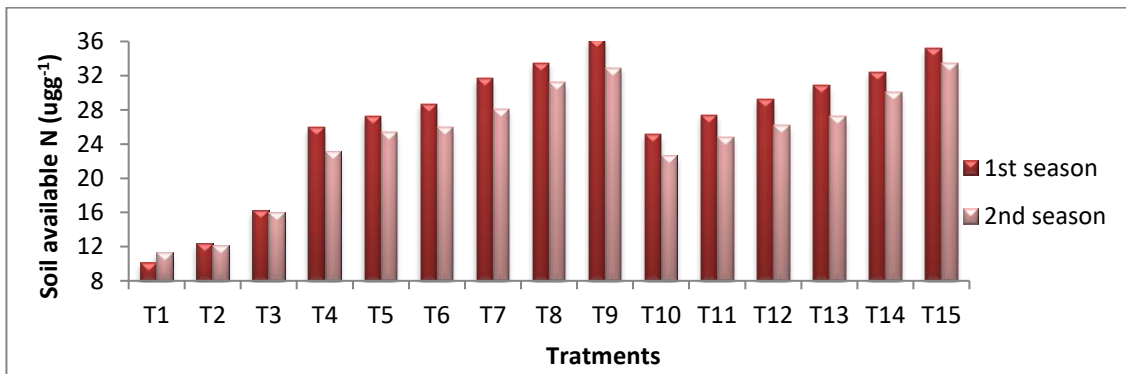


Fig. (2d)

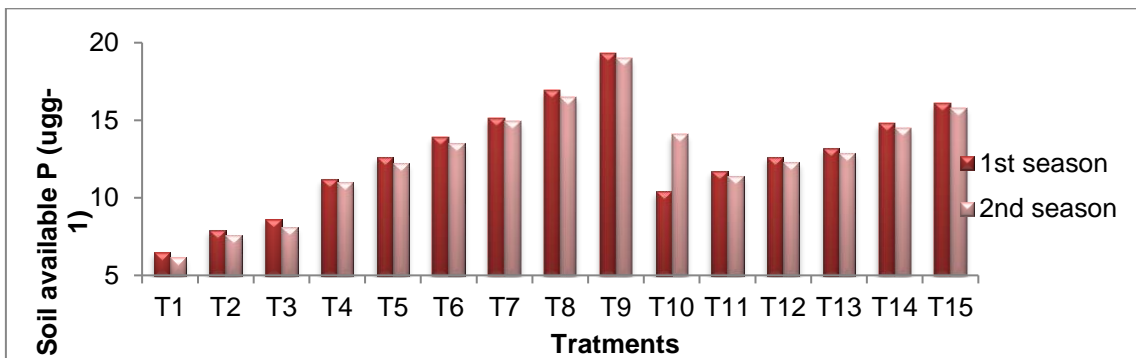


Fig. (2e)

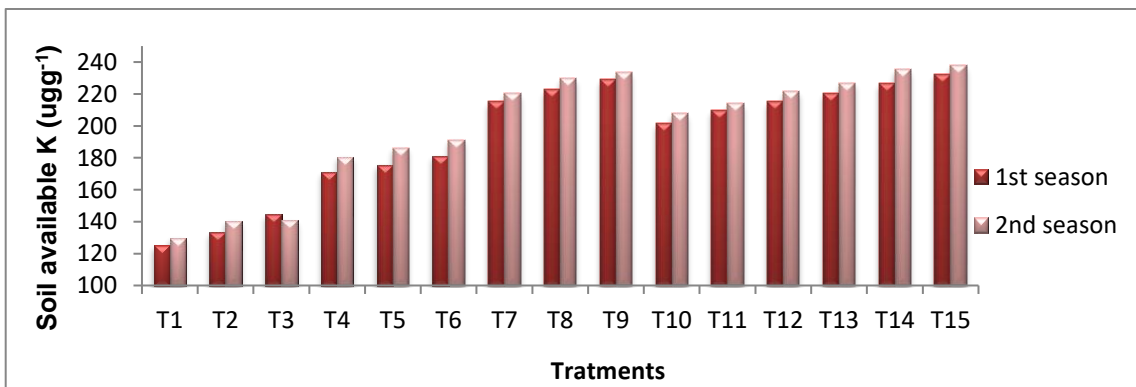


Fig. (2f)

Figs. 2 (a, b, c, d, e and f). Effects of the residual effect of organic manures and inorganic fertilizers on some soil properties after maize harvest

Table 3. Effects of organic and inorganic fertilizers on yield and yield components of wheat

Treatments	Number of spikes/m ²		Number of grains/spikes		1000 grain weight (g)		Grain yield (t/ha ⁻¹)		Straw yield (t/ha ⁻¹)		Biological yield (t/ha ⁻¹)	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
T1	210.8	221.7	39.1	39.4	35.1	36.8	3.01	3.22	2.15	2.24	5.16	5.46
T2	334.1	345.6	46.2	46.3	40.7	40.9	5.93	6.11	3.52	3.66	9.45	10.07
T3	378.2	392.1	48.2	48.6	42.4	42.7	8.13	8.26	3.93	3.97	11.63	11.83
T4	330.7	342.7	45.6	45.8	40.5	40.7	5.81	6.15	3.30	3.41	9.11	9.56
T5	366.9	375.9	47.4	47.9	42.1	42.4	7.30	7.71	3.73	3.79	11.03	11.5
T6	389.5	396.1	49.1	49.3	43.8	44.0	8.35	8.69	3.95	4.03	12.3	12.72
T7	343.2	352.8	47.0	47.4	42.6	42.9	6.82	6.92	3.75	3.81	10.57	10.73
T8	370.9	381.1	49.5	49.7	43.7	43.9	8.01	8.23	3.91	3.98	11.92	12.21
T9	392.5	406.6	51.7	52.9	44.2	44.5	8.89	8.92	4.26	4.31	13.15	13.23
T10	346.4	351.7	47.8	47.9	41.6	41.9	6.76	6.85	3.44	3.56	10.2	10.41
T11	373.5	382.4	48.9	49.1	42.9	43.1	7.81	7.92	3.93	3.99	11.74	11.91
T12	392.1	399.1	49.5	49.7	44.3	44.5	8.55	8.62	4.16	4.23	12.71	12.85
T13	366.1	382.3	51.7	51.9	44.0	44.5	7.88	7.92	3.62	3.71	12.3	12.39
T14	392.5	406.7	52.1	52.6	44.3	44.7	8.25	8.29	3.99	4.02	13.65	13.77
T15	410.5	413.3	53.6	53.5	44.6	45.0	9.01	9.25	4.36	4.42	14.63	14.88
L.S.D at 0.05	6.1	6.7	0.91	0.93	0.80	0.82	0.44	0.46	0.25	0.27	0.62	0.71

Table 4. Effects of the residual effect of organic manures and inorganic fertilizers on yield and yield components of maize

Treatments	Number of rows/ears		Number of grains/rows		100-grain weight (g)		Grain yield (t/ha ⁻¹)		Stover yield (t/ha ⁻¹)		Biological yield (t/ha ⁻¹)	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
T1	9.2	9.3	15.1	15.2	14.7	14.9	1.24	1.36	1.13	1.16	2.37	2.97
T2	14.2	14.3	30.5	33.8	34.2	32.0	6.12	6.44	3.91	4.08	10.03	10.52
T3	14.5	14.6	34.5	34.6	33.8	33.9	6.46	6.78	3.27	3.31	10.90	11.11
T4	13.6	13.7	21.2	21.7	23.6	23.8	2.52	2.76	2.51	2.56	5.03	5.32
T5	14.2	14.2	30.6	30.9	31.5	31.7	5.32	5.52	3.17	3.21	8.49	8.73
T6	14.5	14.6	33.7	33.9	34.1	32.1	6.08	6.40	3.19	3.20	9.27	9.60
T7	14.1	14.2	23.6	23.8	27.1	27.3	3.60	3.84	2.67	2.69	6.27	6.53
T8	14.7	14.8	34.2	34.7	32.5	32.8	6.48	6.76	3.24	3.30	9.72	10.06

Treatments	Number of rows/ears		Number of grains/rows		100-grain weight (g)		Grain yield (t/ha ⁻¹)		Stover yield (t/ha ⁻¹)		Biological yield (t/ha ⁻¹)	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
T9	14.7	14.8	34.2	34.7	32.6	32.8	6.52	6.80	3.26	3.31	9.78	10.19
T10	13.7	13.7	21.9	22.2	24.1	24.2	2.88	3.04	2.63	2.68	5.51	5.72
T11	14.4	14.5	31.2	31.5	33.2	31.9	5.84	6.04	3.22	3.25	9.06	9.29
T12	14.7	14.7	33.9	33.9	34.7	34.3	6.84	7.16	3.25	3.26	10.09	10.42
T13	14.3	14.5	24.5	24.7	28.5	27.5	4.08	4.36	2.73	2.81	6.81	7.17
T14	14.6	14.6	34.6	34.7	33.8	33.9	6.52	6.83	3.28	3.39	10.36	10.44
T15	14.9	14.9	34.7	34.9	33.1	33.3	6.88	6.92	3.32	3.41	10.42	10.52
L.S.D at 0.05	0.22	0.25	0.36	0.38	1.11	1.12	1.03	1.12	0.51	0.56	1.23	1.42

Table 5. Effects of organic and inorganic fertilizers on N, P and K concentrations (%) in grains and straw of wheat

Treatments	Grains						Straw					
	Concentration %						Concentration %					
	N		P		K		N		P		K	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	
T1	1.01	1.07	0.17	0.17	0.26	0.29	0.92	0.93	0.12	0.11	1.03	1.07
T2	1.12	1.27	0.21	0.20	0.43	0.44	0.93	0.95	0.14	0.12	1.34	1.42
T3	1.18	1.31	0.23	0.24	0.44	0.47	1.96	1.98	0.17	0.15	1.47	1.53
T4	1.22	1.32	0.33	0.33	0.51	0.53	1.05	1.09	0.20	0.19	1.81	1.92
T5	1.26	1.36	0.38	0.37	0.60	0.63	1.14	1.16	0.28	0.28	2.11	2.13
T6	1.32	1.39	0.41	0.40	0.67	0.69	1.23	1.27	0.35	0.33	2.25	2.31
T7	1.30	1.35	0.35	0.35	0.57	0.60	1.25	1.29	0.25	0.24	2.01	2.15
T8	1.37	1.40	0.41	0.42	0.67	0.69	1.29	1.32	0.32	0.31	2.31	2.42
T9	1.42	1.45	0.42	0.43	0.73	0.75	1.33	1.35	0.35	0.34	2.64	2.71
T10	1.25	1.30	0.36	0.35	0.57	0.59	1.10	1.17	0.25	0.23	1.90	2.02
T11	1.29	1.33	0.40	0.39	0.64	0.67	1.16	1.20	0.30	0.29	2.27	2.31
T12	1.36	1.39	0.43	0.44	0.71	0.74	1.28	1.31	0.37	0.36	2.30	2.40
T13	1.33	1.37	0.37	0.36	0.62	0.65	1.31	1.35	0.39	0.38	2.12	2.19
T14	1.39	1.42	0.43	0.42	0.72	0.74	1.32	1.37	0.34	0.34	2.39	2.49
T15	1.45	1.47	0.45	0.44	0.75	0.77	1.35	1.40	0.38	0.36	2.76	2.80
L.S.D at 0.05	0.02	0.02	0.03	0.02	0.04	0.04	0.03	0.04	0.03	0.02	0.03	0.04

Table 6. Effects of the residual effect of the organic manure and inorganic fertilizers on N, P and K concentrations (%) in grains and stover of maize

Treatments	Grains						Stover					
	Concentration %						Concentration %					
	N		P		K		N		P		K	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	
T1	1.02	1.06	0.13	0.11	0.10	0.12	0.89	0.92	0.21	0.19	0.97	0.99
T2	1.29	1.29	0.29	0.31	1.25	1.27	0.97	0.99	0.22	0.21	1.21	1.24
T3	1.33	1.34	0.32	0.33	1.32	1.33	1.03	1.05	0.24	0.26	1.26	1.28
T4	1.27	1.29	0.25	0.23	1.22	1.26	0.92	0.94	0.18	0.16	1.15	1.19
T5	1.29	1.30	0.28	0.26	1.25	1.28	0.96	0.97	0.22	0.20	1.20	1.25
T6	1.31	1.33	0.32	0.31	1.30	1.34	1.02	1.04	0.28	0.27	1.26	1.30
T7	1.29	1.31	0.28	0.26	1.26	1.29	0.96	0.98	0.20	0.18	1.19	1.23
T8	1.32	1.34	0.31	0.29	1.30	1.32	1.03	1.05	0.25	0.23	1.22	1.29
T9	1.35	1.37	0.34	0.32	1.31	1.33	1.05	1.08	0.30	0.29	1.29	1.33
T10	1.29	1.33	0.27	0.26	1.26	1.29	0.93	0.96	0.19	0.17	1.18	1.24
T11	1.32	1.35	0.30	0.28	1.30	1.32	0.98	1.01	0.24	0.22	1.22	1.28
T12	1.34	1.36	0.35	0.33	1.31	1.34	1.04	1.06	0.29	0.26	1.27	1.31
T13	1.31	1.34	0.31	0.28	1.29	1.32	0.98	1.02	0.22	0.22	1.21	1.24
T14	1.35	1.36	0.36	0.33	1.33	1.36	1.05	1.07	0.27	0.26	1.25	1.28
T15	1.39	1.39	0.39	0.37	1.35	1.36	1.07	1.09	0.31	0.29	1.31	1.34
L.S.D at 0.05	0.02	0.03	0.02	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.03	0.03

Table 7. Effects of organic and inorganic fertilizers on N, P and K uptake (kg ha⁻¹) in grains and straw of wheat

Treatments	Grains						Straw					
	N uptake kg ha ⁻¹		P uptake kg ha ⁻¹		K uptake kg ha ⁻¹		N uptake kg ha ⁻¹		P uptake kg ha ⁻¹		K uptake kg ha ⁻¹	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
T1	30.40	34.45	5.12	5.47	7.83	9.34	19.78	20.83	2.58	2.46	22.15	23.97
T2	66.42	77.60	12.45	12.22	25.50	26.88	32.74	34.77	4.93	4.39	47.17	51.97
T3	95.93	108.21	18.70	19.82	35.77	38.82	77.03	78.61	6.68	5.96	57.77	60.74
T4	70.88	81.18	19.17	20.30	29.63	32.60	34.65	37.17	6.60	6.48	59.73	65.47
T5	91.98	104.86	27.74	28.53	43.80	48.57	42.52	43.96	10.44	10.61	78.70	80.73

Treatments	Grains						Straw					
	N uptake kg ha ⁻¹		P uptake kg ha ⁻¹		K uptake kg ha ⁻¹		N uptake kg ha ⁻¹		P uptake kg ha ⁻¹		K uptake kg ha ⁻¹	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
T6	110.22	120.79	34.24	34.76	55.95	59.96	48.59	51.18	13.83	13.30	88.88	93.09
T7	88.66	93.42	23.87	24.22	38.87	41.52	46.88	49.15	9.38	9.14	75.38	81.92
T8	109.74	115.22	32.84	34.57	53.67	56.79	50.44	52.54	12.51	12.34	90.32	96.32
T9	126.24	129.34	37.34	38.36	64.90	66.90	56.66	58.19	14.91	14.65	112.46	116.80
T10	84.50	89.05	24.34	23.98	38.53	40.42	37.84	41.65	8.60	8.19	65.36	71.91
T11	100.75	105.34	31.24	30.89	49.98	53.06	45.59	47.88	11.79	11.57	89.21	92.17
T12	116.28	119.82	36.77	37.93	60.71	63.79	53.25	55.41	15.39	15.23	95.68	101.52
T13	104.80	108.50	29.16	28.51	48.86	51.48	47.42	50.09	14.12	14.10	76.74	81.25
T14	114.68	117.72	35.48	34.82	59.40	61.35	52.67	55.07	13.57	13.67	95.36	100.10
T15	130.65	135.98	40.55	40.70	67.58	71.23	58.86	61.88	16.57	15.91	120.34	123.76
L.S.D at 0.05	3.33	3.95	1.02	1.12	2.35	2.68	2.15	2.60	1.00	1.03	2.86	2.95

Table 8. Effects of organic and inorganic fertilizers on N, P and K total uptake of wheat

Treatments	Total uptake					
	N (kg ha ⁻¹)		P (kg ha ⁻¹)		K (kg ha ⁻¹)	
	Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd
T1	50.18	55.28	7.70	7.93	29.98	33.31
T2	99.16	112.37	17.38	16.61	72.67	78.85
T3	172.96	186.82	25.38	25.78	93.54	99.56
T4	105.53	118.35	25.77	26.78	89.36	98.07
T5	134.50	148.82	38.18	39.14	122.50	129.30
T6	158.81	171.97	48.07	48.06	144.83	153.05
T7	135.54	142.57	33.25	33.36	114.25	123.44
T8	160.18	167.76	45.35	46.91	143.99	153.11
T9	182.90	187.53	52.25	53.01	177.36	183.70
T10	122.34	130.70	32.94	32.17	103.89	112.33
T11	146.34	153.22	43.03	42.46	139.19	145.23
T12	169.53	175.23	52.16	53.16	156.39	165.31

Treatments	Total uptake					
	N (kg ha ⁻¹)		P (kg ha ⁻¹)		K (kg ha ⁻¹)	
	Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd
T13	152.22	158.59	43.28	42.61	125.60	132.73
T14	167.35	172.79	49.05	48.49	154.76	161.45
T15	189.51	197.86	57.12	56.61	187.92	194.99
L.S.D at 0.05	4.52	5.13	1.89	1.92	3.35	3.76

Table 9. Effects of the residual effect of organic manures and inorganic fertilizers on N, P and K uptake in grains and stover of maize

Treatments	Grains						Stover					
	N uptake kg ha ⁻¹		P uptake kg ha ⁻¹		K uptake kg ha ⁻¹		N uptake kg ha ⁻¹		P uptake kg ha ⁻¹		K uptake kg ha ⁻¹	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
T1	12.65	14.42	1.61	1.50	1.24	1.63	10.06	10.67	2.37	2.20	10.96	11.48
T2	78.95	83.08	17.75	19.96	76.50	81.79	37.93	40.39	8.60	8.57	47.31	50.59
T3	85.92	90.85	20.67	22.37	85.27	90.17	33.68	34.76	7.85	8.61	41.20	42.37
T4	32.00	35.60	6.30	6.35	30.74	34.78	23.09	24.06	4.52	4.10	28.87	30.46
T5	68.63	71.76	14.90	14.35	66.50	70.66	30.43	31.14	6.97	6.42	38.04	40.13
T6	79.65	85.12	19.46	19.84	79.04	85.76	32.54	33.28	8.93	8.64	40.19	41.60
T7	46.44	50.30	10.08	9.98	45.36	49.54	25.63	26.36	5.34	4.84	31.77	33.09
T8	85.54	90.58	20.09	19.60	84.24	89.23	33.37	34.65	8.10	7.59	39.53	42.57
T9	88.02	93.16	22.17	21.76	85.41	90.44	34.23	35.75	9.78	9.60	42.05	44.02
T10	37.15	40.43	7.78	7.90	36.29	39.22	24.46	25.73	5.00	4.56	31.03	33.23
T11	77.09	81.54	17.52	16.91	75.92	79.73	31.56	32.83	7.73	7.15	39.28	41.60
T12	91.66	97.38	23.94	23.63	89.60	95.94	33.80	34.56	9.43	8.48	41.28	42.71
T13	53.45	58.42	12.65	12.21	52.63	57.55	26.75	28.66	6.01	6.18	33.03	34.84
T14	88.02	92.89	23.47	22.54	86.72	92.89	34.44	36.27	8.86	8.81	41.00	43.39
T15	95.63	96.19	26.83	25.60	92.88	94.11	35.52	37.17	10.29	9.89	43.49	45.69
L.S.D at 0.05	3.05	3.23	1.16	1.02	2.13	2.56	2.13	2.35	1.25	1.19	2.25	2.11

Table 10. Effects of the residual effect of organic manures and inorganic fertilizers on N, P and K total uptake of maize

Treatments	Total uptake					
	N kg ha ⁻¹		P kg ha ⁻¹		K kg ha ⁻¹	
	Seasons		Seasons		Seasons	
	1 st	2 nd	1 st	2 nd	1 st	2 nd
T1	22.71	25.09	3.98	3.70	12.20	13.11
T2	116.88	123.47	26.35	28.53	123.81	132.38
T3	119.60	125.61	28.52	30.98	126.47	132.54
T4	55.09	59.66	10.82	10.45	59.61	65.24
T5	99.06	102.90	21.87	20.77	104.54	110.79
T6	112.19	118.40	28.39	28.48	119.23	127.36
T7	72.07	76.66	15.42	14.82	77.13	82.63
T8	118.91	125.23	28.19	27.19	123.77	131.80
T9	122.25	128.91	31.95	31.36	127.46	134.46
T10	61.61	66.16	12.78	12.46	67.32	72.45
T11	108.65	114.37	25.25	24.06	115.20	121.33
T12	125.46	131.94	33.37	32.11	130.88	138.65
T13	80.20	87.08	18.66	18.39	85.66	92.39
T14	122.46	129.16	32.33	31.35	127.72	136.28
T15	131.15	133.36	37.12	35.49	136.37	139.80
L.S.D at 0.05	4.12	4.36	2.03	2.01	3.56	3.69

Soil properties are very important indicators of soil quality and health for ensuring a sustainable agricultural production. The application of inorganic fertilizers did not alter soil reaction and salinity and soil organic matter after wheat or maize harvested. However, added inorganic N, P and K fertilizers increased soil available N, P and K in soil after wheat and maize. In this concern, Patel et al., (2023) mention that soil available N where increased after wheat harvest due to added high level of nitrogen fertilizer as urea. Although, Hessen et al., (2004) reported that added N fertilizer accelerate the decomposition of soil organic matter and microbial activity, hence stimulate the processes of organic carbon mineralization, consequently released nutrients. Bindraban et al., (2020) pointed out that added P and K fertilizers able to increase the effective P and K content in soil, which may be due to P and K fertilizers promoted P and K rich microbial activity in soil. Liu et al., (2024) mentioned that increasing in P and K in soil may be attributed to P and K fertilizers contain high levels of available P and K and application of high level of them led to increasing P and K availability which reduces the soil ability to fixed more. Similar results were obtained by Brunetto et al., (2015), Liu et al., (2021) and Li et al., (2022). The study also shows that application of FYM or compost before wheat planting or its residual effect on post-harvest wheat or maize soil were positively improved soil pH, soil organic matter as well as soil available N, P and K, while it increased soil

salinity. The reduction in soil pH after wheat or maize harvest caused by FYM or compost application may be attributed to the release of carbon dioxide and organic acid into the soil resulted from manures decomposition (Meena et al., 2018). Similar finding was obtained by Mahmood et al., (2017) and Susmita et al., (2024). Application of manure enhanced total organic carbon compared to non-organic amended treatments. Leogrande et al., (2024) cleared that the use of organic manure characterized by high contents of organic carbon in soil, hence reducing carbon dioxide emissions into the atmosphere and decrease the negative effect of climate change. These results are in line with those obtained by Galal et al., (2017) and Abou El-Nour and Serry (2018). Furthermore, FYM or compost as well as its residual effect were enhanced the N, P and K availability in soil after harvest wheat or maize. Eyheraguibel et al., (2008) and Hafidi et al., (2012) reported that organic manures contain somewhat high content of nutrients. Abedi et al., (2010) added that humic substances in organic manures improved the N, P and K availability in soil. The substantial increases in available nitrogen may be due to the mineralization of nitrogen from organic manures or its residual in the second crop during its decomposition (Panwar, 2008). The solubilize insoluble organic phosphorus fractions during release organic acids, led to enhanced in phosphorus availability (Ma et al., 2023). The improvement in soil

available potassium may attributes to the decomposition of manures in soil resulted in release of organic colloids, which increase the cation exchange capacity, in turn allowing the soil to kept more available potassium (Pathariya et al., 2022). Combined organic manures with inorganic fertilizers yielded the highest nutrient availability after harvest wheat and maize which mainly due to the mineralization of nutrients from native sources through decomposition along with direct addition the nutrients through FYM or compost to available soil pool beside enhanced microorganisms activity (Panwar, 2008). Similar results were obtained by Hao et al., (2008) and Mahmood et al., (2017). Unfortunately, organic manures and its residual effect increased soil salinity in the post-harvest soil of wheat and maize. This may be due to both FYM and compost used having high salinity values (Table 2). In this connection, Soheil et al., (2012) mentioned that high concentrations of some elements can potentially increase the EC value of soil. These results are in harmony with those obtained by Ahmed, (2009) and Galal et al., (2017) and Oueriemmi et al., (2021).

4.2 Crop Yields

Organic manures application is reported in this study to have beneficial effect on soil properties and fertility resulted to higher crop production. Wheat and maize grain and /or straw yields were significantly affected by both in current and residual effects of FYM or compost and its combination with inorganic N, P and K fertilizers. Regardless organic manure, the highest grain and /or straw yields of wheat or maize were recorded under 100 % RRF when compared with no inorganic fertilization and 50 % RRF. Scholl and Nieuwenhuis, (2004) and Patel et al., (2023) stated that inorganic fertilizers have an advantage of rapidly restoring soil fertility, which they contain become ready soluble to plant adsorption. Han et al., (2016) indicated that the efficient action and quick of the inorganic fertilizers may be due to their high nutrient content, which only small quantities is required to improve plant productivity. These results are in according the results of Ahmed et al., (2024) and Titirmare et al., (2024).

The results pointed out that organic manure alone or in combined with inorganic fertilizers improved the yield attributes of wheat, i.e., number of spikes/m², number of grains/spike and 1000-grain weight, also, the residual effect of manure enhanced maize yield attributes, i.e., number of rows/ear, number of grain/row and

100-grain weight; consequently, increases grain yield and /or straw yields. The promotive effect of manures on wheat or maize productivity is mainly due to its positive effect on soil properties and fertility (Singh et al., 2019). In addition, Hafidi et al., (2012) indicated that organic manure supplied a steady source of nutrients to the plants, thus increased its productivity.

It is obvious to notice that the wheat productivity under high meme rate when combined with 50 % RRF is nearly equal to those under 100 % RRF. The enhancement in wheat or maize productivity as affected by combined inorganic fertilizers with organic manures or with its residual effect may be due to inorganic fertilizers provides the plant with readily available nutrients and the improvement in nutrients availability and controlled nutrients release from organic manures (Seran et al., 2010 and Suge et al., 2011). Therefore, combined inorganic fertilizers with organic manure improved fertilizers use efficiency, thus reduce the amount of fertilizers required (Bayu et al., 2006 and Tilahun-Tadesse et al., 2013). It is worthy to notice that the effect of compost on wheat and maize productivity surpassed the effect of FYM. These results agree with those obtained by Abd-Eladl et al., (2010), Demelash et al., (2014) and Leogrande et al., (2024). The superiority of compost than FYM on its effect on soil properties and wheat and maize productivity may be attributed to the composed used has more narrow C/N ratio tan FYM (Table 2). Consequently, release much nutrients than FYM.

4.3 Nutrient Status

The experimental results cleared that there was variation among organic manure or its residual effects alone or in combined with inorganic N, P and K treatments in term of N. P and K concentration and uptake in wheat grain and straw as well as in maize grain and stover. Inorganic fertilizers application alone accumulates more N, P and K in the reproductive organs for wheat or maize than control. The positive effect of RRF on nutrient concentration may be due to the inorganic fertilizers provides the plant with soluble nutrients, which improved root growth, consequently increased nutrients adsorption (Meena et al., 2018). The effect of RRF on nutrient status is proportionally its effect on grain and straw or stover yields, since the uptake calculated by multiplying. The results are similar to those obtained by Ismail et al., (2014), Galal et al., (2017) and Patel et al., (2023). On other hands, FYM or compost alone imprived N,

P and K concentration and uptake of wheat or maize. The promotive effect of manures on nutrient status may be due to microbial activity is higher in soil treated with manures which help to releases N, P and K to soil, hence improved its adsorption (Zaidi et al., 2003). The highest values of N, P and K accumulation were obtained under combined organic manure with inorganic fertilizers, which might be due to the soluble nutrients in inorganic fertilizers encourage the biological activity, which help to manures decomposition (Prajapati et al., 2022). These results are in agreement with those obtained by Abd-Eladl et al., (2010) and Titirmare et al., (2024) who stated that combined organic manure or its residual effect with inorganic fertilizers gave highest nutrient content in grains and straw or stover of wheat and maize crops.

5. CONCLUSION

On basis of the field study on wheat-maize rotation performed for two years, it can be concluded that application of 56 t ha⁻¹ FYM or 34 t ha⁻¹ compost in combination with 100% inorganic N, P and K fertilizers improved post-harvest soil properties, i.e., soil reaction and salinity, soil organic matter and soil available N, P and K after as well as wheat productivity (grain and straw yields) and N, P and K uptake. Also, the residual effect of former treatment was found to be improved soil properties and yield productivity for the succeeding maize crop. Application of 34 t ha⁻¹ compost + 50 %RRF exhibited wheat or maize productivity statistically equal to those under 100% RRF, which means the possibility of save about 50% of chemical fertilizers, hence reduce the production cost and minimums the environmental pollution. In general, compost surpassed FYM on its effect on wheat and maize production and soil improvement.

THE IMPORTANCE OF THIS MANUSCRIPT

- 1- Maximizing wheat and maize productivity
- 2- Minimizing the use of the chemical fertilizers
- 3- Improving soil healthy
- 4- Minimizing the environmental pollution by reducing the use of chemical fertilizers
- 5- Reducing the production coast due to the high price of chemical fertilizers

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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