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EFFECTS OF DIFFERENT FERTIGATION LEVELS ON MAIZE YIELD AND NUTRIENT UPTAKE UNDER SEMI-ARID MEDITERRANEAN CONDITIONS

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Abstract

The aim of the study was to evaluate the effect of four fertigation levels (25, 50, 75 and 100% of fertilizer dose, 240:100:200 kg N:P:K ha^{-1}) and to compare with conventional practices (CP). The fertigation levels F1 25% of total fertilizer (60:25:50 kg N:P:K ha^{-1}) treatments, F2 treatment is 50% of total fertilizer (120:50:100 kg N:P:K ha^{-1}), F3 treatment is 75% of total fertilizer (180:75:150 kg N:P:K ha^{-1}), F4 treatment is 100% of total fertilizer (240:100:200 kg N:P:K ha^{-1}). The experiment was conducted during 2012 summer (from 20 June to 15 September) under the field conditions in the Menzilat soil series (Typic Xerofluvents) which is located in the East Mediterranean coastal part of Turkey. The experiment was designed as a completely randomized-block with three replications. The maize plant (*Zea mays* L.) was sown as second crop following with wheat cultivation. The maize yield was higher in F3 fertigation level treatment (12.47 Mg ha^{-1}) compared to the other treatments. Lowest yield was recorded in F2 (8.45 Mg ha^{-1}) treatment. The results shown that the half of the fertilizer application with conventional practices and the other half with fertigation are more efficient under Menzilat soil series conditions. For future, it is important to see the long term effect of fertigation on soil nutrients dynamic under the Mediterranean soil conditions.

Keywords: Fertigation, maize, second crop, yield.

INTRODUCTION

Shannon *et al*. (2008) as well as Montgomery and Elimelech (2007) reported that the world population is growing rapidly while the problems associated with a lack of fresh water is becoming a known fact affecting drinking water supplies, energy, food production, industrial output, and the quality of our environment ultimately undermining the economies of the world at large. The increasing the efficiency using of water in any irrigation system is becoming more important particularly in arid and semiarid region (Navalawala, 1991). Consequently, irrigated agriculture is compelled to get new techniques to supply the request of water shortage (Pereira, 2006).

Fertigation is used to supply water and fertilizer simultaneously (Castellanos *et al.* 2012). Hagin *et al.* (2002) concluded that, fertigation is a modern agro-technique which reduces environmental pollution as well as enables facility to get maximum yield as a result of increasing fertilizer use efficiency. Patel and Rajput (2000) also reported that the fertigation provides the application of fertilizer uniformly and more efficiently. Kafkafi (2008) confirmed that fertigation has the potential for the application of water and nutrients with respect to requirement of the plant. The some advantage of fertigation compared with conventional method of fertilizer application was emphasized by other researchers (Shigure *et al.* 1999; Mohammad 2004 a,b). In conventional method, application of fertilizers are not effective, however fertigation assures an effective and economical way to supply water and nutrients for the crops (Kafkafi and Kant, 2005; Hanson *et al.* 2006). In addition Singandhupe *et al.* (2003) declared that fertilizer use efficiency increases with fertigation by the reach of fertilizer directly to the plant root zone.

Maize is an important plant for Turkey and half of the total production is done in the Mediterranean. The maize as first and second crop in the region is getting more cultivation. Very recently since cotton shifted to South Anatolia, cotton replaced with maize in Çukurova region where there is high potential for agriculture due to ecological conditions. Çukuruova region has high clay and calcium carbonate ($CaCO_3$) contents and causes limited soil nutrient level for crops grown in the area (Matar *et al.* 1992; Ortas, 2012). So, as a new technique fertigation is very important for nutrient and water deficient regions. With developing new irrigation and fertigation methods, farmers are tempting to increase the amount of land for maize production. Therefore, the maize grown water requirement is high, so it needs to be discussed in detail in terms of water-yield relationship.

The tested hypothesis was as follows: fertigation is more suitable than conventional agricultural fertilizer and irrigation practices. The aim of the study was to evaluate the effect of four fertigation levels (25, 50, 75 and 100% of fertilizer dose, 240:100:200 kg N:P:K ha^{-1}) compare with conventional practices (CP).

MATERIAL AND METHODS

Experimental site and materials

The experiment was carried out during 2012 summer under the field conditions in the Menzilat soil series (Typic Xerofluvents, Entisols) located at the Research Farm of the Cukurova University (37°00'54.31"N, and 35°21'21.56"E and 31 m above mean sea level) in eastern part of the Mediterranean region of Adana–Turkey. The regional climate is typical Mediterranean with long-term average annual air temperature of 19.1°C (ranging from 14.2°C in January–February to 25.5°C in July–August), and precipitation of 670.8 mm. As much as 80% of the annual precipitation is received between November and April, with a mean annual humidity of 66% (Anonymous, 2008). Maize was used as second crop following wheat in present experiment. Before sowing maize, soil samples were taken to determine some of soil properties from 0-30 cm depth and were analyzed according to Page *et al.* (1982) and data are presented in Table 1.

Table 1. Initial values of some soil properties

Property	Depth (0-30 cm)
Sand (%)	47
Clay (%)	31
Silt (%)	22
Organic matter (%)	1.2
pH (H2O)	7.5
Salt (%)	0.04
Lime (%)	27
Available P (kg ha^{-1})	40.1
Available K (kg ha^{-1})	998.3

Experimental design and application of fertilizer

Fertilizers were applied through drip irrigation which including F1, F2, F3 and F4 levels of fertigation at rates of 240 kg N ha^{-1} (N applied as ammonium sulphate), 100 kg P_2O_5 ha^{-1} (P applied as MKP) and 200 kg K_2O ha^{-1} (K applied as KNO3) for maize. Also, details of the treatments are given in Table 2. Maize was sown in the third week of June 20 June 2012 and harvested in the third week of September 17 September 2012. The experiment was established according to complete randomized-block design with three replications. The size of plot was 5.32 m^2 and inter-row spacing and distances between the rows were 19 and 70 cm, respectively. Maize was irrigated with drip irrigation once in every 7-daies and 12 times totally during the growing period.

Table 2. Treatment Details

CP : Conventional Practices	P and K applied to soil at sowing, N applied as two parts
F1 : 25% of fertilizer	60:25:50 kg N:P:K ha^{-1} applied through drip irrigation
F2 : 50% of fertilizer	120:50:100 kg N:P:K ha^{-1} applied through drip irrigation
F3 : 75% of fertilizer	180:75:150 kg N:P:K ha^{-1} applied through drip irrigation
F4 : 100% of fertilizer	240:100:200 kg N:P:K ha^{-1} applied through drip irrigation

Fertilizer dose: 240 kg N ha-1, 100 kg P ha-1, 200 kg K ha-1

Measurement

At harvest maize yield was recorded and also plant leaves N, P, K and microelement concentration (Fe, Zn, Mn, Cu) of maize was determined. Eight maze leaves at flowering sages were taken accordingly (Jones, 1998). Plant leaves were oven-dried at 65°C for 48 h. The dry material was ground using a Tema mill, and 0.2 g of the ground plant material was ashed at 550°C, then dissolved in 3.3% HCl. Leaf P concentration was determined with the vanadate–molybdate yellow colorimetric method using a spectrophotometer and K and microelement concentration was determined by (ICP) (Chapman and Pratt, 1961). Leaf N concentration was determined by using Kjheldal method (Bremner, 1965).

Statistical analysis

Analysis of variance (ANOVA) was applied to determine the significance of differences in yield, N, P, K and microelement concentration of maize plant. Following the ANOVA test, the Tukey test was performed to compare differences in means of the parameters at significance level of 0.05. The statistical analyses were performed using SPSS software (version 20.0).

RESULTS AND DISCUSSIONS

Yield

Effects of different fertigation levels on yields of second crop maize plants are presented in Figure 1.

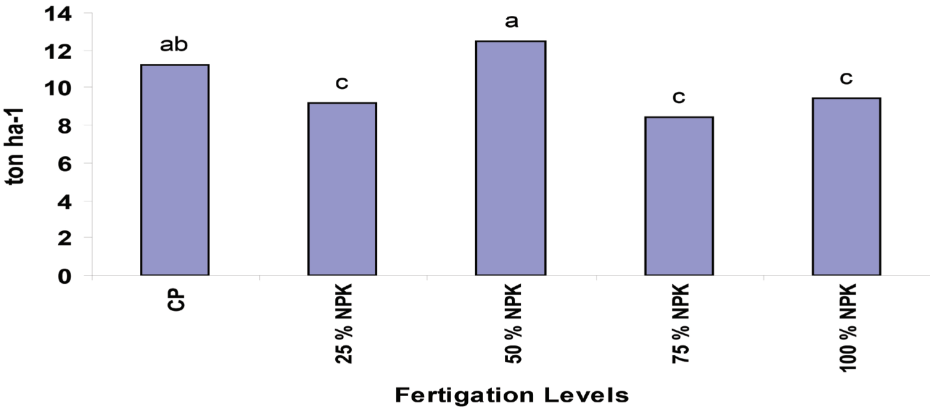

Figure 1. Effects of different fertigation levels on yield of maize.

Current findings revealed that F2 treatments resulted in higher increases in yields than CP and the other treatments (Figure 1). The highest maize yield was obtained as 12.47 Mg ha^{-1} from F2 treatments (50% NPK = 120:50:100 kg N:P:K ha^{-1}). It was followed by CP treatments with 11.24 Mg ha^{-1} yield. While F1, F3 and F4 treatments were not found to be significant, F2 treatments were significant. The yields of second crop maize plants varied between 8.45– 12.47 Mg ha^{-1}. İbrahim *et al.* (2016) carried of a research on maize plants with four different evaporation levels (0.6, 0.8, 1.0 and 1.2) and two different fertigation periods (application of fertilizer doses at 60 and 80% of irrigation duration) and reported improved vegetative growth and yields with increasing irrigation water quantities and fertilization periods. Abd El-Wahed and Ali (2013) compared drip and sprinkler irrigation methods in maize irrigation and indicated that drip irrigation maximized kernel yield and water use efficiency. Muahammad *et al.* (2015) reported maximum maize kernel yields (6.93 Mg ha^{-1}) for 180 kg ha^{-1} nitrogen treatment and the lowest kernel yield for 100 kg ha^{-1} nitrogen treatment.

Macro and Microelement Concentrations

Effects of different fertigation levels on macro and microelement concentrations of second crop maize plants are given Table 3 and Table 4.

Table 3. Effects of different fertigation levels on N, P and K contents of maize plants (%)

Fertigation Levels	N		P		K	
			%			
CP	2.55	±0.03 c	0.30	±0.30 b	1.07	±0.01 b
F1	2.55	±0.00 c	0.36	±0.36 a	1.12	±0.08 b
F2	2.85	±0.26 a	0.30	±0.30 b	1.22	±0.03 a
F3	2.69	±0.03 ab	0.40	±0.40 a	1.25	±0.05 a
F4	2.58	±0.01 c	0.38	±0.38 a	1.10	±0.01 b

$P<0.05$

Effects of fertigation treatments on N concentrations of maize plants are provided in Table 3. The greatest N content (2.85%) was obtained from F2 treatment (120:50:100 kg N:P:K ha^{-1}). It was followed by F3 treatment (180:75:150 kg N:P:K ha^{-1}) with 2.69% N content. Hassan *et al.* (2010) reported maximum N content (1.35%) and N intake (120.42 kg ha^{-1}) for 140 kg N ha^{-1} fertigation treatment. The greatest P content (0.40%) was observed in F3 treatment. It was followed respectively by F4 (0.38%) and F1 (0.36%) treatments but the differences were not found to be significant. These 3 treatments significantly increased P contents of the plants. Similarly, the greatest K contents were observed in F3 (1.25%) and F2 (1.22%) treatments.

Table 4. Effects of different fertigation levels on Fe, Zn, Mn and Cu concentrations (mg kg^{-1})

Fertigation	Fe		Zn		Mn		Cu	
Levels				mg kg^{-1}				
CP	104.27	±9.81 b	34.24	±2.25 a	30.34	±3.37 a-c	6.97	±0.06 d
F1	122.75	±3.04 a	34.39	±1.05 a	23.52	±2.95 bc	7.49	±0.01 c
F2	84.76	±4.70 c	34.62	±0.90 a	21.22	±8.74 c	9.03	±0.25 ab
F3	107.04	±9.92 b	30.50	±0.45 b	30.95	±5.50 ab	9.36	±0.04 a
F4	111.20	±2.40 ab	31.64	±0.68 b	37.62	±0.64 a	8.92	±0.36 b

$P<0.05$

Considering the microelement concentrations of the maize plants, the greatest Fe concentration (122.75 mg kg^{-1}) was observed in F1 treatment, the greatest Zn concentration (34.62 mg kg^{-1}) was observed in F2 treatment. However, Zn concentrations of CP, F1 and F2 treatments were not significantly different

(Table 4). The greatest Mn concentration (37.62 mg kg^{-1}) was observed in F4 treatment and the greatest Cu concentration (9.36 mg kg^{-1}) was observed in F3 treatment. Considering the entire microelements, it was observed that different fertigation doses did not have significant effects on Fe and Zn concentrations of the maize plants, but had significant effects on Cu concentrations. Only F4 treatments had significant effects on Mn concentrations of maize plants.

Table 5. Correlations among variables tested in the experiment

	Yield	N	P	K	Fe	Zn	Mn
Yield							
N	0.426						
P	-0.868**	-0.258					
K	-0.051	0.623*	0.213				
Fe	-0.756**	0.740**	0.518*	-0.365			
Zn	0.665**	0.097	-0.768	-0.260	-0.164		
Mn	0.430	-0.485	0.373	-0.303	0.355	-0.613	
Cu	0.175	0.601*	0.467	0.714**	-0.364	-0.572*	0.136

*Significant at $P<0.05$; **Significant at $P<0.01$

Correlation table for the effects of different fertigation levels on yield and nutrient contents of maize plants revealed that yields positively correlated with Zn and negatively correlated with P and Fe (Table 5). N had positive correlations with K, Fe and Cu and P with Fe; and there was a negative correlation between Zn and Cu.

CONCLUSION

As compared to CP (conventional fertilization), only F2 treatments (120:50:100 kg N:P:K ha^{-1}) significantly increased yields of second crop maize plants ($P<0.05$). But lower and higher doses than F2 significantly ($P>0.05$) reduced yield which clearly indicate the optimum dose for this particular experiment was 120:50:100 kg N:P:K ha^{-1}. Within the treatments other than CP and F2, there were no statistically important differences, which they did not have significant effects on yields of second crop maize plants ($P>0.05$). As compared to CP treatments, fertigation treatments significantly increased N, P and K concentrations of maize plants. Although there were statistically important differences within the treatment by mean of microelement concentration, that differences are not practically important.

REFERENCES

Abd El-Wahed M.H., Ali E.A. (2013). Effects of irrigation system, amounts of irrigation water and mulching on corn yield, water use efficiency and net profit. Agric. Water Manag., 120(31), 64-71.

Anonymous, (2008). Turkish Methorology Service. Ankara, Turkey.

Bremner, J.M. (1965). Method of Soil Analysis. Part 2. Chemical and Microbiological Methods. American S^{oc}iety of Agronomy Inc. Madison, Wise S-1149-1178, USA.

Castellanos, M.T., Tarquis, A.M., Ribas, F., Cabello, M.J., Arce, A., Cartagena, M.C., (2012). Nitrogen uptake dynamics, yield and quality as influenced by nitrogen fertilization in 'Piel de sapo' melon. Spanish Journal of Agricultural Research, (10)3: 756-767.

Chapman, H. D., Pratt. F.P. (1982). Ammonium vandate-molybdate method for determination of phosphorus. *Methods of analysis for soils, plants and water* 1: 184-203.

Hagin, J., M. Sneh, and A. Lowengart-Aycicegi. (2002). Fertigation – Fertilization through irrigation. IPI Research Topics No. 23. Ed. by A.E. Johnston. International Potash Institute, Basel, Switzerland.

Hanson, B.R., Simunek, J., Hopmans, J.W. (2006). Evaluation of urea–ammonium–nitrate fertigation with drip irrigation using numerical modeling, Agric. Water Manage. 86 (1–2) 102–113.

Hassan. S.W., Oad, F.C., Tunio, S.D., Gandahi A.W.,. Siddiqui, M.H, Oad, S.M., and Jagirani, A.W. (2010). Impact of Nitrogen Levels and Application Methods On Agronomic, Physiological and Nutrient Uptake Traits of Maize Fodder. Pak. J. Bot., 42(6): 4095-4101.

Ibrahim, M.M., El-Baroudy, A.A., Taha, M.A. (2016). Irrigation and fertigation scheduling under drip irrigation for maize cropin sandy soil. Int. Agrophys, 30, 47-55.

Jones, B. (1998). Plant Nutrition Manual. Crc Press, Boston.

Kafkafi, U. (2008). Global aspect of fertigation usage. In *Fertigation:* Optimizing the utilization of water and nutrients, eds. P. Imas and M.R. Price, Beijing, 8–22.

Kafkafi, U., Kant, S. (2005). Fertigation, in: H. Daniel (Ed.), Encyclopedia of Soils in the Environment, Elsevier, Oxford, pp. 1–9.

Matar, A., Torrent, J., Ryan, J. (1992). Soil and fertilizer phosphorus and crop responses in the dryland Mediterranean zone. *Advances in Soil Science* 18: 81–146.

Mohammad, M.J., (2004a). Utilization of applied fertilizer nitrogen and irrigation water by drip-fertigated squash as determined by nuclear and traditional techniques. Nutr. Cycl. Agroecosyst. 68 (1), 1–11.

Mohammad, M.J., (2004b). Squash yield, nutrient content and soil fertility parameters in response to fertilizer application and rates of nitrogen fertigation. Nutr. Cycl. Agroecosyst. 68 (2), 99–108.

Montgomery, M.A., Elimelech, M. (2007). Water and sanitation in developing countries: including health in the equation, Environ. Sci. Technol. 41 (1) 17–24.

Muahammad, A. A., Zahoor, A., Quiser, M., Sher, A., Mian, M. A. (2015). "Optimizing Nitrogen Level to Improve Growth and Yield of Spring Planted Irrigated Maize (Zea Mays L.)." Journal of Advanced Botany and Zoology 2 (3): 1-4.

Navalawala, B.N. (1991). Water logging and its related issues in India. J. Irrigation Power 1, 55-64.

Nitrogen fertigation: an integrated agronomic and environmental study. Agricultural Water Management, http://dx.doi.org/10.1016/j.agwat.2012.06.016.

Ortas, I. (2012). The effect of mycorrhizal fungal inoculation on plant yield, nutrient uptake and inoculation effectiveness under long-term field conditions. Field Crops Research 125, 35–48.

Page, A. L. (1982). Methods of soil analysis: chemical and microbiological proerpteis. Amen Society of Agronomy.

Patel, N., Rajput, T.B.S. (2000). Effect of fertigation on growth and yield of onion. In: Micro Irrigation, CBIP publication no. 282, pp. 451–454.

Pereira, L.S. (2006). Irrigated agriculture: Facing environmental and water scarcity challenges. International Symposium on water and land management for sustainable Irrigated Agriculture, Cukurova University April 4-8, 2006, Turkey.

Shannon, M.A. Bohn, P.W. Elimelech, M., Georgiadis, J.G., Marinas, B.J., Mayes, (2008). Science and technology for water purification in the coming decades, Nature 452 (7185) 301–310.

Shigure, P.S. Lallan Ram, Marathe, R.A., Yadav, K.P., Ram, L., (1999). Effect of nitrogen fertigation as vegetative growth and leaf nutrient content of acid lime (Citrus aurantifolia, Swingle) in Central India. Indian J. Soil Conserv. 27 (1), 45–49.

Singandhupe, R.B. Rao, G.G.S.N., Patil, N.G., Brahmanand, P.S. (2003). Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop (Lycopersicon esculentum L.). European Journal of Agronomy 19, 327–340.

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