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INFLUENCE OF IRRIGATION INTERVAL, BIO AND MINERAL FERTILIZATION AND THEIR INTERACTIONS ON SOME PHYSIOLOGICAL, ANATOMICAL FEATURES AND PRODUCTIVITY OF MAIZE

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ABSTRACT: This study was carried out in the Experimental Farm, Fac. Agric., Zagazig Univ., Sharkia Governorate, Egypt, during 2015 and 2016 seasons to find out the effect of irrigation intervals (10 and 16 days) under four bio and mineral fertilization treatments on physiological, anatomical features, growth and yield of yellow maize cultivar single cross 168. The combined analysis detected significant decrease in maize leaf photosynthetic pigments, photochemical activity, histological features, growth and most yield attributes of maize due to prolonging the irrigation interval to 16 days except each of plant height, ear leaf area, ear length and diameter, number of rows per ear and number of grains per ear which were not significantly affected by irrigation interval. The bio and mineral fertilization treatments caused significant effects on all previous traits. Combined application of biofertilizers with 60 or 80% of the recommended levels of NP gave significant increments in values of leaf photosynthetic pigments, photochemical activity, histological features, growth and yield attributes of maize except both plant height and number of rows per ear which were not significantly affected by fertilization treatments. The interactions between the studied factors had significant effects on some growth and yield attributes. These results are quite interesting as they refers to a complementary positive role between biofertization, mineral NP fertilization and soil moisture content and hence help in minimizing the use of mineral NP fertilizers beyond to 40%. Cerealin + Phosphorein + 60% NP under 16-days irrigation interval treatment can be suggested as a recommended treatment to obtain a promising maize grain yield, saving irrigation water and to minimize soil pollution.

Key words: Maize, irrigation, biofertilizers, P, N, grain yield.

INTRODUCTION

In Egypt, maize (*Zea mays* L.) cultivated area is expected to be extended to more than 1.79 million fad., (FAOSTAT, 2014). Optimal water management strategies thus become an important factor due to limitations in the supply of irrigation water caused by increase in rice cultivated area which receives a great part of irrigation water in the summer season. Water deficit is a polygenic stress, considered as one of the main abiotic stress, limiting the productivity of cereal crop and causes significant alternations in plant physiology and biochemistry (Al-Meselamani *et al*., 2012). It changes patterns of plant growth and development, depressed water potential, cell division, organ growth and net photosynthesis (Guttieri *et al*., 2001) and leads to a loss chlorophyll content which directly or indirectly transfer their effects to grains (Al-Meselamani *et al*., 2011). Several studies had carried out to find the effect of irrigation interval on maize yield and its attributes. These studies showed significant decrease in maize grain yield due to prolonging the irrigation interval or irrigation deficit. Assouline (2002), Oktem *et al*. (2003), Ibrahim *et al*. (2005), Hussein and El-Melegy (2006), Ibrahim and Kandil (2007), El-

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Hendawy *et al*. (2008), Mansouri-Far *et al*. (2010) and Hussein and Pibars (2012) reported that, irrigation deficit significantly decreased growth, yield and yield attributes of maize. On the other hand, the ear diameter and length did not show a significant decrease due to prolonging the irrigation interval (Sokht-Abandani and Ramezani, 2012). Hameedi *et al*. (2015) showed that, irrigation every 4 days gave highest plant height, and grain yield compared with irrigation every 7 and 10 days.

The use of mineral nitrogen (N) and phosphorus (P) fertilizers in maize fields is expensive and causes pollution to the environment. Hence, the use of biofertilizers might play important role in minimizing these problems. Application of nonsymbiotic N_2 fixing bacteria have been shown to enhance soil fertility and availability of nutrients for plants (Dodd *et al*., 1999 ; Cardoso and Kuyper, 2006) and to increase photosynthesis and water use efficiency. The composition of *Azosperillium, Azotobacter* and *Pseudomonas* could stimulate chlorophylls biosynthesis and its survival and decrease accessory pigments carotene and xanthophylls (Alireza *et al*., 2014). Many studies have shown that application of biofertilizers played an efficient role in sustaining maize production through improving soil chemical and biological properties. Inoculation of maize with *Rhodotorula* and *Azotobacter* with half of the recommended doses of NP induced results for growth attributes matched those of the recommended doses of NP (Afifi *et al*., 2003). El-Kholy *et al*. (2005) showed that, maize yield and its attributes responded well to biofertilization supported with half doses of NP (100 and 50 kg/fad., respectively) where the differences were not significant when compared with the positive control (100% NP). The superiority effect of biofertilizer can be attributed to the faster and higher uptake of some mineral nutrients specially P that become more available due to the effect of biofertilizer and supplying plant with available P, consequently causing increases in yield and yield components (Khalilian, 2006). The combinations of mycorrhiza and bacteria resulted in the highest increase in growth, yield attributing characters and yield of maize over the control by 20% (Soleimanzadeh and Ghooshchi, 2013). Sofy and Rashid (2014) reported that, application of 33.6 or 50.4 kg P/fad., with phosphate biofertilizer, is recommended to increase maize yield. The combination of biofertilizer and a half dose of NP mineral fertilizer, significantly increase growth and yield of maize (Triadiati and Mubarik, 2014).

Mineral fertilization with N was also reported to increase yield of maize and its components (El-Azab, 2012; Kandil, 2013; Abd El-Rheem *et al*., 2015; George *et al*., 2016). As well as, mineral fertilization with P was also reported to increase yield of maize (Saleem *et al*., 2003; Hussein, 2009; Masood *et al*., 2011; Omar, 2014 ; Abd El-Rheem *et al*., 2015).

Therefore, the present study seeks answers for the following two questions: 1. Is it possible to save one irrigation without any significant decrease in maize grain yield through prolonging the irrigation interval to 16 instead of 10 days? 2. Does biofertilization help in minimizing the use of mineral fertilization?

MATERIALS AND METHODS

The present study was conducted in the Agric. Experiment Station (Ghazala village), Fac. Agric., Zagazig Univ., Egypt (30.11°N, 31.41 °E) during two successive seasons (2015 and 2016) to find out the effect of two irrigation intervals (10 and 16 days) under four bio and mineral fertilization treatments on some physiological, anatomical features and productivity of maize using yellow maize cultivar single cross 168.

Studied Factors

Irrigation interval treatments

1. 10 days.
2. 16 days.

Fertilization treatments

1. 100% NP (mineral fertilizers) as recommended in experimental area (120 kg N and 15.5 P_2O_5/ fad.).
2. Cerealin + Phosphorein.
3. Cerealin + Phosphorein + 60% NP.
4. Cerealin + Phosphorein + 80% NP.

Before planting, maize seeds were inoculated with Cerealin biofertilizer contains *Azotobacter* strain as N_2 fixing bacteria and Phosphorine biofertilizer contains *Bacillus megtherium* var phosphaticum strain as P dissolving bacteria as commercial product both biofertilizers were produced by Agriculture Research Center, Giza, Egypt and used at the recommended dose (1 kg for each biofertilizer). The irrigation interval treatments started from the 3rd irrigation (43 and 49 days after planting in the 1st and 2nd seasons, respectively). In order to complete the addition of NP fertilizers, phosphorus as ordinary superphosphate (15.5% P_2O_5) was band placed at planting. Ammonium nitrate (33.5% N) was partly applied in two splits before the first and second irrigations at 21 and 33 days after planting (DAP). A split plot design with four replications was used, where the irrigation interval treatments were allocated in the main plots, whereas, the fertilization treatments were allocated in the sub plots. Yellow maize cultivar single cross 168 was planted on May 15th in both seasons. Each sub plot (3.5 m × 5 m) included 5 ridges 60 cm apart. Seeds were hand sown on one side of the ridge in hills 25 cm apart. Preceding crop in both seasons was wheat, maize grains were sown using seeding rate of 10 kg/fad. Plants were thinned to one plant per hill (28000 plants/fad.) before the first irrigation (21 DAP). Soil samples were taken at a depth of 0 - 30 cm before planting to determine soil physical and chemical properties at the Central Laboratory, Faculty of Agriculture, Zagazig University, Zagazig, Egypt (Table 1).

Data Recorded

Photosynthetic pigments

The photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) were extracted from fresh leaf samples according to Fadeel's method (Fadeel, 1962), and determined spectro-photo-chemically and then calculated using the formula adapted by Wettstein (1957)

Photochemical activity

Photochemical activity in fresh ear leaf were determined according to Jagendorf (1956) and modified by Avron (1960) using Ferricyanide technique.

Anatomical responses

Microtechnique procedures given by Nassar and El-Sahhar (1998) were followed. At 45 day after sowing, through the second growing season, two plants/ treatment were subjected to anatomical studies. Specimens from the blades of ear leaves were obtained from various treatments. Specimens were killed and fixed for at least 48 hrs in FAA solution, (10 ml formalin, 5 ml glacial acetic acid and 85 ml ethyl alcohol 70%), washed in 50% ethyl alcohol and dehydrated in a series of n-butyl alcohol before embedded in paraffin wax (mp 56-58^{o}C). Transverse sections which were cut on a rotary microtome to a thickness of 20 microns were stained with crystal violet/erythrosin before mounting in Canada balsam.

Maize yield and yield attributes

At silking (60 DAP), a sample of five plants was taken from the second ridge where plant height, stem diameter and ear leaf area were recorded. At harvest, (120 DAP), the following yield attributes were recorded on ten maize plants and ears: ear diameter (cm), ear length (cm), row number per ear (No.), grain number per row (No.), grain number per ear (calculated), hundred grain weight (g) and grain weight per ear (g). Also, the following final yield traits were recorded from the two central ridges: grain yield (ton/fad.) at grain moisture content of 15.5%, ear, biological, stover yields (ton/fad.) and harvest index (HI) *i.e.,* grain to biological yields in percentage.

Table 1. Physical and chemical analyses of the experimental soil site at 30 cm depth (average of two seasons)

Organic matter (%)	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})	pH[a]	Texture
1.02	0.05	8.95	148	7.99	Clay

a: Soil suspension

Statistical Analysis

Data were statistically analyzed according to Steel *et al*. (1997) by using MSTAT-C (1991) where statistical program Version 2.1 was used for analysis of variance (ANOVA). A combined analysis was undertaken for the data of the two seasons after testing the homogeneity of the experimental errors. Duncan Multiple range test was used to compare statistical significant differences (Duncan, 1955).

RESULTS AND DISCUSSION

Photosynthetic Pigments and Photochemical Activity

Irrigation interval effect

Results in Tables 2 and 3 illustrate variations among irrigation intervals for the concentration of chlorophyll content (a, b, a+b), carotenoids and photochemical activity of maize leaves. The results showed that chlorophyll content (a, b, a+b), carotenoids and photochemical activity values were decreased by increasing irrigation interval from 10 to 16 days. Similar trend was reported by Manivannan *et al*. (2007), Kiani *et al*. (2008) and Farooq *et al*. (2009). They noticed that, drought stress produced changes in the ratio of chlorophyll a, b and carotenoids explanation of such finding was mentioned by Reddy *et al*. (2004) who showed that limitation of photosynthesis under drought metabolic impairment is more complex phenomenon than stomatal limitation and mainly through reducing photosynthetic pigments contents. Moreover, drought stress decreases progressively CO_2 assimilation rates due to the reduction of stomatal conductance, and the reduction in the contents and activities of photosynthetic carbon reduction cycle enzymes, including the key enzyme, ribulose-1,5-bisphosphate carboxylase/ oxygenase. Abdul Jaleel *et al*. (2009) recorded that water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield. These changes are mainly related to altered metabolic functions, one of those is either loss or reduced synthesis of photosynthetic pigments. These changes in the amounts of photosynthetic pigments are closely associated to plant biomass yield. The drought induced changes in morphological, physiological and pigments composition in the plants. The reduction of photosynthetic activity under drought stress may be due to stomatal or non-stomatal mechanisms (Del Blanco *et al*., 2000; Samarah *et al*., 2009).

Fertilization treatments effect

The effect of bio-fertilizer Cerealin and Phosphorein with inorganic N and P were enhanced significantly chlorophyll content (a, b, a + b), carotenoids and photochemical activity of maize leaves. The results showed that higher averages of chlorophyll content (a, b, a + b), carotenoids and photochemical activity values were almost obtained by 80% NP combined with inoculation by Cerealin and Phosphorein followed by 60% NP with inoculation by Cerealin and Phosphorein and 100 % NP, while the lowest averages of chlorophyll content (a, b, a + b), carotenoids and photochemical activity were recorded by Cerealin with Phosphorein (Tables 2 and 3). The obtained results are in agreement with those reported by Agamy (2004) who reported that the stimulative effect of NPK and biofertilizers on increasing chlorophyll may be due to the role of NPK in enhancement cholorphyll formation. Also, Hossein and Farshad (2013) found that inoculation maize plant with *Azotobacter chorococum* and *Azospirillum lipoferum* significantly increased leaf chlorophyll as compared to control. While, Alireza *et al*. (2014) indicated that application of *Azosperillium*, *Azotobacter* and *Pseudomonas* increased chlorophyll content (a, b and a + b) and reduce carotenoids of wheat plant. Inoculation with *Azospirillum brasilense* and *Bacillus subtilis* enhanced cholorphyll concentration of wheat plant (Panwar, 2000). The changes in chlorophyll concentration might be ascribed to the influence of mineral and biofertilizers on the development processes leading to synthesis of chloroplasts and chlorophyll, and/or to effects on activities of chloroplast enzymes. Furthermore, the increase of chlorophyll concentration could be attributed to the increase of N and Mg concentrations which known to be main components of chlorophyll molecule (Mohsen and Aly, 2004). It seems reasonable to suggest that, significant increase in photochemical activity as a result of mineral and biofertilizer treatments may be due to the role of nitrogen in the increase of photosynthetic activity of the chloroplast (Nilovskaya *et al*., 1985).

Table 2. Chlorophyll a, chlorophyll b and chlorophyll a + chlorophyll b values of maize leaves as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interaction	Chlorophyll a (mg/g FW)			Chlorophyll b (mg/g FW)			Chlorophyll a + Chlorophyll b (mg/g FW)		
	2015	2016	Comb.	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)									
10 days	1.64	1.62	1.63	0.62	0.60	0.61	2.26	2.22	2.24
16 days	1.48	1.42	1.45	0.46	0.45	0.46	1.93	1.88	1.90
F-test	NS	NS	**	**	NS	**	*	NS	**
Fertilization treatments (F)									
100 % NP	1.54 ab	1.53 b	1.53 b	0.53 a	0.51 b	0.52 b	2.07 a	2.03 b	2.05 b
Cerealin + Phosphorein	1.44 b	1.38 c	1.41 c	0.46 b	0.47 c	0.46 c	1.90 b	1.85 c	1.87 c
Cerealin + Phosphorein + 60 % NP	1.59 a	1.51 b	1.55 b	0.57 a	0.58 a	0.57 a	2.16 a	2.09 b	2.13 b
Cerealin + Phosphorein + 80 % NP	1.67 a	1.66 a	1.66 a	0.59 a	0.57 a	0.58 a	2.26 a	2.22 a	2.24 a
F. test	*	**	**	**	NS	**	**	**	**
Interaction:									
I × F	NS	NS	NS	NS	NS	NS	NS	NS	NS

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Table 3. Caroteniods and photochemical activity values of leaf tissue homogenate in maize as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interaction	Caroteniods (mg/g FW)			Photochemical activity (Micromole/mg chl. per10min.)		
	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)						
10 days	1.15	1.13	1.14	184.9	188.4	186.7
16 days	1.01	1.02	1.02	169.3	168.5	168.9
F-test	*	NS	**	*	*	**
Fertilization treatments (F)						
100 % NP	1.08 a	1.08 a	1.08 a	177.8 a	180.4 b	179.1 b
Cerealin + Phosphorein	0.98 b	0.95 b	0.96 b	168.7 b	167.0 c	167.8 c
Cerealin + Phosphorein + 60% NP	1.12 a	1.13 a	1.13 a	180.2 a	182.9 a	181.5 a
Cerealin + Phosphorein + 80% NP	1.15 a	1.14 a	1.15 a	181.7	183.6 a	182.7 a
F. test	**	**	**	**	**	**
Interaction						
I × F	NS	NS	NS	**	**	**

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Interaction effect

The interaction of mineral and bio-fertilizer with irrigation intervals showed insignificant impact on chlorophyll a, chlorophyll b, chlorophyll a+b and carotenoids of maize plant during two successive season, but appeared to be highly significant on photochemical activity assessment during two successive seasons. It is likely to mention that fertilization as a component in the interaction masked the bad effect of water stress and gained significantly the higher photochemical activity values comparing with untreated plants.

Anatomical Responses

Irrigation interval effect

Results presented in Table 4 and Fig. 1 show that water stress as16 days irrigation interval decreased thickness and width of midrib due to decrease in the thickness and width of midrib vascular bundle. In addition, decreased leaf blade thickness, due to decrease in thickness of mesophell tissue. These results are in harmony with the findings of Khodos *et al*. (1976) and El-Sharkawi *et al*. (1999) on wheat plant. In this connection, Khafagy *et al*. (2009) stated that drought stress may have an inhibition effect on the activity of the various initial cells forming the leaf blade with regard to cell division and enlargement. Generally, the high level of drought stress caused a reduction in the conductive tissues of wheat plant. The decrease in mesophyll tissue, xylem and phloem leads to slow rate in the translocation of photoassimlates towards the developing grains. Furthermore, the decrease in size of vascular bundle in leaf blade result in lowering the accumulation of necessary water required for photosynthesis.

Fertilization treatments effect

Application of 80% NP + biofertilizers recorded the highest averages of blade thickness, mesophyll tissue thickness, length and width of midrib, length and width of midrib vascular bundle and diameter of vessel, followed by 60 % NP + biofertilizers and 100% NP treatment. While, single application of biofertilizers gave the lowest averages of leaf feature (Table 4). The effect of biofertilizer could be confined mainly in improving N_2 fixation, increasing the release of P in the soil, which is reflected on P activity and improving plant growth regulators, these effects may lead to activation cell division and enlargement (Patil, 1985). Similar results were obtained by Medani *et al*. (2000) on sugar beet and on wheat plant and by Matter and Mohamed, (2001) on *Caleudula offienalis* L. Biofertilizers application considered as addition nutrients for plant growing in such poor soil which stimulate the growth of stem and leaf tissue of plants (Mohamed and Medani, 2005).

Table 4. Mean values in micron of certain histological features of fourth leaf blade on maize stem as affected by irrigation intervals and fertilization treatments during the second growing season (2016)

Mail effect	Blade thic. (µ)	Mesophyll tissue thic. (µ)	Length of midrib (µ)	Width of midrib (µ)	Length of midrib VB (µ)	Width of midrib VB (µ)	Diameter of vessel average (µ)
Irrigation intervals (I)							
10 days	250.0	191.5	1500.2	2731.5	292.6	252.7	17.85
16 days	207.5	133.0	1252.9	1359.0	212.8	223.4	14.28
Fertilization treatments (F)							
100% NP	218.1	159.6	1399.2	1954.4	250.0	239.4	14.28
Cerealin + Phosphorein	175.6	111.7	1064.0	1545.3	186.2	196.8	13.09
Cerealin + Phosphorein + 60% NP	255.4	180.9	1463.0	2136.2	282.0	244.7	17.85
Cerealin + Phosphorein + 80% NP	266.0	196.8	1580.0	2545.2	292.6	271.3	19.04

Abbr.: Thic. (Thickness) and V.B. (Vascular bundles)

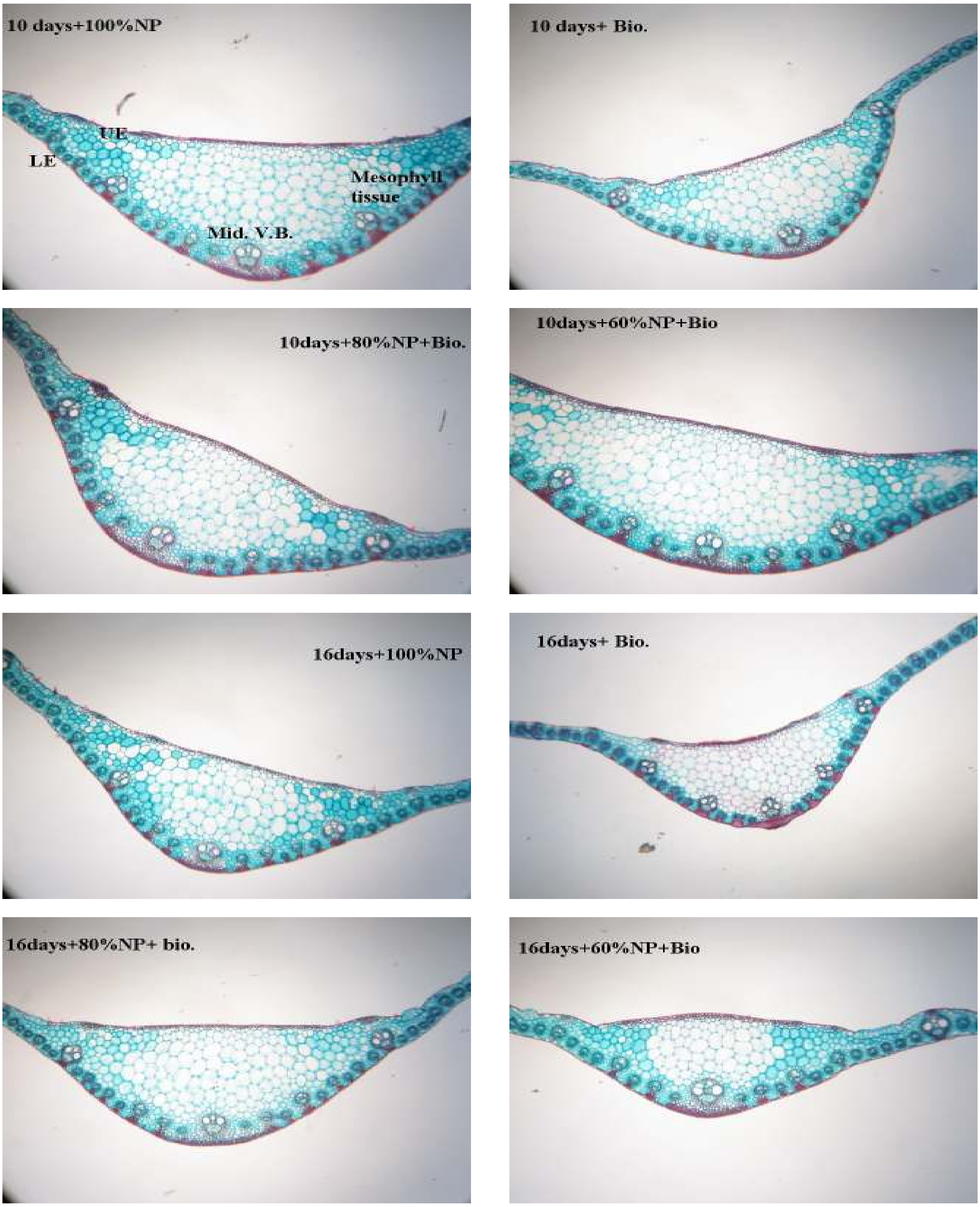

Fig. 1. Transverse sections in the fourth leaf blade on maize stem as affected with the interaction between mineral and biofertilizers and two levels of irrigation intervals during the second growing season (2016)

*UE: Upper Epidermis, LE: lower Epidermis, Mid V.B.: midrib vascular bund.

Maize Grain Yield Attributes

Plant height and diameter and ear leaf area

Irrigation interval effect

In both seasons and their combined, irrigation interval was without significant effect on plant height or stem diameter as well as ear leaf area. However, the combined analysis detected significant differences in stem diameter where, irrigation interval every 10 days recorded higher averages compared with irrigation every 16 days (Table 5). These results does not agree with those reported by Ibrahim *et al*. (2005), Ibrahim and Kandil (2007), El-Hendawy *et al*. (2008), Mansouri-Far *et al*. (2010) and Hussein and Pibars (2012). But, Sokht-Abandani and Ramezani (2012) reported that, ear diameter and length did not show a significant decrease due to prolonging the irrigation interval.

Fertilization treatments effect

In both seasons and their combined analysis a significant increase could be detected in stem diameter due to combined application of biofertilizers with mineral NP or full dose NP compared with single application of biofertilizers. However, in both seasons and their combined analysis significant differences were detected among the four fertilization treatments where Cerealin + Phosphorein + 80% NP treatment gave the highest ear leaf area average whereas, single application of biofertilizers recorded the lowest averages. Otherwise, the fertilization treatments had no significant effects on plant height (Table 5). Similar significant effects were reported by Afifi *et al*. (2003), El-Kholy *et al*. (2005), Khalilian (2006), Soleimanzadeh and Ghooshchi (2013), Triadiati and Mubarik (2014), Abd El-Rheem *et al*. (2015) and George *et al*. (2016).

Interaction effect

According to the combined analysis, stem diameter (Table 5-a) was significantly affected by the fertilization treatments × irrigation interval interaction. Stem diameter was significantly increased by adding 60 or 80% NP with biofertilizer under both irrigation intervals. This effect may be reflected to soil moisture which is necessary to active microorganisms under field irrigated every 10 days. Also, this effect refer to a complementally positive role between biofertilizers, mineral NP fertilization and the water supply of maize plants.

Ear length and diameter

Irrigation interval effect

In both seasons and their combined, the irrigation interval was without any significant effect on maize ear length and diameter (Table 6). These results are in adverse trend with those reported by Assouline (2002), Oktem *et al*. (2003), Ibrahim *et al*. (2005), Hussein and El-Melegy (2006), El-Hendawy *et al*. (2008) and Hussein and Pibars (2012).

Fertilization treatments effect

In both seasons and their combined analysis a significant increase could be detected in maize ear length and diameter due to combined application biofertilization with 60 and 80% NP or full dose NP compared with single application of biofertilizers treatment (Table 6). These results are in harmony with those obtained by Afifi *et al*. (2003), El-Kholy *et al*. (2005), Khalilian (2006), Sofy and Rashid (2014), Triadiati and Mubarik (2014) and Abd El-Rheem *et al*. (2015).

Interaction effect

The interaction between factors under study was without significant effect of ear length and diameter.

Row number per ear and grain number per row and ear

Irrigation interval effect

The results showed that, the irrigation interval was without any significant effect on number of rows per ear or number of grains per row and number of grains per ear. However, the combined analysis detected significant decrease in number of grains per row due to prolonging the irrigation interval to 16 days (Table 7). This insignificant effect was previously observed in plant height, stem diameter and ear leaf area (Table 5) and ear length and diameter (Table 6) and could account for the results obtained herein. These results are not in accordance with those reported by Ibrahim *et al*. (2005), Hussein and El-Melegy (2006), Ibrahim and Kandil (2007), El-Hendawy *et al*. (2008), Mansouri-Far *et al*. (2010) and Hussein and Pibars (2012).

Table 5. Plant height, stem diameter and ear leaf area of maize as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interaction	Plant height (m)			Stem diameter (cm)			Ear leaf area (cm^2)		
	2015	2016	Comb.	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)									
10 days	2.81	2.90	2.86	2.25	2.31	2.28	772.8	828.3	800.5
16 days	2.75	2.90	2.82	2.14	2.14	2.14	771.4	819.6	795.5
F-test	NS	NS	NS	NS	NS	*	NS	NS	NS
Fertilization treatments (F)									
100% NP	2.71	2.94	2.82	2.20 a	2.19 a	2.20 a	732.0 c	815.3 b	773.6 c
Cerealin + Phosphorein	2.66	2.94	2.80	2.04 b	2.09 b	2.07 b	688.5 d	756.3 c	722.4 d
Cerealin + Phosphorein + 60% NP	2.90	2.85	2.88	2.31 a	2.33 a	2.32 a	780.5 b	827.5 b	804.0 b
Cerealin + Phosphorein + 80% NP	2.83	2.88	2.86	2.24 a	2.27 a	2.26 a	887.3 a	896.8 a	892.0 a
F. test	NS	NS	NS	**	**	**	**	**	**
Interaction									
I × F	NS	NS	NS	NS	*	**(5-a)	**	NS	NS

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Table 5-a. Stem diameter (cm) of maize as affected by irrigation intervals and fertilization treatments interaction (combined data)

Irrigation intervals	Fertilization treatments			
	100% NP	Cerealin + Phosphorein	Cerealin + Phosphorein + 60% NP	Cerealin + Phosphorein + 80% NP
10 days	B 2.23 a	C 2.09 a	A 2.44 a	A 2.36 a
16 days	A 2.16 a	B 2.04 a	A 2.20 b	A 2.15 b

Table 6. Ear length and diameter of maize as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interaction	Ear length (cm)			Ear diameter (cm)		
	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)						
10 days	19.07	19.71	19.39	4.61	4.62	4.62
16 days	17.74	19.18	18.46	4.58	4.62	4.60
F-test	NS	NS	NS	NS	NS	NS
Fertilization treatments (F)						
100% NP	18.51 a	20.04 a	19.28 a	4.61 a	4.65 a	4.63 a
Cerealin + Phosphorein	15.29 b	17.46 b	16.38 b	4.49 b	4.56 b	4.52 b
Cerealin + Phosphorein + 60% NP	19.58 a	20.33 a	19.95 a	4.65 a	4.67 a	4.66 a
Cerealin + Phosphorein + 80% NP	20.25 a	19.95 a	20.10 a	4.62 a	4.60 b	4.61 a
F. test	**	**	**	**	**	**
Interaction						
I × F	NS	NS	NS	NS	**	NS

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Table 7. Number of rows per ear, number of grains per row and number of grains per ear of maize as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interaction	Number of rows / ear			Number of grains / row			Number of grains / ear		
	2015	2016	Comb.	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)									
10 days	14.90	14.70	14.80	42.46	44.39	43.43	632.0	652.2	642.1
16 days	15.18	15.13	15.15	39.49	42.96	41.23	600.5	650.2	625.3
F-test	NS	NS	NS	NS	NS	*	NS	NS	NS
Fertilization treatments (F)									
100% NP	15.35	15.25	15.30	41.63 a	43.88 a	42.75 a	637.1 a	667.3 a	652.2 a
Cerealin + Phosphorein	14.75	14.65	14.70	35.05 b	40.75 b	37.90 b	518.1 b	598.0 b	558.0 b
Cerealin + Phosphorein + 60% NP	14.85	14.55	14.70	43.08 a	44.83 a	43.95 a	639.8 a	652.9 a	646.3 a
Cerealin + Phosphorein + 80% NP	15.20	15.20	15.20	44.15 a	45.25 a	44.70 a	670.0 a	686.7 a	678.3 a
F. test	NS	NS	NS	**	*	**	**	**	**
Interaction:									
I × F	NS	NS	NS	NS	NS	NS	NS	NS	NS

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Fertilization treatments effect

Fertilization treatments were without significant effect on number of rows per ear in both seasons and their combined. Otherwise, In both seasons and their combined analysis a significant increase could be detected in number of grains per row and number of grains per ear due to combined biofertilization with 60 and 80% NP or full dose NP compared with single application of biofertilization (Table 7). Similar significant effects were reported by El-Kholy *et al*. (2005), Khalilian, (2006), Hussein, (2009), Masood *et al*. (2011), El-Azab, (2012), Kandil, (2013), Omar, (2014) and George *et al*. (2016).

Interaction effect

Interaction effect between irrigation interval and fertilization treatments was insignificant regarding each of number of rows per ear, number of grains per row or per ear in the combined analysis (Table 7). This clearly indicate the independence of the main effects of the factors in affecting number of rows per ear and number of grains per row and grains per ear.

Grain weight and grain yield

Irrigation interval effect

Though irrigation interval did not reflect any significant effect on 100-grain weight in both seasons, however, the combined analysis detected significant decrease in 100- grain weight due to prolonging the irrigation interval to 16 days. In the first season and the combined analysis significant increases could be detected in grain weight per ear and grain yield per fad., due to narrowing the irrigation interval to 10 days (Table 8). Similar findings were reported by Assouline (2002), Oktem *et al*. (2003), Ibrahim *et al*. (2005), Ibrahim and Kandil (2007), El-Hendawy *et al*. (2008), Mansouri-Far *et al*. (2010), Hussein and Pibars (2012) and Hameedi *et al*. (2015).

Fertilization treatments effect

In both seasons and their combined, the fertilization treatments had significant improving effects on 100-grain weight, grain weight per ear and grain yield/fad., (Table 8). Similar significant increases were observed in all yield attributes (Tables 5, 6 and 7). The combined analysis detected significant increase in 100-grain weight due to combined application of biofertilizers with 80 % NP whereas, the rest of the fertilization treatments were at par with lower averages. However, in both seasons and their combined it is worthy to notice a significant differences among the four fertilization treatments where, combined application of biofertilization with 60 or 80% NP had the higher values of grain weight per ear and grain yield per fad., whereas, single application of biofertilizers had the lowest ones. These results are in harmony with those obtained by Afifi *et al*. (2003), El-Kholy *et al*. (2005), Khalilian (2006), Sofy and Rashid (2014), Triadiati and Mubarik (2014) and Abd El-Rheem *et al*. (2015).

Interaction effect

According to the combined analysis, grain weight per ear (Table 8-a) and grain yield per fad., (Table 8-b) were significantly affected by the interaction between irrigation interval x fertilization treatments. It is evident from Table 8-a that, grain weight per ear was significantly increased with combined biofertilization with 60 and 80% NP or full dose NP compared with single application of biofertilizers in the irrigation interval every 10 days. Single application of biofertilizers recorded the lowest average with the irrigation interval every 16 days. The effect of irrigation interval × fertilization treatments interaction on grain yield per fad., is presented in Table 8-b. Under 10-irrigation interval, the highest grain yield per fad., (3.68 ton/fad.) was obtained by the combined application of biofertilizers with 80% NP whereas, use of biofertilization alone had the lowest grain yield (2.49 ton/ fad.). Likewise, under 16-irrigation interval, the highest grain yield per fad., (3.39 ton/fad.) was obtained by the application of biofertilizers with 60% NP while, single application of biofertilizers had the lowest yield (2.16 ton/ fad.). These data are quite interesting as they refer to a complementary positive role between biofertizers, mineral NP fertilizers and soil moisture content and hence help in minimizing the use of mineral NP fertilizers beyond to 20%. Ati *et al*. (2013) showed that, the irrigation

Table 8. 100-grain weight, grain weight per ear and grain yield per fad., of maize as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interaction	100- grain weight (g)			Grain weight per ear (g)			Grain yield (ton/ fad.)		
	2015	2016	Comb.	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)									
10 days	29.74	29.33	29.54	190.6	187.9	189.3	3.14	3.35	3.25
16 days	28.71	27.57	28.14	149.5	161.5	155.5	2.76	3.05	2.90
F-test	NS	NS	*	*	NS	*	*	NS	*
Fertilization treatments (F)									
100% NP	28.18 ab	29.63 a	28.90 b	174.8 b	180.3 b	177.5 b	2.99 b	3.29b	3.14 b
Cerealin + Phosphorein	28.06 b	26.99 b	27.53 b	142.3 c	140.8 c	141.5 c	2.17 c	2.48c	2.32 c
Cerealin + Phosphorein + 60% NP	29.40 ab	27.20 b	28.30 b	183.0 a	189.0 a	186.0 a	3.27 a	3.53a	3.40 a
Cerealin + Phosphorein + 80% NP	31.26 a	29.99 a	30.63 a	180.3 a	188.8 a	184.5 a	3.37 a	3.50a	3.43 a
F. test	*	*	**	**	**	**	**	**	**
Interaction:									
I × F	NS	NS	NS	**	**	**(8-a)	**	**	**(8-b)

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Table 8-a. Grain weight per ear (g) of maize as affected by irrigation intervals and fertilization treatments interaction (combined data)

Irrigation intervals	Fertilization treatments			
	100% NP	Cerealin + Phosphorein	Cerealin + Phosphorein + 60% NP	Cerealin + Phosphorein + 80% NP
10 days	A 197.0 a	B 173.0 a	A 196.0 a	A 191.0 a
16 days	B 158.0 b	C 110.0 b	A 176.0 b	A 178.0 a

Table 8-b. Grain yield (ton/ fad.) of maize as affected by irrigation intervals and fertilization treatments interaction (combined data)

Irrigation intervals	Fertilization treatments			
	100% NP	Cerealin + Phosphorein	Cerealin + Phosphorein + 60% NP	Cerealin + Phosphorein + 80% NP
10 days	B 3.40 a	C 2.49 a	B 3.41 a	A 3.68 a
16 days	C 2.87 b	D 2.16 b	A 3.39 a	B 3.18 b

improves the efficiency of fertilization. It is worthy to notice that no significant difference was noticed between the two potent treatments of Cerealin + Phosphorein + 80% NP under 10-days irrigation interval and Cerealin + Phosphorein + 60% NP under 16-days irrigation interval. Therefore, the latter treatment can be suggested as a recommended treatment to obtain a promising maize grain yield, saving irrigation water and to minimize soil pollution.

Ear, stover and biological yields per fad., and harvest index

Irrigation interval effect

In the first season and the combined analysis significant increases could be detected in ear and biological yields per fad., due to narrowing the irrigation interval to 10 days. In the same manner, the combined analysis detected significant decrease in stover yield per fad., and HI due to prolonging the irrigation interval to 16 days (Table 9). These results are in accordance with those reported by Oktem *et al*. (2003), Ibrahim *et al*. (2005), Ibrahim and Kandil (2007), El-Hendawy *et al*. (2008) and Hussein and Pibars (2012).

Fertilization treatments effect

In both seasons and their combined, the fertilization treatments showed significant increasing effect on ear, stover and biological yields as well as HI. The combined application of biofertilizers with 60 or 80% NP had the higher ear, biological yields per fad., and HI averages, however the application of biofertilizers only or 100% NP treatments recorded the low averages. Furthermore, biofertilization treatment had a significant effect on stover yield per fad., in both seasons and their combined where, it was significantly decreased due to single application of biofertilizers compared with combined application of biofertilizers with 60 and 80% NP or full dose NP (Table 9). Similar findings were reported by El-Kholy *et al*. (2005), Khalilian, (2006), Hussein, (2009), Masood *et al*. (2011), El-Azab, (2012), Kandil, (2013), Omar, (2014) and George *et al*. (2016).

Interaction effect

According to the combined analysis, ear yield per fad (Table 9-a), biological yield per fad., (Table 9-b) and HI (Table 9-c) were significantly affected by the irrigation intervals x fertilization treatments. It is evident from Table 9-a that, ear yield per fad., was significantly increased with combined biofertilization with 80% NP compared with the rest fertilization treatments under the irrigation interval every 10 days. While, in the irrigation interval every 16 days, the highest ear yield per fad., was obtained due to addition of biofertilizers with 60% NP. Otherwise, single application of biofertilizers recorded the lowest averages. A look in Table (9-b) regarding this interaction effect on biological yield per fad., showed that, the combined application of biofertilizers with 60 or 80% NP and 100% NP had the higher biological yield, however the use of biofertilization treatment alone recorded the lowest average under the irrigation interval every 10 days. Under 16-days irrigation interval, the highest biological yield per fad., was obtained by the combined of biofertilizers with 60% NP. On contrary, single application of biofertilizers had the lowest biological yield average.

The highest HI average (Table 9-c) was obtained due to combined application of biofertilizers with 80% NP whereas, 100% NP treatment had the lowest HI average under 10-days irrigation interval. Likewise, under 16-days irrigation interval, the highest HI average was obtained due to combined of biofertilizers with 60% NP while, single application of biofertilizers had the lowest HI average.

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Table 9. Ear, stover and biological yields (ton/ fad.) and harvest index of maize as affected by irrigation intervals and fertilization treatments and their interaction in both seasons and their combined

Main effects and interactions	Ear yield (ton/ fad.)			Stover yield (ton/ fad.)			Biological yield (ton/fad.)			Harvest index (%)		
	2015	2016	Comb.	2015	2016	Comb.	2015	2016	Comb.	2015	2016	Comb.
Irrigation intervals (I)												
10 days	3.78	4.05	3.92	3.05	3.55	3.30	6.83	7.60	7.21	46.29	44.29	45.29
16 days	3.38	3.74	3.56	2.66	3.30	2.98	6.04	7.04	6.54	45.81	43.39	44.60
F- test	*	NS	**	NS	NS	*	*	NS	**	NS	NS	*
Fertilization treatments (F)												
100 % NP	3.64b	4.01b	3.82b	3.08a	3.49a	3.28a	6.71a	7.49b	7.10b	44.85b	44.05ab	44.45b
Cerealin + Phosphorein	2.67c	3.06c	2.87c	2.26b	2.87b	2.57b	4.93b	5.93c	5.43c	44.45b	42.02b	43.23b
Cerealin + Phosphorein + 60 % NP	3.97a	4.30a	4.13a	2.99a	3.60a	3.29a	6.96a	7.89a	7.42a	47.38a	45.07a	46.22a
Cerealin + Phosphorein + 80 % NP	4.04a	4.22a	4.13a	3.09a	3.76a	3.42a	7.13a	7.98a	7.55a	47.53a	44.22a	45.88a
F. test	**	**	**	**	**	**	**	**	**	**	*	**
Interaction												
I × F	**	**	**(9-a)	NS	**	NS	**	**	**(9-b)	*	**	**(9-c)

*,** and NS indicate statistically significant at 0.05 and 0.01 levels and not significant of differences, respectively.

Table 9-a. Ear yield (ton/fad.) of maize as affected by irrigation intervals and fertilization treatments interaction (combined data)

Irrigation intervals	Fertilization treatments			
	100% NP	Cerealin + Phosphorein	Cerealin + Phosphorein + 60% NP	Cerealin + Phosphorein + 80% NP
10 days	B 4.15 a	C 2.98 a	B 4.15 a	A 4.38 a
16 days	C 3.49 b	D 2.75 b	A 4.11 a	B 3.88 b

Table 9-b. Biological yield (ton/fad.) of maize as affected by irrigation intervals and fertilization treatments interaction (combined data)

Irrigation intervals	Fertilization treatments			
	100% NP	Cerealin + Phosphorein	Cerealin + Phosphorein + 60% NP	Cerealin + Phosphorein + 80% NP
10 days	A 7.90 a	B 5.51 a	A 7.59 a	A 7.85 a
16 days	B 6.30 b	C 5.35 a	A 7.25 a	A 7.25 b

Table 9-c. Harvest index (%) of maize as affected by irrigation intervals and fertilization treatments interaction (combined data)

Irrigation intervals	Fertilization treatments			
	100% NP	Cerealin + Phosphorein	Cerealin + Phosphorein + 60% NP	Cerealin + Phosphorein + 80% NP
10 days	B 43.09 b	AB 45.50 a	AB 45.54 a	A 47.03 a
16 days	A 45.80 a	B 40.97 b	A 46.90 a	A 44.72 b

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تأثير فترات الري والتسميد الحيوي والمعدني والتفاعل بينهما علي بعض الصفات الفسيولوجية والتشريحية وإنتاجية الذرة الشامية

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أجريت هذه الدراسة في مركز بحوث التجارب الزراعية، كلية الزراعة، جامعة الزقازيق، محافظة الشرقية خلال الموسمين الزراعيين ٢٠١٥ - ٢٠١٦، حيث تم دراسة تأثير كل من فترات الري (١٠ و ١٦ يوم) تحت أربع معاملات سمادية مختلفة من التسميد المعدني والحيوي وذلك علي بعض الصفات الفسيولوجية والتشريحية ومحصول الذرة الشامية الصفراء (صنف هجين فردي ١٦٨) ويمكن تلخيص أهم النتائج المتحصل عليها علي النحو التالي: كان لفترة الري تأثيراً معنوياً علي مؤشرات النمو والصفات الفسيولوجية وكذلك محصول الذرة الشامية/ فدان، حيث أدى إطالة فترة الري كل ١٦ يوم إلي انخفاض معنوي في كل من مؤشرات النمو والصفات الفسيولوجية ومعظم مؤشرات محصول الذرة الشامية باستثناء كل من ارتفاع النبات، مساحة ورقة الكوز، طول وقطر الكوز، عدد سطور الكوز وعدد حبوب الكوز والتي لم تتأثر معنويا بفترة الري وذلك خلال التحليل التجميعي للموسمين، أدى التسميد الحيوي والمعدني إلي تأثير معنوي علي مؤشرات النمو والصفات الفسيولوجية وكذلك محصول الذرة الشامية/فدان، حيث أدي إضافة التسميد الحيوي مع إضافة ٦٠ أو ٨٠% من السماد النيتروجيني والفوسفاتي المعدني إلي زيادة معنوية في مؤشرات النمو والمحصول باستثناء ارتفاع النبات وعدد سطور الكوز والتي لم تتأثر معنوياً بالمعاملات السمادية المختلفة، كان هناك تأثير معنوي لتداخل الفعل بين عوامل الدراسة علي بعض مؤشرات النمو والمحصول تحت الدراسة، والذي أتضح منه أن هناك دور تكميلي بين التسميد الحيوي والمعدني ومحتوي الرطوبة بالتربة في ترشيد استخدام الأسمدة المعدنية بمقدار ٤٠%، وتوصي الدراسة تحت نفس الظروف باستخدام السماد الحيوي السريالين + الفوسفورين + ٦٠% من المعدلات الموصي بها من الأسمدة النيتروجينية والفوسفاتية وجدولة الري كل ١٦ يوم عند زراعة الذرة الشامية الصفراء لتحقيق أفضل محصول حبوب/فدان وترشيد استخدام مياه الري والحد من تلوث التربة.

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