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Interactive Effect of Nitrogen Fertilizer Forms, Irrigation Intervals and Soil Conditioners on Maize Productivity Grown on Clay Loam Soil.

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ABSTRACT

Maize is the third important cereal crop in Egypt after wheat and rice. Injection of ammonia gas as a nitrogen fertilizer is used widely comparable with other nitrogen fertilizer forms due to the high nitrogen content (82 %) as well as its cheapest price. Two field trials were carried out at Tameia Agricultural Research Station, Fayoum Governorate, Egypt during 2014 and 2015 summer seasons to study the effect of nitrogen fertilization forms (ammonia gas 82 N% and ammonium nitrate 33.5N%), irrigation intervals and soil conditioners on yield, yield components and water use efficiency (WUE) water use efficiency of maize. Results showed that a combination of ammonia gas, irrigation at 10 days interval and application of compost caused the lowest averages of dry soil bulk density and hydraulic conductivity, whereas, this interaction also recorded the highest value of grain yield in both seasons, as well as, higher values of concentration and uptake of N, P and K in grain. On the other hand, the treatment of ammonia gas, irrigation at 15 days and application of compost remarkably had the higher water use efficiency (WUE) than the irrigation at 10 days with the application of compost. Although, the yield production reduced by 5 to 6 % , it saves irrigation water $400 m^3 ha^{-1}$ water. Hence, the treatment of irrigation at 15 days and application of compost is recommended for adoption in wider areas in Egypt to save irrigation water.

Keywords: Maize, ammonia gas. ammonium nitrate, soil conditioners, water consumptive use, water use efficiency.

INTRODUCTION

Maize is one of the most important summer cereal crop grown in Egypt. It is grown in 1.04 Mha with a production of million 8.06 Mt at an average productivity of 7.76 Mg. ha^{-1} (FAOSTAT2016). Egypt is located among 32 top countries of maize productivity. Maize grain is used for both human and poultry consumption. Therefore, increasing maize production is very important concern to face the gap between production and consumption. Adequate supply of irrigation water and optimum N fertilizer at different forms are two main factors directly affecting the growth and productivity of maize plant as well as soil conditioners. As a consequence of increasing in nitrogen fertilizers prices, the farmers reorient their using of nitrogen fertilizer forms to ammonia gas as a cheaper and more nitrogen content (82% N).

Nitrogen fertilization is very essential to cereal crops as nitrogen element for photosynthetic activity, cell building and protein assimilation rate (King *et al.*, 2003). Total amount of nitrogen utilized by corn plants were higher in the ammonia gas than ammonium nitrate forms (Hamissa *et al.*, 1971); as also was by grain sorghum (Abdou *et al.*, 2011). The yield and its components were increased by using ammonia gas compared with urea or other nitrogen fertilizer sources (Darwish, 2003; Siam *et al.*, 2008). The application of ammonia gas gave the highest recorded data in NPK concentrations in grain, stover yields and also its uptake by plants than urea fertilizer (Siam *et al*, 2008; Abd El-Hafeez *et al.*, 2013).

Water requirements of maize for maximum production varied between 430-490 mm per season depending on climate and season length (Doorenbos *et al.*, 1979). Irrigation requirement was 400mm to obtain grain yield of 9.52-10.85 Mg ha^{-1} with water use efficiency (WUE) of 1.25-1.45 kgm^{-3} while water deficit affected maize yield (Musick and Duesk, 1982). Water consumptive and water use efficiency (WUE) in grain sorghum were significantly increased by using ammonia gas in comparison of urea or ammonium nitrate (Abdou *et al.*, 2011). Extending the irrigation intervals for maize crop reduced vegetative growth; yield components and grain yield (Ibrahim *et al.*, 1992; Atta- Allah, 1996; Charles, 2000; Reza and Mehdi, 2002). Increasing irrigation intervals from 10 to 20 days decreased grain yield significantly from 8.67 to 6.83 Mg ha^{-1} with corresponding decrease in seasonal cumulative crop evapotranspiration (ET_C) from 59.9 to 55.3 cm, daily ET_C from 5.25 to 4.86 mm day^{-1}, WUE from 1.445 to 1.340 kg m^{-3} water (Sharaan *et al.*, 2002). Growth and yield attributes were increased with increasing irrigation based on cumulative pan evaporation (CPE). The highest ET_C (60.32 cm) as well as the highest WUE were resulted from irrigation at 1.2 CPE (El-Tantawy *et al.*, 2007). Increasing irrigation intervals from 7 to 14 or 21 days significantly reduced grain yield by 15.8%, ET_C by 10.8% (Abdel-Maksoud *et al.*, 2008). Irrigation interval at every 14 days gave the highest WUE value (0.972 kg grains m^{-3} water consumed). The K_C values were 0.53, 0.74, 0.99 0.71 and 0.62 for June, July, Aug., Sep. and October months, respectively. Soil organic carbon and nitrogen are important determinants of soil quality because they positively affect water retention, soil aeration, nutrient status and retention, and plant root growth (Mahdi *et al.*, 2005). Application of soil conditioners resulted in improved soil organic matter, bulk density, microbial biomass, aggregate stability, infiltration water holding capacity and cation exchange capacity (Aziz-Nagat, 2002; Ashry, 2003; Abdou, 2004; Eshraga, 2011; Khatab *et al.*, 2015).

This investigation is aimed to study the combination effects of applying two forms of nitrogen fertilizer with three irrigation intervals treatments and applying soil conditioners on yield, yield components and some water relations of maize crop.

MATERIALS AND METHODS

Site description

The present investigation was conducted during 2014 and 2015 seasons at Fayoum Agric. Res. Station (Tameia), Fayoum Governorate, Egypt. The soil physical and chemical properties of the experimental site were determined according to Klute (1986) and Page *et al.* (1982) and the data presented in Table (1). Some soil water constants are illustrated in Table (2). The seasonal weather parameters during crop growth period are presented in Figure 1.

Table 1. Physical and chemical analysis of the experimental field during 2014 and 2015 seasons (average of the two seasons).

Particle size distribution								Organic matter (%)		CaCO$_3$ (%)			
Sand (%)		Silt (%)		Clay (%)		Textural Class		1.49		6.21			
41.02		19.76		39.22		Clay loam							
Soluble cations megL^{-1}				Soluble anions megL^{-1}			EC dSm^{-1}	pH soil paste	C.E.C meq/100g soil	Exchangeable Cations Meg/100g soil			
Ca^{++}	Mg^{+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-}				Ca^{++}	Mg^{++}	K^{+}	Na^{+}
14.32	11.91	33.1	0.6	30.1	4.14	25.69	5.48	8.39	38.17	19.31	12.1	1.32	6.1

Table 2. Soil moisture constants for the experimental site during 2014 and 2015 seasons (average of the two seasons).

Soil depth (cm)	Field capacity (%,wt/wt)	Wilting point (%wt/wt)	Bulk density (gcm^{-3})	Available moisture (%wt/wt)	Available moisture (mm)
00 -15	44.72	21.75	1. 48	22.97	50.99
15 -30	41.32	19.32	1.53	21.47	49.27
30 – 45	37.21	18.41	1.56	18.80	43.99
45 - 60	35.29	17.67	1.58	17.62	41.76

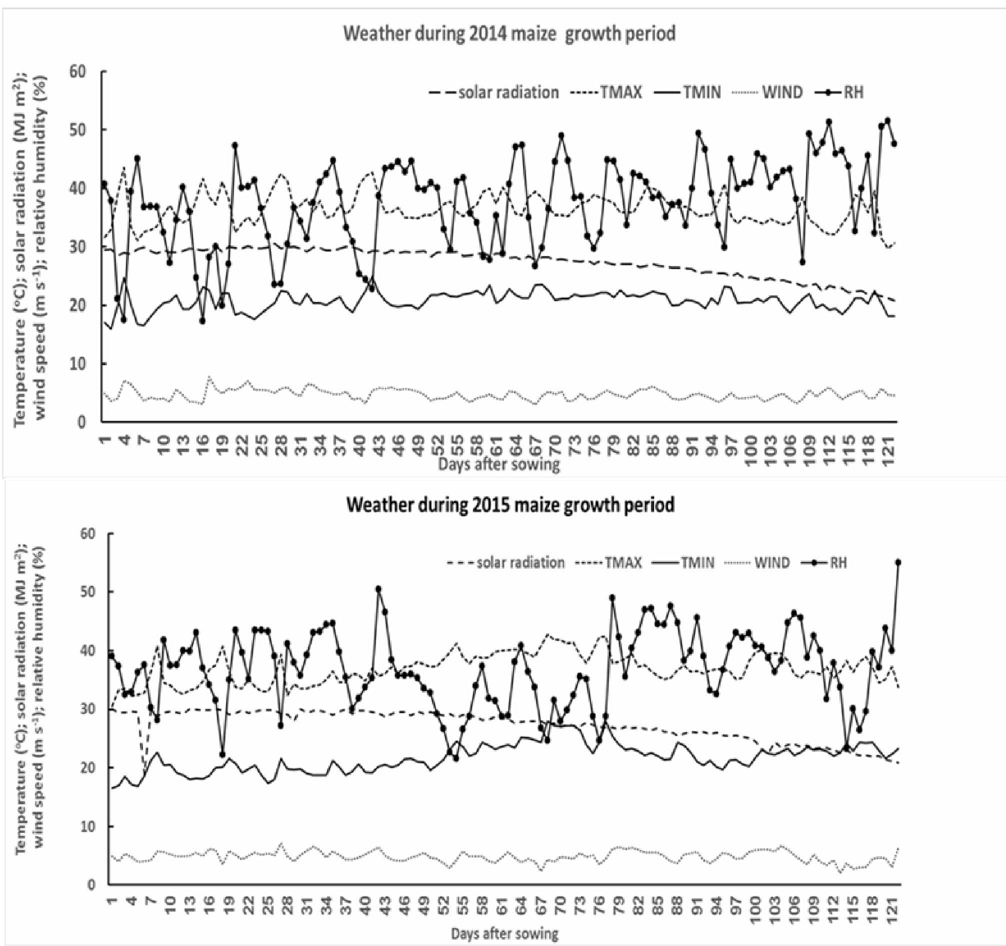

Fig 1. Weather data for Maize growing period during 2014 and 2015 seasons.

Experimental design

This investigation is aimed to study the effects of applying two forms of nitrogen fertilizer with three irrigation intervals treatments and applying soil conditioners on yield, yield components and some water relations of maize crop. The experiment was laid out in a split-split plot design. Main plots were assigned to N fertilizer forms (F_1 and F_2) and the sub-plots were devoted to irrigation intervals while the sub-sub plots were devoted to soil conditioners. Each sub-sub plots area was 21 m^2 (3 x 7 m) and each strip was isolated from the others by allays of 1.5 m wide to minimize the effect of lateral movement of water on next adjacent strip. In the F_1 treatment, nitrogen as ammonia gas (contains 82% N) was injected into the soil at a rate of 259.5kg Nha^{-1} before sowing. In the F_2 treatment, N fertilization was applied at the same rate 259.5kg Nha^{-1} as ammonium nitrate (33.5% N) in two equal doses (at 1st and 2nd irrigation), the irrigation treatments were started from the third irrigation. Three irrigation treatments included irrigation at 10 (I_1), 15 (I_2) and 20 (I_3) days interval. Surface irrigation was adopted to convey the irrigation water to the experimental plots. Soil conditioner treatments include C_1: control (without any addition), C_2: compost, C_3: rice straw and C_4: saw dust. Some chemical analysis of soil conditioners is shown in (Table 3). Different soil conditioners were mixed in the top layer of soil at a uniform rate 2.5 g C/ kg soil according to Total O.C % for each conditioner and the quantities of each conditioner added is showen (Table 4). Fertilization was managed according to the recommendation of the Ministry of Agriculture in Egypt; however, superphosphate and potassium sulphate fertilizers were applied before ridging at rates 150 kg P_2O_5 and 115 kg K_2O ha^{-1}, respectively. Maize grains of variety (TWC 310) were sown at a seed rate of 37.5 kg ha^{-1} in hills of 25cm apart on 1st June in the two successive seasons of 2014 and 2015. After harvest, Soil bulk density, hydraulic conductivity, WUE and data of ear length (cm), ear diameter (cm), 100 grain weight (g), grain weight ear^{-1} (g), grain yield kg ha^{-1} and stover yield kg ha^{-1} were determined. As well as, content and uptake of nitrogen, phosphorus and potassium in grains were estimated. Soil bulk density and hydraulic conductivity determined according (Klute,1965). All the data were subjected to statistical analysis according to Snedecor and Cochran (1980) and the means were compared using least significant difference at 5% level of significance.

Table 3. Some chemical analysis of soil conditioners.

Conditioner	P%	K%	Total N %	Organic C%	C:N ratio
Compost	0.14	1.53	1.72	27.31	16: 1
	P mg/kg	K%	Total N%	Organic C%	C:N ratio
Rice straw	805.88	2.45	0.58	51.62	89:1
Sawdust	57.90	0.08	0.17	39.95	235: 1

Crop - water relations

Crop-water requirements vary during the growing period mainly due to variation in crop canopy and weather conditions, and closely related to agricultural practices, cropping technique and irrigation methods. In order to improve the water management by changing volume and frequency of irrigation, estimates on seasonal consumptive use and water use efficiency are needed.

Table 4. Quantities of different conditioners applied ton ha^{-1}.

Conditioners	O.C %	Dose (g)	Quantities (g/kg)	Quantities tonha^{-1}	Quantities applied tonha^{-1}
Compost	27.31		36.6	87.4	66.04
Rice straw	51.62	2.5g/kg	19.3	46.5	25.14
Sawdust	3959		25.03	60.0	38.64

Seasonal consumptive use (ET_C): Water consumptive use was calculated as soil moisture depletion (SMD) according to Israelsen and Hansen (1962) as follows:

$$CU = SMD = ET_C = (h_2 - h_1)/\ 100 \times Dbi \times Di$$

where

CU= Water consumptive use in the effective root zone (60 cm) in cm,

h_2=Gravimetric soil moisture at 48 h after irrigation (%),

h_1=Gravimetric soil moisture before the next irrigation (%),

Dbi= soil bulk density (g cm^{-3}) for the given soil layer and

Di= soil layer depth (15 cm),

Reference evapotranspiration (ET_0): Reference evapotranspiration (ET_0) reflects the impact of weather condition on evaporation and transpiration. The ET_0 was estimated as a daily rate (mm day^{-1}), using daily weather data of Fayoum Governorate (Fig 1) as per the procedure of the FAO-Penman Monteith equation (Allen *et al.* 1998).

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

where

ET_0: reference evapotranspiration [mm day^{-1}],

Rn: net radiation at the crop surface [MJ m^{-2} day^{-1}],

G: soil heat flux density [MJ m-2 day^{-1}],

T: air temperature at 2 m height [°C],

u_2: wind speed at 2 m height [m s-1],

e_s: saturation vapour pressure [kPa],

e_a: actual vapour pressure [kPa],

$e_s - e_a$: saturation vapour pressure deficit [kPa],

Δ: slope vapour pressure curve [kPa $°C^{-1}$],

y: psychrometric constant [kPa $°C^{-1}$].

Crop Coefficient (K_C): Crop coefficient are characteristics of plants used in estimating evapotranspiration (ET). The most basic crop coefficient, K_C, is simply the ratio of observed ET for a crop (ETc) and ET_0 under same conditions. K_C was calculated by Israelsen and Hansen (1962) equation.

$$K_C = ET_C / ET_0$$

Where: ET_C = Actual crop evapotranspiration (mm day^{-1}) and ET_0 = Reference evapotranspiration (mm day^{-1}).

Water use efficiency (WUE): Water use efficiency was calculated according to Jensen (1983) and as follows:

$$WUE = \frac{Y}{CU}$$

Where:

WUE = Water consumed per each kg grain produced (kg m^{-3}),

Y = Grain yield (kg ha^{-1})

CU = Seasonal water consumptive use (m^3 ha^{-1})

RESULTS AND DISCUSSION

Bulk density (Bd)

It is a matter of fact that, the bulk density is one of the most important parameters in reflecting the effects of soils and water management practices.

The obtained data of soil bulk density values were shows in Table 5, Data revealed that there is insignificant effect from using nitrogen fertilizer forms on soil bulk density values.

Regarding irrigation intervals, the results indicate that irrigation every 10 days decrease averaging in values of soil bulk density in the two successive seasons (1.39 and 1.38 g cm^{-3}), respectively, increasing the irrigation intervals from 10 to 15 days led to increase soil bulk density by about 0.27%, in the two successive seasons. Meanwhile, the increasing the intervals from 10 to 20 days led to increase soil bulk density by (1.44% and 2.17 %) in 2014 and 2015 seasons, respectively.

Concerning soil conditioners, data reveal that the lowest values of soil bulk density were detected from applied compost followed by sawdust and rice straw (1.36, 1.40 and 1.41 g cm^{-3}) in 2014 season, respectively, however, the corresponding values were (1.35, 1.39 and 1.40 g cm^{-3}) in 2015 season, respectively. Applied compost led to decrease the soil bulk density by 5.6% in 2014 season and by 6.9% in 2015 season, respectively, compared with control.

Also, data show that there are insignificant differences among the obtained bulk density values as influenced by interaction effect of both nitrogen fertilizer forms and both irrigation intervals and soil conditioners as well as the interaction between all treatments. The data as well revealed that, there was insignificant effect with the interaction between irrigation intervals and soil conditioners except the influence on top soil layers (0-15cm) in the two successive seasons.

These results may be attributes to the fact that irrigation intervals and soil conditioners treatments caused a reducing bulk density of soil unit as the density of conditioners less than the density of soil, consequently, the soil bulk density has been decreased.

Generally, the mentioned above results cope with those reported by (Aziz-Nagat, 2002; Ashry, 2003; Abdou, 2004; Eshraga, 2011; Khatab *et al*., 2015).

Table 5. The effect of nitrogen fertilizer forms, irrigation intervals, soil conditioners and their interaction on soil dry bulk density (B_d g cm^{-3}) in 2014 and 201 seasons.

Treatment		0-15 (cm)		15-30 (cm)		30-45 (cm)		45-60 (cm)	
		2014	2015	2014	2015	2014	2015	2014	2015
Fertilizer	Ammonia gas	1.40	1.41	1.44	1.45	1.48	1.49	1.52	1.52
Forms (F)	Ammonium Nitrate	1.40	1.41	1.43	1.44	1.48	1.48	1.51	1.52
L.S.D (p=0.05)		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation	10 days	1.39	1.38	1.43	1.43	1.48	1.48	1.51	1.50
interval	15 days	1.40	1.39	1.44	1.44	1.48	1.49	1.52	1.52
(I)	20 days	1.41	1.41	1.45	1.45	1.49	1.49	1.53	1.52
L.S.D (p=0.05)		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Soil	control	1.44	1.45	1.47	1.47	1.50	1.51	1.53	1.53
conditioner	compost	1.36	1.35	1.42	1.42	1.47	1.46	1.51	1.50
(C)	Rice straw	1.41	1.40	1.44	1.44	1.48	1.48	1.53	1.53
	Saw dust	1.40	1.39	1.43	1.42	1.47	1.48	1.52	1.52
L.S.D (p=0.05)		0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
	F I	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Interaction	F C	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
L.S.D (0.05)	I C	0.02	0.02	N.S	N.S	N.S	N.S	N.S	N.S
	F I C	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

Hydraulic conductivity

The obtained results concerning the effects of the applied nitrogen fertilizer forms, irrigation intervals, soil conditioners treatments and their interaction on the hydraulic conductivity along the two successive seasons were shown in (Table 6). Values of the obtained saturated hydraulic conductivity were expressed as K_{sat} (cm hr^{-1}).

According to the present data, it can be noticed that there was insignificant effect of applied nitrogen fertilizer forms, whereas, applied soil conditioners resulted in significant increase of the hydraulic conductivity values (K_{sat}). The more detectable effects have been clearly shown as a result of using short irrigation intervals and compost as soil conditioners. On the other hand, long irrigation intervals without soil conditioner addition (control) gave the lowest values of (K_{sat}).

Consequently, these findings may be attributed to reducing in bulk density, water retention characteristics, geometry and continuity of the pores, in addition to the changes in pore size distribution. The changes in pore sizes as a result of the used applied treatments have tremendous effects on such pores which are considered the main contributors to the passages of drained and percolated water through the studied soil. These findings and statements are consistent with each other and hold true with those reported by (Aziz-Nagat, 2002; Ashry, 2003; Abdou, 2004).

Table 6. The saturated hydraulic conductivity values (K_{sat} cm hr^{-1}) as affected by nitrogen fertilizer forms, irrigation intervals, soil conditioners and their interaction in 2014 and 2015 seasons.

Treatment		0-15 (cm)		15-30 (cm)		30-45 (cm)		45-60 (cm)	
		2014	2015	2014	2015	2014	2015	2014	2015
Fertilizer Forms (F)	Ammonia gas	0.6	0.61	0.48	0.49	0.36	0.36	0.32	0.32
	Ammonium Nitrate	0.6	0.61	0.48	0.48	0.36	0.36	0.32	0.32
L.S.D (p=0.05)		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation interval (I)	10 days	0.63	0.65	0.52	0.53	0.41	0.41	0.37	0.37
	15 days	0.60	0.61	0.48	0.48	0.35	0.35	0.29	0.28
	20 days	0.56	0.55	0.44	0.44	0.33	0.32	0.29	0.28
L.S.D (p=0.05)		0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Soil conditioner (C)	control	0.53	0.52	0.40	0.40	0.33	0.33	0.29	0.29
	compost	0.69	0.73	0.55	0.56	0.39	0.40	0.35	0.35
	Rice straw	0.59	0.61	0.48	0.49	0.37	0.37	0.32	0.33
	Saw dust	0.59	0.61	0.48	0.49	0.37	0.37	0.32	0.32
L.S.D (p=0.05)		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Interaction L.S.D (0.05)	F I	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
	F C	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	I C	0.02	0.02	0.01	0.01	0.02	0.01	N.S	N.S
	F I C	0.01	0.01	N.S	N.S	N.S	N.S	N.S	N.S

Yield and yield components

Effect of N fertilizer forms (F).

The data in (Table 7) showed that injection ammonia gas as a nitrogen fertilizer gave the highest averages values of yield and its components compared to ammonium nitrate treatment. Significant increase in ear length (cm), ear diameter (cm), grain weight ear $^{-1}$, 100- grain weight (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) in the two successive seasons were recorded (Table 7). Range of increase was 4 to 4.5% for ear length, 6.5-8% for ear diameter, 3.4- 4 % for grain weight ear^{-1}, 1.7-1.9% for 100-grain weight (g), 4-6 % for grain yield (kg ha^{-1}) and 10-11% for stover yield (kg ha^{-1}) in the two successive seasons as compared to those obtained with ammonium nitrate form. Ammonia gas is reported to reduce the soil pH leading to an increase in the availability of macro nutrients such as nitrogen, phosphorus and potassium. Such increased availability on nutrients in soil improved their uptake by maize (Darwish, 2003; King *et al.*, 2003; Siam *et al*., 2008; Abd El-Hafeez *et al*., 2013).

Effect of irrigation intervals (I).

Results indicated that maize yield and its components were significantly affected by irrigation interval treatments in both seasons (Table 7). The highest averages values were detected from irrigation maize every 10 days. On contrast, the lowest values were obtained from irrigation maize plants every 20 days in the two successive seasons. Increasing the intervals between irrigations from 10 up to 20 days significantly decreased the ear length by 10.3 – 11.3%, ear diameter by 18.2 – 18.9%, grain weight per plant by 6.3- 7%, 100- grain weight by 5.3 – 6.4%, grain yield by 10.7 – 12% and stover yield by about 19.5 % as compared to irrigation every 10 days for two successive seasons. Increasing irrigation intervals will reduce the available soil moisture in the root zone, which in turn reduced vegetative growth of maize plant and dry matter accumulation during grains filling, as well as reducing nutrients absorption from soil (Ibrahim *et al*., 1992; Atta- Allah, 1996; Abdel-Maksoud *et al*., 2008).

Effect of soil conditioners (C).

Soil conditioners significantly influenced maize yield and its components (Table7). Applying compost gave the highest averages values of yield and its components as compared to application of other two conditioners and control treatment (without any addition), while control treatment gave the lowest ones in the two seasons. Addition of compost led to increase the ear length by 7.3 – 8.1%, ear diameter by 12.8 – 15.9%, grain weight per plant by 4.4 – 4.6%, 100- grain weight by 3 – 3.5%, grain yield by 7.8 – 10% and stover yield by about 19 % as compared with control. The superior performance of compost treated may be due to rapid decomposition of organic matter in the compost as compared to that in rice straw or sawdust. This influences soil physical and chemical properties such as soil organic matter, bulk density, microbial biomass, aggregate stability and soil structure, infiltration water holding capacity and cation exchange capacity (Abdou, 2004; Eshraga, 2011; Khatab *et al*., 2015).

Concerning the interaction between the experimental factors under test, the results indicate that yield and its components affected by the interaction of the three treatments in both seasons. Injection ammonia gas and irrigation maize at 10 days interval with an addition of compost as a soil conditioner gave the highest values for ear length (19.08 – 20.30cm), ear diameter (5.61 – 5.9cm), grain weight per plant (90.7-94.03), 100-grain weight (31.23 – 95.37 g), grain yield (7750 – 7890 kg ha^{-1}) and stover yield (23450 – 23710 kg ha^{-1}) in the two successive seasons, respectively. On the other hand, the control treatment (without any addition) with irrigation at 20 days interval and supplied with ammonium nitrate gave the lowest averages of yield and its components.

Macro- nutrient concentration by plants and its uptake in grain.

Nitrogen(N), phosphorus (P) and potassium (K) concentration by plants and their uptake in grains were significantly affected by the forms of N fertilizers applied in two successive maize seasons (Fig 2 and 3).

The highest averages of N, P and K concentration by maize plants and its uptake in grains were resulted from injection ammonia gas. Irrigation at 10 days interval which gave the highest concentration of macronutrients (N, P, and K) and their uptake in grain. Increasing the intervals between irrigations from 10 to 20 days led to a significant decrease in N, P and K uptake by 25%, 40 and 29 %, respectively. The concentration of these elements decreased in grains by 10%, 32%, and 12%, respectively. In addition, application of compost as a soil conditioner gave highest values for N, P, K uptake and concentration. Whereas, under control treatment the lowest values were obtained in the two successive seasons. Results show that injection N fertilizer as ammonia gas with irrigation at 10 days in the presence compost as a soil conditioner gave the highest values of N, P and K uptake and their concentration in grain. Whereas, the lowest values were attained with application of N fertilizer in ammonia nitrate form with irrigation at 20 days interval and without addition of soil conditioners (control).

Table 7. Effect of N fertilization forms, irrigation intervals and soil conditioners and their interaction on yield components, grain and stover yield of maize crop in 2014 and 2015 seasons.

Treatment		Ear length (cm)		Ear diameter (cm)		Grain weight ear^{-1}		100- grain weight (g)		Grain yield *(kg ha^{-1})*		*Stover yield (kg ha^{-1})*	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Fertilizer Forms (F)	Ammonia gas	18.0	19.1	4.9	5.2	85.4	90.5	30.02	31.0	7955	8280	22160	22440
	Ammonium Nitrate	17.3	18.3	4.6	4.8	82.6	87.0	29.52	30.41	7617	7800	20005	20374
L.S.D (p=0.05)		0.51	0.6	0.2	0.2	2.3	2.7	0.41	0.27	270	331	720	905
Irrigation interval (I)	10 days	18.5	19.5	5.3	5.5	86.8	91.9	30.80	31.79	8246	8510	23476	23850
	15 days	17.9	18.9	4.7	5.1	83.8	88.8	29.68	30.48	7850	8000	20801	21170
	20 days	16.6	17.3	4.3	4.5	81.3	85.5	28.84	30.12	7362	7610	18970	19202
L.S.D (p=0.05)		0.3	0.5	0.15	0.22	2.1	2.25	0.49	0.53	305	370	810	930
Soil conditioner (C)	Control	17.2	17.9	4.4	4.7	82.2	86.9	29.36	30.31	7360	7740	19650	19930
	compost	18.6	19.2	5.1	5.3	85.8	90.9	30.24	31.37	8100	8350	23410	23660
	Rice straw	17.8	18.8	4.8	5.1	84.6	89.2	29.76	30.82	7900	8130	20903	21322
	Saw dust	17.5	18.4	4.6	4.9	83.7	88.5	29.51	30.56	7734	7940	20367	20715
L.S.D (p=0.05)		0.27	0.32	0.11	0.13	1.3	1.6	0.22	0.24	155	170	304	411
Interaction L.S.D (0.05)	F I	032	0.32	0.12	0.14	1.51	1.63	0.16	0.22	201	234	640	819
	F C	0.21	0.27	0.10	0.12	1.0	1.2	0.13	0.17	120	209	284	365
	I C	0.22	0.26	0.10	0.10	1.26	1.43	0.19	0.22	140	155	271	400
	F I C	0.20	0.29	0.10	0.11	1.21	1.36	0.15	0.17	116	131	256	245

Crop water relations

Seasonal evapotranspiration (ET_C)

The averages of seasonal water consumptive use (evapotranspiration ET_C) of maize crop were 56.64 and 57.78 cm in the two successive seasons, respectively. The difference may be due to the variation in weather factors of the two seasons (Figure 1). The highest values of ET_C i.e. 57.32 and 58.51 cm in 1st and 2nd seasons were detected from injection ammonia gas as N fertilizer form. Application of N as ammonium nitrate resulted in reduction of ET_C to 2.37% and 1.25%, compared with ammonia gas in the 1st and 2nd seasons, respectively. This reduction may be attributed to reduced biological growth and yield under ammonium nitrate as compared to those treated with ammonia gas (Abdou *et al*., 2011)

Concerning the effect of irrigation intervals, data in Table (8) show that, irrigating maize at 10 days interval resulted in the highest values of ET_C i.e. 59.05 and 60.71 cm in 1st and 2nd seasons, respectively. Moreover, irrigation at 15 or 20 days interval decreased ET_C by 5.17 % and 10.52 % in the first season and by 5.53 % and 11.61 % in the second season, respectively, as compared to the values of 10 days interval. Such results are attributed to luxury of available soil moisture under 10 days interval, high transpiration rates from plants and evaporation from soil under high available moisture help in transpiration cooling and thus enhancing the crop performance. Under water stress, the transpiration from plants decreases after a threshold when soil is not able to supply enough water to meet the ET demand leading to stomatal closure eventually resulting in poor vegetative growth. Also, as the evaporation decreased from dry soil surface, temperature of soil surface enhances further affecting the growth (Sharaan *et al*., 2002; El-Tantawy *et al*., 2007; Abdel-Maksoud *et al*., 2008). Adding compost as a soil conditioner gave the highest averages of ET_C i.e. 58.44 and 59.57 cm in both seasons, respectively. On the other hand, rice straw or sawdust decreased ET_C by 4.89% and 5.58% and by 4.48% and 3.79 % in the 1st and 2nd seasons, respectively, when compared with the ETc with compost. Increased biomass due to compost application is one of the reasons for such enhanced ETc.

Data revealed that injection ammonia gas, irrigating maize at 10 days interval and application of compost gave the highest values of ET_C i.e. 58.94 and 61.07 cm in 1st and 2nd seasons, respectively. On the other hand, the lowest ET_C values i.e. 52.59 and 53.18 cm were recorded under application of ammonium nitrate, irrigation of maize at 20 days interval and without any soil conditioners addition.

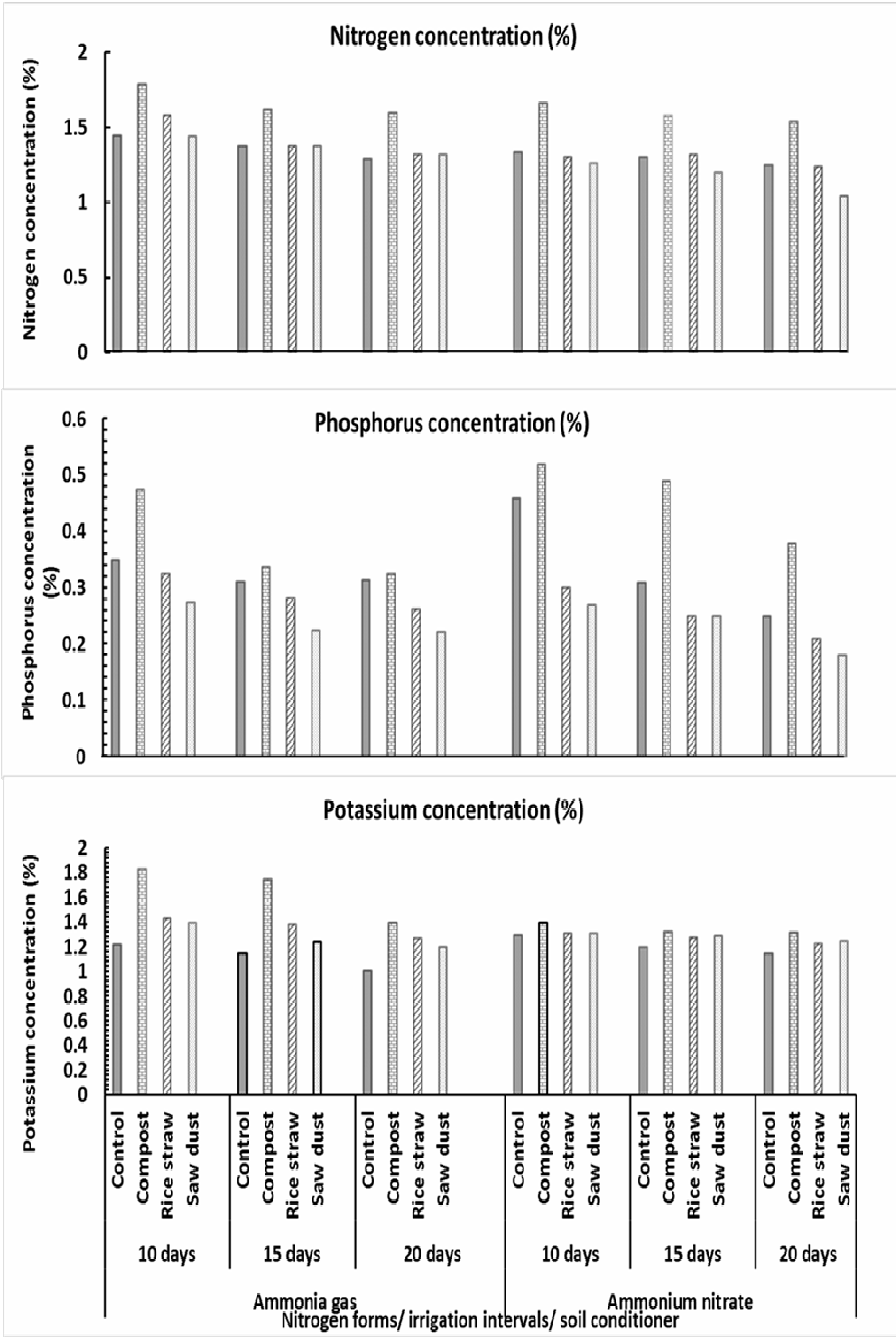

Fig. 2. Nutrient concentration (%) in maize grains as influenced by different treatments of nitrogen, irrigation and soil conditioners (mean values of two seasons).

Reference evapotranspiration

Reference evapotranspiration rate (ET_0 ; mm day^{-1}) during 2014 and 2015 growing seasons of maize was estimated using the FAO Penman- Monteith method and data from the Etsa meteorological station, Fayoum Governorate (Fig1). The estimated data From June to September in both growing seasons indicate that the daily ET_0 rates started with high values during June and get higher during July and gradually decreased during August till September, in both seasons. These results can be attributed to the changes in climatic factors from month to the other. In this connection. The values of ET_0 are depended mainly on the evaporative power of the air as temperature, humidity, wind speed and solar radiation (Allen *et al*., 1998).

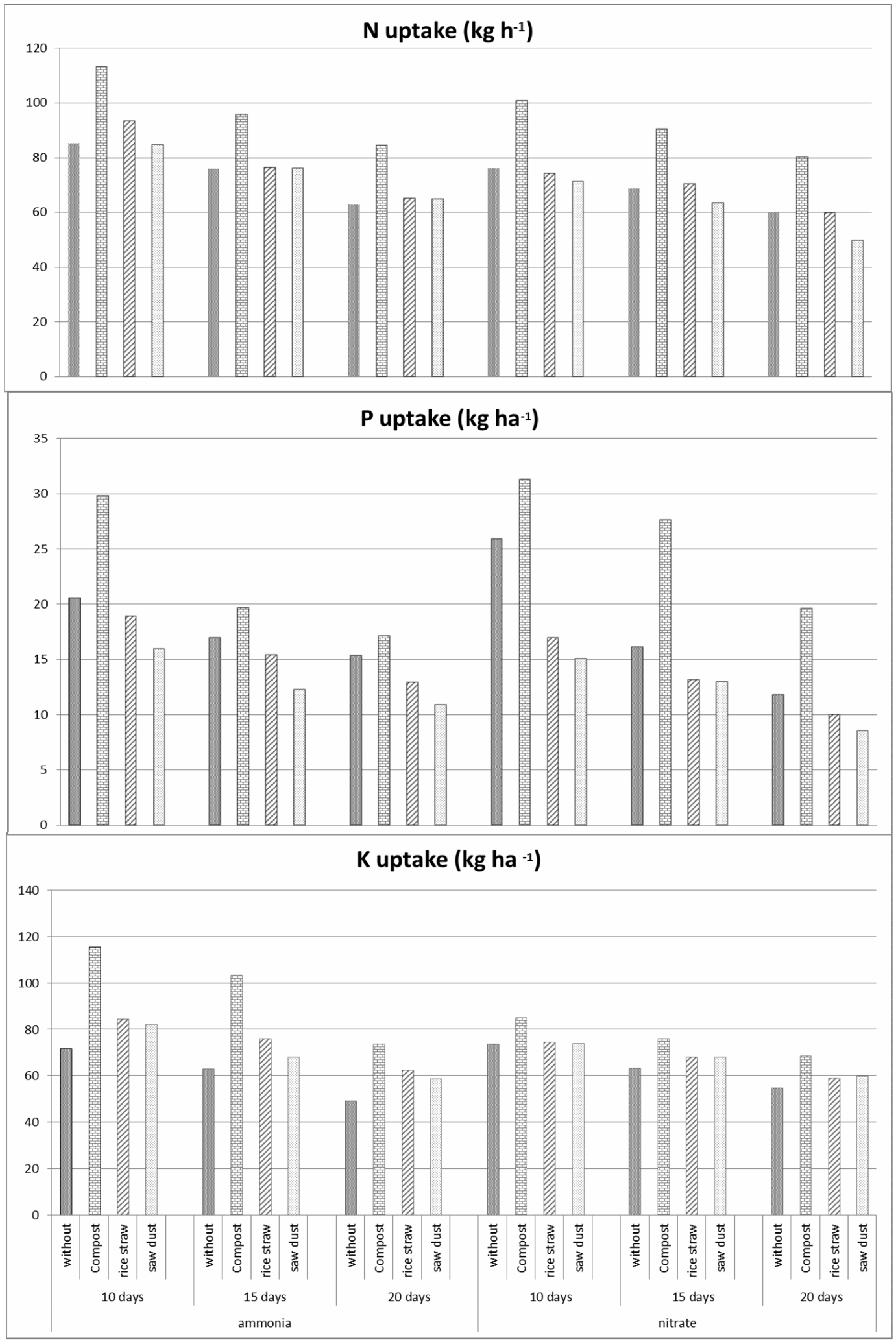

Fig 3. Nutrient uptake by plants under different treatments of nitrogen, irrigation soil conditioners. (Mean values of two seasons).

Crop coefficient (K_C)

Crop coefficient approach is one of the most used techniques to estimate ET (Allen et al. 1998). The K_C values were estimated from daily ET_C and daily ET_0 rates during the two successive growing seasons. The K_C values for ($F_1I_1C_2$) treatment (that gave the highest averages of yield and its components) were low (0.48) during June (germination stage) in two successive seasons. Thereafter, the values increased to 0.72 during July (vegetative growth stage) to reached its maximum values during August, i.e. 1.01 (tassling and silking stage) in the two successive seasons. The K_C values decrease during September to 0.71 and 0.64 in the two successive seasons, respectively. Such results can be referred to the large diffusive resistance to bare soil at the initial stage, which reduced with increasing the crop cover percentage until siliking and grain formation, and then tended to be reduced again at maturity stage (Table 9).

Table 8. Effect of N fertilization forms, irrigation intervals and soil conditioners and interaction on seasonal water consumptive use (cm) in 2014 and 2015 seasons

Treatments	Irrigation Intervals	2014 Control	2014 Compost	2014 Rice straw	2014 Sawdust	2014 Mean	2015 Control	2015 Compost	2015 Rice straw	2015 Sawdust	2015 Mean
Fertilization F_1	I_1	60.69	62.63	59.82	60.22	60.84	61.21	63.20	60.94	61.08	61.61
	I_2	57.88	58.94	56.07	56.27	57.29	58.61	61.07	58.12	58.48	59.07
	I_3	53.66	55.72	52.82	53.15	53.84	54.39	56.96	53.92	54.13	54.85
	Mean	57.41	59.10	56.24	56.55	57.32	58.07	60.41	57.66	57.90	58.51
F_2	I_1	59.46	60.98	57.75	58.02	59.05	60.29	62.03	59.57	60.94	60.71
	I_2	55.71	57.55	55.15	55.57	56.00	56.45	58.42	56.10	56.27	56.81
	I_3	52.59	54.84	51.87	52.05	52.84	53.18	55.73	52.77	52.95	53.66
Mean		55.92	57.79	54.92	55.21	55.96	56.64	58.73	56.15	56.72	57.78
Mean of Irrigation	I_1	60.08	61.81	58.79	59.12	60.75	60.75	62.62	60.26	61.01	61.61
	I_2	56.80	58.25	55.61	55.92	56.64	57.53	59.75	57.11	57.38	57.94
	I_3	53.13	55.28	52.35	52.60	53.34	53.79	56.35	53.35	53.54	54.25
Mean of conditioner		56.67	58.44	55.58	55.88	56.64	57.36	59.57	56.90	57.31	57.78

Table 9. Effect of N fertilization forms, irrigation intervals, soil conditioners and their interaction on crop coefficient (K_C) of maize in 2014 and 2015 seasons for ($F_1I_1C_2$) which gave the highest yield and yield components.

Months	2014 season ET_0	2014 season ET_C	2014 season K_C	2015 season ET_0	2015 season ET_C	2015 season K_C
June	7.5	3.63	0.48	7.6	3.68	0.48
July	7.8	5.59	0.72	7.8	5.58	0.72
August	7.3	7.40	1.01	7.6	7.66	1.01
September	6.2	4.41	0.71	6.6	4.28	0.65

Water use efficiency (WUE)

The overall mean of WUE values were about 1.19 and 1.20 kg grain m^{-3} water consumed in the 2014 and 2015 seasons, respectively Table (10). Applying nitrogen fertilizer in the form of ammonia gas gave the higher WUE values.

The WUE value increased by about 1.69 and 0.8% as compared to those with ammonium nitrate in the two successive seasons, respectively. Irrigating maize crop at 15 days interval gave the highest WUE values. On the other hand, irrigation at 10 or 20 days interval decreased WUE values by 1.68 and 3.42 % in the 2014 season and by 2.5 and 3.36 % in 2015 season, respectively, when compared with irrigation at 15 days interval. It could be concluded that WUE decreased as irrigation interval increased (Mahdi *et al*., 2005; Abdel Maksoud *et al*., 2008; Abdou *et al*., 2011). These underline the importance of providing optimum amount of water to improve the WUE which also helps in improving water productivity. Applying compost as a soil conditioner also enhanced the WUE. The interaction data show that the highest WUE values about 1.26 and 1.28 kg grain m^{-3} water consumed were obtained with N fertilizer in ammonia gas form, irrigation at 15 days interval and compost as soil conditioner in the two successive seasons, respectively.

Table 10. Effect of N fertilization forms, irrigation intervals and soil conditioners and interaction on water use efficiency (WUE, kg m^{-3}) of maize in 2014 and 2015 seasons.

Fertilizer	Irrigation	2014 Conditioners control	2014 Conditioners Compost	2014 Conditioners Rice straw	2014 Conditioners Saw Dust	2014 Mean	2015 Conditioners control	2015 Conditioners Compost	2015 Conditioners Rice straw	2015 Conditioners Saw dust	2015 Mean
F_1	I_1	1.14	1.24	1.21	1.18	1.19	1.15	1.25	1.22	1.19	1.20
	I_2	1.17	1.26	1.24	1.22	1.22	1.18	1.28	1.25	1.23	1.24
	I_3	1.12	1.22	1.20	1.17	1.18	1.14	1.23	1.22	1.19	1.20
	Mean	1.14	1.24	1.22	1.19	1.20	1.16	1.25	1.23	1.20	1.21
F_2	I_1	1.12	1.23	1.20	1.17	1.18	1.13	1.24	1.21	1.18	1.19
	I_2	1.15	1.25	1.22	1.19	1.20	1.16	1.26	1.24	1.21	1.22
	I_3	1.10	1.22	1.19	1.16	1.18	1.11	1.23	1.20	1.17	1.18
	Mean	1.12	1.23	1.20	1.17	1.18	1.13	1.24	1.22	1.19	1.20
Mean of Irrigation	I_1	1.13	1.24	1.21	1.18	1.19	1.14	1.25	1.22	1.19	1.20
	I_2	1.16	1.26	1.23	1.21	1.21	1.17	1.27	1.25	1.22	1.23
	I_3	1.11	1.22	1.20	1.17	1.17	1.13	1.23	1.21	1.18	1.19
Mean of conditioner		1.13	1.24	1.21	1.18	1.19	1.15	1.25	1.22	1.20	1.20

CONCLUSION

The present investigation was carried out to study the combination effects of applying two forms of nitrogen fertilizer with three irrigation intervals treatments and applying soil conditioners on yield, yield components and some water relations of maize (TWC 310 hybrid). Results in 2014 and 2015 seasons, show that:

- The lowest mean values of bulk density and hydraulic conductivity were detected from ammonia gas fertilization and irrigation at 10 days with compost application as soil conditioners.

- The highest mean values of maize yield and it's components were detected from ammonia gas fertilization and irrigation at 10 days with compost application as soil conditioners.
- Injection of ammonia gas increased grain yield by 4-6% and 10-11% for stover yield in the two successive seasons, respectively, as compared to those obtained by ammonium nitrate.
- Increasing the intervals between irrigations from 10-20 days significantly decreased the grain yield by 10.7 – 12% and stover yield by about 19.5%
- Applying compost increased the grain yield and stover yield by 7.8 – 10% and 19%, in both seasons, respectively, as compared to control.
- Seasonal water consumptive use (ET_C) reached its maximum values (62.63 and 63.20 cm in 2014 and 2015 seasons, respectively), when maize was fertilized by ammonia gas and irrigated at 10 days with applying compost as soil conditioner..
- The highest efficiency of water use which amounted to 1.26 and 1.28 kg grains m^{-3} in 2014 and 2015 seasons, respectively**,** were obtained from injection of with ammonia gas and irrigated at 15 days with applying compost.
- It is evident that, injection N fertilization as ammonia gas, irrigation at 15 days and applying compost as soil conditioner is advisable to achieve higher grain and stover yields with high water productivity. It could be concluded that this combination is proposed as a recommendation for farmers.

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التأثير المتبادل لصورالسماد النتروجيني وفترات الري ومحسنات التربه علي انتاجية الذرة الشاميه

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يعد محصول الذرة الشامية ثالث اهم محاصيل الحبوب في مصر بعد محصولي القمح والارز انتشر في الآونة الاخيره استخدام الامونيا الغازيه كصورة من صور التسميد النيتروجيني وذلك لارتفاع محتواها من النتروجيني ٨٢% بالاضافه الي انخفاض سعر وحدة الازوت كمقارنة بصور التسميد النيتروجيني الاخري. هذا وقد تم تنفيذ تجربتين حقليتين بمزرعة طاميه البحثية – محافظة الفيوم خلال الموسم الصيفي ٢٠١٤ ، ٢٠١٥ وذلك لدراسة تأثير التفاعل بين صورتين من صور التسميد النيتروجيني وثلاث فترات للري بالاضافه الي محسنات التربة علي المحصول ومكوناته وبعض العلاقات المائية لمحصول الذرة هجين (TWC310). وقد اظهرت النتائج أن التسميد بالامونيا الغازيه مع الري كل ١٠ ايام واضافة الكومبوست كمجسن للتربة قد اعطي اقل متوسطات للكثافه الظاهريه بالتربه والتوصيل الهيدروليكي وكذا اعلي متوسطات لمحصول الحبوب ومكوناته في كلا الموسمين بالاضافه الي ارتفاع محتوي الحبوب من النيتروجين، الفوسفور ، البوتاسيوم وكذا الممتص منهم من التربه . من ناحية اخري فإن التسميد بالامونيا الغازية والري كل ١٥ يوم واضافة الكمبوست كمحسن للتربه اعطي اعلي كفاءة لاستخدام المياه .