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Influence of Different Levels of Water Deficit and Nitrogen Fertilization on Maize Productivity, Nitrogen Uptake and Soil Properties

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Abstract. Two field experiments were conducted at Hada Al-Sham Experimental Station of King Abdulaziz University, to study the effect of three different rates of irrigation, based on depletion ratios of 50%, 25%, 10% (IR_1, IR_2, IR_3) and four different rates of nitrogen fertilization (urea), zero, 100, 200, 300 kg/ha (N_0 , N_1, N_2, N_3) during two successive seasons (autumn 1994 and spring 1995) on total dry matter yield and its components (ear and straw), and nitrogen uptake of hybrid maize plant (AGA 215 cultivar). The purpose was also to detect changes in the chemical properties of the soil as influenced by these parameters. The irrigation scheduling processes were designed by applying water of 90.15 cm/autumn (9015 m^3/ha/autumn season) and 82.1 cm/spring (8210 m^3/ha/spring season), respectively, where the irrigation frequency was changed. There was a highly significant difference between seasons as regard dry matter production, with the first season (autumn) gave higher weight of straw, ear, total yield of dry matter, and nitrogen uptake than the second season (spring). Irrigation treatments significantly affected yield traits. The irrigation treatment IR_3 had higher values for dry weight of ears, and total yield of dry matter. Also, nitrogen treatments significantly affected some plant yield variables; where treatment number N_3 gave higher values of weight of straw, total yield of dry matter and nitrogen uptake. The season affected significantly the potassium and organic matter content in soil. Irrigation levels affected significantly only the soil potassium (K). Meanwhile the applied nitrogen rates affected significantly soil pH , nitrogen (N) and potassium (K) soil content. The reported results can be used as a guideline for the investigators in the field of maize irrigation and similar field crops.

1. Introduction

Maize (*Zea mays* L.) is considered one of the most important grain crop worldwide. It is ranked as the third important cereal crop after wheat and rice. USA, China, Brazil, Mexico, France, Argentina, India, Italy, and Canada are the top producing countries, (FAO, 2001).

Water is considered one of the effective factors efficiening the chemical fertilizer and consequently maize productivity. Hence, researchers were interested in studying the effect of nitrogenous fertilizer with various water requirements. In this respect, Panchanathan *et al.* (1987) studied the effect of different irrigation rates (5330, 4490, 4290 and 3510 m^3/ha) with nitrogenous fertilizer from 0.0 to 180 kg N/ha on maize productivity. They observed a significant interaction of irrigation water × nitrogen rates. Sexton *et al.* (1996), found that when water deficit was used to schedule irrigation, nitrogen fertilization (202 and 234 kg N/ha, as urea) gave the maximum maize grain yield, due to the reduction in nitrate leaching. Paliwal *et al.* (1999), concluded that the means of maize yield components and N, P, and K uptakes increased with the increasing of nitrogen N. Raju and Iruthayaraj (1995) detected that the highest maize grain yield and N, P, and K uptakes with the highest N fertilizing application with irrigation at condition of IW:CPE ratio of 0.75. Moreover, Surendra and Sharanappa (2000), found that N fertilization increased maize yield. The highest grain yield was recorded at a rate of 120 kg N/ha with water rates of 4490 and 4290 m^3/ha of irrigation water. Also, Stutler *et al.* (1981) obtained the highest productivity by adding 120 kg N/ha with irrigation. Highly significant interaction was also recorded between irrigation water and nitrogen. Also, Filip and Petrovici (1982) obtained the highest yield from application of 120 kg N/ha and irrigation with 7000 m^3/ha, while highest yields (7.51 and 7.88 ton/ha) were obtained by Petrovici and Ailincai (1984) by 180 kg N/ha with 1500 and 2100 m^3 irrigation water/ha, respectively. However, Thorat and Ramteke (1988) found that the highest yield was recorded at N rate of 180 kg/ha with 60 mm as irrigation water. The application of N rates from 0.0 to 350 kg/ha were evaluated with and without irrigation during various growth stages by Eck (1984), where he found a significant stress interaction for nitrogen × water on grain yields. Moreover, he reported that adequate N slightly increased grain yield under stress and greatly increased with irrigation. Boquet *et al.* (1985), observed that N application and irrigation increased grain yield and there was no significant interaction effect. They reported that the utilization of N was greatest at the highest level of irrigation but lacked response at lower irrigation ones to more than 179 lb N/acre. Bar *et al.* (1988), found that N application by more than 270 kg N/ha did not influence grain yield, where the irrigation frequency varied for its influence on maize cultivars.

Chen (1992), studied that the effects of applied N on irrigation water use efficiency for maize varied with cultivar and soil type. Francis (1990), found that the maize yield and N content were positively correlated with fertilizer N rate. Bar *et al.* (1988) concluded that N application with greater than 275 kg/ha did not increase maize yield, and irrigation frequency (1-6 days) did not alter yield of maize.

Experiments conducted by Boquet *et al.* (1985) found that, when nitrogen rates were applied as liquid fertilizer, the N application increased ears, grain number and specific grain weight, where irrigation increased ears number, plant height, specific grain weight and significantly reduced grain number/ear.

Boquet *et al.* (1989) studied the effect of nitrogen rates on grain yield and yield components, where they found that increasing of N rate increased grain yield, number of ears, number of grains/ear and grain weight. While, Pirani and Agostinelli (1989) found that maize grain yield was not significantly affected by nitrogen rates between 0.0 and 230 kg N/ha.

Boquet *et al.* (1986) mentioned that the increasing of water irrigation caused decreasing grain protein content. Singh *et al.* (1997) obtained the highest yield and nutrient uptake by corn with irrigation at an irrigation water equivalent to cumulative pan evaporation ratio 1:2 throughout the season. Crop yields increased and water use efficiency decreased with increasing of irrigation level as was described by Saren and Jana, (1999). Nutrient uptake by the grain and stove was significantly increased by increasing of irrigation frequency and application of fertilizers (Banga *et al.*, 1998). Efimov and Naumenlco (1980) reported that grains protein content increased with increasing of nitrogen rates up to 90 kg N/ha with irrigation.

For determining optimum season and best nitrogenous fertilizer rate under spring as well as autumn seasons, Hane (1981) studied the influence of nitrogen application from 0.0 to 252 kg N/ha on autumn season and 0.0 to 336 kg N/ha in spring one. The results indicated that grain and dry matter weights recorded lower values in autumn than those in spring season.

Irrigation frequency and nitrogen levels are considered the most effective inputs maize yield. Due to the water deficit problem in the Kingdom of Saudi Arabia and the high costs of nitrogen fertilization, the estimation of optimum irrigation water and nitrogen fertilization level are necessarily required to achieve the optimum maize yield. Thus, the objective of this study was to estimate the optimal irrigation level and nitrogen fertilization treatment to produce the maximum maize yield and its components.

2. Materials and Methods

2.1 Experimental Procedures

Two field experiments were conducted at the Research Station of King Abdulaziz University in Hada El-Sham, which is located at 120 km North-East of Jeddah, during the period from 14/10/1994 to 6/6/1995. Two factors were investigated to identify the optimum yield of maize crop. These factors were, three irrigation regimes (IR_1, IR_2 and IR_3) and four levels of nitrogen fertilization (N_0, N_1, N_2 and N_3). Split Plot Design was followed by considering the irrigation as main plot and the nitrogen as sub-plot with three replications and repeated over the two seasons. The sowing dates of the two seasons was 14/10/1994 (Autumn) and 16/2/1995 (Spring), respectively.

Land leveling processes were followed to minimize the water losses due to non-uniformity of irrigation water, where good land leveling was made before cultivation.

Each sub-plot consisted of 75 cm furrows of 5 m in length. Spacing of hills within rows was 30 cm. Three kernels were drop per hill of the AGA 215 maize cultivar. After the complete emergence hills were thinned to a single seeding hill. Plots were fertilized with superphosphate (46% P_2O_5) at the rate of 500 kg/ha and potassium sulphate (50% K_2O) at the rate of 400 kg/ha, at the beginning of the season. After that, the experimental area received the scheduled irrigation program according to the irrigation treatments (IR_1, IR_2, IR_3). All the recommended practices for growing maize were followed.

2.2 Environmental Conditions of the Experiments

2.2.1 Climatic Parameters

The different climatic parameters were recorded at the meteorological station of Hada El-Sham as illustrated in Table (1). These data were used for calculating the evapotranspiration rate for each season. Meanwhile, the different data concerning the crop coefficients were collected from FAO report (1988).

2.2.2 Soil Analysis

Random samples were taken from the experimental area at four different sites and two different layers *i.e.*, 0 to 30 cm, and 30 to 60 cm layers, respectively. Soil texture was determined using the hydrometer method as described by Day (1956) at 25ºC using pyrophosphate as differential factor. The different physical properties of soil samples at different depths were measured using the different experiments methodology as was described by Black *et al.* (1965). Meanwhile, the bulk and particle densities and the soil porosity were measured using the oven dry weight method as was described by Black *et al.* (1965). Data of soil texture analysis are given in Table (2).

TABLE 1. Monthly recorded temperature and humidity at the experimental site during the two growing seasons.

Month	Autumn 1994-1995						Month	Spring 1995					
	Temperature (ºC)			Humidity (%)				Temperature (ºC)			Humidity (%)		
	Min.	Max.	Mean	Min.	Max	Mean		Min.	Max.	Mean	Min.	Max.	Mean
October	19.0	42.0	30.5	21	99	61.0	February	10.3	33.7	22.65	22	97	61.5
November	16.2	39.0	27.1	30	99	65.0	March	10.9	92.2	27.00	17	96	54.50
December	11.0	34.9	24.1	27	98	59.0	April	13.8	44.5	30.15	20	92	54.6
January	15.0	35.5	25.3	27	100	62.0	May	16.3	46.6	33.7	19	92	48.9
February	10.3	33.7	22.50	22	97	61.5	June	22.8	51	36.05	22	92	48.4

TABLE 2. Soil texture and physical properties of soil analysis.

Soil depth	Coarse sand %	Med. sand %	Fine sand %	Silt & clay %	% Error	Uniformity coeff.	Soil tex.	Bulk D. (g/cm^3)	Porosity	Part D (g/cm^3)
0-30 cm	5.7	42.8	43.8	7.8	0.1%	4.9	Sandy	1.64	0.369614	2.71
30-60 cm	6.6	41.6	47.2	4.2	– 0.4%	6.2	Sandy	1.69	0.254567	2.63

Soil pH and electrical conductivity (EC) were determined by mixing soil with water by 1:1 weight-volume (W:V) ratio using glass rod. The total organic matter (O.M.) in the soil was determined using Walkeley and Black's method as described by Jackson (1973). The soil nitrogen was estimated according to the method of Bremner (1965). The soil nitrogen content was measured by Kjeletec Auto 1030 analyzer. The total quantities of phosphorus and potassium were determined after they were extracted by digestion method with perchloric and nitric acids (Shelton and Harper, 1941). Phosphorus content was determined at light wave length 640 nanometer using Turner spectro-photometer model 2000, whereas, potassium concentration was measured in the extraction using flame photometer (Maizeing 400). The data of water and soil chemical analysis were tabulated in Tables (3) and (4).

The saturated hydraulic conductivity for each soil layer was measured in the laboratory using the Constant Head Method. The relationship between soil and water was estimated in the laboratory, where the soil moisture retention curves were estimated using the Pressure Plate method as described by Hillel (1982) Fig. (1).

TABLE 3. Chemical analysis of irrigation water.

pH	Ec ds^{-1}	Na^{+} (mgl)	K^{+} (mgl)	Ca^{++} (mgl)	Mg^{+} (mgl)	Cl^{-} (mgl)	SO_4^{-} (mgl)	NO_3^{-} (mgl)	HCO_3^{-} (mgl)	$CO_3^{=}$ (mgl)
7.40	1.58	164	24.6	160	41	246	221.6	123	246	0

TABLE 4. Chemical analysis of soil of the experimental site.

Soil depth	Chemical analysis								
	pH	EC ds^{-1}	O.M. %	N (mg/kg)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)
0-30 cm	7.89	1.61	0.5	0.32	0.129	2.5	3.6	6.3	16.8
30-60 cm	8.25	0.38	0.41	0.3	0.108	2.2	0.9	1.4	6.6
60-90 cm	8.17	0.39	0.41	0.28	0.40	2.0	1.5	5.9	3.8

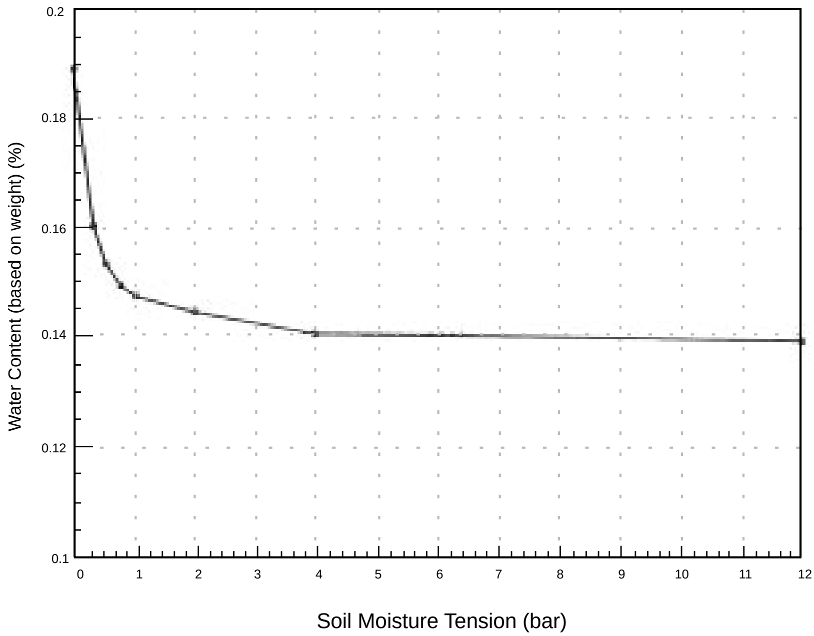

FIG. 1. Soil-moisture retention curve for soil samples.

The same chemical analysis and experiments which were done in initial soil conditions were followed for the collected soil samples at the end of each harvest dates (Spring and Autumn) where the chemical analyses included the analysis of nitrogen (N) phosphorus (P), potassium (K), electric conductivity (EC), power of hydrogen (pH), and organic matter (O.M.).

2.3 Practical Steps of the Two Trial Conditions

2.3.1 Nitrogen Application

Each nitrogen rate was applied as hand place under each plant at three equal doses in 15 days intervals. First dose after 30 days from sowing, 2nd dose after 45 days from sowing, and the last one 60 days from sowing. The four nitrogen doses (N_0, N_1, N_2, N_3) were 0, 100, 200, and 300 kg/ha, respectively.

2.3.2 Irrigation Treatments

The moisture depletion ratio method was followed for designing the irrigation treatments. The method assumed a constant rate of water losses by evapotranspiration at each irrigation period, while the available water in soil is considered as the main factor for irrigation scheduling design. Following this method, the total quantity of water for irrigation (over season) was estimated and applied with different irrigation frequencies. Each treatment was based on the allowable depletion ratio from the total available soil moisture.

Three different depletion ratios were applied for irrigation scheduling processes, these ratios were 50%, 25%, and 10% from the soil total available water, designated as IR_1, IR_2, and IR_3, respectively. The total available water for plant over the soil-root depth was calculated, by using the different properties of soil-water. The crop water requirements during the two successive crop seasons were calculated in monthly rate using FAO method which illustrated the growth season as four different periods. The water losses during water application (surface run-off and deep percolation) were considered for estimating the gross irrigation water requirements, where the irrigation efficiency definition was applied.

The steps for calculating the water requirements and irrigation frequencies can be described as follows:

$$\mathrm{TAW} = \frac{FC - WP}{100} * \frac{\rho_b}{\rho_w} * dr \tag{1}$$

where, TAW is the total available water (cm^3) in soil root depth dr (cm^3), FC and WP are the soil moisture content (weight basis) (g/g) at field capacity and permanent wilting point, respectively, ρ_b is the bulk density of soil (g/cm^3), ρ_w is the water density (g/cm^3), and dr is the soil root depth (cm).

Assuming that the soil is homogenous over the depth, the total allowable net water depth D_n (cm) as depleted water depth from soil root depth D_r (cm) can be calculated by using,

$$D_n = R * TAW \tag{2}$$

where, R is the allowable depletion ratio, which was illustrated by 50%, 25%, and 10% for the three irrigation treatments, IR_1, IR_2, and IR_3 respectively.

Meanwhile, the gross irrigation water depth D_g (cm) and the irrigation frequency, T, were calculated using the following expressions,

$$D_g = \frac{D_n}{\eta} \tag{3}$$

$$T = \frac{D_n}{ET_c} \tag{4}$$

where, η is the application efficiency of water on farm level, and ET_c is the evapotranspiration of crop (cm^3/day).

The different irrigation treatments, frequencies and irrigation water requirements were described in Table (5) for the two seasons, respectively.

2.3.3 Irrigation System and Network

The 36 sub- plots were arranged in three replications each of 12 sub- plots. Each replication has 3 irrigation and 4 nitrogen treatments. An underground pipe network was conducted at the experimental area to achieve the required water volume for each treatment basin. A two-inch PVC main pipe line was diverted into secondary network. Each 4 basins was having one Division Box (distributor) having 4 rectangular sharp weir to distribute an equal water quantity for the same irrigation treatment. Moreover, discharge flow meter was installed at the network inlet to measure the input flow and control the water application process.

2.3.4 Weight of Yield and its Parts

At the end of each season, one hundred plants from each sub- plot were taken, and total biomass yield of plant, straw weight, and ear weight were recorded. In addition, the total dry matter and its parts (straw and ear) (kg/ha) were also estimated. The statistical analysis for analysis of variance and mean comparison were made by using the statistical program MSTAT.

3. Results and Discussion

3.1 Dry Matter Production and Its Components

3.1.1 Total Yield of Dry Matter

The treatments of season and nitrogen rates, affected significantly the total yield production (at level $p < 0.01$), while, the ears were significantly affected by season and irrigation treatment. The effect of irrigation treatments, and the

TABLE 5. Irrigation treatments for autumn and spring seasons.

Stage no.	1		2		3		4	
Duration (day)	Autumn 14/10 – 2/11	Spring 16/2 – 6/3	Autumn 3/11 – 2/12	Spring 7/3 – 5/4	Autumn 3/12 – 11/1	Spring 6/4 – 15/5	Autumn 12/1 – 10/2	Spring 16/5 – 4/6
Soil-root depth (D) cm	10		20		30		30	
Evaporation								
ETC (mm/day)	4.17	3.49	6.0	6.58	8.67	9.6	7.50	7.89
TAW (cm)	3.1	3.1	6.2	6.2	9.3	9.30	9.3	9.30
Net water depth (Dn) cm								
Dn_1	1.39	1.55	3	3.1	4.34	4.65	4.5	4.65
Dn_2	0.7	0.83	1.19	1.55	1.73	2.3	2.3	2.3
Dn_3	0.35	0.47	0.6	0.96	0.9	0.96	0.75	0.93
Gross water depth (cm)								
Dg_1	2.78	3.1	6	6.2	8.68	9.3	9	9.3
Dg_2	1.4	1.67	2.38	3.1	3.46	4.6	4.6	4.6
Dg_3	0.7	0.9	1.2	1.92	1.8	19.2	1.5	1.86
Irrigation Interval (T) (d)								
T_1	4	3	5	4	5	4	6	5
T_2	2	2	2	2	2	2	3	2
T_3	1	1	1	1	1	1	1	1
Total water requirement ($m^3/25^2$)								
Vg_1	0.7	0.78	1.5	1.55	2.17	2.33	2.25	2.33
Vg_2	0.35	0.4	0.6	0.78	0.87	1.15	1.15	1.15
Vg_3	0.18	0.225	0.3	0.48	0.45	0.48	0.38	0.47

Assuming 50% water losses of field level due to deep percolation and non-uniformity of soil surface.
Total net water volume = 90.15 cm/season = 9015 m^3/ha/season (autumn).
Total gross water volume = 180.3 cm/season = 18030 m^3/ha/season (autumn).
Total net water volume = 82.108 cm/season = 8210 m^3/ha/season (spring).
Total gross water volume = 164.216 cm/season = 16421.8 m^3/ha/season (spring).
ETC = Evapotranspiration of crop.
TAW = The total available water soil depth.

interaction between season multiplied by irrigation treatments significantly affected the total yield (at level $p < 0.05$) (Table 6). Mean of autumn season was higher than spring season for total dry matter yield and its parts (Table 7). Reddy and Patil (1982) reported that the autumn results were superior to spring when applying 120 kgN/ha, while Berdnikov and Gulchuk (1987), found an increase of maize yield during spring than that during autumn under the same of nitrogen rate.

TABLE 6. Probability levels of significance for the ANOVA of maize straw weight, ear weight and biological yield and nitrogen uptake of two seasons of maize plant.

S.O.V.	D.F.	Dry matter (kg/ha)			Nitrogen uptake (kg/ha)
		Straw weight	Ear weight	Total yield	
(S)	1	**	**	**	**
Rep (S)	4	*	**	**	*
Irrigation (I)	2	ns	*	ns	ns
(SI)	2	ns	ns	ns	ns
M.S. Error (a)	8	525125	189422	2782793	3013
Nitrogen (N)	3	*	ns	**	**
(SN)	3	ns	ns	ns	ns
(IN)	6	ns	ns	ns	ns
(SIN)	6	ns	ns	ns	ns
M.S. Error (b)	36	977302	1572049	2475212	1791

Ns,*, ** indicate non significance and significance at the 0.05 and 0.01 levels of probability, respectively.
ANOVA : Analysis of variance.
S.O.V. : Source of variation.

TABLE 7. Means of total dry matter yield and its parts and nitrogen uptake for maize experiment.

Factors		Dry matter (kg/ha)			Nitrogen uptake (kg/ha)
		Straw weight	Ear weight	Total yield	
Season	Autumn	6599 A	10456 A	17055 A	320.4 A
	Spring	3208 B	8414 B	11622 B	210.1 B
L.S.D. .05		314	434	513.6	5.2
Irrigation	$IR_1$50%	4968 A	9263 B	14232 AB	266.2 A
	$IR_2$25%	4885 A	8854 B	13739 B	246.3 A
	$IR_3$10%	4857 A	10187 A	15045 A	283 A

TABLE 7. Contd.

Factors		Dry matter (kg/ha)			Nitrogen uptake (kg/ha)
		Straw weight	Ear weight	Total yield	
L.S.D. .05		–	772.92	913.536	36.54
Nitrogen level (kg/ha)	N_0 0	4537 B	9032 A	13569 B	215
	N_1 100	4620 B	9282 A	13903 B	244.7 B
	N_2 200	4861 B	9680 A	14541 AB	258.1 B
	N_3 300	5597 A	9745 A	15342 A	343.3 A
L.S.D. .05		645.63	–	1054.86	28.6

For each factor, means having common letters are significantly different at 0.05.

Nitrogen rate of 300 kgN/ha gave significantly the highest total yield production, followed by rates 200-100-0 kgN/ha, respectively (Table 7). Russel (1984), found that the rate of 60 kgN/ha was sufficient to produce maximum grain yield of maize. Vance (1987), Sureridra and Sharanappa (2000), and Frye and Blevrins (1989), found that the maize yield increased in parallel with the increase of nitrogen rates from 0.0 to 100 kgN/ha. In contrast, Pirani and Agostinelli (1989), and Bar *et al.* (1988) found no significant difference in maize yield due to nitrogen rate up to 230 kgN/ha.

As regarding of irrigation treatment, the third irrigation treatment (IR_3 = 10%) gave the highest total yield dry matter and weight of ears followed by IR_2 = 25% and IR_3 = 50%, as seen in Table (7). Panchanathan *et al.* (1987) detected a significant effect of the interaction between irrigation and nitrogen on yield of maize, where he applied 5330, 4490, 4290 and 3510 m^3/ha with nitrogen fertilization from 0 to 180 kgN/ha. But Stutler *et al.* (1981), obtained the highest maize yield with 120 kgN/ha added at different irrigation treatments. Filip and Petrovici (1982), also obtained the highest maize yield with 120 kgN/ha added with 700 m^3/ha water. Petrovici and Ailincai (1984), got the highest maize yield when they added 180 kgN/ha with 1500 m^3 or 2100 m^3 irrigation water/ha, while Thorat and Ramteke (1988) got the highest yield by adding 160 kgN/ha with 1500 or 2100 m^3/ha irrigation water. Raju and Iruthayaj (1995) detected the highest maize yield with the highest N fertilizer application with irrigation at IW:CPE ratio 0.75%. Moreover, Bar *et al.*(1988) detected no alteration in maize yield as a result of irrigation frequency (1 and 6 days).

Fig. (2) shows the effect of the interaction between season and multiplied by irrigation treatments on total yield, where the first season was dominating the second season, and the third irrigation treatment (IR_3 = 10%) surpassing both the second (IR_2 = 25%) and the first (IR_1 = 50%) irrigation treatments.

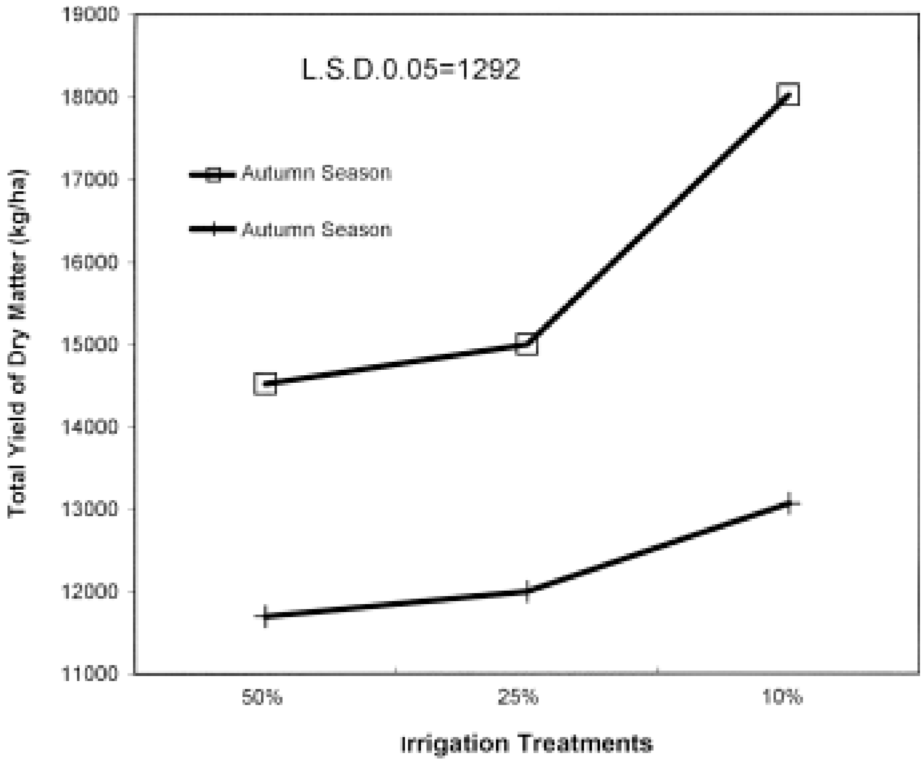

FIG. 2. Effect of different irrigation treatments on total yield of dry matter during two seasons of maize plant.

3.1.2 Straw Dry Matter

Both season and nitrogen applied rates showed significant effect on the means of the dry matter of straw after the removal of ears (at the level $p < 0.01$), Table (6). Autumn season produced 6599 kg/ha higher than spring season with 3208 kg/ha straw dry matter. Nitrogen rate of 300 kgN/ha was significantly higher in straw dry matter giving 5597 kg/ha, followed by the 200,100,0 kgN/ha rates which gave in a decreasing order 4861, 4620 and 4537 kg/ha, respectively (Table 7).

The obtained results matched with the finding by other investigators like Njoku and Odurukwe (1987), who found an increase in straw dry matter from 4 to 16% with applying nitrogen rates of 50-100-150 kgN/ha where 100 kgN/ha rate being the optimum rate. Ogunlela *et al.* (1988), obtained the highest yield in straw production at nitrogen rate 200 kgN/ha. When splitting nitrogen rates Abdel-Aziz *et al.* (1986), found a continuous increase in straw dry matter production up to 214 kgN/ha while, Badreshia and Patal (1987), pointed out that

120 kgN/ha was contributed a significant increase in straw dry matter production.

Irrigation treatment gave no significant difference in the values of straw dry matter (Table 7). In contrast, Woodruff *et al.* (1984), found that the straw dry matter differed significantly by applying irrigation water at water depths ranging 35-70-100 cm.

3.2 Nitrogen Uptake

There were significant differences between the nitrogen uptake and the season ($p < 0.01$), nitrogen rates ($p < 0.01$), interaction treatments, season × nitrogen rates at level ($p < 0.05$). Irrigation treatments had no significant effect (Table 6).

Nitrogen uptake by maize plant was significantly higher in the autumn season (115.55 kgN/ha) than the spring season (99.62 kgN/ha). As far applied nitrogen rate, treatment 300 kgN/ha gave the highest nitrogen uptake (117.4 kgN/ha), followed by 200 kgN/ha (110.9 kgN/ha), rate 100 kgN/ha gave (103.4 kgN/ha), and the least was the zero treatment (99.6 kgN/ha), Table (7). These results were similar to the results reported by Francis (1990), Benjamin *et al.* (1997), and Paliwal *et al.* (1999). As regarding the effect of irrigation treatment on the nitrogen uptake by maize plant, it showed no such effect. This result is in contrast with the result obtained by Singh *et al.* (1997), and Banga *et al.* (1998). Fig. (3) indicates the effect of season × nitrogen rate with the amount of nitrogen uptake by maize plant. Meanwhile nitrogen rate of 300 kgN/ha gave the highest nitrogen uptake than the rates 200 kgN/ha, 100 kgN/ha, and zero kgN/ha, respectively.

3.3 Soil Analysis

3.3.1 pH Value

The applied nitrogen rates affected significantly the soil pH (at level $p < 0.05$) while the interaction between irrigation treatments × nitrogen rates affected pH at level ($p < 0.01$), as shown in Table (8).

The zero N rate gave significantly the highest soil pH 8.32, followed by rates 100-200-300 kgN/ha with pH values of 8.16, 8.16 and 8.14, respectively (Table 9). The decrease of soil pH as affected by addition of nitrogen fertilizer (urea) or organic waste treatments could be attributed mainly to acids produced by the nitrification process (Larry and Morris, 1972, and Sims, 1986). They found that nitrogen application increased soil acidity after four months. The observed drop in soil pH was caused by the nitrification of NH_4-N. Fig. (4) shows the com-

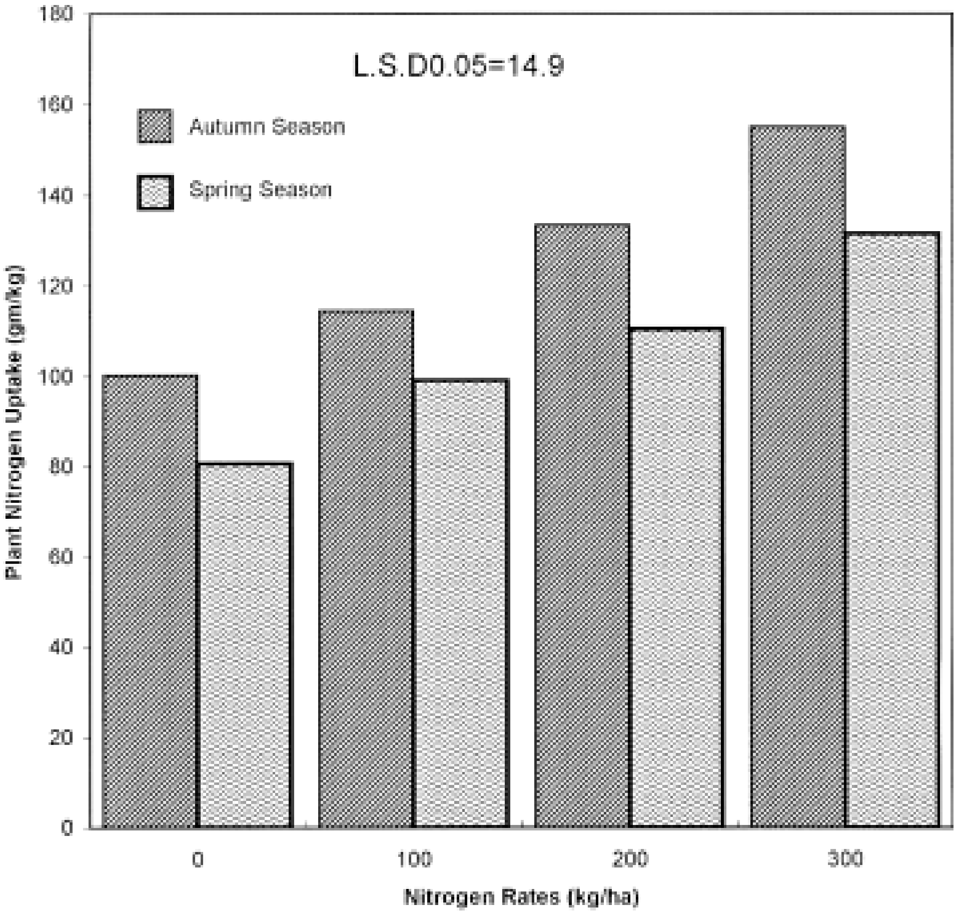

Fig. 3. Plant nitrogen uptake as affected by different nitrogen rates during two seasons of maize plant.

Table 8. Significance levels of the ANOVA of pH, nitrogen, phosphorus, potassium and organic matter content combined over the two seasons.

S.O.V.	D.F.	pH	E.C. ds^{-1}	Nitrogen	Phosphorus	Potassium	O.M. (%)
				(mg/kg)			
Season (S)	1	ns	ns	ns	ns	*	**
Rep / season	4	ns	ns	ns	ns	ns	**
Irrigation (I)	2	ns	ns	ns	ns	**	ns
(SI)	2	ns	ns	ns	ns	**	ns
M.S. Error (a)	8	0.082	0.014	0.001	0.002	0.089	0.0001

Table 8. Contd.

S.O.V.	D.F.	pH	E.C. ds^{-1}	Nitrogen	Phosphorus	Potassium	O.M. (%)
				(mg/kg)			
(N)	3	*	ns	**	ns	*	ns
(SN)	3	ns	ns	ns	ns	ns	ns
(IN)	6	**	ns	ns	ns	**	ns
(SIN)	6	ns	ns	ns	ns	ns	ns
M.S. Error (b)	36	0.043	0.009	0.001	0.001	0.121	0.0001

Ns,*, ** indicate non significance and significance at the 0.05 and 0.01 levels of probability, respectively.
ANOVA : Analysis of variance.
S.O.V. : Source of variation.

Table 9. Final chemical analysis of soil for NPK and organic matter for the maize experiment.

Factor		pH	EC ds^{-1}	N	P	K	OM (%)
				(mg/kg)			
Season (S)	Autumn	8.224 A	0.56 A	0.190 A	0.164 A	0.296 B	0.484 A
	Spring	8.170 A	0.532 A	0.194 A	0.188 A	0.493 A	0.478 B
Irrigation (IR)	IR_1 50%	8.16 A	0.51 A	0.19 A	0.17 A	0.671 A	0.48 A
	IR_2 25%	8.19 A	0.58 A	0.20 A	0.18 A	0.26 B	0.48 A
	IR_3 10%	8.24 A	0.56 A	0.19 A	0.18 A	0.26 B	0.48 A
L.S.D. .05		–	–	–	–	0.196	–
Nitrogen (N)	N_0 0	8.32 A	0.50 A	0.18 C	0.18 A	0.633 A	0.48 A
	N_1 100	8.16 B	0.55 A	0.18 BC	0.17 A	0.38 B	0.48 A
	N_2 200	8.16 B	0.56 A	0.20 B	0.18 A	0.317 B	0.48 A
	N_3 300	8.14 B	0.58 A	0.22 A	0.18	0.25 B	0.48 A
L.S.D. .05		0.14	–	0.015	–	0.235	–

For each factor, means having common letters are significantly different at .05.

bined effect of irrigation × nitrogen rates on soil pH. Increasing nitrogen rates from 0, 100, 200 up to 300 kgN/ha decreased pH value throughout irrigation treatments, IR_1, IR_2, IR_3. Both irrigation treatments IR_2 and IR_3 surpassed the first irrigation treatment (IR_1).

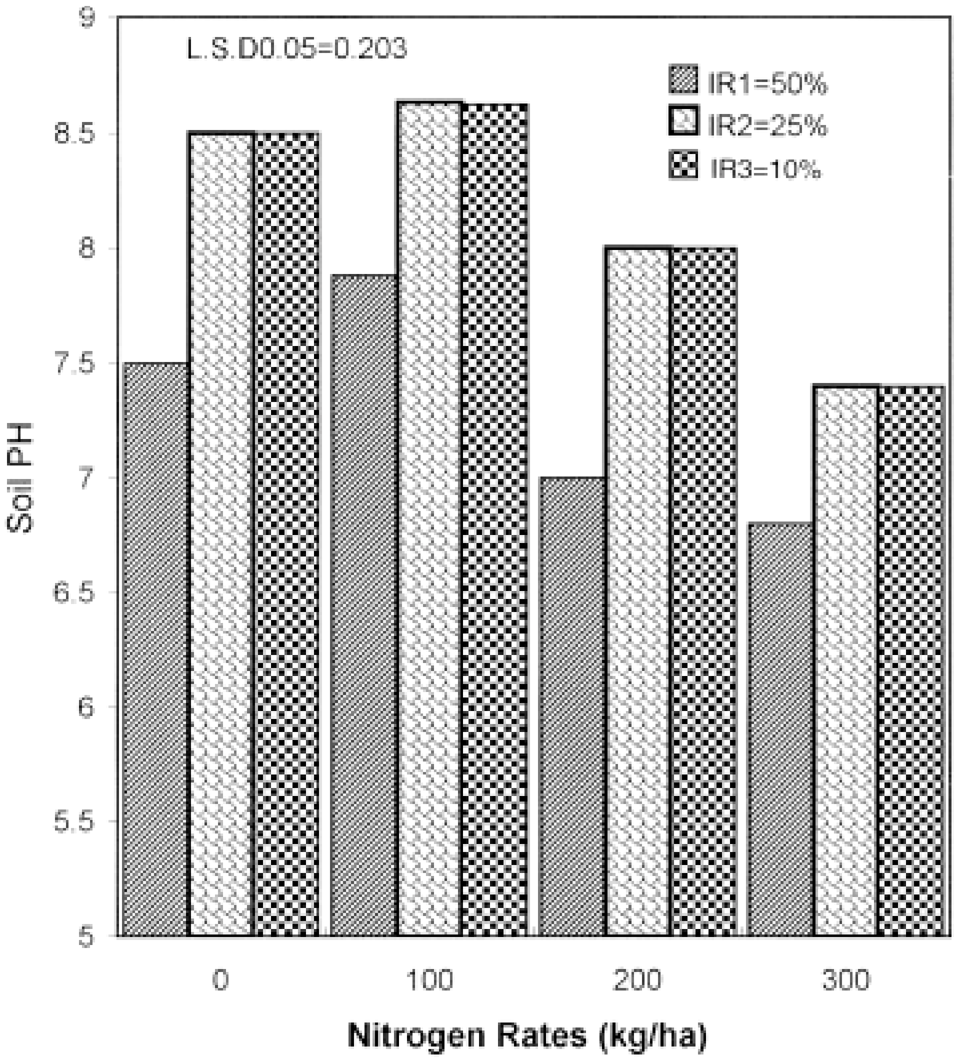

FIG. 4. Effect of different irrigation and nitrogen treatments on soil pH during growth of maize plant.

3.3.2 Soil Salinity (EC)

The electric conductivity (E.C.) of the soil was not affected by the three factors under study (Tables 8 and 9).

3.3.3 Soil Nitrogen Content

Soil nitrogen content was significantly affected by only nitrogen rates ($p < 0.01$), as shown in Table (8).

Nitrogen rate 300 kgN/ha gave the highest soil nitrogen content 0.22 mg/kg followed, respectively in a decreasing order by rates 200, 100, 0 kgN/ha and gave respectively 0.2, 0.18 and 0.17mg/kg, soil nitrogen content (Table 9). Similar results were reported by Nimje and Seth (1988). They studied the effect of nitrogen application rates on some soil properties. They found that total nitrogen was increased with increasing nitrogen rate, as seen in Table (9).

3.3.4 Soil Phosphorus Content

The soil phosphorus content was not affected by the three factors under study (Tables 8 and 9).

3.3.5 Soil Potassium Content

Soil potassium content was significantly affected by the season ($p < 0.05$), irrigation treatments ($p < 0.01$), nitrogen rates ($p < 0.05$), and the interaction treatments between season and irrigation and between irrigation and nitrogen rates ($p < 0.01$), as seen in (Table 8).

Spring season was significantly higher (giving 0.497 mg/kg K) than autumn season with 0.352mg/kg K. Regarding irrigation treatments, the highest soil potassium content was attained by (IR_1 = 50%) which gave 0.76 mg/kg K followed by the second then the third irrigation treatment with 0.26 mg/kg K. As for the nitrogen treatments rate, 0 kgN/ha gave the highest soil potassium content (0.81 mg/kg K), followed respectively in a decreasing order by rates 100, 200, 300 kgN/ha with 0.37 mg/kg K, 0.26% K, 0.25 mg/kg K values, respectively, as seen in Table (9).

Fig. (5) shows the combined effect of season between and irrigation treatments on soil potassium content. Irrigation one (IR_1 = 50%) gave the highest soil potassium content where season two was dominating season one at all the three irrigation treatments.

3.3.6 Soil Organic Matter Content

Soil organic matter content was significantly affected by only the season ($p < 0.01$), as shown in Table (8).

Autumn season was significantly higher with 0.35% organic matter than spring season with 0.34% soil organic matter.

Conclusions

As a main conclusion, irrigation at 50% water deficit had higher ears, dry weight, and total dry matter. The irrigation rate resulted in affected yield characters. Meanwhile, the nitrogen fertilization rate affected significantly some

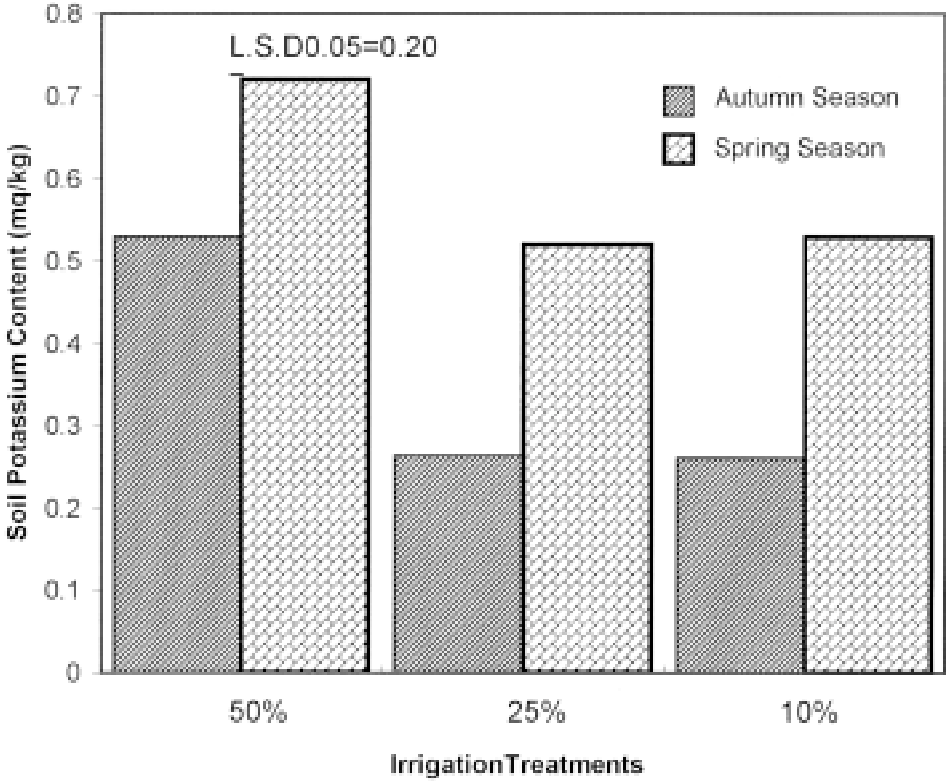

FIG. 5. Soil potassium content as affected by different irrigation treatments during two seasons of maize plant.

components of the total yield. The season affected significantly the potassium and organic matter content in soil. The nitrogen fertilization rate significantly affected the nitrogen content, potassium and pH of soil. Only potassium content in soil was significantly affected by irrigation treatments.

References

Abdel-Aziz, I.M., Mahmoud, M.H., Ashoub, M.A. and **Osman, A.O.** (1986) Growth and yield of maize (*Zea mays* L.) as influenced by nitrogen and zinc fertilization. *Annals of Agric. Sci., Ain Shams Univ.,* **31**(2): 1211-1226.

Badreshia, R. and **Patel, P.G.** (1987) Studies on split application of nitrogen to hybrid maize in summer season under south Gujarat conditions. *Gujarat Agric. Univ. Res. J.,* **12**(2): 48-49.

Banga, R.S., Tej-Singh, Yadav, S.K. and **Singh,T.** (1998) Effect of irrigation and fertility levels on nitrogen and phosphorus uptake in winter maize under shallow water table conditions in Haryana. *Ind. J. of Soil Conservation.* **26:** 135-136.

Bar, T.A., Saadi, H., Nahman, N., Kafkafi, U. and **Bar, Y.B.** (1988) Yield of corn for grain and silage under intensive cultivation. 1 – Yield and yield components as influenced by trickle irrigation frequency, high nitrogen fertilizer, and population density. *Hassadeh,* **68:** 645-646.

Benjamin, J.G., Porter, L.K., Duke, H.R. and **Ahuja, L.** (1997) Corn growth and nitrogen uptake with furrow irrigation and fertilizer. *Bands.* **89**(4); 609-612.

Berdnikov, A.M. and **Gul'Chuk, O.P.** (1987) Effect of nitrogen fertilizers applied on various dates in combination with green manure on maize yield on adernopodzolic soil. *Agrokhimiya*. **7:** 3-6.

Bertyrand, A.R. and **Kohnke, H.** (1957) Sub-soil conditions and their effects on oxygen supply and the growth of maize roots. *Soil Sci. Soc. Am. Proc.* **21:** 135.

Black, C.A., Evans D.D., Ensminger, L.E., White, J.L. and **Clark, F.E.** (1965) Methods of Soil Analysis Part 1. Physical and Mineralogical Properties, American Society of Agronomy, Inc., Publisher, Madison, Wisconsin, USA.

Boquet, D.J., Coco, A.B. and **Johnson, C.C.** (1989) Maize's response to irrigation and nitrogen. Louisiana *Agric.* **39**(2): 18-19.

Boquet, D.J., Coco, A.B. and **Summers, D.E.** (1985) Response of maize grown on sharkey clay soil to irrigation and nitrogen rate. In Annual Progress Report, Northeast Res. Stn., St. Joseph, La. and Macon Ridge Res. Stn. Winnsboro, La. Baton Rouge, Louisiana, USA; Louisiana State Univ. (undated) 73-77.

Boquet, D.J., Coco, A.B., Summers, D.E. and **Johnson, C.C.** (1986) Response of maize grown on sharkey clay to irrigation and nitrogen rate. In Annual Progress Report, Northeast Res. Stn., St. Joseph, La. and Macon Ridge Res. Stn. Winnsboro, La. Baton Rouge, Louisiana, USA; Louisiana State Univ. (undated) 88-91.

Bremner, J.M. (1965) Nitrogen availability indexes. In. C.A. Blact *et al.* (ed.). Methods of Soil Analysis. Part 2. *Agronomy.* **9:** 1324-1345.

Chen, S.S. (1992) Irrigation water and nitrogen use efficiency of spring corn under drought conditions. *J. Agri. and Forestry.* **4:** 1-12.

Day, R.A. (1956) Comparative Analysis (3rd ed.), Eaglewood, California, Prentice-Hall, Inc.

Eck, H.V. (1984) Irrigated maize yield response to nitrogen and water. *Agron. J.* **76**(3): 421-428.

Efimov, I.T. and **Naumenko, V.P.** (1980) The dependence of yield and quality of irrigated high-lysine maize on forms of nitrogen fertilizers. *Biologiya.* **15**(1): 120-122.

FAO and Ministry of Agriculture and Water (1988) "Guide for Crop Irrigation Requirements in the Kingdom of Saudi Arabia", Department of Agriculture , Saudi Arabia.

FAO Production Yearbook (2001) FAOSTAT Database-Statistical Agriculture Data.

Filip, S. and **Petrovici, P.** (1982) Investigations regarding the influence of irrigation and fertilizers in maize culture on sloping lands in Moldavia Tableland. Cercetari *Agron. in Moldova.* **4:** 59-63.

Francis, D.J. (1990) Nitrogen uptake by corn. Fertilizer Abstracts International. *B-Sciences and Engineering.* **50:7**, 2681B-2682B.

Frye, W.W. and **Blevins, R.L.** (1989) Economically sustainable crop production with legume cover crop and conservation tillage. *Journal of Soil and Water Conservation.* **44**(1): 57-60.

Hane, J.W. (1981) Nitrogen behaviour and uptake by maize as affected by time of application, nitrapyrin, supplemental winter heat. *Dissertation Abstract International,* **B.42**(6): 2169.

Hillel, D. (1982) Introduction to Soil Physics: Academic Press, New York.

Jackson, M.L. (1973) Soil Chemical Analysis, Prentice-Hall, New Delhi, India.

Larry, D.K. and **Morris, H.D.** (1972) Land disposal of liquid sewage sludge. II. The effect of soil pH, manganese, zinc, growth and chemical composition of rye. *J. Environ. Qual.* **4:** 425-429.

Nimje, P.M. and **Seth, J.** (1988) Effect of nitrogen on growth, yield and quality of winter maize. *Indian J. of Agron.* **33**(2): 209-211.

Njoku, B.O. and **Odurukwe, S.O.** (1987) Evaluation of nitrogren fertilizer sources and rates for a cassava-maize intercrop. Proc. of the 3rd Triennial Symp. of the International Soc. for Tropical Root Crops – Africa Branch, Ottawa, Canada; International Dev. Res. Center, 30-33 ISBN 0-88936-498-2.

Ogunlela, V.B., Amoruwa, G.M. and **Ologunde, O.O.** (1988) Growth, yield components and micronutrient nutrition of field-grown maize (*Zea mays* L.) as affected by nitrogen fertilization and plant density. *Fertilizer Res.* **17**(2): 189-196.

Paliwal, A.K., Singh, R.N., Mishra, R.K., Dwivedo, R.K. and **Chaudhary, S.K.** (1999) Effect of nitrogen and zinc application on the growth, yield and nutrient uptake in rainfed maize (*Zea Mays*). *Adv. in Plant Sci.* 12: 223-226.

Panchanathan, R.M., Mohandas, S. and **Kandaswamy, P.** (1987) Effect of moisture regimes and nitrogen application on maize. *Ind. J. of Agron.* **32:** 471-472.

Petrovici, P. and **Ailincai, C.** (1984) Effect of irrigation and fertilizers on wheat and maize grown on sloping land on the Moldavian plain. Cercetari *Agron. in Moldova* **2**(66): 26-28.

Pirani, V. and **Agostinelli, C.** (1989) Irrigation with nitrate polluted ground water. Informatore *Agario.* **45**(28): 53-55.

Raju, R.S. and **Iruthayaraj, M.R.** (1995) Effect of irrigation, methods of irrigation levels on nutrient uptake by maize. *Madras Agri. J.,* **82:** 215-216.

Reddy, M.R. and **Patil, S.J.** (1982) Response of hybrid maize to different sources, levels and split doses of nitrogen application under irrigated conditions. *Mysore J. of Agric. Sci.* **16**(4): 404-407.

Russell, W.A. (1984) Further studies on the response of maize inbred lines to N fertilizer. *Maydica.* **24:** 141-150.

Saren, B.K. and **Jana, P.K.** (1999) Effect of irrigation and intercropping system on yield, water-use, concentration and uptake of nitrogen, phosphorus grown as sole and intercrop. *Ind. J. Agri. Sci.* **69**(5): 317-320.

Sexton, B.T., Moncrief, J.E., Rosen, C.J., Gupta, S.C. and **Cheng, H.H.** (1996) Optimizing nitrogen and irrigation inputs for corn based on nitrate leaching and yield on a coarse-textured soil. *J. Envir. Quality*. **25:** 982-992.

Shelton, W.R. and **Harper, H.J.** (1941) A rapid method for the determination of total phosphorus in soil and plant material. Iowa State College, *J. of Sci.* **15:** 403-413.

Sims, J.T. (1986) Nitrogen transformations in a poultry manure-amended soil: temperature and moisture effects. *J. Environ. Qual*. **15:** 54-63.

Singh, A.K., Singh, G.R. and **Dixit, R.S.** (1997) Influence of plant population and moisture iegimes on nutrient uptake and quality of winter maize (*Zea Mays*). *Ind. J. of Agron.,* **42:** 107-111.

Stutler, R.K., James, D.W., Fullterton, T.M., Wells, R.F. and **Shipe, E.R.** (1981) Maize yield functions of irrigation and nitrogen in Central America. *Irrigation Sci*. **2:** 79-88.

Surendra, S.T., Sharanappa, M.R. (2000) Integrated management of nitrogen and phosphorus in Maize (*Zea mays*) and their residual effect on Cowpea (*Rigna Ungiuculata*). *Ind. J. of Agric. Sci.* **70:** 119-121.

Thorat, S.T. and **Ramteke, J.R.** (1988) Dry matter accumulation in forage maize as influenced by irrigation and nitrogen levels. *J. of Maharashtra Agric. Univ.* **13:** 211-212.

Vance, P.N. (1987) Agronomic studies on maize in papua New Guinea. *Res. Bull., Dept. of Agric. and Livestock, Papua New Guinea.* **39:** 51.

Woodruff, J.R., Ligon, J.T. and **Smith, B.R.** (1984) Water table depth interaction with nitrogen rates on sub-irrigated maize. *Agron. J.* **76:** 280-283.

تأثير مستويات مختلفة من العجز المائي والتسميد النيتروجيني على إنتاجية نبات الذرة الشامية وامتصاصها للنيتروجين وخواص التربة

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جـــدة – المملكة العربية السعودية

المستخلص . تم عمل تجربتين حقليتين بمحطة الأبحاث الزراعية بهدى الشام التابعة لجامعة الملك عبد العزيز وذلك لدراسة تأثير ثلاثة معدلات مختلفة من الري مبنية على نسب استنزاف ٥٠٪، ٢٥٪، ١٠٪ (IR_1 , IR_2 , IR_3) وأربعة معدلات سماد نيتروجين (يوريا) هي صفر، ١٠٠ ، ٢٠٠ ، ٣٠٠ كجم / هكتار (N_0 , N_1 , N_2 , N_3) على إنتاجية المادة الجافة الكلية لنبات الذرة الشامية (صنف هجين أجا ٢١٥) وأجزاءه (القش والكوز) وعلى امتصاصه للنيتروجين على مدار موسمين زراعيين (خريف ١٩٩٤ م وربيع ١٩٩٥ م) . وكذلك لاختبار التغيرات الكيميائية للتربة تحت تأثير هذه المعاملات ولقد صممت جدولة الري بحيث كانت كمية المياه المستخدمة ثابتة لمختلف معاملات الري المختلفة خلال الموسم الواحد وهي ٩٠,١٥ سم / موسم الخريف (٩٠١٥ م^3 / هكتار) و٨٢,١٠٨ سم / موسم الربيع (٨٢١٠ م^3 / هكتار) على التوالي (حيث اختلفت فقط تكرار الريات) . كان لموسم الزراعة تأثيرا معنويا عاليًا للإنتاجية الجافة حيث تفوق الموسم الأول (الخريف) على الموسم الثاني (الربيع) في وزن كل من القش والكوز وإنتاجية المادة الجافة الكلية والنيتروجين الممتص بواسطة النبات، وكان لمعاملات الري تأثيراً معنوياً على بعض مكونات المحصول حيث كانت المعاملة الثالثة IR_3 الأعلى في الوزن الجاف للكوز وإنتاجية المادة الجافة الكلية للنبات ، وكذلك أثرت معاملات السماد النيتروجيني معنويًا على بعض مكونات المحصول إذ أعطت المعاملة رقم N3 أعلى نتيجة فيما يتعلق بوزن القش وإنتاجية المادة

الجافة الكلية والنيتروجين الممتص بواسطة النبات عن باقي المعاملات. أثر الموسم معنويًا على محتوى التربة من البوتاسيوم والمادة العضوية. ولقد أثرت معاملات الري معنويًا على محتوى التربة من البوتاسيوم. كما أثرت معاملات السماد النيتروجينية معنويًا على رقم حموضة ((pH التربة ومحتواها من النيتروجين والبوتاسيوم. نتائج هذا البحث يمكن أن تكون دليلاً للباحثين والعاملين في مجال الذرة الشامية وما شابهها من المحاصيل الحقلية.