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Article

Determination of Grain Yield Inputs of the Maize Hybrid Giza 168 Using a Six-Factor Central Composite Design in Mediterranean Regions Under Irrigation

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Abstract

The maize single hybrid Giza 168 was evaluated for grain yield in a six-factor central composite design in 2015 and 2016 summer seasons. The six factors included; surface irrigation level (I), potassium (K), phosphorus (P), nitrogen (N), sowing date (SD), and plant density (PD). The CROPWAT schedule module was applied for evaluation of irrigation practices and to develop alternative improved water delivery schedules. The six studied factors explained 57% of the variation in grain yield, with significant linear effects for PD (0.48*), I×K interaction (-0.45*), and P×N interaction (-0.69*). The highest grain yields (8.05 and 8.06 t/ha) were obtained from two combinations, i.e., high irrigation with high K, low P, high N, late SD, and high PD; and low irrigation with high K, high P, low N, late SD, and low PD, respectively.

Simulation of irrigation scheduling indicated that the quantity of irrigation water could be reduced by 22% and the irrigation interval extended to 15 days without any loss in grain yield. The results showed that application of 270 kg N/ha, 100 kg K2O/ha, 34.5 kg P2O5/ha, and sowing at 20 to 30 May with a plant density of 65,000 plants/ha will realize the highest yield potential of the hybrid Giza 168.

Keywords: Zea mays L., six-factor central composite design, grain yield, CROPWAT

1. Introduction

Productivity of maize in Mediterranean regions, as in other field crops, is affected by numerous factors; however, agricultural inputs and practices are the main determinants of proper growth and grain yield. These include the choice of a suitable sowing date to provide the plants with ideal environmental conditions for growth and transition from the vegetative to productive stage and to avoid biotic stresses (diseases and insects) at critical growth stages. Differences in sowing dates can greatly affect maize production. For example, Jaliya et al. (2008) and Rah Khosravani et al. (2017) reported that the early sowing in the10th and 15th of June, respectively of maize resulted in higher grain yield as compared to later sowings on 30th June and 1st of July. However, Dahmardeh and Dahmardeh (2010) found that late sowing in August gave higher yields than did early sowing in July. Also, seeding at the appropriate plant density will increase yield by decreasing intra-crop competition and realizing optimum or near-optimum stand at harvest. Intermediate plant density, ranging from 60,000– 66,000 plants/ha, gave higher grain yield in comparison to lower or higher densities (Turgut et al. 2005; Ramu and Reddy, 2007 and Abuzar et al., 2011). Moreover, the interaction between plant density and nitrogen (N) level plays a main role in maize production. Dahmardeh (2011) and Zakir et al. (2017) reported that, high plant density (66,000-100,000 plants/ha) gave higher grain yield with high N levels (300-350 kg N/ha).

Similarly, water plays an essential role in germination, growth, nutrient and photosynthates translocation, and facilitation of biochemical processes in the plant, and governs pollination and fertilization. Hence, determination of water requirements is necessary to avoid either the drastic effects of drought or excessive irrigation on plant growth and productivity. Several studies have reported that shortening irrigation intervals (higher irrigation levels) resulted in higher grain yields relative to longer irrigation intervals, which can result in drought stress, especially at critical stages of growth such as grain-filling stage (Dahmardeh, 2011; Hammad et al., 2012; Zare et al., 2014 and Ashraf et al., 2016). Interactions between irrigation and N level have also been reported. Ashraf et al. (2016) reported that the best grain yield was achieved at full irrigation and 250 kg N/ha.

Finally, the nutritional status of the plant has a substantial effect on its growth and productivity. The important roles played by the three macro-elements, i.e., nitrogen (N), phosphorus (P), and potassium (K), in growth, biochemical processes, yield, and quality of maize are well documented; however, rates of application should be determined to avoid deficient or excess application since both cases affect plant growth and productivity and/or have hazardous effects on the environment. Concerning application of macronutrients, Nejad et al. (2010) found that higher K levels (up to 150 K2O/ha) increased grain yield, while Hussain et al. (2007) reported that increasing both K and P fertilization levels up to 60–90 kg/ha for each, gave the highest grain yield. Moreover, Martineau et al. (2017) found that increasing irrigation with increasing K fertilization levels gave higher grain yield. With regard to P fertilization levels, Amanullah and Khalil (2010) and Zhihui et al. (2016) reported that intermediate to high P levels had favorable effects on grain yield. Similarly, for N fertilization levels, Hammad et al. (2011), Wang et al. (2014), Zhang et al. (2014), and Ali and Anjum (2017) found that the highest grain yield was obtained with intermediate to high N application levels.

Yield is a measure of crop response to changes in levels of applied quantitative factors. Hence, experimental designs could describe yield as a function of the levels of multifactor. Response surface methodology (RSM) is a powerful technique for testing multiple factors using fewer experimental units compared to the study of one variable or combinations of variables, at a time. Also, significant interactions between factors can be identified and quantified by this technique (Cochran and Cox, 1957 and Peterson, 1985).

The objective of this study was to examine the effect of six main factors (irrigation, macro-elements; N, P and K fertilization levels, sowing date and plant density) on grain yield of the hybrid maize cultivar Giza 168 under the Mediterranean conditions in Egypt.

2. Materials and Methods

The study was performed at the Agricultural Research Station, Faculty of Agriculture, Alexandria University, Egypt (31°12'53.0"N, 29°59'13.0"E), during the summer seasons of 2015 and 2016. The cultivar used in both seasons was the maize single hybrid Giza 168 (Giza 658 × Giza 639), developed by the Maize Research Program, Agriculture Research Center, Ministry of Agriculture, Egypt. Before sowing, soil samples were collected from the site (at a depth of 35 cm from the top soil) to determine the soil chemical and physical properties for the two seasons (Table 1). The meteorological data for the two seasons are presented in Fig. (1). These included minimum and maximum temperatures (°C), humidity (%), wind speed (km/h), sunlight duration (hours), and reference evapotranspiration (ETo) in mm. The data were obtained from the Alexandria-Nouzha Meteorological Station.

Table 1: Soil physical and chemical properties as an average of the two seasons

Physical properties		Nutritional properties	
Clay %	62.5	Av. N (%)	0.01
Silt %	20.0	Av. P (ppm)	9.60
Sand %	17.5	Av. K (meq/L)	0.84
Texture	Clay	Organic matter (%)	0.52
Chemical properties			
pH	8.36	Cl^- (meq/L)	15.00
EC (dS/m)	2.23	CO_3^{-2} (meq/L)	2.40
Ca^{+2} (meq/L)	7.50	HCO_3^- (meq/L)	4.00
Mg^{+2} (meq/L)	4.00	SO_4^{-2} (meq/L)	10.31
Na^+ (meq/L)	20.21	$CaCO_3$ (%)	9.86
SAR	5.96		

A five-level, six-factor rotatable central composite design, proposed by Box and Wilson (1951), was employed in this study. The design included 32 factorial points (F1-32) resulting from confounding 64 treatments, using the six-factor interaction as defining contrast, 12 central points (2 × number of factors; C1-12), and 12 star points (2 × number of factors; S1-12) as seen in Table 2. The total number of experimental units used was 56. The experimental unit area was 28 m2 (10 ridges each of width 0.7 m and 4 m length). Sowing was in hills, on one side of the ridge (the distance between hills for experimental unit varied according to the levels of plant density), and the plants were thinned to one plant/hill 24 days after sowing.

All irrigation levels were applied in nine irrigations (12-day intervals) as surface irrigation. The amount of water applied during each irrigation event varied with the level of irrigation and plant growth stage according to the CROPWAT model. Irrigation was terminated 10 days before harvesting. All K applications were done in split doses just before the fourth and fifth irrigations after sowing. All P levels were applied at land preparation. All N applications were applied in two split doses at 24 days after sowing and at the subsequent irrigation, except 380.8 kg N/ha, which was added in three doses (142.8, 142.8, and 95.2 kg N/ha) at 24 days after sowing, and the two subsequent irrigations.

Surface irrigation was applied through a gated pipe system attached with a water meter to measure the amount of water applied. The model of the water meter was TURBO-IR-A DN 80 (3"), manufactured by Bermad Irrigation (Qmin = 6 m3/h ± 5%, Qmax = 150 m3/h ± 2%, and minimum reading unit = 0.01 m3).

Wide borders and deep furrows were used to isolate plots to eliminate any carryover resulting from groundwater levels at different irrigation levels. P was applied in the form of calcium monophosphate (15.5% P2O5), while N was applied in the form of urea (46.5% N) and K was applied in the form of potassium sulfate (48% K2O). Experimental units were kept weed-free through hand hoeing at early stages and hand pulling at later stages to eliminate the weed effect.

Grain yield (ton/ha) was determined from the four inner guarded ridges of each plot and transformed to yield/ha. The error of the two years for the characteristics studied was homogenous, as determined by a test of homogeneity of error (Hartley, 1950); hence the data from the two years of study were pooled.

Statistical analysis was carried out according to Peterson (1985). Response surface and contour diagrams for significant linear × linear interactions were performed by STATISTICA 7.0 (StatSoft, 2012), while linear and quadratic responses of main effects were performed by Curve Expert v.1.34 (Hyams, 2005).

Simulation of irrigation scheduling was achieved using CROPWAT (Swennenhuis, 2009) to guarantee efficient water use in the irrigation process and to control surplus water use.

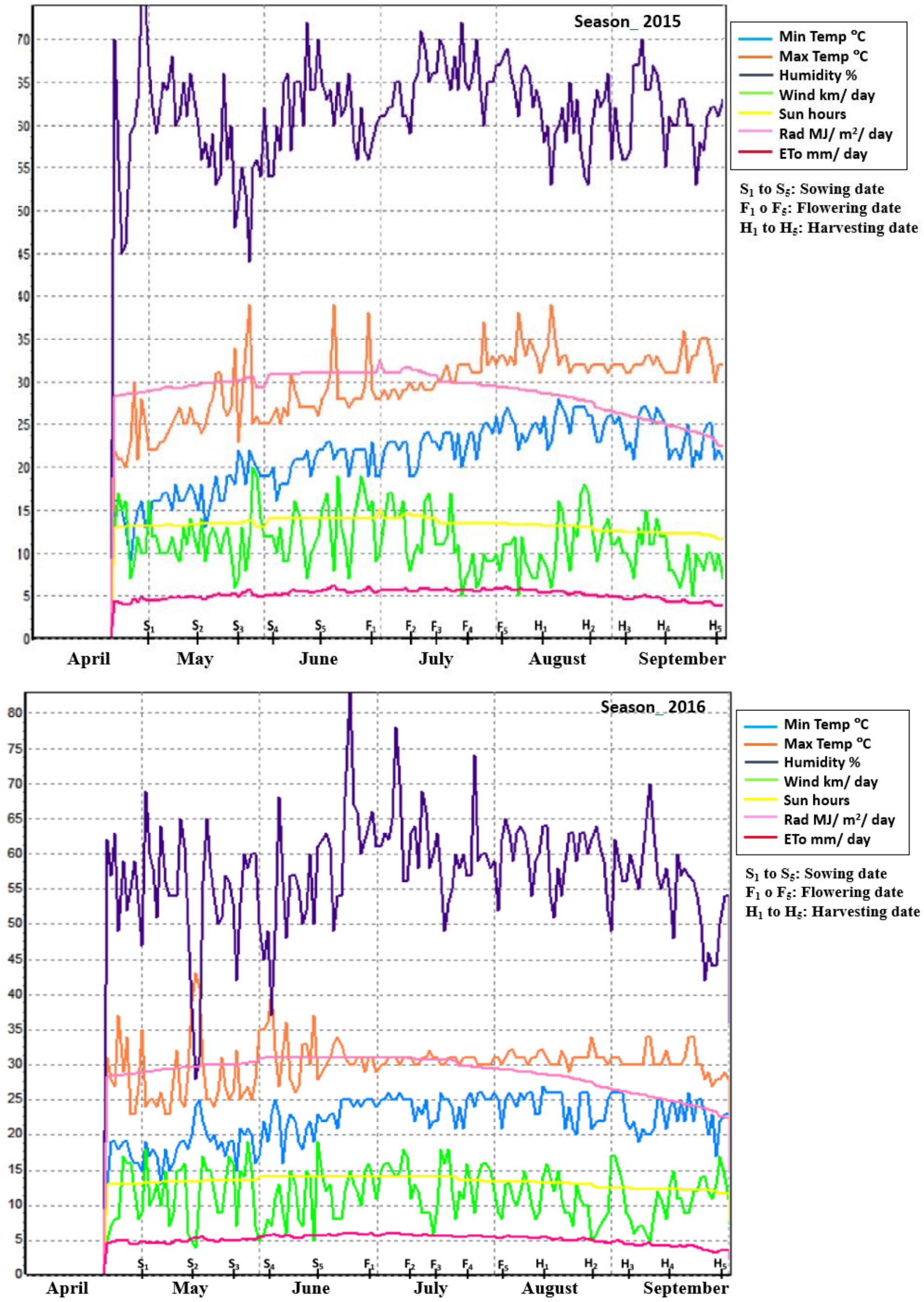

Fig. 1. Meteorological data during the summer seasons of 2015 and 2016

Table 2: Coded and actual levels of the studied factors in the central composite design

Coded level Factors			Units	-S ·α(-2.374)	- F (-1)	Central point (0)	+F (+1)	+S α(+2.374)
Irrigation levels	(I)	X_1	m^3/ha	4879	6388	7259	8130	9639
Potassium levels	(K)	X_2	kg/ha	0.0	41.4	71.4	101.4	142.8
Phosphorus levels	(P)	X_3	kg/ha	0.0	34.5	59.5	84.5	119
Nitrogen levels	(N)	X_4	kg/ha	0.0	110.9	190.4	270.4	380.8
Sowing date	(SD)	X_5		15/6	3/6	24/5	13/5	1/5
Plant density	(PD)	X_6	plants/ha	38080	54621	66640	78659	95200

S: Star points, F: Factorial points, -, +: minimum and maximum levels, respectively.

3. Results and Discussion

3.1. Effect of six main factors on grain yield

The six studied factors explained 57% of the variation in grain yield (R2 value, Table 3). However, the components that showed significant effects were the linear component for plant density (0.48*), irrigation × K level (-0.45*), and P × N fertilization level (-0.69*), as shown in Table 3. Hence, the regression equation that explains the relationship between grain yield and significant components will be: Y = 6.84 + 0.48 X6 - 0.45 X1X2 - 0.69 X3X4.

The regression of grain yield on plant density (Fig. 2) showed that the trait increased with increasing plant density/ha in both the linear and quadratic relationships, showing R2 values of 0.77 and 0.88, respectively. The coefficient of variation (CV%) for grain yield was 15.8%, indicating intermediate variability for that trait, which indicated that grain yield was affected by the difference in factor levels, and by lesser magnitude by other factors such as environmental conditions. These findings were confirmed by the mean grain yield, where the highest value (8.05 ton/ha) was achieved at high levels of I, K and N fertilization, and plant density, late sowing date, and low levels of P (F27, Table 4). However, at lower plant densities, levels of N fertilization and irrigation, combined with high K and P fertilization levels and late sowing date, gave high grain yields (F13) (8.06 ton/ ha) comparable to those with input levels of F27.

Table 3: Analysis of variance and regression coefficients (β) for grain yield (ton/ha) as affected by irrigation (I), potassium (K), phosphorus (P), and nitrogen fertilization (N), sowing date (SD), and plant density (PD) levels and their interactions.

S.O.V.		d.f.	M.S.	B value
	β0			6.84*
(1) I (L)	β1	1	0.239	0.07
I (Q)	β11	1	0.278	-0.07
(2) K (L)	β2	1	2.096	0.22
K (Q)	β22	1	0.036	0.02
(3) P (L)	β3	1	1.487	0.19
P (Q)	β33	1	1.160	0.14
(4) N (L)	β4	1	1.720	0.20
N (Q)	β44	1	3.281	-0.23
(5) SD (L)	β5	1	0.490	0.11
SD (Q)	β55	1	4.546	-0.27
(6) PD (L)	β6	1	10.020*	0.48*
PD (Q)	β66	1	0.651	-0.10
I × K (L)	β12	1	6.381*	-0.45*
I × P (L)	β13	1	0.036	-0.03
I × N (L)	β14	1	2.850	0.30
I × SD (L)	β15	1	1.916	0.25
I × PD (L)	β16	1	0.079	-0.05
K × P (L)	β23	1	0.001	0.004
K × N (L)	β24	1	0.064	0.05
K × SD (L)	β25	1	2.767	-0.29
K × PD (L)	β26	1	0.355	0.11
P × N (L)	β34	1	15.056*	-0.69*
P × SD (L)	β35	1	0.004	-0.01
P × PD (L)	β36	1	0.077	-0.05
N × SD (L)	β45	1	0.114	0.06
N × PD (L)	β46	1	0.236	-0.09
SD × PD (L)	β56	1	0.254	0.09
Lack of Fit		17	1.805	
Pure Error		11	1.038	
Total SS		55		
R^2				0.57

Linear component (L) and Quadratic component (Q).
*: significant at 0.05 probability level.

Table 4: Means of grain yield combined over the two seasons, as affected by irrigation (I), potassium (K), phosphorus (P), and nitrogen fertilization (N), sowing date (SD), and plant density (PD) levels

	Levels						Grain yield (ton/ha)
Trt's	I	K	P	N	SD	PD	
C_{1-12}	0	0	0	0	0	0	6.78
S_1	-	0	0	0	0	0	7.72
S_2	+	0	0	0	0	0	7.10
S_3	0	-	0	0	0	0	6.79
S_4	0	+	0	0	0	0	9.06
S_5	0	0	-	0	0	0	7.51
S_6	0	0	+	0	0	0	9.61
S_7	0	0	0	-	0	0	5.51
S_8	0	0	0	+	0	0	7.47
S_9	0	0	0	0	-	0	6.21
S_{10}	0	0	0	0	+	0	6.31
S_{11}	0	0	0	0	0	-	5.41
S_{12}	0	0	0	0	0	+	9.01
F_1	-1	-1	-1	-1	-1	-1	3.96
F_2	-1	-1	-1	-1	1	1	6.24
F_3	-1	-1	-1	1	-1	1	5.37
F_4	-1	-1	-1	1	1	-1	4.80
F_5	-1	-1	1	-1	-1	1	6.90
F_6	-1	-1	1	-1	1	-1	4.98
F_7	-1	-1	1	1	-1	-1	4.28
F_8	-1	-1	1	1	1	1	5.65
F_9	-1	1	-1	-1	-1	1	5.93
F_{10}	-1	1	-1	-1	1	-1	4.61
F_{11}	-1	1	-1	1	-1	-1	7.67
F_{12}	-1	1	-1	1	1	1	7.18
F_{13}	-1	1	1	-1	-1	-1	8.06
F_{14}	-1	1	1	-1	1	1	7.50
F_{15}	-1	1	1	1	-1	1	5.48
F_{16}	-1	1	1	1	1	-1	4.96
F_{17}	1	-1	-1	-1	-1	1	4.92
F_{18}	1	-1	-1	-1	1	-1	6.44
F_{19}	1	-1	-1	1	-1	-1	6.68
F_{20}	1	-1	-1	1	1	1	7.79
F_{21}	1	-1	1	-1	-1	-1	5.97
F_{22}	1	-1	1	-1	1	1	6.88
F_{23}	1	-1	1	1	-1	1	5.40
F_{24}	1	-1	1	1	1	-1	7.59
F_{25}	1	1	-1	-1	-1	-1	3.44
F_{26}	1	1	-1	-1	1	1	5.18
F_{27}	1	1	-1	1	-1	1	8.05
F_{28}	1	1	-1	1	1	-1	6.14
F_{29}	1	1	1	-1	-1	1	7.17
F_{30}	1	1	1	-1	1	-1	5.75
F_{31}	1	1	1	1	-1	-1	4.45
F_{32}	1	1	1	1	1	1	6.41

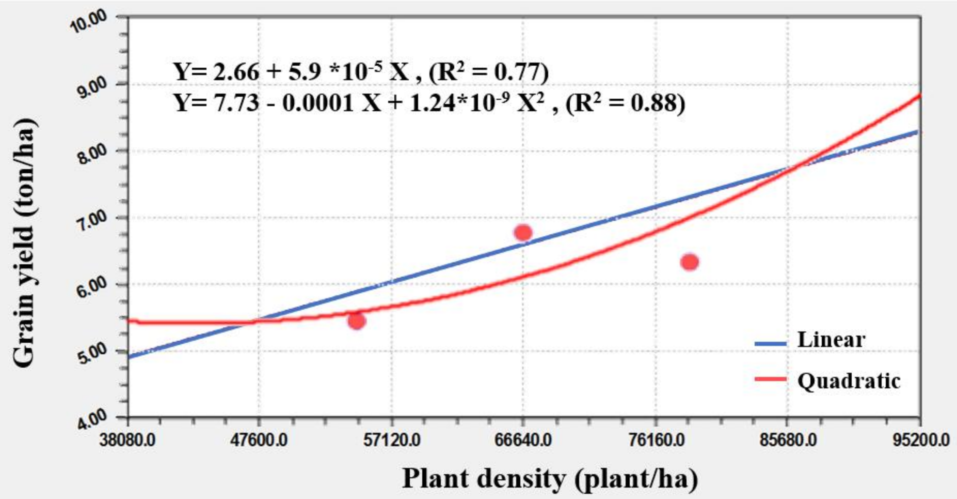

Fig. 2. Effect of plant density on grain yield

The interaction between irrigation and K fertilization was significant and had a negative relationship with grain yield. The response surface **(Fig. 3)** showed that grain yield increased with increasing levels of either factor individually, whereas the combined application of both factors, either at their lowest or highest levels, gave lower values than application of the highest levels of individual factors.

Also, the relationship between the P and N fertilization interaction and grain yield was significant and negative. The response surface **(Fig. 4),** showed that grain yield increased when P and N fertilization levels increased independently. However, application of both macronutrients in combination gave lower grain yield values relative to application of independent macronutrients.

Grain yield is the ultimate goal for variety improvement and productivity inputs. The main task for agronomists is to determine the optimal combinations of inputs to realize the yield potential of a maize variety, taking into consideration the interaction between input factors. The results obtained from the present study, considering each factor alone, revealed that high grain yields were realized with sowing from May 24 to June 3 with application of high irrigation, N and K levels, and plant density. Grain yield increased with increasing plant density, up to 95,200 plants/ha. That may be explained by the growing conditions of the maize in this study where maize was grown under irrigation scheduling to ensure that no water deficit was encountered during the key growth stages of the plant.

Higher irrigation levels, especially under Mediterranean conditions where incidence of drought can be expected, increased grain yield and its components (Nejad et al., 2010; Dahmardeh, 2011 and Zare et al., 2014). Asharf et al. (2016). Wang et al. (2017) reported similar results and added that increased N fertilization levels with increasing irrigation levels enhanced grain yield and its components. Concerning application of macronutrients, Nejad et al. (2010) found that higher K levels (up to 150 K_2O/ha) increased grain yield, while Hussain et al. (2007) reported that increasing both K and P fertilization levels up to (60–90 kg/ha for each) gave the highest grain yield. Moreover, Martineau et al. (2017) found that increasing irrigation with increasing K fertilization levels gave higher grain yield and yield components.

In the present study, sowing at May 24 to June 3 gave the highest grain yield (Table 4), while sowing at earlier or later dates resulted in reduction of grain yield. Under growing conditions in Egypt, earlier sowing will subject maize plants to higher infestation by borers (*Ostrinia* spp.). The same condition applies for later sowing dates, in addition to higher temperatures, which affect pollen grain viability and fertilization, thus reducing grain setting and, finally, grain yield. Existing literature shows contradictory results where Jaliya et al. (2008) and Dahmardeh and Dahmardeh (2010) found that a later sowing date gave higher grain yield and yield components, whereas Rah Khosravani et al. (2017) found that earlier sowing dates resulted in superior grain yield and yield components. This may be explained by differing environmental conditions and possibly the different maize varieties used and their responses to the prevailing environment.

Most of the literature suggests that intermediate plant density (around 66,000 plants/ha) results in higher biological yield, grain yield, and yield components (Turgut et al., 2005; Singh and Singh, 2006 and Ramu and Reddy, 2007). Zakir et al. (2017) found that the same plant density with application of 300 kg N/ha resulted in the highest grain yield.

The negative relationship between irrigation levels and K fertilization levels could be explained by the high solubility of K fertilizer (potassium sulfate), which, in the case of increasing irrigation levels, would lead to increased leaching of the fertilizer from soil, lowering its use efficiency and consequently reducing grain yield.

Concerning the negative P × N interaction, the response surface (**Fig. 4**) showed that grain yield progressively increased with increasing levels of both macronutrients up to central levels of each. However, further increases in both or either macronutrient(s) reduced grain yields. Onasanya et al. (2009) reported similar findings and stated that increasing P levels might cause nutrient imbalance and consequently yield depression in maize.

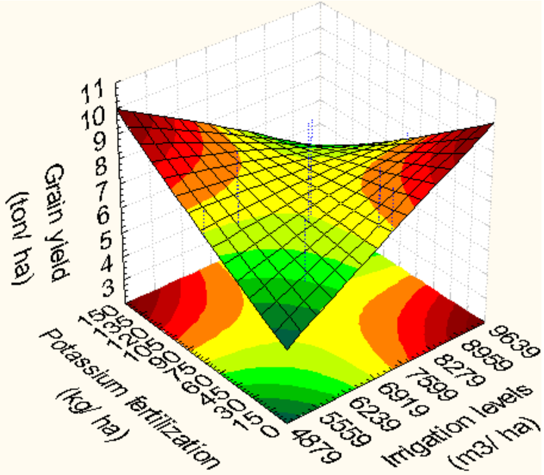

Fig. 3. Response surface for grain yield as affected by irrigation levels and potassium fertilization at the central levels of phosphorus and nitrogen fertilization, plant density, and sowing date.

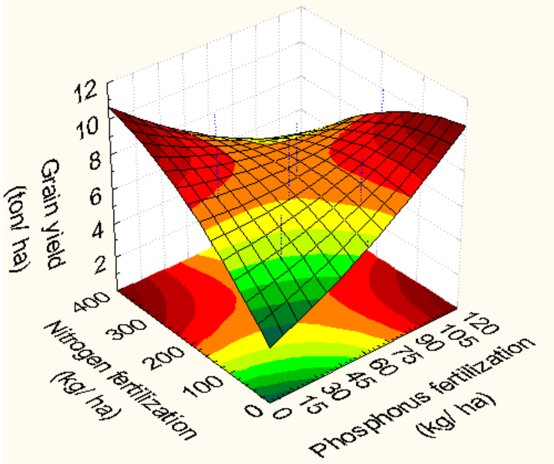

Fig. 4. Response surface for grain yield as affected by phosphorus and nitrogen fertilization levels at the central levels of irrigation, potassium fertilization, plant density, and sowing date.

3.2 Simulation of irrigation scheduling

Irrigation is a major agricultural input for crops, since it determines the germination, establishment, growth, and yield of crop plants. Proper application and scheduling of irrigation water, taking into consideration soil and climatic conditions, will affect maize productivity. This study revealed that surface irrigation performed by farmers decreased water use efficiency (WUE) to application of irrigation water in an amount greater than plant requirement, resulting in losses of water to deep percolation. This may be accompanied by a loss in applied nutrients and delay in the transition of plants from the vegetative to reproductive growth stage.

The CROPWAT model display basically incorporates controls, creating a water balance in the soil that enables creation of characteristic irrigation schedules to improve water consumption, assess irrigation schedules and their related yield water profitability, and create optimal water plans under confined water supply conditions (Swennenhuis, 2009 and El-Shafei et al., 2015).

Scheduled irrigation levels in this study **(Table 5)**, which ranged from 4879 m^3/ha (-S) to 9639 m^3/ha (+S) every 12 days (9 irrigations), were higher than actual crop use, which ranged from 4070 m^3/ha (+F) to 4311.3 m^3/ha (C). That resulted in irrigation water losses ranging from 680 to 5439 m^3/ha and a decrease in WUE and efficiency of irrigation scheduling (EIS) in the range from 41.3 to 54.1%. According to the CROPWAT model, a slight decrease in grain yield (1.1%) was calculated with the lowest irrigation level (-S) due to water stress conditions at the end of the growing season **(Fig. 5 a)**. Actually, at the lowest irrigation level (-S), there was an increase in grain yield of 13.86% relative to the central value (C) **(Table 4)**. This was attributed to the difference between the actual and assumed value of critical depletion of this maize variety. However, several researchers have reported decreases in maize grain yield with water deficit (stress) relative to incidence of stress (stage of growth) and intensity of stress (Farré and Faci, 2009; Nejad et al., 2010; Ashraf et al., 2016 and Wang et al., 2017).

In an attempt to decrease water loss and increase WUE, using the CROPWAT module, we rescheduled the lowest level of irrigation (-S) at 15-day intervals **(Fig. 5 b)**. Although there were deep percolation losses at five irrigation supplies (**Fig. 5 a**), these were necessary for good distribution of water and fertilizer application for field surface irrigation. The resulting schedule **(Table 5)** indicates an increase in the efficiency of irrigation scheduling when compared with that at 12-day intervals (63.8 vs. 54.1%), elimination of stress at end of season **(Fig 5 b)**, and no loss in grain yield **(Table 5)**. The distribution of irrigation water according to each interval indicated a high similarity between the irrigation scheduling at both intervals, which allows flexibility in the application of irrigation water at different intervals according to irrigation rotations in the region. The results in **Table 5** and **Figs. 5 b and 5 c,** clearly showed that application of 4879 m^3/ha at 15-day intervals was more efficient than the generally applied level of irrigation (C, 7259 m^3/ha) at 12-day intervals (EIS 63.8 vs 48.8%), without any reduction in grain yield. Several researchers have reported that rescheduling of irrigation water with decreasing amounts of applied water may give higher, or at least similar, grain yield in cereals relative to higher levels of applied irrigation water (Zhang and Oweis, 1999; Kharrou et al., 2011 and El-Shafei et al., 2015).

Table 5: CROPWAT module for actual crop use, irrigation losses, efficiency of irrigation scheduling, and reduction in yield for applied and predicted irrigation levels.

Irrigation levels (m^3/ha)	Total net irrigation	Actual crop use	Irrigation losses	EIS*	Yield reduction (%)
With 12-days interval:					
4879 (-S)	4879	4199	680	54.1	1.1
6388 (- F)	6388	4072.3	2315.7	52.7	0.0
7259 (C)	7259	4311.3	2947.7	48.8	0.0
8130 (+ F)	8130	4070	4060	46.5	0.0
9639 (+S)	9639	4200	5439	41.3	0.0
With 15-days interval:					
4879 (-S)	4879	4189	690	63.8	0.0

*EIS: Efficiency of irrigation schedule.

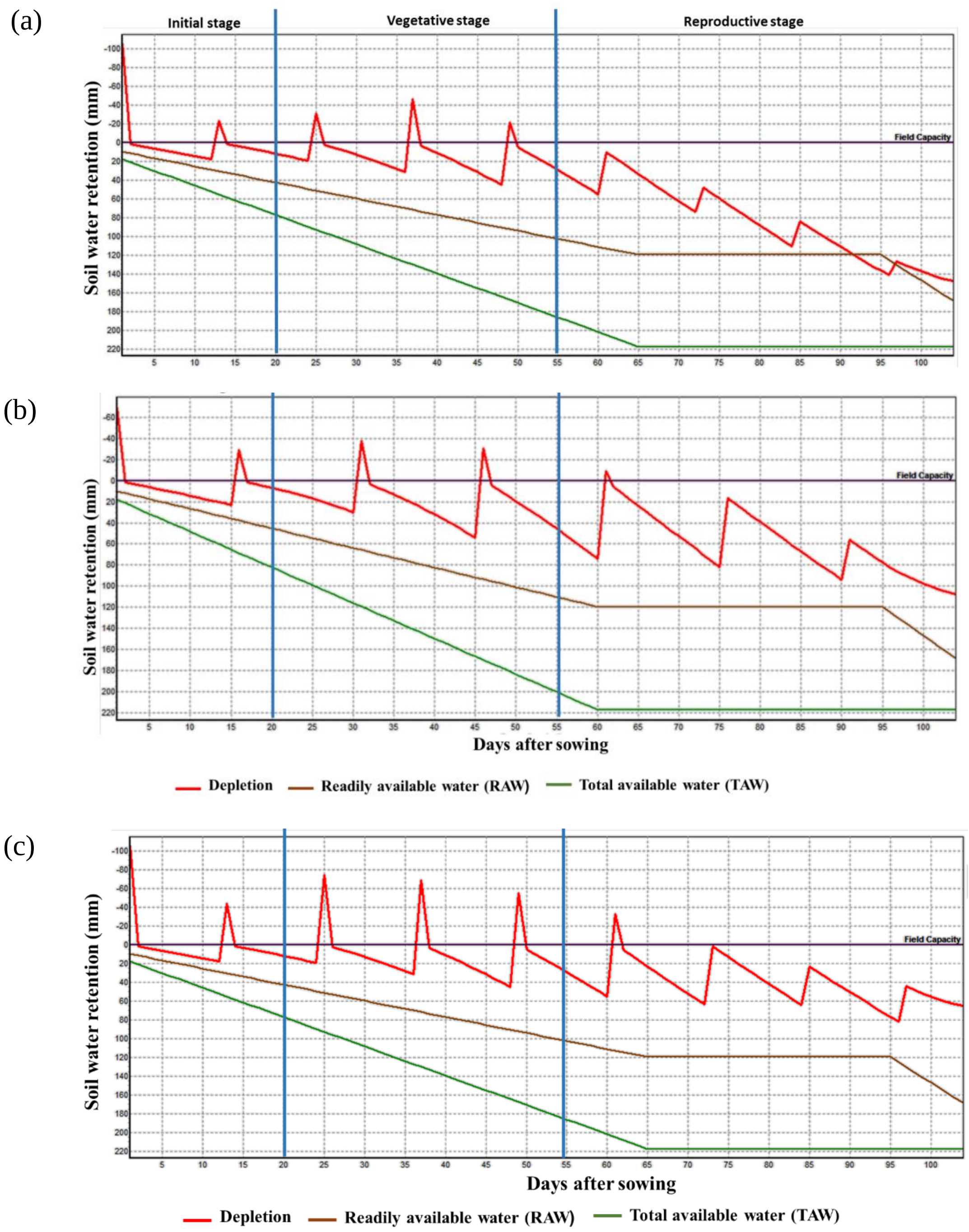

Fig. 5: Soil water balance during the growth season for the May 24; a: sowing date at 4879 m^3/ha for 12, b: 15-day intervals and c: sowing date at 7259 m^3/ha for 12-day intervals.

4. Conclusion

The irrigation method presently used for maize production (surface irrigation) leads to huge losses in irrigation water and water use efficiency. The proposed level of 5700 m^3/ha at 12- or 15-day intervals overcame those disadvantages and decreased amount of applied water by 21%. The results also indicated a quadratic response of the studied characteristics to levels of applied macronutrients and interaction between them. Application of high levels (+F) of N and K but low levels (-F) of P (thus saving 42% of applied P) is recommended. The data also suggests that to obtain high grain yield, sowing on the 20 to 30 May with a plant density of 65,000 plants/ha will result in high yield potential for the maize single hybrid Giza 186, in Mediterranean Regions under irrigated conditions.

5. References

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الملخص العربى

تم تقييم هجين الذرة الشامية الفردى جيزة 168 فى موسمى صيف 2015 و2016 لصفة محصول الحبوب باستخدام التصميم المركب المركزى لستة عوامل و هى: معدلات كل من الرى السطحى (I)، التسميد البوتاسى (K)، التسميد الفوسفاتى (P)، التسميد النيتروجينى (N) بالإضافة إلى مواعيد الزراعة (SD)، الكثافة النباتية (PD). استخدم برنامج CROPWAT لتقييم معاملات الرى وتطوير جدولة بديلة محسنة لعملية الرى. فسرت العوامل الستة المدروسة 57% من الاختلافات فى محصول الحبوب والذى تأثر معنوياً بالكثافة النباتية (0.48*) و التفاعل بين I×K (−0.45*)، و كذلك التفاعل بين P×N (−0.69*). تم الحصول على أعلى محصول حبوب حوالى 8 ton/ ha من معاملتين، الأولى إشتملت على المستويات العالية من الرى والكثافة النباتية والتسميد النيتروجينى والبوتاسى مع المستويات المنخفضة من الفوسفور والزراعة المتأخرة، والثانية إشتملت على المستويات المنخفضة من الرى والنيتروجين والكثافة النباتية بالإضافة إلى المستويات العالية من البوتاسيوم والفوسفور مع الزراعة المتأخرة.

أظهرت محاكاة جدولة الرى باستخدام CROPWAT أن كمية مياه الرى يمكن خفضها بحوالى 22% مع زيادة الفترة بين الريات إلى 15 يوم بدون نقص فى المحصول. و خلصت النتائج إلى أن إضافة 270 kg N/ha و 100 kg K_2O/ha و 34.5 kg P_2O_5/ha و الزراعة فى الفترة ما بين 20−30 مايو و الكثافة النباتية 65,000 plants/ha تعطى أعلى محصول حبوب للهجين الفردى جيزة 168.