Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURAL SCIENCES JOURNAL
Volume 1, Issue 2, 2018, Pages 23–35
Available online at www.agricuta.edu.eg
The 1st International Conference on Applied Agricultural Sciences and Prospective Technology

Optimum rate of nitrogen fertilization for drip irrigated maize under semi-arid conditions

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Abstract

Water and nitrogen are major limiting factors for crop growth and development in arid regions. A field experiments were carried out at the semi-arid region of Upper Egypt, Assuit governorate during 2014 and 2015 growing seasons. The experiments were conducted to investigate the response of drip irrigated maize to three levels of nitrogen (N) fertilization (N_{220}=220, N_{290}=290, and N_{360}=360 kg ha^{-1}). The measured growth parameters of maize were significantly higher when N was applied at a rate of 360 kg per hectare compared to other N rates (220 and 290 kg ha^{-1}). The highest N supply (N_{360}) increased the uptake of N, P, and K by 43, 41, and 53%, respectively, as compared to the lowest rate (N_{220}). N360 increased maize grain yield by 56 and 62% in the first and second season, respectively, as compared to N_{220}. N_{360} increased the water use efficiency (WUE) by 54 and 40% in the first and second season, respectively, compared to N_{220}. Based on the obtained results, it is recommended to fertilize drip irrigated maize by $_{360}$ kg per hectare.

Keywords: drip irrigation, N fertilization, nutrients uptake, water use efficiency.

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1. Introduction

Maize is one of the most important crops in the world and using drip irrigation in its production is commonly known. Drip irrigation system maximized maize grain yield and water use efficiency compared to the sprinkler irrigation system (Abd El-Wahed and Ali. 2013). Drip irrigation has several advantages over traditional methods, such as better water and nutrients management (Eissa *et al.*, 2013), increasing crops yield and quality (Aujla *et al.*, 2007; Eissa *et al.*, 2013), and efficient use of water and nutrients (Al-Omran *et al.*, 2005; Mathieu *et al.*, 2007; Eissa *et al.*, 2013; Liang *et al.*, 2014). In modern irrigation systems, water and nutrients are supplied simultaneously (fertigation), mainly by drip irrigation devices (Bar-Yosef, 1999) which is considered to be the most effective method to supply water and nutrients to plants (Zhang *et al.*, 2013). Fertigation is the addition of fertilizers through irrigation water. It is particularly important for irrigated agriculture in soils where large quantities of fertilizers should be applied to meet crop requirements and to prevent loss by leaching (El-Hendawy *et al.*, 2008; Vijayakumar *et al.*, 2010; Feleafel and Mirdad, 2013) that the drip irrigation system has many advantages. It saves water, machinery and labour, application of fertilizers is more accurate and uniform, and nutrient uptake by roots is improved. Drip irrigation proves its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of the root zone. Fertilizer application, also, is the most important factor of increasing yield per unit area. Nitrogen is considered as one of major nutrients required by the plants for growth, development and yield (Singh *et al.*, 2003). N and K fertilizer applications had significant effect on yield of maize (Abdel Mawly and Zanouny, 2005). All nitrogen treatment a positive effect of over the control regarding yield in maize (Ma and Subedi, 2005). Increasing nitrogen application resulted increase in maximum stem length, 100-grain weight and grain yield of maize (Wajid *et al.*, 2007). Nitrogen is the most important element for plant growth and development. Nitrogen is an integral component of many compounds essential for maize growth processes including chlorophyll and enzymes. Nitrogen also mediates the utilization of potassium, phosphorous and other element in plants (Brady, 1984). Nitrogen affected cell metabolism and enzyme activity and regulates cell osmosis and photosynthesis. The previous studies indicated that abundant nitrogen encouraged cell division and elongation increased leaves number which consequently enhanced plant growth, and this may explain the favorite effect of increasing N rate on plant growth (Abdel-Mawly and Zanouny, 2005; El-Hamdi *et al.*, 2008). The increment of NPK concentration in maize plants and grains might be due to higher availability of the nutrients with increasing the N fertilizer levels which finally resulted in better root growth and more physiological activities for nutrients absorbance. These results are in accordance with those obtained by Ibrahim and Kandil (2007) and El-Hamdi *et al.* (2008). Maize (*Zea mays*) is one of the most important cereals for both human and animal consumption. It is planted for grain and forage. In terms of global production, maize is the third most important food crop after rice and wheat (USDA, 2011). Irrigation and fertilization are crucial factors for successful establishment of annual food crops such as cereal crops (Konopka *et al.,* 2009; Eissa *et al.,* 2013). Maize (*Zea maize* L.) is considered one of the most important cereal crops in Egypt. Total annual area cultivated with maize varieties was estimated 625-840 Thousand hectares. Total area under cultivation of maize in Egypt is 2.215 million faddans (1 feddan = 4200 m² = 0.42 hectares = 1.038 acres) which is about 25.00 % of the total cultivated agricultural land while average yield is 3.40 ton grains fa-1. (FAO, 2016). The objectives of the present study were to investigate the effect of nitrogen rates on maize yield, its components, nutrients uptake and some water relations such as water use efficiency under drip irrigation method in Upper Egypt.

2. Materials and methods

2.1 The experiments

The present experiments were carried out at the farm of Agricultural Experimental Station of the Faculty of the Agriculture, Assiut University, Egypt (Latitude: 27^{o} 12 N and longitude 310^{o} 09 E longitude at an altitude of 51 m a.s.l.). The soil was classified as Typic, Torri fluvents according to Soil Taxonomy (Soil Survey Staff, 2016) and Table 1 shows some physical and chemical properties of the experimental site. The experiment included three rates of nitrogen (N_{220}=220, N_{290}=290, and N_{360}=360 kg ha$^{−1}$). The experimental site was irrigated using a drip irrigation system. The in-line GR dripper laterals were installed 0.7 m apart. The emitters were spaced 0.30 m apart with a flow rate of 2.1 L h$^{−1}$. Maize grains (*Zea mays* L., CV Single Hybrid 10) at rates of 24 kg ha^{-1} were sown on were sown on June 14th, 2014 and June 13th 2015 in the first and second season respectively. Grains were sown on one side of the drippers' jet with 70 cm between irrigation lines. Two grains were drilled in holes 3-4 cm deep and at 30 cm distance between plants spacing along the drip line and after 15 days the plants were thinned at one plant per each. The approximate plant population was 48000 plants ha-1. All the agriculture practices were applied at the recommendations of the Ministry of Agriculture and Land Reclamation (Egypt). Phosphorus in the form of super phosphate (15.5% P_2O_5) at a rate of 149 kg ha$^{−1}$ was added directly to the soil in one dose before planting. Potassium fertilizer in the form of potassium sulphate (48% K_2O) at a rate of 119 kgha$^{−1}$ was added with the irrigation water in two equal portions (37 and 50 days after sowing). Nitrogen fertilizer levels were applied with the irrigation water in the form of urea (46%N) at five equal doses (initiated 15 days post planting and were administered on a 10 days interval). Maize plants were harvested on October 7th, 2014 and October 8th, 2015 in the first and second seasons respectively.

2.2 Calculation of irrigation water requirements

The daily reference evapotranspiration (ET_o) was estimated using Penman–Monteith's modified equation (Allen *et al.,* 1998). The actual evapotranspiration (ET_c) was calculated according the equation ($ET_c = ET_o \times K_c$). K_c values used for maize were 0.60, 0.83, 1.20 and 0.90 for growth stages initial, development, mid, and end, respectively (Allen *et al.*, 1998). The scale of growth stages is 20, 30, 30, and 20 days of sowing for initial, development, mid, and end stages, respectively (Allen *et al.,* 1998). Based on the climate data in Table 2, the ET_c values for wheat were calculated. The estimated ET_o was 698 and 687 mm and the ET_c was 645 and 634 mm in 2014 and 2015, respectively. The total irrigation water requirement during the whole growth season was 834.4 and 820.9 mm in the first and second season, respectively, (the application efficiency for drip irrigation (%) (E_a = 85) and the leaching fraction was considered as 10% of water requirement). Water use efficiency (WUE) was calculated using the equation (WUE = GY/ ET_c). Where, GY equals grain yield, ET_c equals seasonal actual evapotranspiration (mm).

Table (1): Some physical and chemical soil properties (0-30 and 30-60 cm).

Properties	0-30 cm	30-60 cm
Sand (%)	24.1	24.3
Silt (%)	62.4	62.5
Clay (%)	13.5	13.2
Texture	Silty Loam	Silty Loam
Field capacity (v %)	42.7	42.5
Witling point (v %)	21.1	20.1
$CaCO_3$ (%)	5.42	5.08
pH (1:2.5 suspension)	7.54	7.78
EC_e^* (dS m^{-1})	0.99	0.95
Organic matter (g kg^{-1})	24.1	22.5
Total N (mg kg^{-1})	560	520
Available N (mg kg^{-1})	67.2	62.4
Available Olsen P (mg kg^{-1})	11.78	11.32
Available K (mg kg^{-1})	258.1	477.4

Each value represents a mean of three replicates. $^*EC_e$: the Electric conductivity of the saturated soil extract.

2.3 Soil samples analysis

Composite soil samples were collected at the beginning of the growing season from two depths (0-30 cm and 30-60 cm). Air-dried, crushed, and sieved to pass through 2-mm. selected physical and chemical properties of the soil were determined according to Burt (2004). The soil pH was measured in 1:2.5 soils to water suspension using a digital pH meter. The electrical conductivity (EC) was estimated using the salt bridge method (Page *et al*., 1982b). Available soil nitrogen was extracted by 2 M potassium chloride, and then nitrogen in the extractable was determined using micro-kjeldahl method (Burt, 2004). Available soil phosphorus was extracted by 0.5 M sodium bicarbonate solution at pH 8.5 according to Olsen *et al.* (1954) and phosphorus was determined by spectrophotometer. Available potassium was extracted by ammonium acetate method and was measured by flame photometry (Jackson, 1973).

Table (2): Average monthly maximum (T_{max}) and minimum (T_{min}) temperature, relative humidity (RH), wind speed (WS) and reference evapotranspiration (ET_o) during 2014 and 2015 growing seasons.

Month	T_{max}	T_{min}	RH (%)	WS (km day^{-1})	ET_o (mm)
Frist season 2014					
June,2014	37.8	22.3	33.2	148.8	7.54
July,2014	38.3	23.6	32.0	153.6	7.66
August,2014	38.4	23.9	33.8	172.8	7.67
September,2014	35.8	22.1	33.6	189.6	6.87
October,2014	31.3	16.9	36.7	117.6	4.44
Second season 2015					
June,2015	36.6	21.3	37.4	156.3	7.43
July,2015	38.8	22.8	35.9	98.4	6.74
August,2015	40.3	24.8	38.6	100.8	6.71
September,2015	38.5	23.8	38.5	175.2	6.93
October,2015	33.0	19.5	51.3	195.6	5.35

Rainfall was zero for the two growth season. Data were obtained from Assuit weather station and Central Laboratory for Agricultural Climate.

2.4 Plant samples analysis

Composite plant samples each consisted of three plants were taken from each experimental unit after 60 days of planting and were used to study some growth parameters and the uptake of nitrogen, phosphorus, and potassium. These plant samples were cleaned, washed with tap and distilled water, air dried, then dried in oven at 70 ^{o}C until constant weight, ground and stored for chemical analysis. To determine the total N, P, and K in plant samples, 0.5 g of each sample was digested with 10 ml of digestion mixture (350 ml H_2O_2 + 0.42 g selenium powder + 14 g $LiSO_4$. H_2O + 420 ml concentrated H_2SO_4) (Parkinson and Allen, 1975). Then the digest was analyzed for N, P, and K according the standard methods described by Page *et al*. (1982a). Grain (GY), straw (SY), and biological yield (BY) of maize recoded for each exponential unit and expressed in kg ha^{-1}.

2.5 Data analysis

The experimental design was Randomized Complete Block Design with four replicates. The Analysis of Variance (ANOVA) and Duncan multiple range tests at 5% level of probability were used to test the significant of differences between the treatments. Data statistical analyses were performed using SPSS statistical software, version 15.

3. Results and Discussion

3.1 Effect of N fertilization on maize growth

N fertilization significantly (P<0.05) affected on the height of drip irrigated maize as shown in figure1. On average N_{360} caused a 14 and 12 % increase in the plant height in the first and second seasons, respectively, compared to N_{220}. Figure 2 and 3 illustrated the effect of N fertilization rates on the fresh and dry weight of maize. The highest significant values of dry weights were obtained when maize amended with 360 kg N ha^{-1}. N_{360} significantly increased the dry weights by 35 and 23% in the first and second season, respectively, compared to N_{220}. The current study indicates that increasing nitrogen fertilization rates increased the growth of drip irrigated maize. Nitrogen plays a vital role in all living tissues of the plants and is a constituent of many fundamental cell components such as nucleic acids, amino acids, enzymes, and photosynthetic pigments (Bungard *et al.*, 1999). Terman *et al.* (1977) observed that the application of nitrogen increased the plant height by increasing length and number of internodes and the increase in leaf number and size would result in more and larger photosynthetic apparatus by increasing total leaf area and leaf area index (LAI) of the crop consequently influencing assimilates production, which has direct bearing on dry matter production per plant and per unit area. LAI and leaf greenness determine the capture and use of solar radiation by maize plant, hereby they affected the conversion rate of available radiation to dry matter accumulation (Mansouri-Far *et al.*, 2010). The previous studies indicated that abundant nitrogen encouraged cell division and elongation increased leaves number which consequently enhanced plant growth, and this may explain the favorite effect of increasing N rate on plant growth (Abdel-Mawly and Zanouny, 2005; El-Hamdi *et al.*, 2008).

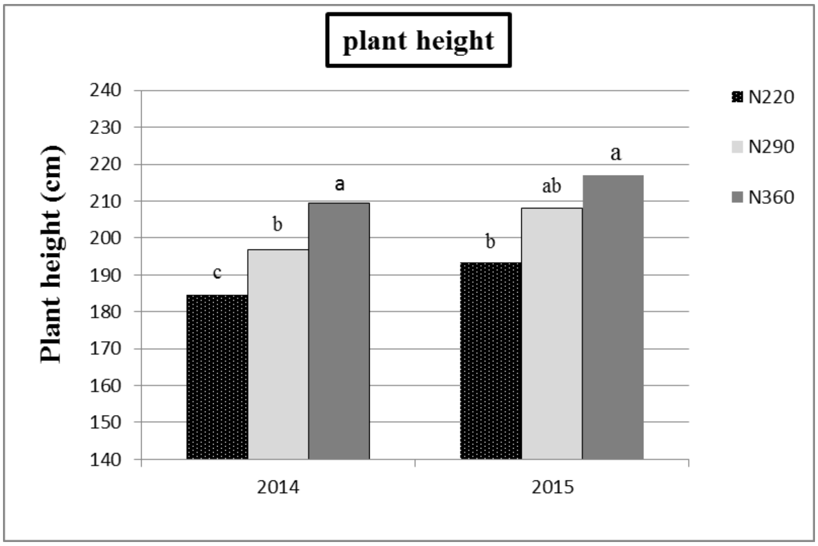

Figure (1): Plant highest of 60 days-old maize (cm) as affected by N fertilization rates.

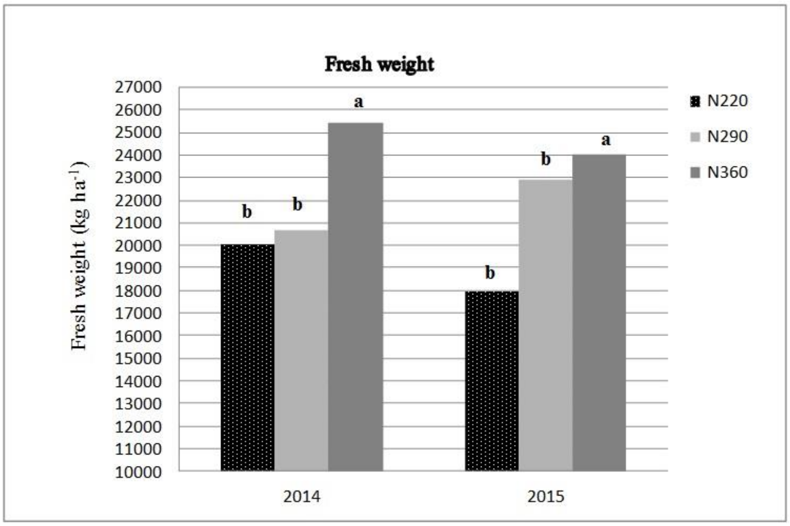

Figure (2): Fresh weight of 60 days-old maize (kg ha^{-1}) as affected by N fertilization rates.

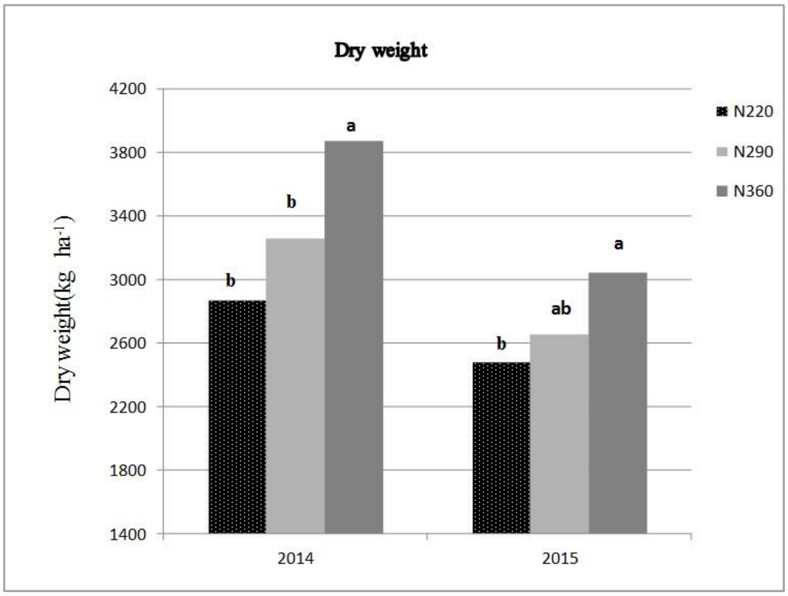

Figure (3): Dry weight of 60 days-old maize (kg ha^{-1}) as affected by N fertilization rates.

3.2 Effect of N fertilization rates on N, P, and K concentrations and uptake

The data illustrated in Table 3 show the nitrogen N, P, and K uptake by the 60 days-old maize as affected by the nitrogen fertilization rates. The application of nitrogen to drip irrigated maize significantly (*P*<0.05) affected on the uptake of N, P, and K. The highest significant uptake of N, P, and K were obtained when maize amended N_{360}. N_{360} increased the uptake of N by 56.6 and 30.2 % in the first season and second season, respectively, compared to N_{220}. N_{360} increased the uptake of P by 35.7 and 47.0 % in the first season and second season, respectively, compared to N_{220}. N_{360} increased the uptake of K by 66.8 and 39.2 % in the first and second season, respectively, compared to N_{220}. Based on the data in Table 3, the concentrations and uptake of N, P, and K by drip irrigated maize responded to all the studied nitrogen rates and the highest significant values were recorded when N was applied at a N_{360}. The application of nitrogen improves the root growth and this will increase the ability of roots to explore more soil and increases the uptake of nutrients. Moreover, the application of nitrogen may be increase the availability of other nutrients in soil. These results are in accordance with those obtained by Ibrahim and Kandil, 2007 and El-Hamdi *et al.* (2008).

Table (3): Aboveground N, P, and K concentrations (g kg^{-1}) and uptake (kg ha^{-1}) by 60 days-old maize as affected by N fertilization rates.

N rates	2014						2015					
	N		P		K		N		P		K	
	conc.	uptake	conc.	uptake	conc.	Uptake	conc.	uptake	conc.	uptake	conc.	uptake
N_{220}	21.51^{b}	67.15^{b}	5.21^{a}	14.95^{b}	19.15^{b}	55.68^{b}	22.00^{a}	54.63^{b}	5.18^{a}	12.72^{b}	21.02^{a}	52.30^{c}
N_{290}	23.35^{b}	73.13^{b}	5.28^{a}	17.17^{ab}	19.54^{b}	63.64^{b}	22.97^{a}	60.99^{ab}	5.83^{a}	15.47^{ab}	22.67^{a}	59.78^{b}
N_{360}	24.30^{a}	105.15^{a}	5.60^{a}	21.78^{a}	24.17^{a}	92.86^{a}	23.23^{a}	71.14^{a}	6.16^{a}	18.70^{a}	23.88^{a}	72.78^{a}

Means (within columns) denoted by the same letter indicate no significant difference according to Duncan's test at $P<0.05$.

3.3 Effect of N fertilization rates on yield

In both growing seasons the grain yield ranged from 5398 to 9744 kg ha^{-1} while the straw yield ranged from 20961 to 25410 kg ha^{-1}. Maize biological yield ranged from 21624 to 35154 kg ha^{-1} (table 4). Application of N to drip irrigated maize significantly ($P<0.05$) affected on yield and yield components of maize in both the two season. The highest significant grain, straw, and biological yield was obtained when maize was amended with N_{360}. N_{360} increased GY, SY and BY by 56, 21and 29% in the first and second season and by 62, 9 and 20% in second season, respectively, compared to N_{220}. In general, yield and yield components of drip irrigated maize responded to all the studied nitrogen rates and the highest significant GY, SY, and BY were recorded when N was applied at N_{360}. Tollenaar (1977) and Uhart and Andrade (1995) argue that the increase in seed yield due to nitrogen use may increase the number of grains per ear and grain weight gain is associated. However, the values of the studied vegetative growth parameters were slightly higher in 2014 than those in 2015 as a result of better weather conditions prevailing in 2015.

Table (4): Grain (GY), straw (SY), and biological yield (BY) of maize as affected by N fertilization rates.

N rates	2014			2015		
	GY	SY	BY	GY	SY	BY
N_{220}	6249[c]	20961[b]	27210[b]	5398[c]	21624[a]	27021[b]
N_{290}	8629[b]	23342[ab]	28471[a]	7192[b]	22084[a]	29277[ab]
N_{360}	9744[a]	25408[a]	35152[a]	8743[a]	23593[a]	32336[a]

Data are in kg ha^{-1}. Means (within columns) denoted by the same letter indicate no significant difference according to Duncan's test at P<0.05.

3.4 Effect of N fertilization on water use efficiency and irrigation water use efficiency

N application significantly (P<0.05) affected on water use efficiency (WUE) in both growing seasons (Fig. 4). Increasing N_{360} increased the WUE by 54 and 40% in the first and second season, respectively, compared to N_{220}. In the current study, drip irrigated maize used water more efficiently under the high rate of nitrogen. This may be related to the increases of gain yield by increasing N levels. Increasing water use efficiency requires increasing photosynthetic capacity; therefore, more nitrogen will required (Martin *et al.*, 2010).

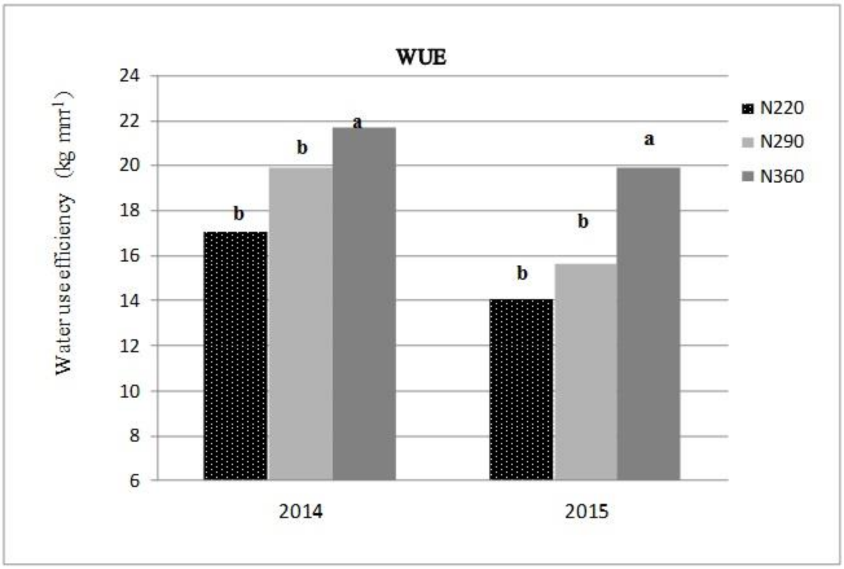

Figure (4): Water use efficiency (WUE) of maize (kg grain yield mm^{-1} of water) as affected by N fertilization rates.

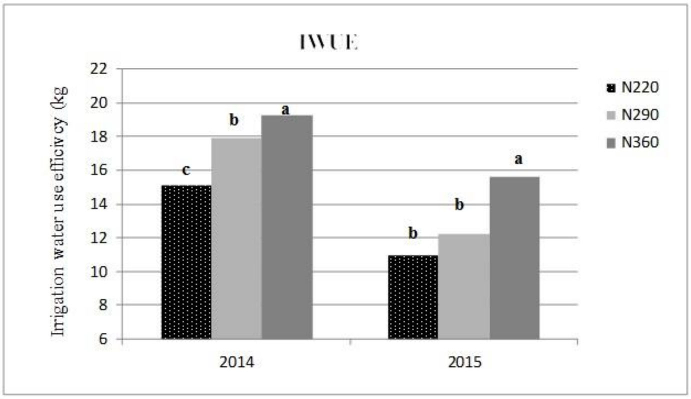

Figure (4): Irrigation water use efficiency (IWUE) of maize (kg grain yield mm^{-1} of water) as affected by nitrogen fertilization rates.

Nitrogen is a major limiting factor of plant growth and development. Nitrogen is an integral part of DNA, RNA, chlorophyll and proteins, plays an important role in cell metabolism, affects photosynthetic capacity of leaves by increasing stromal, roots growth and more physiological activities for nutrients absorbance and thylakoid proteins in leaves (Marschner, 1995; Bungard *et al.*, 1997; Ibrahim and Kandil, 2007; El-Hamdi *et al*., 2008).

4. Conclusions

A two years field study was conducted to explore the effect of three N fertilization rates on yield and nutrient uptake by drip irrigated maize grown in arid conditions. N rates were 220, 290, and 360 kg ha^{-1}. It may be concluded that, nitrogen fertilization enhanced the growth and yield of maize. Moreover, N application improved the uptake of nutrients and enhanced water use efficiency. The maximum maize yield was obtained when N was added at a rate of 360 kg. The higher N requirement under the current study is due to the higher maize yield compared to conventional agriculture methods. Based on the obtained results, 360 kg per hectare is the optimum nitrogen level for drip irrigated maize.

References

Abd El-Wahed M. H. and Ali, E. A. (2013), "Effects of irrigation system, amounts of irrigation water and mulching on corn yield, water use efficiency and net profit", *Agricultural Water Management Journal*, Vol. 120 No. 31, pp. 64–71.

Abdel-Mawly, S. E. and Zanouny, I. (2005), "Irrigation and Fertilization management for maximizing crop-water Effeciencies of Maize" *Minia Journal of Agricultural Research and Development,* Vol. 25 No. 1, pp. 125–146.

Allen, G. R., Pereira, L. S., Raesand, D. and Smith, M. (1998), *Crop* *evapotranspiration guidelines for competing crop water requirements*, FAO irrigation and drainage paper 56, Rome, Italy.

Al-Omran, A. M., Sheta, A. S., Falatah, A. M. and Al-Harbi, A. R. (2005), "Effect of drip irrigation on squash (*Cucurbitapepo*) yield and water-use efficiency in sandy calcareous soils amended with clay deposits", *Agricultural Water Management Journal*, Vol. 73 No. 1, pp. 43–55.

Aujla, M. S., Thind, H. S. and Buttar, G. S. (2007), "Fruit yield and water use efficiency of eggplant (*Solanum melongema L.*) as influenced by different quantities of nitrogen and water applied through drip and furrow irrigation", *Scientia Horticulturae Journal*, Vol. 112 No. 2, pp. 142–148.

Brady, C. (1984), *The nature and properties of soils*, Macmillan Publishing Company, New York, USA.

Bar-Yosef, B. (1999), "Advances in fertigation", *Advances in Agronomy*, Vol. 65, pp. 1–79.

Bungard, R. A., McNeil, A. and Morton, J. D. (1997), "Effect of nitrogen on the photosynthetic apparatus of *Clematis vitalba* grown at several irradiances", *australian journal of plant physiology*, Vol. 24, pp. 205-214.

Bungard, R.A., Wingler, A. J., Morton, D. and Andrews, M. (1999), "Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in *Clematis vitalba*", *Plant Cell and Environment*, Vol. 22, pp. 859-866.

Burt, R. (2004), *Soil Survey Laboratory methods manual*, Soil Survey Investigations Report No. 42, Version 4.0, Natural Resources Conservation Service, United States Department of Agriculture, USA.

Eissa, M. A., Nafady, M., Ragheb, H. and Attia, K. (2013), "Effect of soil moisture and forms of phosphorus fertilizers on corn production under sandy calcareous soil", *World Applied Sciences Journal*, Vol. 26 No. 4, pp. 540–547.

El-Hamdi, K. H., Meshref, H. A., Abd El-Hafez, S. A. and El-Atawy, G. S. (2008), "Effect of irrigation, nitrogen and organic fertilization on yield and nutrient contents of *Zea maize* crop Scientific", *Mansoura University Journal of Agricultural Sciences*, Vol. 33 No. 7, pp. 5419–5428.

El-Hendawy, S. E., Abd El-Lattief, E. A., Ahmed, M. S. and Schmidhalter, U. (2008), "Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn", *Agricultural water management*, Vol. 95, pp. 836 – 844

Feleafel, M. N. and Mirdad, Z. M. (2013), "Optimizing the nitrogen, phosphorus and potash fertigation rates and frequency for eggplant in arid regions", *International Journal of Agriculture and Biology*, Vol. 15 No. 4, pp. 737–742.

Ibrahim, S. A. and Kandil, H. (2007), "Growth, yield and chemical constituents of corn (*Zea maize* L.) as affected by nitrogen and phosphors fertilization under different irrigation interval", *Journal of Applied Sciences Research*, Vol. 3 No. 10, pp. 1112–1120.

Jackson, M. L. (1973), *Soil chemical analysis*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, New Delhi, India.

Konopka, B., Pages, L. and Doussan, C. (2009), "Soil compaction modifies characteristics of seminal maize roots", *Plant, Soil and Environment*, Vol. 55, pp. 1–10.

Liang, X., Gao, Y., Zhang, X., Tian, Y. and Zhang, Z. (2014), "Effect of optimal daily fertigation on migration of water and salt in soil, root growth and fruit yield of cucumber (*Cucumis sativus* L.) in solar-greenhouse", *Plos One*, Vol. 9, No. 1, pp. e86975.

Ma, B. L. and Subedi, K. D. (2005), "Development, yield, grain moisture and nitrogen uptake of Bt corn hybrids and their conventional near-isolines", *Field Crops Research Journal*, Vol. 93, No. 2, pp. 199–211.

Mansouri-Far, C. S. A., Sanavy, M. M. and Saberali, S. F. (2010), "Maize yield response to deficit irrigation during low sensitive growth stages and nitrogen rate under semi-arid climatic conditions", *Agricultural Water Management*, Vol. 97 No. 1, pp. 12–22.

Marschner, H. (1995), Mineral nutrition of higher plants, Academic Press, London, England.

Martin, K. C., Bruhn, D., Lovelock, C. E., Feller, I. C., Evans, J. and Ball, M. C. (2010), "Nitrogen fertilization enhances water use efficiency in a saline environment", *Plant Cell and Environment*, Vol. 33, pp. 344–357.

Mathieu, N., Wang, G. Y. and Goldy, R. (2007), "Withholding of drip irrigation between transplanting and flowering increases the yield of field-grown tomato under plastic mulch", *Agriculture Water Management*, Vol. 87 No. 3, pp. 285–291.

Olsen, S. R., Cole, C. V., Watanabeand, F. S. and Dean, L. A. (1954), *Estimation of available phosphorus in soils by extraction with sodium bicarbonat*e, United States Department of Agriculture, Circular, Vol. 939, Washington, DC, USA.

Page, A. L. Miller, R. H. and Keeney, D. R. (1982a), *Methods of Soil analysis: Chemical and microbiological properties*, Part 2, American Society of Agronomy and

Soil Science Society of America, Madison, Wisconsin, USA.

Page, A. L. Miller, R. H. and Keeney, D. R. (1982b), "Soluble salts", in Bower, C. A. and Wilcox, L. V. (Ed.), *Methods of Soil analysis: Chemical and microbiological properties*, Part 2, American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA.

Parkinson, J. A. and Allen, S. E. (1975), "A wet oxidation procedure suitable for the determination of nitrogen and mineral nutrients in biological materials", *Communications in Soil Science and Plant Analysis*, Vol. 6, pp. 1–11.

Singh, S. S., Gupta, P. and Gupta, A. K. (2003), *Handbook of Agricultural Sciences*, Kalyani Publishers, New Delhi, India, pp. 184–185.

Soil Survey Staff, (2016), *Keys to Soil Taxonomy*, 11th ed., USDA-Natural Resources Conservation Services, Washington, DC, USA.

Terman, G. L., Noggle, J. C. and Hunt, C. M. (1977), "Growth Rate-Nutrient Concentration Relationships During Early Growth of Corn as Affected by Applied N, P, and K", *Soil Science Society of America Journal*, Vol. 41, pp. 363–368.

Tollenaar, M. (1977), "Sink source relationship during reproductive development in maize: A review", *Maydica*, Vol. 22, pp. 49–75.

Uhart, S. A. and Andrade, F. H. (1995), "Nitrogen deficiency in maize: I: Effects of crop growth, development, dry matter partitioning, and kernel set", *Crop Science*, Vol. 35, pp. 1384–1389.

USDA, (2011), *Grain: World markets and trade. Foreign Agriculture Service*, Circular Series FG 09-11, Foreign Agricultural Service, United States Department of Agriculture, Washington, DC, USA.

Vijayakumar, G., Tamilmani, D. and Selvaraj, P. K. (2010), "Irrigation and fertigation scheduling under drip irrigation in brinjal (*Solanum melongena* L.) crop", *International Journal of Biological and Medical Research Management*, Vol. 1 No. 2, pp. 72–76.

Wajid, A., Ghaffar, A., Maqsood, M., Hussain, K. and Nasim, W. (2007), "Yield response of maize hybrids to varying nitrogen rates", *Pakistan Journal of Agricultural Sciences*, Vol. 44 No. 2, pp. 217–220

Zhang, Q. Q., Xu, H. L., Fan, Z. L., Ye, M., Yu, P. J. and Fu, J. Y. (2013), "Impact of implementation of large-scale drip Irrigation in arid and semi-arid areas: case study of Manas River Valley", *Communications in Soil Science and Plant Analysis*, Vol. 44 No. 13, pp. 2064–2075.