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STATUS OF N, P AND K IN SOIL AND PLANT AS AFFECTED BY SOIL MOISTURE AND IRRIGATION SYSTEMS

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ABSTRACT

A field experiment was carried out to study the effect of irrigation plant to attain soil moisture status of 75, 100 and 125 % available water (AW) under two irrigation systems: drip and furrow on status of macronutrients in soil and maize (Zea mays cv Giza 602) (at flowering, 60 days after planting; and harvest, 120 days after planting).

Increased AW decreased available-N particularly with the furrow system. The 125 % AW decreased available N in soil at flowering by 28.8 % immediately beneath the dripper, corresponding of 10 and 25 cm from the dripper were 27.7 and 48.6 % respectively. With furrow irrigation the decrease was 35.3 %. Similar trend occurred at harvest. Available-N were higher with drip than with the furrow system. Available-N increased with distance from the dripper and decraase with depth.

Increased soil moisture was associated with increased available-P particularly with furrow system. Available-P increased with increase in irrigation level and 100; 125 % AW gave 8.7 and 81.7 % more available-P than the 75 % AW treatment, in the surface layer immediately beneath dripper at flowering. Comparable values for the furrow were 30.9 and 49.5 % in the same order. A similar trend occurred at harvest. Available-P was higher under furrow system that under drip and available-P decreased going away from the dripper point in both vertical and horizontal directions. With furrow values decreased with depth.

Increasing soil moisture level was associated with increasing available-K in soil particularly with the furrow system. Available-K in soil was higher under furrow than under drip system, with a tendency of decreasing away from the dripper's point in both vertical and horizontal directions. Available-K at the furthest point from the dripper's point decreased that located immediately beneath the dripper's point. Similar trend was occurred at harvest.

Shoot dry yield was greater at 100 % AW in relation to either 75 % or 125 % AW. Indicating that 100 % AW was the most appropriate AW. Shoot dry weight at flowering was higher than at harvest by about 3, 3 and 3.3 times under drip system for treatments 1, 2 and 3 respectively. Corresponding values for furrow were 2.8, 3.7 and 3.4 times in the same order. Shoot dry yield with drip was greater than with the furrow. Shoot dry yield with the drip system was greater than with the furrow. Similar trends were recorded at harvest.

NPK-uptake was increased as soil moisture incraased. NPK-uptake with drip system were greater than with furrow.

Values of all the studied characters were higher at flowering stage as compared with that at harvest. Drip irrigation showed superior values for yield, as well as uptake of N, P and K along with available-N.

Keywords: Drip and furrow systems, NPK available and uptake, moisture, vertical, horizontal.

INTRODUCTION

Since most of cultivated area and new reclaimed soils in Egypt is almost sand in texture characterized by deep or very deep profiles and highly permeable soils hence the removal of nutrient is easy.

The basic purpose of irrigation is to supply plants with water as needed to obtain optimum yield and the desired quality of plant produce. Irrigation should take place while the soil water potential is still high enough so that the soil can supply water fast enough to meet the plant demands without placing the plant under a stress that would reduce yield and impair the quality of the harvested crop.

Fertilizers are added to the soil in order to supply plants with one or more of the essential nutrients. Recovery of fertilizer nutrients by crop varies widely with plant species, soil and climate. So, it is of interest to apply special techniques of irrigation such as drip irrigation to increase the efficiency of fertilizers since it minimizes the loss of water and nutrients outside the root zone.

Not only soil moisture affects growth and yield of crops, but it also determines the nutritional status of plants. Decan (1970) explained the favourable effect of soil moisture at low tensions on N-uptake as due to (1) increased nitrification, (2) increased efficiency of root surface, increased root growth and increased availability of soil NO_3-N. Goldberg *et al.* (1971) found in their study on elements distribution under drip irrigation system that, NO_3-N tended to increase at the edges of the bed as well as in the region between nozzle.

Hegazi (1982) found that highest concentration of NO_3-N existed mainly at the top of furrow sides under furrow irrigation whereas, under drip irrigation the concentration increased as the distance from dripper increased. Sherief (1987) reported that, under furrow irrigation, the highest concentration of nitrate N was near the surface due to surface evaporation. Mansour (1981) reported that the increase of soil moisture from 40 to 100 % of the maximum available moisture enhanced N-uptake by plant by about 30 folds.

Arnaout (1995) and Hassan (2000) concluded that drip irrigation can be successfully used to irrigate most of crops under Egyptian conditions.

Concerning available-P in soil, Lutz *et al.* (1971) mentioned that, irrigation appeared to have a little effect on the available-P content of 0-15 cm soil depth and Rizk (1979) found that available-P was highest in the top 0-30 cm depth. Hegazi (1982) found that, the highest available-P was in the middle of the furrow.

Concerning the effect of soil moisture on K, Branton *et al.* (1973) showed that K concentration in plants was very high under low moisture stress. Mengel *et al.* (1973) demonstrated that when soil moisture was maintained at pF 2, a highly significant linear relationship between K diffusion rate and total K-uptake by maize plants was obtained.

Kharkar and Deshmukh (1977) mentioned that soil available-K increased by increasing soil moisture content. Uriv *et al.* (1977) stated that, when K was applied through drip irrigation, the highest values of available-K were immediately beneath the dripper and decrease gradually with increasing distance from dripper vertically or horizontally.

Yacoub (1969) pointed out that increasing soil moisture up to 45 % of water holding capacity increased the yield of dry matter of shoots and root of wheat plants

El-Sherif (1967) reported increased dry matter content of maize plant with the increasing in soil moisture to 50-70 % of the maximum holding capacity. Mengel *et al.* (1973) reported that highest yield as well as uptake of N, P and K were obtained when groundnut plants were grown in soil with continued supply of moisture allowing no depletion of available water.

Barrada *et al.* (1959) mentioned that, the maximum uptake of plant nutrients by cotton plant occurred at the flowering stage. Rizk (1979) found that plant growth and nutrients uptake increased with increased available moisture in soil. Mackay and Barber (1985) stated that increasing soil moisture increased K-uptake in maize.

Hagag (1989) reported that as soil moisture was raised from limited to optimum, total N-uptake by maize increased by 25.8 % and 20.0 % at 60 and 90 days respectively; P and K-uptake also increased. Jordan (1952) reported that P-uptake by plant increased with increasing the soil moisture content.

The aim of this work was to assess response of plant growth and uptake of macronutrients as affected by irrigation levels ranging from a rather low application (irrigation till reaching 75 % of available water) up to a liberal application (125 % of available water) using drip or furrow irrigation system. This would help in finding the most optimum soil moisture condition, for maize growth in a sandy clay loam soil.

MATERIALS AND METHODS

A field experiment was carried out to study the status of some macronutrients in soil and plant through season in relation to applied irrigation water and irrigation system.

The work was carried out at Qualubia governorate, where the different layers (down to 150 cm) of the soil were Nile alluvial and their texture ranged between sandy loam to sandy clay loam having 10-34 % clay, 12-18 % silt and 58-88 % sand and contain 2-5 % calcium carbonate. The bulk density ranged between 1.65 to 1.75 g cm^{-3}. The infiltration rate was between 1.2 to 2.2 m/day. The irrigation water had an electrical conductivity of 0.75 dS/m; and ranges of available NPK in soil were 22-47, 8.2-16.3 and 500-680 (mg/kg) for N, P and K, respectively. Experiment was under drip and furrow irrigation.

The drip irrigation area consisted of 16 plots each of 8×8 m to cover an area of 1024 m^2 (about 0.24 fed.). It was installed 50 cm apart with dripper placed on the line at 1 meter intervals. Dripper discharge rate, 4 L/h per orifice at 1.5 bar. The furrow irrigation area contained 12 plots each of 8×6 m to cover an area of 576 m^2 (about 0.4 fed.). The irrigation treatments were as follows:

1- Supply irrigation water so that available water (AW) would reach 75 % of its maximum (i.e. 75 % AW) (coded M_1: adequate moisture treatment).
2- Supply irrigation water so that available water (AW) would reach its maximum (i.e. 100 % AW) (coded M_2: optimum moisture treatment).
3- Supply irrigation water so that available water (AW) would reach its maximum plus 25 % of it (i.e. 125 % AW) (coded M_3: the wet moisture treatment).

Planting and fertilizer treatments:

All agricultural management practices were the same for all treatments and 20 m^3 of farmyard manure were added before planting. Maize plant (Zea Mays) was planted on 10th June 2000. Fertilizer application was as follow:

1- N was applied at 115 kg N/fed. as ammonium sulphate (20 % N) in three equal doses, at bud break (BB), (BB+ 2 weeks), (BB+ 4 weeks), respectively.
2- P was applied at 75 kg/fed. (before planting), as calcium superphosphate (6.5 % P) before planting.
3- K was applied at 72 kg/fed. (before planting), as potassium sulphate (42 % K) in two equal doses, the first after thinning and the second after 20 days of the first.

Sampling:

Soil samples were collected from each plot in two directions around the dripper to represent three successive lateral points at 0, 10 and 25 cm midway between two successive drippers. At each point five successive samples were taken to represent the depth of 0-10, 10-20, 20-30 and 30-60 cm. Soil samples were collected from every position as follows:

Daily samples were taken to determine the soil moisture in order to determine the time of irrigation. Other samples were taken to determine available NPK in two stages (1) at flowering, (2) at harvest.

Methods of analysis:

Soil:

Mechanical analysis of the soil was done according to the pipette method described by Piper (1950). Soil moisture content was done relative to oven drying at 105 °C (Black, 1965). Bulk density was determined according to method described by Black (1965).

pH was done in the soil paste, EC was measured in the soil paste extract, calcium carbonate and available NPK were measured according to Jackson (1976).

Plant:

Upper parts of plants were sampled in two stages as follows:

1- Midseason stage (flowering stage, 60 days after planting).
2- Late season stage (end of the experiment, harvest stage, 120 days after planting).

Samples were oven dried at 70 °C then digested using a concentrated mixture of perchloric + sulphuric acids for analysis of P and K and using concentrated sulphric acid for analysis of N (Black, 1965). Phosphorus was measured spectrophotometrically using the molybdenum blue method, potassium was measured using the flame photometer according to the method described by Jackson (1976). N was determined by using the Semi-microkjeldahl method (Jackson, 1976)

RESULTS AND DISCUSSION

Available NO_3-N in relation to irrigation levels:

Values of available NO_3-N are shown in Table 1 and Fig. 1. In this concern increasing soil moisture through increasing applied water from 75 % AW to 100 % and 125 % AW (treatment 1,2 and 3 respectively) decreased available NO_3-N in soil. The rate and magnitude of decrease along the 0-60 cm in soil depth varied widely. The increase of soil moisture from 75 % AW to 125 % AW decreased available NO_3-N at flowering, at the dripper by an average of 28.8 %; corresponding values at 10 and 25 cm away from the dripper were 27.7 and 48.6 % respectively. In the furrow irrigation, the decrease was 35.3 %. Similar trends occurred in soil at harvest. Therefore higher soil moisture was associated with lower values of available NO_3-N.

Available NO_3-N in relation to the applied irrigation systems:

Data in Table 1 and Fig. 1 show that the values of available NO_3-N were higher under drip irrigation in all the studied positions as compared with that under furrow irrigation.

Greater available NO_3-N in the drip system (at 0-cm beneath the dripper) over the furrow system in the surface layer at flowering reached to 15.9, 30.5 and 17.8 % in treatments 1, 2 and 3, respectively. Corresponding increases at harvest were 18.4, 15.4 and 16.8 % respectively. This may be due to the drip irrigation supplying the water through slow application to the soil and allowing water to dissipate under low pressure to supply each plant with very little loss of soluble-N by leaching.

Regarding the distribution pattern of available NO_3-N in soil, data in Table 1 and Fig. 1 show that under drip irrigation, available NO_3-N increased along the direction from the dripper's point to the edge of the wetting front, but decreased with depth, in the case of the furrow system, there was also a decrease with depth.

At the furthest point from the dripper, the values of available NO_3-N at flowering were about 4.2, 2.2 and 2.8 times those related at the point of the dripper in irrigation water treatments 1, 2 and 3 respectively. Corresponding values at harvest were 2.7, 1.5 and 1.0 times. This seems to correspond to the decrease in soil moisture content (Goldberg *et al.* 1971).

Available NO_3-N was higher at flowering than that harvest either under drip or furrow systems. This reflects the continuous removal of nitrogen by plant along with the mass flow of water with the progress of time. This behaviour was more pronounce in the treatment of the highest amount of water.

Values of available NO_3-N at flowering as compared with those at harvest were higher by 101.0, 90.8 and 83.5 % in irrigation treatments 1, 2 and 3 respectively under the drip system at the surface layer 0-5 cm immediately beneath the dripper's point. Corresponding percentages for the furrow system were 105.3, 68.6 and 81.9 % respectively. A high negative significant correlation was obtained between available NO_3-N and soil moisture content ($r = -0.980^{**}$ and -0.958^{**} for drip and furrow system, respectively.

Table (1): Values and behavior of available-N (mg/kg) (2 $\underline{N}$ KCl-extractable) in soil in relation to irrigation levels and irrigation systems.

Soil irrigation levels % of AW	Depth (cm)	Drip irrigation						Furrow irrigation	
		Distance from dripper (cm)							
		0		10		25			
		F	H	F	H	F	H	F	H
75	0-5	58.1	28.9	66.7	16.0	246.0	77.9	50.1	24.4
	5-15	41.3	11.3	46.5	12.7	96.9	42.1	35.1	13.6
	15-30	36.1	19.9	37.1	19.9	86.4	25.7	28.6	14.9
	30-60	36.3	21.9	35.5	15.3	45.0	35.3	23.9	13.6
100	0-5	45.8	24.0	54.5	20.2	100.1	36.1	35.1	20.8
	5-15	30.9	18.3	45.5	22.8	96.0	29.8	29.1	16.0
	15-30	31.2	14.5	36.1	14.5	55.7	18.9	26.1	12.8
	30-60	14.5	11.0	34.3	19.6	41.3	29.0	23.8	11.6
125	0-5	34.5	18.8	53.6	16.0	92.2	19.9	29.3	16.1
	5-15	28.2	17.7	42.7	17.7	80.9	13.7	27.6	10.4
	15-30	30.8	16.6	20.0	18.9	43.6	18.9	24.0	13.9
	30-60	18.2	14.3	18.2	13.7	27.3	17.3	22.2	12.8

F = Flowering stage. H = Harvest stage.
L.S.D (0.05) for drip irrigation: 0.42 (For mean values, at 0 cm from dripper at flowering)
L.S.D (0.05) for furrow irrigation: 0.69 (For mean values at flowering).
No statistical analysis was done regarding harvest or 10, 25 cm from dripper

Available-P in relation to irrigation levels:

Values of available-P are presented in Table 2 and Fig. 1. Available-P increased with increase in irrigation level, and treatments 2 and 3 gave 8.7 and 81.9 % more available-P at flowering stage as compared to contents of available-P in treatment 1 in the surface layer 0-5 cm immediately beneath the dripper's point. Comparable values for the furrow system at the same stage were 30.9 and 49.5 % in the same order. A similar pattern occurred with regard to contents at harvest.

Available-P in relation to the irrigation systems:

Regarding the effect of irrigation system on the status of available-P, data (Table 1) reveal that in all irrigation treatments the furrow system showed higher values of available-P than the drip system. The increase at flowering reached to 72.3, 107.5 and 41.6 % as compared with the drip system at the surface layer 0-5 cm immediately beneath the dripper. Similar trend was observed at harvest.

Table (2): Values and behavior of available-P (mg/kg) (0.5 N Na_2HCO_3-extractable) in soil in relation to irrigation levels and irrigation systems.

Soil irrigation levels % of AW	Depth (cm)	Drip irrigation						Furrow irrigation	
		Distance from dripper (cm)							
		0		10		25			
		F	H	F	H	F	H	F	H
75	0-5	33.2	12.0	19 5	10.8	18.5	15.5	57.2	38.1
	5-15	20 1	9.3	12.9	9.3	15.0	9.3	38.5	23.9
	15-30	17.3	7.2	12.9	7.7	12.0	7.2	16.6	16.6
	30-60	12.0	7.2	11.5	9 3	8.6	8.2	16.4	16.4
100	0-5	36.1	15.5	25.2	14.1	21.6	16.5	74.9	35.5
	5-15	21.6	9.9	19.5	11.0	15.8	10.3	41.2	21.0
	15-30	18.3	8.8	19.5	9.10	14.5	11.3	22.5	21.4
	30-60	14.4	9.8	14.4	7.7	13.7	9.6	18.3	17.5
125	0-5	60.4	17.0	29.5	19.6	27.3	18.5	85.5	28.1
	5-15	26.6	16.5	21.0	17.5	18.7	16.5	47.9	18.9
	15-30	22.1	15.5	19.7	12.4	18.0	15.5	31.9	20.1
	30-60	21.9	9.3	18.7	7.9	18.0	14.4	21.1	17.9

F = Flowering stage. H = Harvest stage.
L.S.D (0.05) for drip irrigation: 0.29 (For mean values, at 0 cm from dripper at flowering)
L.S.D (0.05) for furrow irrigation: 1.0 (For mean values at flowering)
No statistical analysis was done regarding harvest or 10, 20 cm from dripper

The vertical and horizontal distribution pattern of available-P (Table 1) in soil followed a trend of decreasing with horizontal distance away from dripper, as well as with depth. With the furrow system, P decreased with depth.

Values, at flowering, of available-P at the furthest point from the dripper were lower than at the point of the dripper. Such values were 44.2, 40.2 and 54.8 % for treatments 1, 2 and 3 respectively at surface layer of 0-5 cm.

The values of available-P were higher at the flowering stage compared with at harvest. Contents at flowering were 2.8, 2.3 and 3.6 times those at harvest in the top 0-5 cm immediately beneath the dripper for irrigation treatments 1, 2 and 3 respectively. Comparable values for the furrow system were 1.5, 2.0 and 3.0 times in the same order respectively. This reflects continuous uptake of P by plant along with the movement of P with the mass flow of water out-side the root area.

Increasing soil moisture was associated with increasing P contents ($r= 0.871^{**}$ and 0.997^{**} for drip and furrow systems, respectively).

Available-K in relation to irrigation levels:

Data in Table 3 and Fig. 1 show that available-K increased with the increase in irrigation water application. Available-K for treatments 2 and 3 showed greater contents over that of treatment 1 amounting to 13.2 and 44.1 % respectively at flowering; and 7.7 and 8.9 % respectively at harvest for the 0-5 cm surface layer immediately beneath the dripper. Comparable increases for the furrow system were 21.9 and 35.5 % at flowering and 14.1 and 17.8 % at harvest. These results agree with those by Kharkar and Deshmukh (1977) who mentioned that, available-K in soil increased with increasing soil moisture content.

Table (3): Values and behavior of available-K (mg/kg) (1 $\underline{N}$ NH_4 OAC-extractable) in soil in relation to irrigation levels and irrigation systems.

Soil Irrigation Levels % of AW	Depth (cm)	Drip irrigation						Furrow irrigation	
		Distance from dripper (cm)							
		0		10		25			
		F	H	F	H	F	H	F	H
75	0-5	652	513	573	552	552	513	739	602
	5-15	594	493	550	514	494	474	677	533
	15-30	513	436	510	494	428	494	535	397
	30-60	493	413.2	502	494	428	436	496	366
100	0-5	739	553	594	873	652	523	900	687
	5-15	676	533	552	532	533	513	767	543
	15-30	573	513	513	513	494	494	664	513
	30-60	513	494	507	513	494	435	552	396
125	0-5	940	559	920	573	776	639	1001	709
	5-15	860	535	840	718	715	635	945	690
	15-30	739	615	739	635	552	533	878	494
	30-60	567	514	615	515	533	513	656	413

F = Flowering stage. H = Harvest stage.
L.S.D (0.05) for drip irrigation: 6 (For mean values, at 0 cm from dripper at flowering)
L.S.D (0.05) for furrow irrigation: 30 (For mean values at flowering)
No statistical analysis was done regarding harvest or 10, 25cm from dripper

Available-K in relation to the applied irrigation systems:

Available-K in soil (Table 3 and Fig. 1) was higher under furrow irrigation compared with under drip irrigation. Available-K in the 0-5 cm layer at flowering under furrow compared to that at the dripper's point was greater by 13.3, 21.9 and 6.5 % for irrigation treatments 1, 2 and 3 respectively. High values of available-K may be attributed to sampling collection being rather towards microlocations of fertilizer applications.

Regarding the behaviour and distribution pattern of available-K thorough different soil layers, data show a slight increase in the upper soil layers. Under drip system there was a tendency to decrease away from the dripper. Values of available-K at the furthest point from the dripper decreased than at the dripper's point by 15.3, 11.7 and 17.4 % in irrigation treatments 1, 2 and 3 respectively at flowering. Similar trend of K status were observed at harvest. These results agree with those of Uriv *et al.* (1977) who reported that, when K was applied through a drip irrigation system, the highest values of available-K were immediately beneath the dripper and decreased with increasing the distance from the dripper in both vertical and horizontal directions.

The values of available-K were highest at the flowering stage compared to those at harvest. Contents at flowering were 1.3, 1.3 and 1.7 times those at harvest, in the top 0-5 cm immediately beneath the dripper related to treatments 1, 2 and 3, respectively. Comparable values for the furrow system were 1.2, 1.3 and 1.4 times in the same order.

Increasing soil moisture was associated with increasing K contents ($r= 0.925^{**}$ and 0.998^{**} for drip and furrow irrigation, respectively).

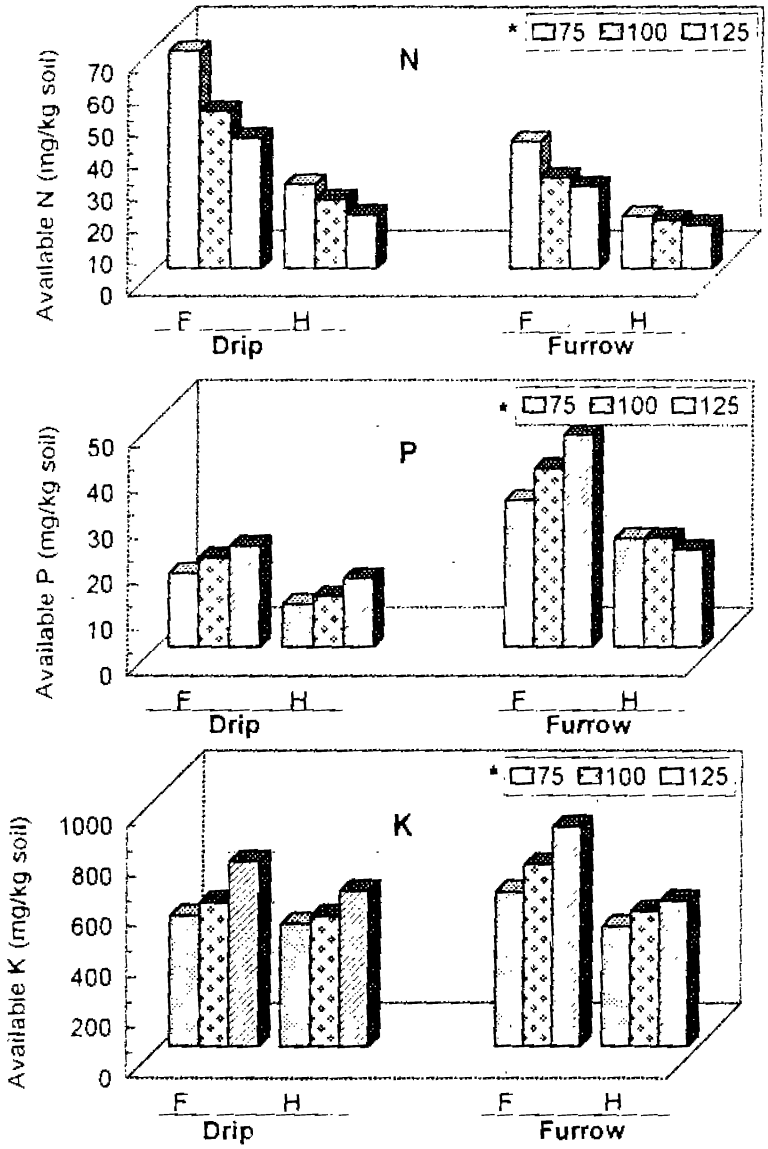


Fig. (1): Available N, P and K in relation to irrigation levels and irrigation systems at different stages of maize plant.

(Values for drip system denote means of three points along the 25 cm distance from dripper and 60 cm soil depth.)

F Flowering, 60 days after emergence H: harvest, 120 days after emergence

*Irrigation levels Irrigation water as to acheive 75, 100 or 125% of available moisture in soil

Plant growth and related measurements:

Dry weight of shoots in relation to soil moisture levels:

Data in Table 4 and Fig. 2 show that shoot dry weight of plant increased with increased application of irrigation water up to treatment 2; then a decrease occurred at treatment 3. Raising the amount of water from treatment 1 to treatment 2 increased dry matter yield by 28.9 %. Raising soil moisture from treatment 2 to treatment 3 was associated with 6.5 % decrease at flowering stage; under drip irrigation. Under furrow irrigation comparable values were 19.8 and 3.7 % respectively.

The direct favourable effect of soil moisture on increasing plant growth occurred up to treatment 2 indicating that 100 % AW was more appropriate for plant growth than 75 % or 125 % AW. Increasing irrigation from treatment 1 to 3 increased yield, but treatment 2 was the most effective. High soil moisture would enhance plant growth (Hassan, 2000).

Dry weight of shoots in relation to irrigation systems:

Table 4 show that drip irrigation system gave higher dry matter yield than furrow irrigation system. Increases at flowering for the drip system over the furrow one were 5.7, 13.7 and 10.7 % for treatments 1, 2 and 3, respectively.

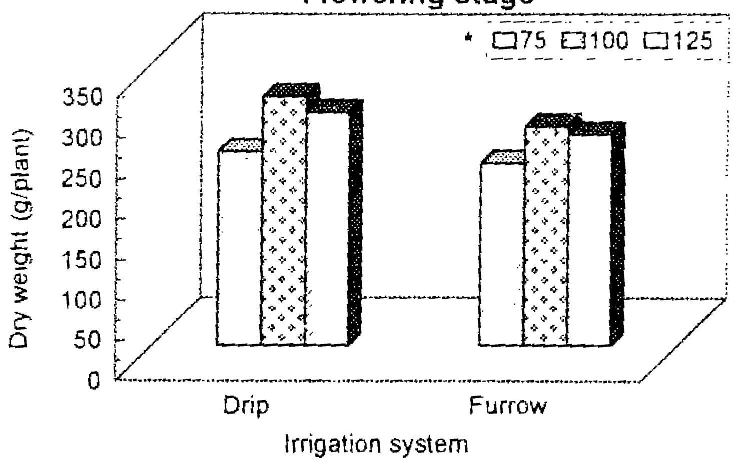
Dry matter yield was higher at the flowering stage than at harvest. The rate and magnitude of increase varied with respect to the period after planting. The increase of soil moisture levels from treatment 1 to treatment 3 increased dry matter yield by 19.5, 14.9 and 17.6 % under the drip system for irrigation treatments 1, 2 and 3 respectively. Comparable values under the furrow system were 21.5, 15.8 and 18.8 % respectively. The flowering stage represent the period of plant growth where the plant is in its most active state (Hagag, 1989).

Increasing soil moisture content was positively correlated with dry matter yield ($r = 0.902^{**}$ and 0.953^{**} for drip and furrow irrigation respectively).

Table (4): Fresh and dry weight of maize shoots (g/plant) in relation to irrigation levels and irrigation systems.

Soil irrigation levels % of AW	Drip irrigation				Furrow irrigation			
	Fresh weight		Dry weight		Fresh weight		Dry weight	
	F	H	F	H	F	H	F	H
75	1050	650	239	200	846	525	226	186
100	1351	901	308	268	1100	867	271	234
125	262	811	288	245	1062	751	260	220
$LSD_{0.05}$			4.19	1.75			1.67	0.92

F = Flowering stage.
H = Harvest stage.



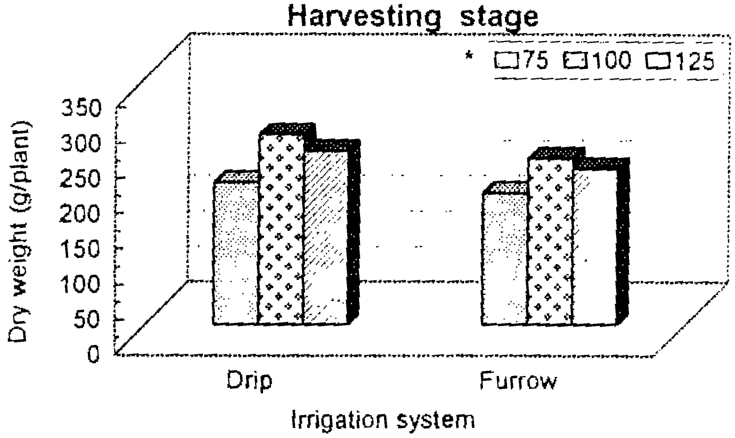


Fig. (2): Dry weight of maize shoots (g/plant) in relation to irrigation levels and irrigation systems at different stages of plant growth.

(Values for drip system denote means of three points along the 25 cm distance from dripper and 60 cm soil depth)

F Flowering, 60 days after emergence H harvest, 120 days after emergence

*Irrigation levels. Irrigation water as to acheive 75, 100 or 125% of available moisture in soil

N-uptake in relation to irrigation levels:

Data in Table 5 and Fig. 3 show the effect of soil moisture level on N-uptake by maize plant. Increasing application of water increased N-uptake by plant. N-uptake under drip irrigation at flowering showed increases of 43.4 and 44.7 % at treatments 2 and 3 respectively as related to treatment 1. Comparable values under the furrow system were 20.1 and 21.5 % respectively. Similar tendency of increase in N-uptake upon increasing applied irrigation water also attained at harvest stage. At harvest, increases for treatments 2 and 3 over treatment 1 were 58.2 and 64.1 % under drip irrigation against 31.7 and 37.7 % under furrow irrigation. These results are in agreement with those obtained by Mansour (1981) who reported that, the increase of soil moisture from 40 to 100 % of the maximum available moisture enhanced N-uptake by maize plant about 30 folds.

Table (5): N, P and K uptakes in maize shoots at flowering and harvest stages in relation to irrigation levels and irrigation systems.

Irrig. System	Irrig. Levels % of AW	Nitrogen Uptake (mg/shoot)		Phosphorus Uptake (mg/shoot)		Potassium Uptake (mg/shoot)	
		F	H	F	H	F	H
Drip	75	356	251	26.3	20.0	40.7	28.0
	100	511	397	39.0	28.2	61.5	42.9
	125	515	412	46.1	31.9	72.0	51.5
	$LSD_{0.05}$	0.08		0.001		0.0014	
Drip	75	293	208	20.3	14.8	33.9	20.4
	100	352	274	32.2	17.3	51.4	35.2
	125	365	286	36.5	19.8	52.1	30.8
	$LSD_{0.05}$	0.08		0.001		0.87	

F = Flowering stage.
H = Harvest stage.
Statistical analysis was done only for N, P and K uptake at flowering.

N-uptake in relation to irrigation systems:

Data in Table 5 and Fig. 3 clarifies the effect of the irrigation system on N-uptake. N-uptake was higher under the drip system than under the furrow one. The increase due to the drip system over the furrow one at flowering was 21.5, 45.2 and 44.7 % at treatments 1, 2 and 3 respectively. Corresponding values at harvest were 20.7, 44.9 and 44.1 %, respectively.

Drip irrigation would allow water and plant nutrients to dissipate to supply plants with sufficient moisture and nutrients.

N-uptake was higher at flowering than that at harvest. N-uptake at flowering exceeded that at harvest by 41.8, 28.8 and 25.0 % under the drip system with treatments 1, 2 and 3 respectively. Corresponding values under the furrow system are 40.9, 28.5 and 27.7 % respectively. This reflects the considerable effect of the flowering stage, which represents the maximum stage of plant growth, along with the continuous translocation of the element from the shoots to the ear till maturity occurred (Hagag, 1989).

There was a positive correlation between soil moisture content and N-uptake ($r = 0.993^{**}$ and 0.998^{**} for drip and furrow irrigation system, respectively).

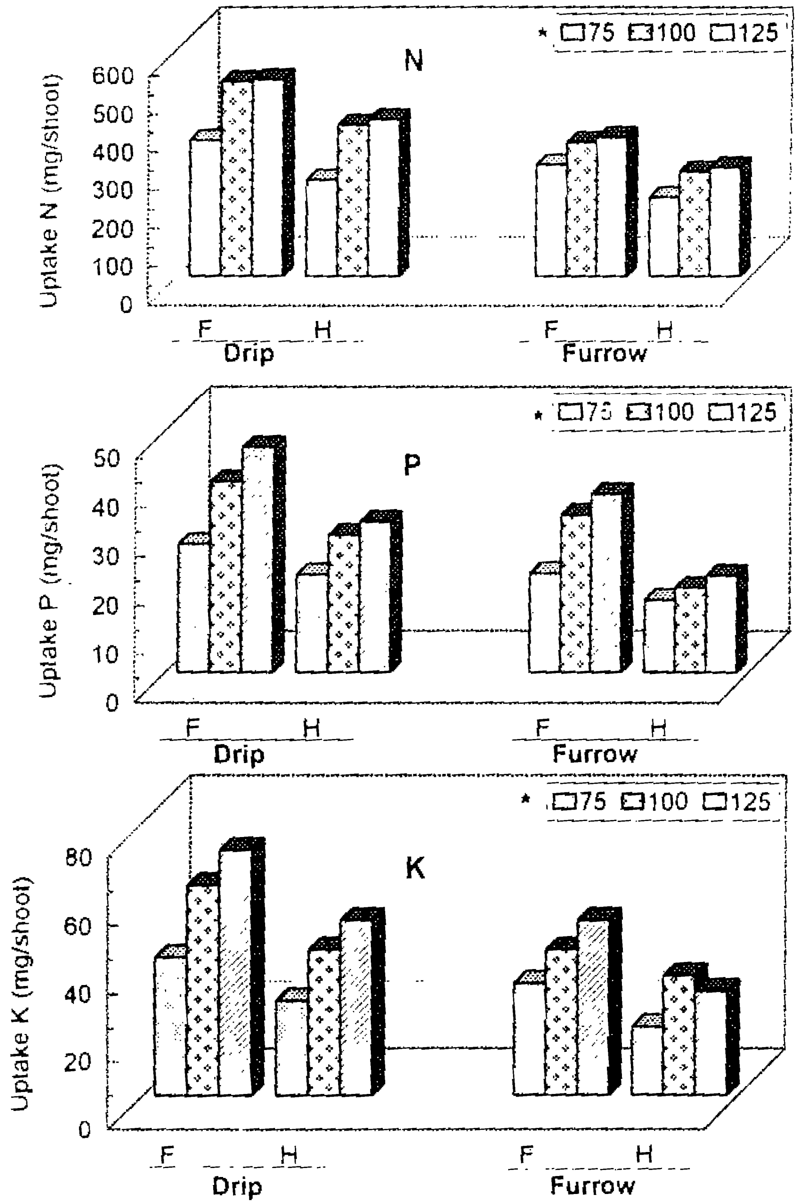


Fig. (3): N, P and K uptakes in relation to irrigation levels and irrigation systems at different stages of maize plant.

F Flowering, 60 days after emergence H harvest, 120 days after emergence
*Irrigation levels Irrigation water as to acheive 75, 100 or 125% of available moisture in soil.

P-uptake in relation to irrigation levels:

As shown in Table 5 and Fig. 3, treatments 2 and 3 exceeded treatment 1 by 48.3 and 75.3 %, respectively under drip irrigation system against 58.6 and 79.8 % under the furrow one at flowering stage. Comparable values for the harvest stage were 41.0 and 59.5 % under the drip system; 16.9 and 33.8 % under the furrow one. The positive effect of greater moisture must have enhanced mobility of soluble-P to root and more available could uptake by plant.

P-uptake in relation to irrigation systems:

Table 5 and Fig. 3 show that under drip irrigation and at flowering P-uptake was higher as compared to that under furrow irrigation by 29.5, 21.3 and 26.3 %, at treatment 1, 2 and 3 respectively. Comparable values at harvest were 35.1, 63.0 and 61.0 %, respectively.

P-uptake at flowering exceeded that at harvest by 31.6, 38.3 and 44.6 % for treatments 1, 2 and 3, respectively under drip irrigation; 37.0, 86.1 and 84.3 % respectively under furrow irrigation one.

Soil moisture was positively correlated with P-uptake by plant ($r = 0.995^{**}$ and 0.941^{**} for drip and furrow irrigation, respectively).

K-uptake in relation to irrigation levels:

The effect of irrigation levels is drown in Table 5 and Fig. 3. At flowering, K-uptake for treatment 2 and 3 exceeded that at treatment 1 by 51.1 and 77.0 %, respectively under drip; 51.6 and 53.6 %, respectively under the furrow system. Respective values at harvest were 53.2 and 83.9, respectively under drip; 72.5 and 51.0 %, respectively under furrow.

Increasing soil moisture levels by increasing applied water enhanced K-uptake and treatment 3 (of 125 % AW) showed the highest K-uptake. High soil moisture would enhance absorption of K by plant.

K-uptake in relation to the irrigation systems:

Data in Table 5 and Fig. 3 show that under drip irrigation, K-uptake was greater than under furrow irrigation. At flowering, K-uptake of the drip-irrigated plants exceeded that of the furrow-irrigated ones by 20.1, 19.6 and 38.1 % with irrigation treatments 1, 2 and 3, respectively. Comparable values at harvest were 37.3, 21.9 and 67.2 %, respectively. Therefore such a trend of greater K-uptake under drip irrigation than under furrow irrigation was rather similar to the trends of P-uptake and N-uptake as well as the trend of plant growth (expressed as dry matter yield). It reflects the greater efficiency of drip irrigation over surface furrow irrigation.

Data also reveal a positive correlation between soil moisture and K-uptake ($r = 0.909^{**}$ and 0.964^{**} for drip and furrow irrigation, respectively).

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تأثير مستوى الرطوبة ونظم الرى المستخدمة على حالة النتروجين والفوسفور والبوتاسيوم فى التربة والنبات.

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أجريت تجربة حقلية لدراسة تأثير ثلاث مستويات رطوبة مختلفة (٧٥ ، ١٠٠ ، ١٢٥ % من الماء الميسر) تحت نظامى رى مختلفين (رى بالتنقيط ورى بالغمر) على حالة وسلوك بعض العناصر الغذائية الكبرى (ن، فو ، بو) فى التربة والنبات (نبات الاذرة صنف جيزة ٦٠٢) خلال فترتين مختلفين من نمو نبات الأذرة فترة التزهير (٦٠ يوما من الزراعة) وفترة الحصاد (١٢٠ يوما من الزراعة).

وقد أوضحت النتائج أن زيادة المحتوى الرطوبى بالتربة أدى إلى نقص تركيز النتروجين الميسر فى التربة وكان معدل النقص أكثر وضوحا تحت نظام الرى بالغمر وقد أدى زيادة المحتوى الرطوبى إلى ١٢٥ % من الماء الميسر إثناء فترة التزهير إلى نقص تركيز النتروجين الميسر فى التربة بنسبة ٢٨ % خاصة فى المنطقة الواقعة مباشرة تحت النقاط بينما بلغ هذا النقص فى المسافات الواقعة على بعد ١٠ ، ٢٥ سم من النقاط حوالى ٢٧,٧ ، ٤٨,٦ % على التوالى فى حين بلغ هذا النقص ٣٥,٣ % تحت نظام الرى بالغمر. وقد لوحظ هذا السلوك أيضا أثناء فترة الحصاد. كذلك ارتفع مقدار النتروجين الميسر فى التربة تحت نظام الرى بالتنقيط عنة تحت نظام الرى بالغمر. كذلك يزداد مقدار النتروجين الميسر فى التربة بزيادة المسافة الأفقية من النقاط بينما يقل رأسيا مع العمق كذلك تناقص التركيز رأسيا مع العمق تحت نظام الرى بالغمر.

وبالنسبة لعنصر الفوسفور الميسر فى التربة فقد زاد تركيزه بزيادة المحتوى الرطوبى وكانت الزيادة أكثر وضوحا تحت نظام الرى بالغمر. هذا وقد أدى زيادة المحتوى الرطوبى من ٧٥ % إلى ١٠٠ ، ١٢٥ % من الماء الميسر إلى زيادة فى مقدار الفوسفور الميسر تترلوح بين ٨,٧ ، ٨١,٧ % للمعاملات ٢ ، ٣ على التوالى خاصة فى الطبقة السطحية (٠-٥ سم) فى المنطقة أسفل النقاط مباشرة أثناء فترة التزهير مقابل ٣٠,٩ ، ٤٩,٥ % تحت نظام الرى بالغمر. كذلك يزداد مقدار الفوسفور الميسر تحت نظام الرى بالغمر مقارنة بمثيله تحت نظام الرى بالتنقيط. يتضح أيضا من النتائج أن مقدار الفوسفور الميسر يتناقص تدريجيا كلما ابتعدنا من مصدر الرى (النقاط) كذلك فانه يتناقص راسيا بزيادة العمق. كذلك يتناقص الفوسفور رأسيا بزيادة العمق فى حالة الرى بالغمر. وقد سلك الفوسفور الميسر أثناء فترة الحصاد سلوكا مشابها لمثيلة أثناء فترة التزهير وإن اختلفت القيم.

كذلك تشابه سلوك البوتاسيوم الميسر فى التربة من حيث تأثره بالمحتوى الرطوبى مع الفوسفور حيث زاد التركيز فى التربة بزيادة المحتوى الرطوبى كما أنه يتناقص تدريجيا بالبعد من مصدر الرى (النقاط) كذلك يتناقص التركيز راسيا بزيادة العمق. وفى حالة الرى بالغمر فان التركيز يتناقص راسيا بزيادة العمق. وقد زاد تركيز البوتاسيوم تحت نظام الرى بالغمر عنه تحت نظام الرى بالتنقيط وذلك أثناء فترة التزهير. كان سلوك البوتاسيوم الميسر فى الحصاد مشابها لمثيله أثناء فترة التزهير وإن اختلفت القيم لانتقال جزء من العنصر إلى الحبوب (الكوز).

أدى زيادة مستوى الرطوبة فى التربة إلى زيادة الوزن الجاف وقد سجل المستوى الرطوبى ١٠٠ % من الماء الميسر أعلى القيم مقارنة بالمستويات الأخرى تحت الدراسة. كذلك زاد الوزن الجاف للمجموع الخضرى أثناء فترة التزهير عنه أثناء فترة الحصاد لانتقال نسبة من المادة الجافة إلى الحبوب (الكوز). وتشير النتائج أيضا إلى زيادة مقدار الوزن الجاف للمجموع الخضرى تحت نظام التنقيط مقارنة بمثيله تحت نظام الغمر.

أدى زيادة المحتوى الرطوبى بالتربة من ٧٥ % من الماء الميسر إلى ١٠٠ ، ١٢٥ % إلى زيادة ن ، فو ، بو الممتص. وقد احتفظ الرى بالتنقيط بأعلى القيم مقارنة بالرى بالغمر.

ومما هو جدير بالذكر أن كل القيم التى تم دراستها كانت ذات قيم أعلى أثناء فترة التزهير عنها اثناء فترة الحصاد. كذلك أظهر الرى بالتنقيط تفوقا بالنسبة لكل من الوزن الجاف للمجموع الخضرى وكذلك ن ، فو ، بو الممتصة إلى جانب النتروجين الميسر.