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Agricultural practices for maize crop water production under pivot irrigation in Toshka, Egypt

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Abstract

A field experiment was conducted at Toshka area in Aswan government, South Egypt to study the effect of tillage and gypsum practices on maize production for two seasons 2020 and 2021. The treatments were deep tillage without gypsum (DT), deep tillage with gypsum (DT+G), surface tillage without gypsum (ST) and surface tillage with gypsum (ST+G). The yield parameters were determined as well as maize water relations. The tillage treatments affect maize yield and its components. The highest maize straw or grain production was realized at surface tillage with gypsum application for both seasons, followed by deep tillage without gypsum, then deep tillage with gypsum, and lasted by surface tillage without gypsum. The highest value of grain yield (5.43ton ha^{-1}) was recorded at ST+G treatment in the 1st season. The lowest value of grain yield (4.19ton ha^{-1}) was recorded at ST treatment in the 1stseason. The water consumptive use (CU) of maize was decreased by agricultural practices (deep tillage and gypsum application) during both growing seasons. The highest value of crop water productivity, CWP, (0.93 kg/ m^3 water) was recorded at deep tillage with gypsum applied (DT+G) in the 1st season. The lowest value of CWP (0.69 kg / m^3 water) was recorded at surface tillage without gypsum application (ST) in the 1st season. The positive effect of tillage treatments and gypsum application on soil moisture constants (SP, FC, WP, and AW) could be arranged in the descending order of DT+G > ST+G >DT >ST. It could be concluded that tillage practices and gypsum application enhanced soil properties whether physical or chemical and increased soil fertility as well as realized high maize production with minimum irrigation water application. It was noticed that the best treatment was deep tillage with gypsum application.

Keywords: maize, tillage, gypsum, consumptive use, yield components, pivot irrigation.

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1. Introduction

Toshka area lies in the southeastern of the Western Desert, Egypt, covering an area of 15,000 km^2. It is located at the west of the High Dam Lake (HDL), between latitudes 22°30'N and 23°30'N and longitudes 31°0'E and 32°0'E. Toshka area is limited from the east by the shoreline of the HDL. The Toshka area has been subjected to alternative arid and wet periods that left their effect on the present land features. The Toshka project aims to achieve self-sufficiency in food, especially grain crops. According to a documentary aired during the inauguration, the project can decrease Egypt's imports of wheat to only a quarter of total consumption (Alfaran, 2013). Center-pivot irrigation is a method of crop irrigation in which equipment rotates around a pivot and crops are watered with sprinklers. Most center pivots were initially water-powered, however today most are propelled by electric motors. Center-pivot irrigation systems are beneficial due to their ability to efficiently use water and optimize a farm's yield. The systems are highly effective on large land fields. Center-pivot irrigation uses less labor than many other surface irrigation methods, such as furrow irrigation. It also has lower labor costs than ground-irrigation techniques that require digging of channels. Also, center-pivot irrigation can reduce the amount of soil tillage. Therefore, it helps reduce water runoff and soil erosion that can occur with ground irrigation. Less tillage also encourages more organic materials and crop residue to decompose back into the soil. It also reduces soil compaction (Cooley *et al*., 2021). The newly reclaimed and cultivated lands constitute an important part of Egypt's plan for horizontal expansion. Large areas of these lands can be cultivated by maize so reduce the imported quantities that are used as fodder. Maize is considered one of the main grain crops in Egypt due to its importance for human, animal and poultry nutrition. It is used in the manufacture of dry fodder at rates up to 70% and in the bread industry by 20%. It is also involved in some industries such as the extraction of glucose, fructose and oil. There is a great effort to promote this important crop under the conditions of the new lands following the most appropriate agricultural management to overcome the encountered problems such as very low organic matter content, nutrients and moisture retained (Field Crops Research Institute, Maize Research Program, 2006). Dağdelen *et al*. (2006) found that water deficit significantly affected cotton and corn yields. The average water uses efficiency (WUE) ranged from 1.65 to 2.15 kg/m^3 water for corn, while for cotton its average ranged from 2.30 to 3.52 kg/m^3 water. Adeyemo and Agele (2010) found that tillage combined manure application produced higher values of soil organic matter, total nitrogen and available phosphorus over tillage alone. Khan *et al*. (2010) found that tillage methods significantly improved soil physical properties since saturated hydraulic conductivity was increased with deep tillage method and the opposite trend was found for soil bulk density. Caires et al. (2011) found that adding gypsum at rate of 9 ton/ha significantly increased corn grain yield by 8%. Khaledian *et al.* (2011) showed that direct seeding into mulch

(DSM) could mitigate N losses and improve water productivity (WP) for corn and sorghum. Also, they showed that WP increase from 77 kg/m^3 water with convention tillage (CT) to 102 kg/m^3 water with DSM. DSM can improve WP and save a water application depth of 40 mm compared to CT, which is interesting in a context with water scarcity. Aikins and Afuakwa (2012) revealed a significant effected on soil penetration resistance, dry bulk density, moisture content, and total porosity by tillage treatments. Miriti *et al*. (2012) showed that tied-ridge tillage had the greatest plant available and water content while subsoiling-ripping tillage had the least for all seasons. Kamel *et al*. (2016) demonstrated that adding compost or gypsum to the soils improved soil-water retention and hydraulic conductivity. Generally, the residual soil organic matter increased but the soil bulk density decreased in such soils. Also, Luan *et al*. (2018) calculated the average total water footprints of wheat, corn and sunflower which they were 1.036, 0.774 and 1.510 kg/ m^3 water, respectively. This study aims to assess the effect of tillage treatments and gypsum application on maize yield and its components. Also to find maize water productivity under centre pivot irrigation system in Toshka area, Aswan, Egypt.

2. Materials and methods

The experiment site was conducted in non-saline soil in Toshka area, Aswan government, South Egypt (23° 11' 35.03" N - 31° 36' 50.25" E) for two seasons 2020 and 2021. The samples were taken from 0-20 and 20-40 cm soil depths for chemical and physical properties and their relevant analysis are presented in Table (1). The experimental site was divided according to the transactions that were planted. The dimensions of each treatment were 29 m length X 6 meters wide (174 m^2 ≈ one carat per treatment). The treatments were as follows:

- Deep tillage (60 cm soil depth) without gypsum (DT).
- Deep tillage (60 cm soil depth) with gypsum addition (DT + G).
- Surface tillage (15 cm soil depth) without adding gypsum (ST).
- Surface tillage (15 cm soil depth) with gypsum addition (ST + G).

Table (1): The physical and chemical properties of experimental site.

Soil property	Soil depth (cm)		Soil property	Soil depth (cm)	
	0-20	20-40		0-20	20-40
Sand (%)	78.40	73.40	SP	30.00	29.00
Silt (%)	5.00	10.00	FC %	16.00	15.00
Clay (%)	16.6	16.6	WP %	7.00	7.00
Textural Class	Sandy loam	Sandy loam	Bulk density (Mg m^{-3})	1.41	1.40
pH (1:2.5)	8.36	8.37	EC_e (dS m^{-1})	0.73	0.57
$CaCO_3$ (%)	5.39	5.33	CEC (meq./100g)	12.01	18.64
OM (g kg^{-1})	3.10	2.40	Available N (ppm)	70.00	85.00
Available P (ppm)	9.88	7.65	Available K (ppm)	386.00	253.00

pH = soil reaction, OM = organic matter, P = phosphorus, SP = saturation percent, FC = field capacity, WP = wilting point, EC = electrical conductivity, CEC = cation exchange capacity, N = nitrogen, K = potassium.

Maize seeds (Triple Hybrid variety 168) were planted on 20th and 25th of July 2020 and 2021, respectively by seeded on lines; the distance between plants was 18 cm and 75 cm among the lines consuming 9 kg/feddan (feddan = 4200 m² = 0.420 hectares = 1.037 acres). All irrigation and agricultural practices were done according to the farm work set by agriculture ministry and the plants were harvested 120 days after planting. After harvest, some traits were recorded as follows:

- Straw and grain yield (kg ha^{-1}).
- Plant height (cm).
- Seed index (g).
- NPK in straw and grain.

Also, after harvest, soil samples from two depths (0-20 and 20-40 cm) were taken from each treatment with three replicates. The soil sodicity and salinity (pH and EC), Available N, P and K, bulk density and saturation percent were determined. The evapotranspiration (ET_o) values for both growing seasons were calculated by using the data from weather station established at Nubaria Research Station (Table 2), using CROPWAT model (Smith, 1991) based on FAO, Penman-Monteith method.

Table (2): Some meteorological data and the evapotranspiration (ETo) of experimental site.

Property	Month	T. min (ºC)	T. max (ºC)	RH (%)	WS (m/h)	ETo (mm)
Year 2020	July	26.25	40.93	19.07	3.83	10.88
	August	26.86	41.31	20.78	4.03	10.90
	September	26.14	42.17	19.02	3.61	10.20
	October	22.95	38.11	22.83	3.98	9.20
	November	13.82	27.32	39.18	2.80	5.00
Year 2021	July	27.64	41.98	19.07	3.70	11.02
	August	27.18	42.18	20.78	3.86	10.85
	September	24.49	39.51	19.02	3.57	9.76
	October	21.20	36.58	22.83	3.48	8.17
	November	16.79	31.40	39.18	3.33	6.00

T. min = minimum temperature, T. Max = maximum temperature, RH = relative humidity, WS = wind speed.

Some soil physical and chemical properties were determined according to the standard methods described by Page et al. (1982) and Klut (1986). The crop evapotranspiration (ETc) values were calculated according to following equation:

$$ETc = ET_o \times K_c$$

Where: ET_c= Crop evapotranspiration (mm day^{-1}). ET_o = reference evapotranspiration (mm day^{-1}). K_c = Crop coefficient. Irrigation water productivity (IWP) and water Productivity (WP) were calculated according to Ali *et al*. (2007) using the following equations:

$$IWP = GY / IW$$

$$WP = GY / CU$$

Where: IWP= productivity of irrigation water (kg/ m^3 water). GY = grain yield, IW= Applied irrigation water (m^3/ ha). WP= water productivity (kg/ m^3 water), CU= Water consumptive use (m^3ha^{-1}).

Plant samples were taken and washed with deionized water, oven dried at 70°C, mill ground and kept for chemical analysis. Dried grounded plant material of 0.2 g was digested using 10 mL of a mixture of 7:3 ratios of sulfuric to perchloric acids (Jackson, 1973). Total nitrogen was measured in the digested sample by distilled with 20 ml of 40% sodium hydroxide using a micro Kjeldahl's distilling unit (Jackson, 1973). Total phosphorus was measured in the extract by using the chloro stannous ammonium molybdate method while K was measured in the extract by using flame photometer (Burt, 2004). Two-way analysis of variance (ANOVA) and Duncan's multiple range test was used to determine the statistical significance of the difference between the treatments' effects on soil properties and yield data using COSTAT software, and $p<0.05$ was considered statistically significant. All the results are shown as mean values (n = 3) ± standard deviation (SD).

3. Results and Discussion

3.1 Agricultural practices and maize water relationships

The effect of tillage practices and gypsum application on water consumptive use (CU), applied irrigation water (AIW), crop water productivity (CWP) and irrigation water productivity (IWP) through both growing seasons are shown in Table (3). The amounts of applied irrigation water were 8370 and 8333 m^3 ha^{-1} in the 1st and 2nd seasons, respectively. The water consumptive use (CU) of maize was decreased by agricultural practices (deep tillage and gypsum application) during both growing seasons. The highest value of CU (6069.81 m^3 ha^{-1}) was recorded at surface tillage without gypsum application (ST) in the 2nd season. The lowest value of CU (5780.43 m^3 ha^{-1}) was recorded at deep tillage with gypsum application (DT+G) in the 1st season (Table 3). The IWP was significantly increased due to tillage and gypsum practices. The highest value of IWP (0.65 kg m^{-3} water) was recorded at surface tillage with gypsum application (ST+G) in the 1st season. The lowest value of IWP (0.50 kg m^{-3} water) was recorded at surface tillage without gypsum application (ST) in the 1st season (Table 3). The CWP was significantly increased due to the tillage and gypsum application through both growing seasons. The highest value of CWP (0.93 kg m^{-3} water) was recorded at deep tillage with gypsum applied (DT+G) in the 1st season. The lowest value of CWP (0.69 kg m^{-3} water) was recorded at surface tillage without gypsum application (ST) in the 1st season (Table 3). These results were combatable with those found by Payero *et al*. (2008) who evaluated the effect of different seasonal irrigation depths on corn evapotranspiration, yield, water use efficiency, and dry matter production in the semiarid climate. They found a reduction in seasonal Etc value for all treatments that averaged 630 mm and ranged from 580 to 663 mm. Also, Dağdelen *et al*. (2006) studied the effect of water deficit on crop yield, water use efficiencies, dry matter content and leaf area index of cotton and corn crops. They found that water deficit significantly affected both crop yields. The average water uses efficiency ranged from 1.65 to 2.15 kg m^{-3} water for corn, while the average irrigation water use efficiency was between 2.30 and 3.52 kg m^{-3} water for corn. Also, Miriti *et al*. (2012) showed that tied-ridge tillage had the greatest plant available water content while sub-soiling ripping tillage had the least in all seasons.

Table (3): Effect of tillage practices and gypsum application on maize water relationships.

Treatments	Applied irrigation water (m^3 ha^{-1})		Water compositive use (m^3 ha^{-1})		Irrigation water productivity (Kg/ m^3)		Crop water productivity (Kg/ m^3)	
	2020	2021	2020	2021	2020	2021	2020	2021
ST	8370.00	8333.00	6055.74	6069.81	0.50^{b}	0.52^{b}	0.69^{c}	0.72^{c}
DT	8370.00	8333.00	5912.05	5934.40	0.53^{b}	0.55^{b}	0.75^{b}	0.78^{b}
ST+G	8370.00	8333.00	5884.36	5905.64	0.65^{a}	0.64^{a}	0.92^{a}	0.90^{a}
DT+G	8370.00	8333.00	5780.43	5801.71	0.64^{a}	0.64^{a}	0.93^{a}	0.92^{a}
LSD 0.05					0.07	0.05	0.07	0.06

S = surface, D = deep, T = tillage, G = gypsum.

3.2 Effect of agricultural practices on soil moisture constants

Soil water is very essential for the proper plant growth and development. Soil moisture constants are necessary to determine the moisture that is present in the soil under any certain condition and at any instant of time. Soil water moves mainly through three types as saturated, unsaturated and water vapour movement. Infiltration and other modes of water entry into the soil contribute to the formation of water reservoir in soil (Chauvin *et al*., 2011). During both growing seasons, tillage treatments and gypsum application pronounced increases in soil saturation percentage (SP) The SP of the studied soil ranged from 33.1 to 36.7% in the surface layer and from 31.2 to 35.5% in the subsurface layer observed decreasing values with soil depth (Table 4). The positive effect of tillage treatments and gypsum application on SP values could be arranged in the descending order of DT+G > ST+G > DT > ST. Also, the agricultural practices realized increases in soil field capacity (FC). The FC values of the studied soil ranged from 17.50 to 18.85% in the surface layer and from 16.55 to 17.75% in the subsurface layer which their values decreased with soil depth (Table 4). Also, the agricultural practices realized increases in soil wilting point (WP). The WP values of the studied soil ranged from 8.05 to 9.20% in the surface layer and from 7.30 to 8.25% in the subsurface layer showing the same trend of SP and FC values (Table 4). Consequently, the agricultural practices realized increases in available water (AW) of the soil (Table 4). The AW of the studied soil ranged from 9.45 to 9.75% in the surface layer and from 9.25 to 8.50% in the subsurface layer which their values decreased with soil depth (Table 4). The positive effect of tillage treatments and gypsum application on soil moisture constants (SP, FC, WP and AW) could be arranged in the descending order of DT+G > ST+G >DT >ST. These results agreed with those obtained by Agbede (2006) and Adeyemo and Agele (2010) who found that soil tillage increased soil moisture contents. Habashy and Ewees (2011) found that adding gypsum and organo-mineral fertilizer (OMF) to a saline soil encouraged the creation of medium and micro-pores among simple packing sand particles and in turn increasing the capillary potential. They attributed this result to an increase in soil moisture content at field capacity and then the available water content due to the increase in the total fibres (32.3–33.1%) and water holding capacity (WHC) of OMF (6.18–6.32g water/g OMF). The effects of OMF components on improving soil properties such as aggregation, aeration, permeability, and WHC were positively, which led to maintain the appropriate water content in the soil and hence increasing the activity of the immune plant system. These results agreed with those obtained by Kamel *et al*. (2016) who demonstrated that the application of compost or gypsum improved soil-water retention and, at the same time, improved soil hydraulic conductivity.

Table (4): Effect of agricultural practices on soil moisture constants during both growing seasons.

Treatment	Soil depth (cm)	Saturation percent (%)		Field capacity (%)		Wilting point (%)		Available water (%)	
		2020	2021	2020	2021	2020	2021	2020	2021
ST	0-30	33.00	33.20	17.40	17.60	8.00	8.10	9.40	9.50
	30-60	31.30	31.10	16.50	16.60	7.40	7.20	9.10	9.40
DT	0-30	34.00	33.60	17.70	17.90	8.10	8.30	9.60	9.60
	30-60	32.80	31.90	16.80	16.90	7.60	7.50	9.20	9.40
ST+G	0-30	36.60	35.30	18.30	18.70	8.90	8.60	9.40	10.10
	30-60	33.30	33.50	17.50	17.50	8.10	8.00	9.40	9.50
DT+G	0-30	37.00	36.30	18.90	18.80	9.10	9.30	9.80	9.50
	30-60	35.40	35.60	17.70	17.80	8.20	8.30	9.50	9.50
LSD 0.05	0-30	1.64	2.03	0.80	1.50	0.34	0.51	0.70	1.00
	30-60	1.24	1.04	1.10	1.00	0.41	0.26	0.80	0.70

S = surface, D = deep, T = tillage, G = gypsum.

3.3 Effect of agricultural practices on available nitrogen, phosphorus and potassiumin

During both growing seasons, tillage treatments and gypsum application increases nitrogen (N), phosphorus (P) and potassium (K) availability is shown in Table (5). Tillage treatments and gypsum application pronounced increases in available nitrogen (N) for both growing seasons. The available N of the studied soil ranged from 58.91 to 62.72 mg kg^{-1} in the surface layer and from 55.17 to 58.77 mg kg^{-1} in the subsurface layer which they are decreased with soil depth. The positive effect of tillage treatments and gypsum application on available N could be arranged in the descending order of ST+G > ST > DT+G > DT. Tillage treatments and gypsum application pronounced increases in available phosphorus (P) in both growing seasons. The available P of the studied soil ranged from 12.34 to 13.36 mg kg^{-1} in the surface layer and from 10.90 to 11.47mg kg^{-1} in the subsurface layer which they are decreased with soil depth. The positive effect of tillage treatments and gypsum application on available P could be arranged in the descending order of ST+G > DT+G > DT > ST. Tillage treatments and gypsum application pronounced increases in available potassium (K) in both growth seasons. The available K of the studied soil ranged from 215.00 to 245.50 mg kg^{-1} in the surface layer and from 207.09 to 237.35mg kg^{-1} in the subsurface layer which they are decreased with soil depth. The positive effect of tillage treatments and gypsum application on available K could be arranged in the descending order of ST+G > DT > ST > RDT+G. These results were in harmony with those obtained by El-Rashidi *et al*. (2010) who found that adding gypsum increased the solubility of N, K, Ca, Mg, Mn, Cl and S whereas it decreased the solubility of P, Na, Fe, Cu, Zn and B. They conclude that understanding the effects of gypsum on both the nutrient solubility and absorption by plants would improve land management practices and help in increasing soil productivity.

Table (5): Effect of agricultural practices on available nutrients.

Treatment	Spil depth (cm)	Available N (mg kg^{-1})		Available P (mg kg^{-1})		Available K (mg kg^{-1})	
		2020	2021	2020	2021	2020	2021
ST	0-30	61.00	60.23	12.40	12.27	232.70	235.71
	30-60	57.31	55.74	10.93	10.87	207.30	206.87
DT	0-30	59.32	58.50	12.74	12.13	230.86	229.72
	30-60	55.75	54.58	11.00	11.13	231.45	232.00
ST+G	0-30	62.31	63.12	13.12	13.60	245.70	245.30
	30-60	58.32	59.21	11.40	11.53	237.00	237.70
DT+G	0-30	60.23	60.31	12.73	12.60	214.65	215.34
	30-60	56.72	56.56	11.53	11.33	212.00	211.30
LSD 0.05	0-30	2.59	1.37	0.87	1.22	10.68	6.85
	30-60	1.91	1.81	0.65	0.82	9.96	6.95

S = surface, D = deep, T = tillage, G = gypsum.

Adeyemo and Agele (2010) found that soil tillage influenced the N, P and K availability. Although the soil exhibited adequate physical characteristics (Bertollo, 2014), chisel plowing may have favored water infiltration through the soil profile (Camara and Klein, 2005) and the vertical displacement of S-SO_4 from gypsum dissolution, thus increasing nutrient availability and their absorption by corn (Maschieto, 2009).

3.4 Agricultural practices and maize traits and its yield

Maize traits and its yield as affected by tillage and gypsum in summer season of 2020 and 2021 are presented in Table (6). Maize traits and its yield were significantly increased due to tillage and gypsum application. The greatest value of plant height (266.7 cm) was recorded at surface tillage with adding gypsum (ST+G) in the 2nd season. The lowest value of plant height (226.7 cm) was recorded at surface tillage without gypsum application (ST) in the 2nd season (Table 6). The highest value of seed index (37.82 g) was recorded at deep tillage with adding gypsum (DT+G) in the 2nd season. The lowest value of seed index (30.49 g) was recorded at ST treatment in the 2nd season (Table 6). The highest value of straw yield (15.17 ton ha^{-1}) was recorded at ST+G treatment in the 2nd season. The lowest value of straw yield (10.89 ton ha^{-1}) was recorded at ST treatment in the 2nd season (table 6). The highest value of grain yield (5.43ton ha^{-1}) was recorded at ST+G treatment in the 1st season. The lowest value of grain yield (4.19 ton ha^{-1}) was recorded at ST treatment in the 1stseason (Table 6). These results were agreed with those obtained by Caires *et al.* (2011) who found that adding 9 ton ha^{-1} gypsum resulted a significantly increased in corn grain yield by 8%. Also, Quincke et al. (2007) reported that ploughing ones can be done without yield loss, but the evidence of increased yield in the short term due to change of surface soil properties is weak. Soil tillage practices increased maize growth and its yield (Adeyemo and Agele, 2010).

Table (6): Effect of tillage and gypsum application on maize yield and its components during both growing seasons.

Treatments	Plant height (cm)		Weight of 100 seeds (g)		Straw yield (ton ha^{-1})		Grain yield (ton ha^{-1})	
	2020	2021	2020	2021	2020	2021	2020	2021
ST	236.3^{d}	226.7^{d}	30.80^{d}	30.49^{d}	11.58^{c}	10.89^{c}	4.19^{c}	4.34^{a}
DT	243.3^{c}	246.7^{c}	34.64^{c}	35.20^{c}	14.30^{b}	14.64^{b}	4.46^{b}	4.61^{b}
ST+G	263.3^{a}	266.7^{a}	36.95^{b}	36.43^{b}	14.70^{a}	15.17^{a}	5.43^{a}	5.33^{a}
DT+G	262.7^{b}	264.6^{b}	37.72^{a}	37.82^{a}	14.62^{ab}	14.86^{ab}	5.35^{a}	5.31^{a}
LSD 0.05	10.62	12.22	3.06	2.85	0.84	0.65	0.28	0.17

S = surface, D = deep, T = tillage, G = gypsum.

3.5 Agricultural practices and nitrogen content on grain and straw yield

Grain and straw nitrogen content as affected by tillage and gypsum in both growing seasons of 2020 and 2021 is presented in Table (7). The deep tillage and gypsum application treatments affected grain nitrogen content through both seasons. The highest value of grain nitrogen (3.17 %) was recorded at deep tillage with adding gypsum (DT+G) in the 2nd season. The lowest value of grain nitrogen (2.55%) was recorded at surface tillage (ST) without gypsum application in the 1st season (Table 7). The highest value of straw nitrogen (1.87%) was recorded with DT+G treatment in the 1st season. The lowest value of straw nitrogen (1.53%) was recorded with ST in the 1st season (Table 7). These results are inconsistence with those obtained by Adeyemo and Agele (2010) who found that soil tillage practices increased grain and straw nitrogen content of maize crop.

Table (7): Effect of tillage practices and gypsum application on nitrogen content of grain and straw yield during both growing seasons.

Treatments	Grain N (%)		Straw N (%)	
	2020	2021	2020	2021
ST	2.55	2.46	1.53	1.48
DT	2.64	2.69	1.61	1.62
ST+G	2.83	2.77	1.67	1.71
DT+G	3.09	3.17	1.87	1.81
LSD 0.05	0.12	0.11	0.08	0.10

S = surface, D = deep, T = tillage, G = gypsum.

It could be concluded that tillage practices and gypsum application enhanced soil properties whether physical or chemical and increased soil fertility as well as realized high maize production with minimum irrigation water application. It was noticed that the best treatment was deep tillage with gypsum application.

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