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The effects of poultry manure and inorganic fertilizer applications on nitrogen and irrigation water use efficiency in forage corn cultivars

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Abstract: This research was conducted to determine the effects of different fertilizer treatments [organic (F1), inorganic (F2) and ½ organic + ½ inorganic (F3)] on nitrogen and water use efficiency of hybrid corn cultivars [PR 31Y43 (C1), OSSK-644 (C2), and Lacasta (C3)] in the years 2011 and 2012 under the ecological conditions of Eskipazar-Karabuk. In both research years, fertilizer treatments were statistically significant on nitrogen and irrigation water use efficiency. The highest irrigation water and nitrogen use efficiency values were obtained from F2 and F3 fertilizer treatments. The highest nitrogen uptake efficiency values were obtained from F2 fertilizer treatment. As a result of the research, the highest values of nitrogen and irrigation water use efficiency were obtained from F2 and F3 fertilizer treatments in all three corn cultivars (C1, C2, and C3). Integrated use of chemical fertilizer and poultry manure may be a good approach for sustainable production of crops. When we consider the sums paid for the import of inorganic fertilizers and the negative effects of these inorganic fertilizers on human and environmental health, we may see that F3 fertilizer application would be preferable in the regions where corn is grown.

Key Words: Poultry manure, corn, inorganic fertilizer, nitrogen and irrigation water use efficiency

Silajlık mısır çeşitlerinde inorganik ve tavuk gübresi uygulamalarının azot ve sulama suyu kullanım randımanı üzerine etkileri

Özet: Bu araştırma Karabük-Eskipazar ekolojik koşullarında 2011 ve 2012 yıllarında farklı gübreleme uygulamalarının [organik (F1), inorganik (F2) and ½ organik + ½ inorganik (F3)] hibrit mısır çeşitlerinin [PR 31Y43 (C1), OSSK-644 (C2), and Lacasta (C3)] azot ve sulama suyu kullanım randımanı üzerine etkilerini belirlemek amacıyla yürütülmüştür. Her iki araştırma yılında gübreleme uygulamaları azot ve sulama suyu kullanım randımanı üzerine istatistiki olarak etkili olmuştur. En yüksek azot ve sulama suyu kullanım randımanı değerleri F2 ve F3 gübreleme uygulamalarından elde edilmiştir. En yüksek azot alım randımanı değerleri ise F2 gübreleme uygulamasından elde edilmiştir. Araştırma sonuçlarına göre, her üç mısır çeşidinde (C1, C2 ve C3) en yüksek azot ve sulama suyu kullanım randımanı değerleri F2 ve F3 gübreleme uygulamalarından elde edilmiştir. Kimyevi ve tavuk gübrelerinin birlikte kullanımı sürdürülebilir bitkisel üretim için iyi bir yaklaşım olabilir. İnorganik gübre ithalatı için ödediğimiz miktarı ve bunların insan ve çevre sağlığı üzerine olan olumsuz etkilerini düşündüğümüzde, F3 gübreleme uygulamasının mısır yetiştirilen bölgeler için tercih edilebilir olduğu söylenebilir.

Anahtar Kelimeler: Tavuk gübresi, mısır, inorganik gübre, azot ve sulama suyu randımanı

1. Introduction

Corn forage is considered as a half-concentrated feed due to its high energy value. This high energy value is a result of its almost 50% grain content in dry product. This quality makes corn forage superior to other plant forages, and reduces the need of concentrate feed for animals at a rate of %33-50 (Sade and Soylu 2008). The yield and quality of forage corn is related to climate and soil factors, altitude, planting time, plant density, irrigation, harvest and especially genotype (Cusicanqui and Lauer 1999).

It is estimated that the global inorganic fertilizer use will be 183.4 million tons in 2013 and economic value of this will be 59.2 billion dollars. Nitrogenous fertilizers consists of 60% of this number (FAO 2011). In general, maize is an exhaustive crop and requires very high doses of nitrogen and other nutrients. While the nitrogen use efficiency depends on production management applications and product types, world average is 50%. It is understood that 17.7 billion dollars' worth of nitrogen lost through nitrification and leaching. Economic values of negative impacts on human and environmental health due to global warming and pollution of groundwater cannot be counted. Therefore, the importance of researches on nitrogen use efficiency increases day by day. The negative effects of inorganic fertilizers on human health are revealed by scientific research. However, organic based fertilizers did not change the nitrate content in the plants compared to the plants those treatment no inorganic fertilizer (Anastasios et al. 2007; Nasim et al. 2012).

Water is most used (70%) in agriculture globally (FAO 2002). Although the importance of irrigation increases more and more, the amount of water resources used for agricultural purposes in many parts of the world decreases steadily (Gencoglan and Yazar 1999). In near future, one of the biggest problems to be solved is to increase agricultural production using less water. Therefore, effective use of irrigation water is of vital importance (Simsek et al. 2011). The more effective use of water and the use of modern irrigation methods are even more important for arid and semi-arid regions. Irrigation efficiency is nearly 40% in furrow irrigation, 70% in sprinkler irrigation, and 90% in drip irrigation. Since less water is used in drip irrigation method, leaching of fertilizer and other nutrition elements in the soil is minimized and thus environmental pollution can be prevented (Yildirim and Kodal 1998; Kirnak et al. 2003; Bozkurt et al. 2011). While yield increases with effective use of water and fertilizer, mismanagement of water and fertilizer leads to pollution and decrease of water resources. Therefore, maintaining water quality and quantity has vital importance for sustainable agriculture.

This study focuses on the effects of poultry manure and inorganic fertilizer applications on nitrogen and irrigation water use efficiency in forage corn cultivars.

2. Materials and Methods

The research was conducted in the years 2011 and 2012 under the ecological conditions of the district of Eskipazar in the province of Karabuk, Turkey. Three different [PR 31Y43 (C1), OSSK-644 (C2), and Lacasta (C3)] hybrid corn cultivars (*Zea mays* L. *indentata* S.) were used as materials in this research. Three different fertilizer treatments were applied [organic (F1), inorganic (F2) and ½ organic + ½ inorganic (F3)] to these cultivars. The poultry manure named Organica® which was pelletized after fermentation was used in organic fertilizer treatments, while composite fertilizer 13.24.12.10.1.1 (13% N, 24% P_2O_5, 12% K_2O, 10% SO_3, 1% Zn and 1% Fe) was applied as base fertilizer and ammonium nitrate (33% N) was used as top-dressing fertilizer in inorganic fertilizer treatments. Drip irrigation method was used in irrigation which the system consisted of hydro PCND driplines having 16 mm diameter emitter with a flow rate of 2.35 lt h^{-1} with emitter spacing of 50 cm.

The experimental design was a randomized complete block in a split plot arrangement with three replications. The fertilizer treatments (F1, F2, and F3) were placed randomly on the main plots and the corn cultivars (C1, C2, and C3) were placed randomly on the split plots. The split plots size was 2.8 by 5 m with four rows per plot. The plant density were arranged to be 70 x 12 cm (119040 plant ha^{-1}) in all plots.

The planting was made by hand on May 25 in the first year of the research and on May 10 in the second year of the research. Two seeds were sown in each plant densities and thinned by hand after emergence. After the plants are emerged and the rows became clear, the first hoeing was made when the plant was 4-5 leafed and driplines were placed to the plots. The driplines were placed 1.4 m apart and each dripline was centered between two corn rows spaced 70 cm. The irrigation water quality that was used in the research was good (EC = 0.65 dS m^{-1} and pH = 7.2).

A transition climate between the Black Sea and continental climate is seen in Eskipazar district where the research was carried out. Some of the climate data recorded in Eskipazar district during the corn growing season of the years 2011-2012 when the research was carried out, and the long term means of these data (1985–2006) were given in Table 1.

From the examination of Table 1, it can be seen that the total rain, temperature and relative humidity means in the research years of 2011 and 2012, have been close to the long term means.

Table 1. Climatic data of the research location in the years 2011 and 2012 with the long term means (1985-2006) at Eskipazar, Turkey.

Months Aylar	Precipitation (mm) Ort. (mm)			Mean Temperature (°C) (º C)			Relative Humidity (%) Ort. (%)		
	2011	**2012**	**Long term**	**2011**	**2012**	**Long term**	**2011**	**2012**	**Long term**
May	68.4	68.2	57.1	13.4	15.4	14.3	73.9	66.7	60.2
June	54.8	21.8	54.8	16.9	20.2	17.9	72.3	58.7	60.8
July	8.2	51.4	24.8	21.6	22.6	20.9	63.1	57.7	55.4
August	17.0	48.0	22.9	19.9	19.9	21.1	62.0	59.9	53.9
September	4.4	6.0	21.6	17.1	18.7	16.3	57.4	54.7	57.5
Total/Mean	**152.8**	**195.4**	**181.2**	**17.8**	**19.4**	**18.1**	**65.7**	**59.5**	**57.6**

Soil samples were taken from 0-30 cm depths and analysed in order to determine the physical and chemical properties of the research soils. The analysis results of the soil samples were given in Table 2. As seen from this table, the soils are clay-loam textured and the organic matter content is low (1.49%).

Table 2. Physical and chemical soil properties of the research location at Eskipazar, Turkey

Properties		Properties	
Sand (%)	38.0	pH	7.60
Silt (%)	20.0	Salt (%)	0.04
Clay (%)	42.0	Lime (%)	37.59
Texture Class	Clay-Loam	Field Capacity (%), (v v^{-1})	26.32
Total N (kg ha^{-1})	0.34	Wilting Point (%), (v v^{-1})	16.25
P_2O_5 (kg ha^{-1})	23.60	Bulk Density (g cm^{3-1})	1.23
K_2O (kg ha^{-1})	170.10	Organic Matter (%)	1.49

TDR (time domain reflectometry) device was used for measurement of the soil moisture for determining the irrigation program during the research. This method is based on measuring the travelling time between two points in the soil of the electromagnetic waves sent from a voltage source through the metal bars buried in soil that are parallel to each other.

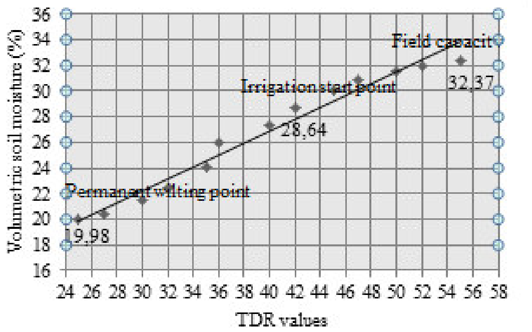

Figure 1. Relationship between volumetric soil moisture and TDR values

To determine the relationship between volumetric soil moisture and TDR readings, a 40 x 70 x 25 cm plastic case was placed and an undisturbed soil sample was taken from the research field and completely saturated with water. Later, the undisturbed soil samples were taken periodically and the gravimetrical moisture estimations were made using an oven and these estimations were transformed into volumetric values and the related TDR readings were recorded (Figure 1).

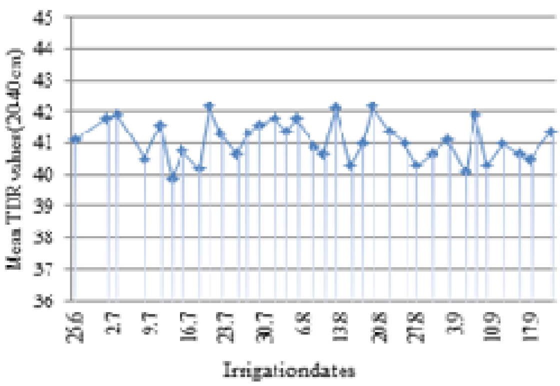

Figure 2. Mean TDR values (20 – 40 cm) before irrigation in first year

The irrigation was started when the consumption of 30% readily available soil moisture and the water was given from the system by calculating the water amount in a manner to bring 25 cm soil profile to the field capacity in the first periods and 50 cm soil profile to the field capacity after the stem elongation period (Figure 2 and 3).

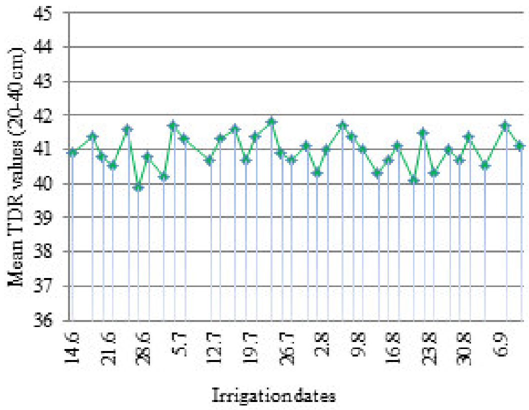

Figure 3. Mean TDR values (20 – 40 cm) before irrigation in second year

The irrigation amounts measured with water counters were recorded, and the total amounts used at the end of the season were defined (Figure 4 and 5).

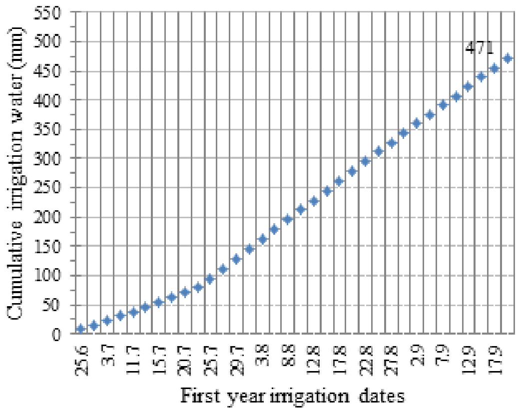

Figure 4. First year cumulative irrigation water (mm)

When the plants grow to a height about 40 cm, secondary hoeing were made. Three different fertilization treatments (F1, F2, and F3) were applied to all cultivars. The total N dose of the fertilizer treatments were determined as 3 g $plant^{-1}$. Composite fertilizer 13.24.12.10.1.1 (13% N, 24% P_2O_5, 12% K_2O, 10% SO_3, 1% Zn, 1% Fe) was applied as base fertilizer and ammonium nitrate (33% N) was used as top-dressing fertilizer in inorganic fertilizer treatment.

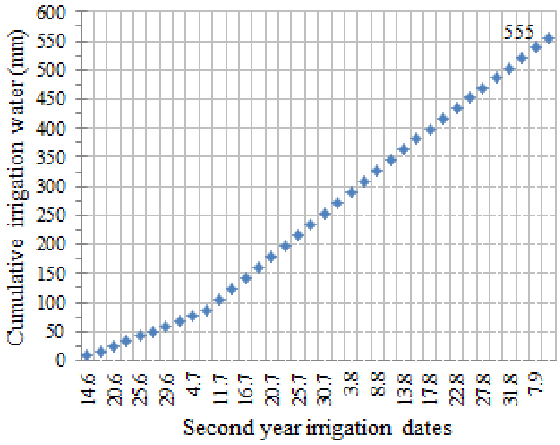

Figure 5. Second year cumulative irrigation water (mm)

A part of the nitrogen, the whole of the phosphorus and the potassium (0.75 g plant^{-1} N, 1.4 g plant^{-1} P_2O_5, 0.7 g plant^{-1} K_2O) were given as the base fertilizer on the plots where inorganic fertilizing treatment was made. The rest of the nitrogen (2.25 g plant^{-1}) were given with each irrigation in the form of ammonium nitrate (33% N). In organic fertilizer treatments, 5 units of water were added to the 1 unit of pelleted poultry manure and waited for 2 days then filtered through 200 mesh filter and then the poultry manure was applied in each irrigation through drip irrigation system (Table 3).

Table 3. Some properties of pelleted and diluted poultry manure used in research (2011-2012).

Pelleted poultry manure		Diluted poultry manure (1 5^{-1})	
Total N (%)	2.30	Total N (%)	0.42
P_2O_5 (%)	5.86	P (ppm)	343.50
K_2O (%)	3.31	K (ppm)	350.82
Organic Matter (%)	61.40	Organic Matter (%)	2.07

In organic fertilizer treatments 54 kg of diluted poultry manure solutions were applied in each irrigation and 3 g $^{-1}$ plant N, 0.24 g plant^{-1} P_2O_5, 0.25 g plant^{-1} K_2O were given in total. In ½ organic + ½ inorganic fertilizer treatments half of the N dose (1.5 g plant^{-1}) were provided from the poultry manure and the other half (1.5 g plant^{-1}) were provided from inorganic fertilizers. In this treatment 3 g plant^{-1} N, 0.82 g plant^{-1} P_2O_5, 0.47 g plant^{-1} K_2O was given in total.

After removing border effects, two center rows of each split plot were harvested. The harvesting was made at milk-line was between 50 and 75%. The plant based measurements were made on five plants randomly selected from two center rows of each split plot. The dry matter yield (t ha^{-1}), irrigation water use efficiency (kg m$^{3\ -1}$), nitrogen uptake and nitrogen use efficiency (kg kg $^{-1}$) were examined (Howell et al. 1988).

All data were analyzed using ANOVA according to experimental design of randomized complete block in a split plot. The LSD procedure was used to separate mean values when the F test was significant (Mstat-C 1980).

3. Results and Discussion

In both research years, fertilizer treatments were statistically significant on dry matter yields (p < 0.05). The highest dry matter yield values were obtained from F2 (18.7, 23.3 respectively) and F3 (16.7, 22.5 respectively) fertilizer treatments and took place in the first group (a) (Table 4). Organic material applications combined with inorganic fertilizer had no unfavorable effects on the yield and forage quality of silage maize. A combined use of organic materials with inorganic fertilizer may not only maintain forage supply from silage maize but also reduce dependence on inorganic fertilizer on agricultural lands, even if not completely. Therefore, it may have a positive impact on the environment and soil fertility. (Nazli et al. 2014).

In both research years, fertilizer treatments were statistically significant on irrigation water use efficiency (p < 0.05). The highest irrigation water use efficiency values were obtained from F2 (3.9, 4.2 respectively) and F3 (3.5, 4.0) respectively) fertilizer treatments and took place in the same group (a) (Table 4). When water is a limiting factor, plant development cannot reach the desired level through fertilizer applications. If there is available adequate water in the plant root zone, the yield increase by fertilization is more pronounced (Ertek 2014).

In both research years, fertilizer treatments were statistically significant on nitrogen uptake efficiency ($p < 0.01$). The highest nitrogen uptake efficiency values (0.87 and 0.73) were obtained from F2 fertilizer treatments and took place in the first group (a) (Table 4).

In second research year, hybrid corn cultivar treatments were statistically significant on nitrogen uptake efficiency ($p < 0.05$). The highest nitrogen uptake efficiency value (0.69) was obtained from C1 cultivar treatment and took place in the first group (a) (Table 4).

In both research years, fertilizer treatments were statistically significant on nitrogen use efficiency ($p < 0.05$). The highest nitrogen use efficiency values were obtained from F2 (52.2, 65.3 respectively) and F3 (46.7, 62.9 respectively) fertilizer treatments and took place in the same group (a) (Table 4).

Those results correspond with the lower effectiveness of nitrogen from organic fertilizer on the irrigation water use efficiency, nitrogen uptake and use efficiency compared with the nitrogen from inorganic fertilizer. The sole use of organic manures cannot compensate the produce obtained by inorganic applications (Ahmad et al. 2012). Integrated use of chemical fertilizers and organic material may be a good approach for sustainable production of crops (Bekeko 2013).

The integration of organic sources and synthetic sources of nutrients not only supply essential nutrients but also have some positive interaction to increase nutrient use efficiency and thereby reduce environmental hazards (Khaliq et al. 2004). The results obtained from many researches, that are made on the effects of organic, inorganic and ½ organic + ½ inorganic fertilizer treatments on corn (*Zea mays* L.) are supporting our findings (Basarajavu 2007; Martins et al. 2008; Shah et al. 2009; Achieng et al. 2010; Ali et al. 2012; Nasım et al. 2012; Unagwu et al. 2012; Karasahin 2014) In some of the researches where the same treatments were applied, higher results were obtained in organic fertilizer treatments (Elamin and Elagib 2001; Khaliq et al. 2004; Hirzel et al. 2007; Salmeron-Miranda 2008; Cheema et al. 2010; Quansah 2010; Kasim et al. 2011; Verma 2011; Ahmad et al. 2012; Bekeko 2013) and in some of these researches lower results were obtained (Makinde and Ayoola 2010; Cerny et al. 2012).

The similarities and differences in the research results regarding the fertilizer treatments may be due to the ecological conditions, irrigation methods and the differences and similarities of the genetics of the cultivars used in these researches.

4. Conclusions

As a result of the research, the highest values of irrigation water use efficiency, nitrogen uptake and use efficiency were obtained from F2 and F3 fertilizer treatments in all three corn cultivars (C1, C2, and C3). When we consider the sums paid for the export of inorganic fertilizers and the negative effects of these inorganic fertilizers on human and environmental health, we may see that F3 fertilizer applications would be preferable in the regions where corn is grown.

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Table 4. Effects of fertilization and hybrid corn cultivars on dry matter yield (t ha^{-1}), irrigation water use efficiency (kg $m^{3\ -1}$), nitrogen uptake and use efficiency (kg kg $^{-1}$).

Fertilization (F)	Cultivars (C)	Dry Matter Yield (t ha^{-1})		Irrigation Water Use Efficiency		Nitrogen Uptake Efficiency (kg kg^{-1})		Nitrogen Use Efficiency (kg kg^{-1})	
		2011	2012	2011	2012	2011	2012	2011	2012
	PR-31Y43	11.9	17.8	2.5	3.2	0.39	0.56	33.3	49.8
Organic	OSSK-644	14.2	15.9	3.0	2.8	0.48	0.42	39.7	44.4
(F1)	Lacasta	13.1	16.1	2.8	2.9	0.42	0.36	36.7	45.1
	PR-31Y43	16.7	23.2	3.5	4.1	0.76	0.77	46.7	65.0
Inorganic	OSSK-644	21.6	24.0	4.5	4.3	1.01	0.71	60.4	67.1
(F2)	Lacasta	17.7	22.8	3.7	4.1	0.85	0.71	49.6	63.7
	PR-31Y43	17.1	22.6	3.6	4.0	0.62	0.74	47.9	63.2
O+I	OSSK-644	16.4	24.4	3.4	4.4	0.60	0.71	45.8	68.4
(F3)	Lacasta	16.6	20.4	3.5	3.7	0.82	0.57	46.4	57.2
F	Organic	13.1 b	16.6 b	2.7 b	2.9 b	0.43 c	0.45 b	36.6 b	46.4 b
Average	Inorganic	18.7 a	23.3 a	3.9 a	4.2 a	0.87 a	0.73 a	52.2 a	65.3 a
	O+I	16.7 a	22.5 a	3.5 a	4.0 a	0.68 b	0.67 ab	46.7 a	62.9 a
LSD		2.72*	5.17*	0.56*	0.94*	0.15**	0.22**	7.62*	14.51*
EMS		4.33	15.65	0.18	0.52	0.005	0.01	33.98	122.90
C	PR-31Y43	15.2	21.2	3.2	3.8	0.59	0.69 a	42.6	59.4
Average	OSSK-644	17.4	21.4	3.6	3.9	0.69	0.61 ab	48.7	59.9
	Lacasta	15.8	19.8	3.3	3.6	0.68	0.55 b	44.2	55.4
LSD		ns	ns	ns	ns	ns	0.09*	ns	ns
EMS		-	-	-	-	-	0.009	-	-
FXC int.	**LSD**	ns	ns	ns	ns	ns	ns	ns	ns
EMS		-	-	-	-	-	-	-	-

*, **: Significant at P=0.05 and P=0.01 probability level
NS : Not significant, EMS : Error mean square
F1: Organic, F2: İnorganic, F3: ½ Organic + ½ İnorganic
C1: PR-31Y43, C2: OSSK-644, C3: Lacasta

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