The Effect of Tillage and Gypsum Application on Hibiscus Production Under Center Pivot System in Toshka Area

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ABSTRACT

A field experiment was conducted in Toshka project located in the south part of Egypt. The study is implemented to evaluate the effect of tillage with or without gypsum application under pivot system on plant growth parameters and water relationship of hibiscus plant. Two successive seasons with the application of four treatments: a surface tillage (ST), deep tillage (DT), surface tillage with gypsum (ST+G), and deep tillage with gypsum application (ST+G) were performed. Measurements of yield components, moisture content constants (Saturation percent (SP), Field Capacity (FC), Wilting Point (WP) and Available Water AW), Consumption Use (CU), Irrigation Water Productivity (IWP), Crop Water Productivity (CWP) and total N, P, K in straw and grain in addition to available N, P, K in soil. The best treatment for plant growth parameters (dry almonds weight, weight of 1000 seeds and plant height) was ST+G treatment followed by DT+G treatment. In contrast the lowest plant growth parameters were surface tillage treatment (ST). Soil moisture constant (SP%, FC%, PW% and AW%) increased under ST+G treatment followed by DT+G treatment. Application of gypsum beside tillage practices increased crop water production and irrigation water productivity. In addition, it improved soil nutrient availability and hence increased total nutrient (N, P and K) in straw and yield contents. It could be concluded that surface tillage practices with addition of gypsum amendment enhance some soil physical, chemical characteristics and nutrient availability. So, it could be recommended to use surface tillage practice beside gypsum amendment for best management in Toshka area to enhance soil properties, water holding capacity and plant productivity.

Keywords: Gypsum, tillage, pivot system, Toshka, hibiscus.

INTRODUCTION

Agriculture sectors in Egypt consume around 80% of available water. Crop water demand is affected by climate conditions as well as others factors related to crop type and its variety. Therefore, crop water demand is highly affected by climatic change (IDSC, 2021). A precise measurement of crop water demand is essential for any water conservation study in crop production.

Water scarcity is a significant problem for semi-arid and arid areas, especially with extreme global climatic changes. Climate change is expected to have a greater impact on agriculture because of changes in precipitation intensity, and higher temperatures. All these parameters will increase the demand of irrigation water (Alotaibi *et al.*, 2023). Use of modern irrigation methods is inevitable for those areas. The application of modern irrigation techniques is to conserve and economize water use efficiency. Pivot irrigation systems are among the most resource saving methods of agricultural irrigation, with up to 98% water use efficiency compared to traditional methods such as surface irrigation. Pivot irrigation is considered the most efficient method of irrigating large areas. It is suitable for most plant varieties such as soybeans, corn, grains, potatoes and vegetables also can be adapted to orchards and vines. Also is widely used for fertigation and chemigation (Valin *et al.*, 2012). It is widely used in irrigation in Toshka, which is a new reclaimed areas located in the southern part of the western desert of Egypt. There is a need to know more about this area, especially physical, chemical and fertility of soil. Also to try to best management of soil, irrigation and crops to achieve highly crop production.

Gypsum (calcium sulphate dihydrate) is one of the most cost-efficient amendments used as a soil amendment to reclaim sodic-soil through removes the Na^+ from the root zone and decreases the pH of soils (Lim *et al.*, 2011 and Murtaza *et al.*, 2013). Application of gypsum to sandy soil to fertilize it by nutrient, restructure soil, enhance water holding capacity, enhance plant growth and increase yield (Abdel-Fattah *et al.*, 2015 and Mitchell *et al.*, 2016). Also, Kamel *et al.* (2016) revealed adding of gypsum improved soil-water retention and hydraulic conductivity.

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Tillage is one of the most basic agriculture practices, it prepares seedbed, decrease soil erosion, improve soil aeration, improve water infiltration that prepare better production condition (Mohammad, 2013). No tillage or less tillage enhances the availability of plant residues to decompose and release nutrients into the soil. Also, it reduces soil compaction (Cooley *et al.*, 2021). Yang *et al.* (2016) showed that minimum-tillage gave higher yields than deep tillage.

Hibiscus *(Sudanese hibiscus)* is annual or perennial herbs planted in tropical and subtropical regions; it is a highly deciduous flowering shrub. It is widely used in traditional medicine (Ling *et al.*, 2009). It is planted in delta and oases of western desert in Egypt. Also, it is widely planted in south of Egypt near Aswan.

The objective of this study was to evaluate the effect of tillage practices with or without gypsum application on some soil physical properties, crop water productivity, yield and yield components for Hibiscus crop irrigated by center pivot irrigation system in Toshka area.

MATERIALS AND METHODS

Soil characteristics and analysis:

The experiment site was conducted in Toshka, Aswan Government, south Egypt (23° 11' 35.03" N - 31° 36' 50.25" E). Soil samples were taken from 0-30 and 30-60 cm soil depths to determine the chemical and physical properties are presented in Table (1). Soil particle size distributions were measured according to Klute and Dirksen (1986). Field capacity (FC) and wilting points (WP) were measured by pressure plate apparatus at 0.1 and 15 bar, respectively according to Israelsen and Hansen (1962). Available water content can be calculated as the difference between FC and WP. Available water content can be calculated as the difference between FC and WP. Total porosity was calculated using bulk and particle density as proposed by the formula of Brady and Weil (1996). Total calcium carbonate was determined by Collin's calcimeter according to Nelson and Sommers (1982). Organic matter content was determined according to Nelson and Sommers (1982). Soil salinity and soluble ions: total soluble salts, soluble ions of saturated soil extract were determined using the standard methods described by Sparks *et al.* (2020). Soil reaction (pH) was measured in (1:2.5) soil-water extract using Beckman pH meter as reported by Page *et al.* (1982). Other physical and chemical properties were determined according to Black (1965). The result of these properties is presented in Table (1).

Field experiments and treatments:

Hibiscus crop (*Sudanese hibiscus)* was planted for two consecutive growing seasons (25 July 2023 and 25 July 2024), by seeder on lines; the distance between plants was 30 cm and 75 cm among the lines. All irrigation and agricultural practices were done according to the farm work set by agriculture ministry and the plants were harvested 140 days after planting. Tillage treatments were used with soil conditioner (agricultural gypsum) (7.5 ton ha^{-1}). The dimensions of each treatment were 29 m length and 6 meters wide. The crop was irrigated using pivot center, and the speed of the pivot and the rate of water entry per hour were recorded by the counters of the pivot irrigation device. The irrigation was applied when the available water depletion (AWD) reached 50% the total available water capacity (AWC). Moisture measurements were taken before and after irrigation for each cycle in all treatments during the season with three replications.

Table 1. The physical and chemical analysis of experimental sites

Soil property	Soil depth (cm)		Soil property	Soil depth (cm)	
	0 - 30	30 - 60		0 – 30	30 - 60
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	EC_e (dS m^{-1})	0.73	0.57
pH (1: 2.5)	8.36	8.37	CEC (meq./ 100g)	12.01	18.64
$CaCO_3$ %	5.39	5.33	Available N (ppm)	34.00	23.00
OM (g kg^{-1})	3.10	2.40	Available K (ppm)	135.00	105.00
Bulk density (g cm^{-3})	1.41	1.40	Available P (ppm)	9.88	7.65

The treatments were as follows:

1-Deep Tillage (60 cm soil depth) without gypsum (DT).

2-Deep Tillage (60 cm soil depth) with gypsum addition (DT+G).

3-Surface Tillage (15 cm soil depth) without adding gypsum (ST).

4-Surface Tillage (15 cm soil depth) with gypsum addition (ST+G).

After harvest, plant parameters which were measured straw and grain yield (kg ha^{-1}), plant height (cm), seed index (g), N in straw and grain. Soil samples were taken in each treatment after harvesting, in three replicates at two depths (0 to 30 cm) and (30 to 60 cm) by using a spiral auger. In the laboratory, the samples were air dried ground and sieved through a 2 mm sieve and prepared for physical and chemical analysis. The collected soil samples were dried and crushed with the help of wooden petal and passed through a 2 mm sieve, then were used for the determination of soil reaction, organic matter, and macronutrients content by the standard laboratory methods.

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. Total nitrogen was measured by Jackson (1973), total phosphorus measured by Olsen *et al.* (1954) and total potassium was measured by Page *et al.* (1982).

The evapotranspiration (ETo) calculation for both growing seasons were calculated by using the data from the weather station established at Toshka, using CROPWAT model (Smith, 1992) based on FAO, Penman- Monteith method. Results are presented in Table (2).

Actual Evapotranspiration (ETa):

Determination of the Actual Evapotranspiration (ETa):

Actual evapotranspiration of Hibiscus crop was estimated by soil sampling method to calculate soil moisture according to the method of Israelsen and Hansen (1962) using the following formula:

$$ETa = CU = (\theta 2 - \theta 1)\ Bd * ERZ$$

Where CU is the amount of consumptive water use (mm),

θ2 is soil moisture percentage after irrigation,

θ1 is soil moisture percentage before the following irrigation, Bd is bulk density (g/cm^3) and

ERZ is the Effective Root Zone (cm).

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

YEAR	Mon	T min	T max	RH %	WS m/hr	ETo mm
2023	Jan	6.52	20.46	44.91	3.27	3.92
	Feb	8.61	23.86	37.32	3.24	4.83
	Mar	13.49	30.74	24.58	3.96	6.86
	Apr	17.26	33.9	20.29	3.4	8.22
	May	22.59	38.82	16.85	4.15	10.64
	Jun	24.98	41.05	15.96	3.76	10.88
	Jul	26.25	40.93	19.07	3.83	10.88
	Aug	26.86	41.31	20.78	4.03	10.90
	Sep	26.14	42.17	19.02	3.61	10.20
	Oct	22.95	38.11	22.83	3.98	9.20
	Nov	13.82	27.32	39.18	2.8	5.00
	Dec	12.05	26.73	36.7	2.96	4.80
2024	Jan	9.55	25.00	44.91	3.21	4.47
	Feb	10.22	25.35	37.32	3.64	5.37
	Mar	13.67	31.15	24.58	3.51	7.23
	Apr	17.93	35.68	20.29	3.70	8.87
	May	23.11	40.08	16.85	3.84	10.49
	Jun	25.64	41.49	15.96	3.07	9.89
	Jul	27.64	41.98	19.07	3.70	11.02
	Aug	27.18	42.18	20.78	3.86	10.85
	Sep	24.49	39.51	19.02	3.57	9.76
	Oct	21.2	36.58	22.83	3.48	8.17
	Nov	16.79	31.4	39.18	3.33	6.00
	Dec	10.18	23.67	36.7	3.52	4.80

T = temperature C° RH = relative humidity WS = wind speed

Irrigation water productivity (IWP):

The Irrigation water use efficiency (IWUE) was calculated according to Du *et al.* (2017) using the following equations: -

$$\text{IWP (kg m}^{-3}\text{) = Y/ I}$$

Where Y is the grain yield (kg ha^{-1}) and I is the irrigation water applied (m^3 ha^{-1}).

Crop water productivity (CWP):

Crop water productivity (CWP) describes the efficiency of the water applied for yield production. It is calculated as described by Zwart and Bastianssen (2004) as follows: -

$$\text{CWP (kg m}^{-3}\text{) = Y/ ETa}$$

Statistical analysis:

Two-way analysis of variance (ANOVA) and Duncan's multiple range test was used to determine the statistical significance of the difference between treatments effects on soil properties and yield data using COSTAT software, and $p < 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Effect of agriculture practices on yield components:

Tillage practice and irrigation method can alter microclimatic which affect wetting of soil and crop characteristics. Factors such as the increase of soil salinity, decrease water availability, increase drought stress and poor soil management will decrease crop development and its production (Roushdi, 2024). Tillage types can change soil structure and water infiltration which affect crop development.

The addition of gypsum to saline-sodic soil to mitigate the negative effect of salinity on soil and crops. It has high calcium content that balanced with the sodium ratio in soil. Also, gypsum amendment improves soil structure by introducing binding between calcium and soil particles, enhance soil aggregates and nutrient availability (Bello *et al.*, 2021).

This research is trying to understand the effect of combining gypsum amendment and tillage practice (surface or deep tillage) on physical, nutrient and crop production. Table (3) presented hibiscus yield components under field treatments. All treatments had almost no significant differences on yield components except treatment ST+G and ST in straw yield and weight of 1000 seeds. The maximum straw yield (21.49 Ton.ha^{-1} in 2nd season), weight pf almonds (1. 155 Ton.ha^{-1} in 1st season), weight of 1000 seeds (33.5g in 2nd season), number of almonds (61.33 in 1st season) and plant height (207 cm in 2nd season) were achieved in ST+G treatment in both seasons but the lowest value is achieved in ST treatment. Our results showed that the addition of gypsum beside tillage practice increased yield component (straw yield, weight of 1000 seeds, weight pf almonds, number of almonds) and plant height. Since the addition of gypsum with tillage can reduce soil compaction, increase water infiltration, and improve soil aeration, that increase nutrient uptake by plant through increase root growth and plant nutrient uptake. As well as gypsum could increase nutrient availability which it is essential in metabolic processes in plant growth. Finally, it is increased yield production (Radwan *et al.*, 2024).

Table 3. Effect of treatments on yield components

Treatments	Straw Yield (ton ha^{-1})		Weight of almonds after air drying (ton ha^{-1})		Weight of 1000 seeds(g)		Number of almonds per plant		plant height(cm)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
ST+G	20.5a	21.49a	1.155a	1.133a	31.37 a	33.5 a	61.33a	58.33a	203a	207a
DT+G	16.98ab	16.86ab	1.326a	1.338a	27.97 a	27.37ab	56.67a	58a	196.5ab	211b
DT	14.56ab	13.96ab	0.956a	0.967a	27.03ab	26.77ab	52a	55.67a	180b	183.33b
ST	9.09a	9.58a	0.899a	0.935a	21.63b	20.53b	51a	44a	159c	162c
mean	15.28	15.5	1.1	1.1	27.0	27.0	55.3	54.0	184.6	190.8
LSD 0.05	10.78	8.00	0.96	0.72	7.65	10.75	35.39	111.60	88.30	102.41

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

Effect of agriculture practice on hibiscus water relationship:

Table (4) revealed that the soil moisture constants (SP%-FC%- PW%- AW%) decrease with increasing soil depth.

It also showed that surface tillage treatment at both depth (30 and 60 cm) with the addition of gypsum had a significant difference for these soil moisture constants. Addition of gypsum with surface tillage increases all water content constants (SP%-FC%- PW%- AW%) in soil in comparison with other treatments (DT+G, ST, and DT) which gave no significant differences between them. The highest values of soil moisture constant were 37%. 19.37%, 10.142% and 9.229% for SP%, FC%, PW% and AW%. Regardless the lowest values were 25.67%. 13.44%, 7.036% and 6.402% (30-60 cm depth) for SP%, FC%, PW% and AW%, respectively. Our finding in this study, addition of gypsum with surface tillage increased all soil moisture constant (Saturation percent (SP), Field Capacity (FC), Wilting Point (WP) and Available Water (AW)) followed by deep tillage with gypsum. This can be attributed that addition of gypsum with surface tillage improves soil porosity which encourage the creation of medium and micropores (Habashy and Ewees, 2011), so it is conserved more water in soil profile. So, tillage practices beside gypsum application will be used as water management practices to conserve more water and increase water holding capacity of soil. Costa *et al.* (2016) found the same results tillage practices beside gypsum application reduced bulk density its due to masking effect of gypsum as soil amendment through increase total porosity and decrease bulk density of soil in both tillage practice surface and deep.

Table (5) revealed the effect of tillage practices with or without gypsum application on water consumptive use (CU), crop water productivity (CWP) and irrigation water productivity (IWP) through two consecutive growing seasons. The amount of irrigation using pivot system were 10234 m^3/ha and 10436 m^3/ha in the 1st season and 2nd season, respectively. The highest value of CU (8130 m^3 ha^{-1}) was recorded in the 2nd season in treatment of ST+G and the lowest value (7078 m^3 ha^{-1}) was recorded in the 1st season in treatment of ST. The highest value of IWP (0.15 Kg/m^3) was recorded in the 1st and 2nd season in treatment of ST+G and the lowest value (0.11 Kg/m^3) was recorded in the 1st and 2nd season in treatment of ST. The highest value of CWP (0.22 Kg/m^3) was recorded in the 1st and 2nd season of ST+G and the lowest value (0.1 Kg/m^3) was recorded in the 1st and 2nd season in treatment of ST. It was noticed that increasing of irrigation water productivity (IWP), crop water productivity (CWP) in surface tillage beside gypsum amendment followed by deep tillage beside gypsum amendment in comparison with tillage practices only. It could be discussed by increasing in water availability in soil using the combination of tillage and gypsum amendment.

Table 4. Effect of treatment on water relations in two tillage depths

Depth 30 cm										
Treatments	SP%		FC%		WP%		AW%		Bulk density (g/cm3)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
ST+G	37a	37a	19.37a	19.37a	10.142 a	10.142 a	9.229a	9.229a	1.36b	1.353b
DT+G	29.5b	29.33b	15.45b	15.36b	8.086b	8.041b	7.359b	7.317b	1.447a	1.463a
DT	29.17b	29b	15.27b	15.18b	7.995b	7.949b	7.275b	7.234b	1.463a	1.457a
ST	28.67b	29b	15.01b	15.18b	7.858b	7.949b	7.151b	7.234b	1.497a	1.503a
mean	31.09	31.1	16.3	16.3	8.5	8.5	7.8	7.8	1.4	1.4
LSD 0.05	0.78	1.66	0.41	0.87	0.21	0.45	0.19	0.41	0.10	0.07
Depth 30-60 cm										
Treatments	SP%		FC%		WP%		AW%		Bulk density (g/cm³)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
ST+G	31.33a	31.33a	16.4a	16.4a	8.589a	8.589a	7.816a	7.816a	1.36b	1.373ac
DT+G	27.67b	27b	14.49b	14.14b	7.584b	7.401b	6.901b	6.735b	1.46ab	1.463abc
DT	27.67b	27.5b	14.49b	14.4b	7.584b	7.538b	6.901b	6.86b	1.467ab	1.463ab
ST	25.67b	25.67b	13.44b	13.44b	7.036b	7.036b	6.402b	6.402b	1.493a	1.493a
mean	28.1	27.9	14.7	14.6	7.7	7.6	7.0	7.0	1.4	1.4
LSD 0.05	3.0	3.8	1.6	2.0	0.8	1.0	0.7	0.9	0.17	0.09

Table 5. Effect of tillage practices and gypsum application on Hibiscus water relationships

treatments	AIW (m^3 ha^{-1})		CU (m^3 ha^{-1})		IWP (Kg/m^3)		CWP (Kg/m^3)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
ST+G	10234	10436	8076	8130	0.15	0.15	0.22	0.22
DT+G	10234	10436	7775	7835	0.13	0.14	0.19	0.21
DT	10234	10436	7639	7678	0.11	0.11	0.17	0.17
ST	10234	10436	7078	7111	0.10	0.10	0.17	0.17
LSD 0.05					0.09	0.1	0.1	0.1

Figure (1) showed that the tillage practices and gypsum application increased water consumption use (CU) with an average for both seasons was 8103 m^3 ha^{-1}, irrigation water productivity (IWP) with an average for both seasons was 0.15 Kg/m^3, and crop water productivity (CWP with an average for both seasons was 0.22 Kg/m. The CU, IWP and CWP were increased with tillage practice and gypsum application in comparison with tillage practice only. The best practice was surface tillage practice beside gypsum application then deep tillage beside gypsum application.

Effect of agricultural practices on nutrient content in straw and grain:

Table (6) showed the nutrient contents of total N%, P% and K% in straw and grain components. Agricultural practices, tillage and/or gypsum addition have no significant differences between all treatments. But the highest percent in total N%, P% and K% for straw and grain for both seasons were found in treatment ST+G (3.93%, N in 1st season, 0.1755 % P in 1st season and 1.405% K in 2nd season). In contrary the lowest values for nutrient happened in ST treatment (3.547%, N in 2nd season, 0.0578 % P in 1st season and 1.213 % K in 2nd season).

The gypsum effect besides tillage is increased total nutrient contents in straw and grain. Our study showed that combination of gypsum with tillage increased nutrient content in straw and grain yield. This resulted in good agreement El-sayed *et al.* (2023) who is found tillage practices with addition of gypsum increased nutrient content in straw and grain. The benefit effect of addition of gypsum in plant growth is enhancing soil structure and increase nutrient availability. Through its effect on decreasing of soil pH (Khan *et al.,* 2019), increase nutrient availability after that it increases ion uptake by plants (Qadir *et al.,* 2007).

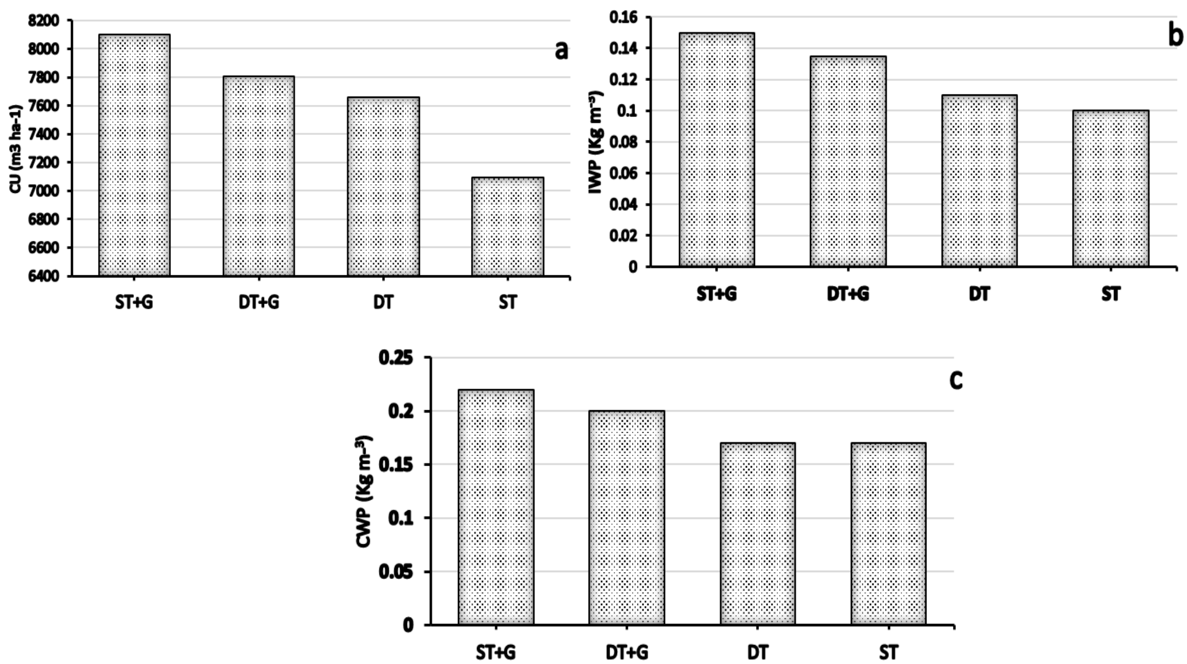

Figure 1. Effect of tillage practices and gypsum application on hibiscus water relationships as average value of both growing seasons

Table 6. Effect of agricultural practices on available nitrogen, phosphorus and potassium

treatments	straw						grain					
	Total N %		Total P%		Total K%		Total N %		Total P%		Total K%	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
ST+G	3.92a	3.92a	0.1755a	0.1725a	1.395a	1.405a	8.26a	8.26a	0.359a	0.3513a	1.443a	1.407a
DT+G	3.9١ a	3.687a	0.15a	0.155a	1.383a	1.363a	7ab	7.047a	0.3435a	0.3278 a	1.433a	1.423a
DT	3.78a	3.593a	0.0853a	0.1027a	1.292a	1.308a	6.347 b	6.3a	0.3265a	0.3375a	1.323a	1.34a
ST	3.593a	3.547a	0.0578a	0.0747a	1.223a	1.213a	6.253 b	6.253a	0.3215a	0.316a	1.27a	1.247a
mean	3.8	3.7	0.12	0.13	1.32	1.32	6.97	6.97	6.97	6.97	1.37	1.35
LSD 0.05	2.4	0.9	0.07	0.11	0.25	0.44	1.5	2.7	0.2	0.2	0.2	0.2

Effect of agricultural practices on available nitrogen, phosphorus and potassium

Table (7) shows that there was a significant difference for available N and K between tillage practices and the application of gypsum in all treatments in both seasons. No significant difference was found for available P. Treatment ST+G was the highest value in available N%, K% and P% in surface and subsurface depths also for both seasons for ST+G treatment (50, 11, 150 mg/Kg respectively) then DT+G treatment. The lowest values in available N%, K% and P% in surface and subsurface depths also for both seasons pronounced in surface tillage treatment. Table (7) also revealed that the available N%, K% and P% in soil were reduced with increasing in soil depth tillage. Addition of gypsum with tillage increased soil availability of N%, K% and P% because it is reducing soil pH and enhance release of nutrient. So, it is increased nutrient availability in soil as it has been shown in this study. Thus, the increase of available nutrient will increase plant production. The study also shows that the addition of gypsum affects available nutrients more in depth 0-30 cm tillage than the 30-60 cm tillage. Our research revealed that the total nutrients (N, P, K) were higher in 30 cm depth than on 30-60 depth. This finding is in good agreement with Gashi *et al.* (2025).

Table 7. Effect of agricultural practices on available nitrogen, phosphorus and potassium

Depth 0 - 30 cm						
Treatment	Available N (mg/kg)		Available P (mg/kg)		Available K (mg/kg)	
	1st	2nd	1st	2nd	1st	2nd
ST+G	50.0a	50.0a	11.0a	11.0a	150.0a	150.0a
DT+G	45.0ab	44.0b	10.2a	10.0a	130.0ab	132.0ab
DT	41.0ab	42.0b	9.8a	9.7a	125.0ab	129.0ab
ST	30.0b	30.0c	8.0a	7.5a	115.0b	118.0b
Mean	**41.5**	**41.5**	**9.75**	**9.55**	**130**	**132.25**
LSD 0.05	17.3	17.5	2.4	2.3	28.8	27.5
Depth 30 - 60 cm						
Treatment	**Available N (mg/kg)**		**Available P (mg/kg)**		**Available K (mg/kg)**	
	1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**
ST+G	45.0b	46.0b	10.0a	9.8a	145.0a	148.0a
DT+G	42.0a	43.0a	9.5ab	9.2a	140.0a	138.0a
DT	39.0ac	40.0c	8.3abc	8.0a	120.0b	123.0b
ST	28.0c	29.0d	7.0ac	6.8a	125.0b	120.0b
Mean	**38.5**	**39.5**	**8.7**	**8.45**	**132.5**	**132.25**
LSD 0.05	14.8	15.5	1.2	1.1	20.2	19.6

CONCLUSION

In conclusion, this study showed that tillage practices with addition of gypsum amendment to soil significantly enhanced soil physical, chemical characteristics and nutrient availability. It would improve land management and increase soil productivity. Also, it is improving crop water productivity and irrigation water productivity and enhance yield components. Combining surface tillage with gypsum amendment revealed a good management soil practice to enhance crop water production and irrigation water productivity. In addition to it is improved nutrient availability in soil which increased total nutrient (N, P and K) in straw and yield contents. It could be concluded that surface tillage practices with addition of gypsum amendment enhance some soil physical, chemical characteristics and nutrient availability. So, it could be recommended to use surface tillage practice beside gypsum application.

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الملخص العربي

تأثير الحرث وتطبيق الجبس على إنتاج الكركدية تحت نظام الري المحوري في منطقة توشكى

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أجريت تجربة حقلية في مشروع توشكي في جنوب مصر. تم تنفيذ الدراسة لتقييم تأثير الحرث مع أو بدون إضافة الجبس تحت نظام الري المحوري على معايير نمو النبات والعلاقات المائية لنبات الكركديه. تم إجراء التجربة علي موسمين متتاليين مع تطبيق أربع معاملات: الحرث السطحي (ST) والحرث العميق (DT) والحرث السطحي مع اضافة الجبس (ST + G) والحرث العميق مع اضافة الجبس (ST + G). تم قياس مكونات المحصول وثوابت محتوى الرطوبة (نسبة التشبع (SP) والسعة الحقلية (FC) ونقطة الذبول (WP) والمياه المتاحة (AW) ومعدل الاستهلاك (CU) وإنتاجية مياه الري (IWP) وإنتاجية مياه المحاصيل (CWP) وإجمالي النيتروجين والفوسفور والبوتاسيوم في القش والحبوب بالإضافة إلى النيتروجين والفوسفور والبوتاسيوم المتاح في التربة. كانت أفضل معاملة لمعبار نمو النبات (وزن اللوز الجاف ووزن ١٠٠٠ بذرة وارتفاع النبات) هي معاملة ST + G تليها معاملة DT + G. على النقيض من ذلك، كانت أدنى معايير نمو النبات هي معاملة الحراثة السطحية. زادت ثوابت محتوى الرطوبة (SP٪ وFC٪ وPW٪ وAW٪) تحت معالجة ST + G تليها معالجة DT + G. أدى تطبيق الجبس إلى جانب ممارسات الحرث إلى زيادة إنتاجية مياه المحاصيل وإنتاجية مياه الري. بالإضافة إلى ذلك، فقد حسّن توافر العناصر الغذائية في التربة، وبالتالي زاد من إجمالي العناصر الغذائية (N، P، وK) في القش والمحصول. الخلاصة بأن ممارسات الحرث السطحية مع إضافة الجبس اضافة الجبس المحسن تُحسّن بعض الخصائص الفيزيائية والكيميائية للتربة واتاخية العناصر الغذائية. لذا، يُوصى باستخدام ممارسات الحرث السطحي إلى جانب الجبس لتحسين الإدارة في منطقة توشكى، بما يُحسّن خصائص التربة وقدرتها على الاحتفاظ بالمياه وإنتاجية النباتات.

الكلمات المفتاحية: الجبس، الحرث، نظام الري المحوري، توشكى، الكركديه.