Effect of N–P–K Fertilization on Mineral Content and Fatty Acid Compounds of Corn Seed

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Abstract: Corn (*Zea mays* L.) is one of the major crops around the world. It has been produced for the food industry both as a carbohydrate and oil source in past decades. The purpose of research was to determine the effect of nitrogen (N), phosphorus (P), potassium (K) fertilization on nutrient contents (N, P, K, Ca, Mg, Fe, Zn, Cu, Mn) and fatty acid composition of corn seed. The study was carried out as a field experiment, randomized block design, including two different applications: fertilized (250–80–80 kg NPK ha^{-1}) and unfertilized (control). The result of study indicating that fertilized (NPK) significantly affected saturated fatty acid content of seed as compared to control. Under the fertilize conditions lignoceric and arachidic acids were significantly increased, whereas myristic and palmitic acids were decreased. On the other hand, fertilization had no significant changing on unsaturated fatty acid content observed except eicosenoic acid. Moreover, Mn content of seed was decreased, while the other nutrient contents of seed were increased under the fertilized conditions. It could also suggested that further breeding work toward increasing oil content and especially unsaturated fatty acid composition with fertilization programs.

Keywords: corn oil, fatty acid, fertilization, mineral content

N-P-K Gübrelemesinin Mısır Tanesinde Minarel Kapsam ve Yağ Asidi Bileşenleri Üzerine Etkisi

Özet: *Mısır (Zea mays L.) dünyanın en önemli bitkilerinden biridir. Son yıllarda, mısır gıda endüstrisinde hem karbonhidrat hem de yağ kaynağı olarak üretilmektedir. Bu çalışmanın amacı azot (N), fosfor (P) ve potasyum (K)'lu gübrelemenin mısır tanesinin besin elementi içeriklerine (N, P, K, Ca, Mg, Fe, Zn, Cu, Mn) ve yağ asidi kompozisyonuna etkisini belirlemektir. Tesadüf blokları desenine göre bir tarla denemesi şeklinde yürütülen çalışmada iki farklı uygulama: gübrelenmiş (250–80–80 kg NPK ha^{-1}) ve gübrelenmemiş (kontrol) bulunmaktadır. Araştırma sonuçlarına göre, NPK gübrelemesi kontrole göre tane doymuş yağ asitleri içeriklerine önemli bir etkide bulunmuştur. Gübreleme koşulları altında, lignoserik ve araşidik asit içerikleri önemli biçimde artmış, miristik ve palmitik asit içerikleri ise azalmıştır. Öte yandan gübrelemenin, özosenoik asit dışında doymamış yağ asidi içeriklerinde önemli bir değişime neden olmadığı gözlenmiştir. Ayrıca tanenin Mn içeriği azalmış, diğer besin elementi içerikleri ise artmıştır. Bitkilerin yağ içeriğinin ve özellikle doymamış yağ içeriklerinin arttırılması için gelecekteki ıslah çalışmalarına gübreleme programlarının da dahil edilmesi önerilmektedir.*

Anahtar Kelimeler: *mısır yağı, yağ asidi, gübreleme, mineral kapsam*

INTRODUCTION

Corn (*Zea mays* L.) is one of the outstanding crops in worldwide. It has been used both human and animal consumptions. At the same time, it has been produced for the food industry both as a carbohydrate and oil source in past decades (Goffman and Bohme, 2001). Owing to fatty acid, carbohydrate and protein contents of seed, it has gained significantly importance for the global food supply (Alonso *et al.*, 2010). The oil yield depends on the corn seed yield, the cob weight, the cob length and the oil content of the corn seed. Corn oil identified to "healthful" fats for consumer because of its saturated acids low and monounsaturated acids high (Dunlap *et al.,* 1995). Fatty acid composition of vegetable oil, synthesized mainly inside plastids in plants (Weaire and Kekwick, 1975). Many factors (i.e. nutritional status or balance, depot, varieties, and time on feed) affected its composition (Duckett *et al.*, 1993; Aharoni *et al.*, 1995; Scollan *et al.*, 2001). In a similar manner, oils contents are also influenced by environmental factors such as temperature, drought, and fertilizer nutrient (Ahmad and Abdin, 2000; Reynolds *et al.,* 2005). Fertilizer use a considerable impact on quality of fatty acid on oilseed crops (Mohammadi and Rokhzadi, 2012). Such as palm oil needs especially high amounts of potassium, nitrogen and phosphorus (Woittiez *et al.,* 2017). Similarly nutrients content of corn seed is changed by many environmental factors or agricultural practices such as temperature, locations, water dose, planting year and fertilizer (Abdel-Aal *et al.*, 1995; Piergiovanni *et al.*, 1996; Ruibal-Mendieta *et al.*, 2005; Gomez-Becerra *et al.*, 2010). We aimed to determine impact of NPK fertilization on fatty acid composition and nutritional status of corn seed. Additionally, fertilization habit will be evaluated by comparing these properties.

MATERIALS and METHODS

Site Properties

The research was carried out in Aydin conditions, located in the west of Turkey at 37° 44' N 27° 44' E at 65 m above sea level, in 2013 over the main crop growing period. The soil was found sandy loam, had alkaline character and a low organic matter. Additionally, soil available phosphorus content, extractable cations (Na, Ca, Mg) and available micro nutrient contents (Fe, Zn, Cu, Mn) were adequate, but K was found deficient. Initial soil physical and chemical properties were given in Table 1.

Experimental Design

The experiment was conducted as a randomized complete block experimental design with 3 replications. Fertilized and unfertilized (control) plots were prepared and corn seedlings sowed 18 cm intervals at April 25, 2013 and the first seed emergence observed at May 13, 2013. The corn cultivar is Lucroso variety used as the test material. Lucroso is a hybrid (F1) single cross corn variety, which was produced by Syngenta Turkey Co. Ltd. Each plot area was 28 m^2 (5 m x 5.6

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Table 1. Soil some physical and chemical properties sampled at 0–30 cm depth

Texture	pH	OM	N	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu
		%		mg kg^{-1}								
Sandy Loam	8.4	1.2 low	0.07 low	21 high	176 low	2978 high	594 very high	101 medium	19 high	1.1 adequate	5.6 adequate	1.8 adequate

OM: Organic matter; N: Nitrogen; P: Available phosphor; K: Extractable potassium; Ca: Extractable calcium; Mg: Extractable magnesium; Na: Extractable sodium; Fe: Available iron; Zn: Available zinc; Mn: Available manganese; Cu: Available copper

m) and consisted of 8 rows. A one–factor factorial design that consisted of two treatments, fertilized (250–80–80 kg NPK ha^{-1}) and unfertilized (control). According to soil analysis, NPK levels identified as a standard recommendation. To explore the effects of NPK fertilizer, 533 kg ha^{-1} 15–15–15 composite (15N%, 15P_2O_5%, 15K_2O%) 217 kg ha^{-1} urea (46N) and 200 kg ha^{-1} Ammonium Nitrate (33N%) were applied to soil. All plots (fertilized and unfertilized) was irrigated totally 5 times as a standard procedure by taking climate conditions and plant requirements.

Nutrients Analysis

Seed samples collected each plots and dried at 70°C for 48 h in an oven. Dry seed materials were grounded Wiley Mill and weighed (0.5 g). Samples were digested by dry ashing method (Kacar and İnal, 2008). The digested sample was filtered and used for the determination of seed mineral content. Total nitrogen (N) in digests was determined by the Kjeldahl method (Bremner, 1965). Phosphorus (P) was analyzed by yellow color spectrophotometric method using "Shimadzu UV-160A" spectrophotometer (Jackson, 1958). K, Na and Ca were determined by "Jenway, PFP–7" flame photometer and Mg, Fe, Zn, Cu and Mn also determined by "Varian, 220FS" atomic absorption spectrophotometer (Kacar and İnal, 2008).

The Analysis of Fatty Acid Composition of Corn Oil

The corn oil samples were determined to solvent extraction methods by gas chromatography (Agilent 7890A, Santa Clara, CA) equipped with DB–23 fused silica capillary column (60 m, 0.25 mm i.d. and 0.25 µm film thickness). Fatty acid methyl esters (FAME) were prepared to the International Union of Pure and Applied Chemistry (Anonymous, 1987). As a carrier gas helium used a flow rate of 1 ml/min. Injector port temperature ramped to 230°C, the column and detector temperatures were 195 and 240°C, respectively.

Statistical Analysis

All the data analyzed statistically using the TARIST package software (Açıkgöz *et al.*, 1994). Calculated means were compared using Least Significant Difference (LSD) at $p \leq 0.05$ probability.

Table 2. According to US National Nutrient Database, fat composition of 100 g corn oil (Anonymous, 2017)

Type	Vegetable Oils					
	Saturated fatty acids (g)	Monounsaturated fatty acids (g)		Polyunsaturated fatty acids (g)		
		Total mono	Oleic acid	Total poly	Linolenic acid	Linoleic acid
Corn	12.9	27.6	27.3	54.7	1	58

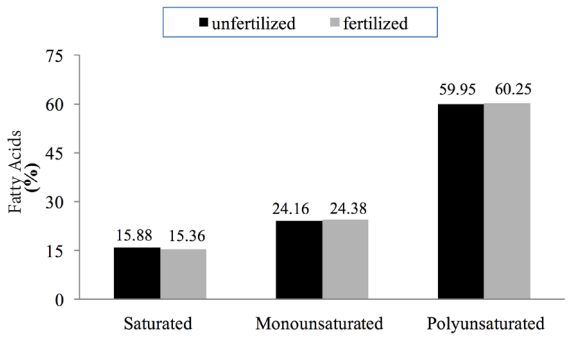

Figure 1. The ratio of saturated, monounsaturated and polyunsaturated fatty acids of corn oil

RESULTS and DISCUSSION

Saturated fatty acid content of the Lucroso variety (15.62% mean) was found to higher than US National Nutrient Database value (12.9%) (Table 2). Similarly, Lucroso's polyunsaturated fatty acid content (60.10% mean) was found higher than US database value (54.7). However, our monounsaturated value (24.27% mean) was found lower than US database value (27.6%).

It was determined that saturated, monounsaturated and polyunsaturated acid ratios of corn oil were shown in Figure 1. It was found that monounsaturated (↑0.22) and polyunsaturated (↑0.30) fatty acid rates were increased by fertilization while saturated (↓0.52) fatty acid rate was decreased.

It was given that change of saturated fatty acids rate of corn oil under fertilized and unfertilized conditions in Table 3. It was determined that lignoceric (24:0), arachidic (20:0) and stearic (18:0) fatty acids of corn oil were increased by under the fertilized conditions whereas myristic (14:0) acid and palmitic (16:0) acid rates of corn oil were decreased. On the contrary, heptadecanoic (17:0) acid ratio was not affected by treatments. Lignoceric (24:0), arachidic (20:0) and palmitic (16:0) acid rates changed significantly, but the others found non significant.

The changing of unsaturated fatty acids rate of corn oil under the fertilized and unfertilized conditions given in Table 4. Fertilizer use increased heptadecenoic (17:1), eicosenoic

Table 3. The changing of saturated fatty acids rates in corn oil (%)

	Saturated fatty acids					
	Myristic	Palmitic	Heptadecanoic	Stearic	Arachidic	Lignoceric
Treatment	14:00	16:00	17:00	18:00	20:00	24:00
Unfertilized	0.09	14.06	0.06	1.52	0.13	0.01
Fertilized	0.06	13.36	0.06	1.56	0.27	0.04
Average	0.08	13.71	0.06	1.54	0.2	0.03
Changing (%)	**33**↓	**5**↓	↔	**3**↑	**108**↑	**300**↑
LSD	**ns**	***0.35**	**ns**	**ns**	****0.01**	****0.01**

** P <0.01, * P<0.05, ns: non significant

Table 4. Changing of unsaturated fatty acids ratios in corn oil (%)

	Unsaturated fatty acids					
	Palmitoleic	Heptadecenoic	Oleic	Eicosenoic	Linoleic	Linolenic
Treatment	16:1	17:1	18:1	20:1	18:2	18:3
Unfertilized	0.22	0.02	23.87	0.05	58.91	1.04
Fertilized	0.18	0.09	23.99	0.13	59.12	1.13
Average	0.20	0.06	23.93	0.09	59.02	1.09
Changing (%)	**18**↓	**350**↑	**1**↑	**160**↑	**0.4**↑	**9**↑
LSD	**ns**	**ns**	**ns**	***0.06**	**ns**	**ns**

* P<0.05, ns: non significant

Table 5. Mineral content of corn grain under fertilized and unfertilized conditions

	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn
			%				mg kg^{-1}		
Unfertilized	0.91	0.16	0.37	0.03	0.11	34.50	30.28	6.00	19.75
Fertilized	1.13	0.17	0.41	0.03	0.12	74.95	34.12	6.15	10.39
Average	1.02	0.17	0.39	0.03	0.12	54.73	32.20	6.08	15.07
Changing (%)	**24**↑	**6**↑	**11**↑	↔	**9**↑	**117**↑	**13**↑	**3**↑	**47**↓
LSD	****0.08**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	***5.88**

** P <0.01, * P<0.05, ns: non significant

(20:1), linolenic (18:3), oleic (18:1) and linoleic (18:2) acids of corn oil while palmitoleic (16:1) acid decreased. The only significant change was found eicosenoic acid of corn oil by statistically.

Changes of corn oil fatty acids rates and nutrient concentrations of seed resulting were observed in the present study. The results indicate that fertilizer use affected to fatty acid composition of corn oil. But, their changes were found limited quantity. The most of previous studies reported that genotypic factors much more impact than phenotypic factors on fatty acid composition in plants (Jellum and Marion, 1966). The oil composition is accepted as a genetic inheritance, it may be necessary to apply the breeding programs to change the fatty acid composition (Poneleit and Alexander, 1965; Windstrom and Jellum, 1975). Although some studies reported that N fertilization didn't influence on profile of fatty acid (Jellum *et al.,* 1973; Ashraf *et al.,* 2006), Present study results are supported by Kheir *et al.* (1991), who observed that the higher N rate increased the ratio of unsaturated fatty acids and decreased the saturated fatty acids of flax oil. El-Sayed *et al.* (2000), who reported that increased levels of both N and P fertilizers increased essential oil of black cumin seed. But, several reports contradicted that increase in N uptake leads to decrease of oil content (Grant *et al.,* 2011; Mohammadi and Rokhzadi, 2012). Due to N concentrations, protein synthesis increases while carbohydrate synthesis decreases, thus, oil synthesis decreases eventually (Rathke *et al.,* 2005).

On the other hand, unsaturated fatty acids ratios in corn oil is important with regard to public health (Dunlap *et al.,* 1995) and global food supply (Alonso *et al.*, 2010). It was determined that unsaturated acids rate were found higher than saturated acids in corn oil. These findings supported by Sawan *et al.* (2001), who said that it is desirable that the ratio of saturated fatty acid is low compared to unsaturated acids.

It was revealed that different response to different treatments in terms of N, P, K, Ca, Mg, Fe, Zn, Cu and Mn (Table 5). Most of evaluated nutrients were affected by fertilizer treatment. N, P, K, Fe, Zn, Cu and Mg concentrations were increased by fertilizer use whereas Mn was decreased. Solely Ca was unaffected to changing application treatment. The highest increase was observed Fe and N concentrations of seed compared with control.

NPK fertilization and fertilizer use habits so important that in terms of corn seed yield, cob yield, and corn oil quality. Inadequate fertilization limits growth rate and photosynthesis rate (Aguirrezabal *et al.,* 2009) which leads to decrease yield, oil synthesis finally oil quality drops. Our findings observed that many nutrient concentrations of seed increased under the fertilization conditions except Ca whereas Mn concentrations was decreased. Although the soil Mn content was adequate, the seed Mn concentrations is reduced. It has antagonistic effect (unadequate Mn level) because of excess makro fertilization (NPK). It can be argued that this decline, mutually antagonistic impact, can be attributed to Fe or Zn uptakes by plant. In comparison with the ordinary cultural practices recommend fertilization, it is so apparent that applications of such N, P and K increase yield and could bring about better impact on corn seed yield, seed oil content, seed protein content and unsaturated fatty acids.

CONCLUSION

As a general conclusion it can be stated that fertilization increased unsaturated oil content. Fertilizer use slightly effected on the oil fatty acid composition. Our results suggest that the nutrient balance in fertilization, very important, could be increased the unsaturated fatty acids of corn. On the other hand, it could also suggested that further breeding work toward increased oil content and unsaturated fatty acid composition with fertilization programs.

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