



Effects of foliar boron fertilization at early vegetative stages on silage yield and quality parameters of maize

Erken gelişme döneminde yapraktan bor uygulamasının mısırın hasıl verimi ve kalitesi üzerine etkileri

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Ö Z E T / A B S T R A C T

Aims: This study was conducted to determine the effects of various boron quantities applied at different vegetative growth stages of maize as foliar application on hay and silage yield and quality in Mediterranean ecological conditions.

Methods and Results: Different boron fertilizer doses (0, 4, 6, 8 kg ha⁻¹ disodium octaborate tetrahydrate (ETIDOT-67 (Na₂B₈O₁₃.4H₂O)) applied at early vegetative stages of maize (V2, V4 and V2+V4 as two portions) and the effects of boron on yield and quality parameters of maize were examined. As a result of study, higher silage and hay yields were observed at all boron applications in comparison with control and the highest yields (68.43 ton ha⁻¹ silage and 21.58 ton ha⁻¹ hay yield) were obtained at 8 kg ha⁻¹ boron application. Also other boron doses had the statistically similar results. Although the highest yields in terms of application times were observed at boron applications at V2+V4 stages as two portions, the differences between the application times were not statistically significant.

Conclusions: We recommend that 4 kg ha⁻¹ boron fertilizer application at early vegetative stages of maize for high silage yield and quality.

Significance and Impact of the Study: Limited researches were performed on boron effects on hay and silage yields and qualities of maize up to now. This study revealed that the effects of boron application at early vegetative period of maize. Also, it is expected to be a source for further studies.

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INTRODUCTION

Maize is one of the most important cereal crops for human nutrition and livestock feeding (Gozubenli et. al 2010; Konuskan et. al 2015). Maize production for hay and silage yield increased in Turkey in recent years. It was realized 152.417 tons green forage and 25.499.870 tons silage production in 507.413 ha areas in Turkey in 2019 (Anonymous, 2019). Green forage and silage productions from maize crop increased 2.7-fold in the last decade in Turkey. This rises are remarkable for maize production as fodder crop.

Increases in yields and qualities depend on soil productivity and nutritional sufficiency. Beside macronutrients, micronutrients are essential elements for plant growth and development despite low requirements. Boron deficiencies is the second important micronutrient constraint to crop production after zinc in the worldwide (Ahmad et al., 2012). Boron deficiency is common issue and its availability to plants decreases with increasing soil pH, especially in calcareous soils. Its distribution in the plants is primarily managed by transpiration, and also phloem mobile and might be retranslocated in considerable amounts (Marschner, 1997). Boron deficiencies can cause

decreases in yield and quality of plants (Yarnia et al., 2013). Boron applications can increase maize yield with low quantities (Güneş et al., 2011). Various studies were performed on boron effects on grain yield of maize, previously (Aref, 2011; Kaur and Nelson, 2015; Horuz and Özcan, 2017; Konuskan et al., 2017, Wasaya et al., 2017; Nelson and Meinhardt, 2011). However, insufficient researches were performed on boron effects on hay and silage yields and qualities of maize. This study was performed to determine the effects of foliar boron fertilization at early vegetative growth stages of maize on hay and silage yield and quality.

MATERIALS and METHODS

This study was conducted in Hatay province of Turkey in 2015 and 2016 maize growing seasons. In this study, Etidot-67 (disodium octaborate tetrahydrate ($\text{Na}_2\text{B}_8\text{O}_{13}\cdot 4\text{H}_2\text{O}$)) which produced by Eti Maden Inc. for usage as plant fertilizer containing 20.9% boron, used as boron source.

Soil properties of experimental area were clay loam textured, mild alkaline (pH 7.7-7.75), not salty (0.049-0.039 dS m^{-1}), containing 28.79- 28.82% CaCO_3 , low organic matter (1.04-1.06%) and 0.53-0.67 mg kg^{-1} NaOAc extractable boron. Some climatic data occurred at experimental station were given in Table 1.

Table1. Some climatic data for experimental area in 2015-2016 growing seasons

	Years	April	May	June	July	August
Maximum Temperature ($^{\circ}\text{C}$)	2015	31.5	39.1	36.3	38.4	42.7
	2016	36.6	35.4	40.8	39.2	41.1
Minimum Temperature ($^{\circ}\text{C}$)	2015	4.4	9.5	12.8	18.5	18.4
	2016	4.2	9.6	13.4	18.2	20.4
Average Temperature ($^{\circ}\text{C}$)	2015	15.8	22	24.6	28.2	29.4
	2016	19.4	21.5	26.8	28.9	29.3
Total Precipitation (mm)	2015	63.2	7	0	0.2	0
	2016	5.0	29.6	4.8	0	0
Relative Humidity (%)	2015	65.1	58.5	56.1	56.8	55.1
	2016	54.4	58.8	53.5	57.3	59.4

Field study was arranged as a randomized split plot design with three replications. Boron application times (V2 stage, V4 stage and V2+V4 stages) were in main plots and boron levels (0, 4, 6 and 8 kg ha^{-1} Etidot-67) were in sub-plots. Sub-plot sizes were $2.8\text{m}\times 5\text{m}=14 \text{ m}^2$. Field experiments were seeded on April 10, 2015 and April 5, 2016 with pneumatic seeder in 10 plant m^{-2} density. 80 kg ha^{-1} N, P_2O_5 and K_2O applied as basal fertilizer and 184 kg ha^{-1} N applied at V6 stage which knee height as top fertilizer. Boron levels of 0, 4, 6 and 8 kg ha^{-1} Etidot-67 applied at V2 stage (2nd leaf collar visible), V4 stage (4th leaf collar visible) and V2+V4 stages in two portions. Yield, yield related traits and quality parameters were examined at center two rows of plots. NDF and ADF contents of plant samples were determined with Ankom filter bag technique in A220 fiber analyzer according to Van Soest et al. (1991).

All data were subjected to analysis of variance procedures using the MSTAT-C. Duncan multiple range

test was used to determine statistical differences between treatments ($\text{pd}\leq 0.05$)

RESULTS and DISCUSSION

Plant heights and stem diameters were not affected by boron applications in early vegetative stages of maize. These results indicated that boron applications at early growth stages had no significant effects on maize plant growth. Plant growth and elongation closely related with environmental conditions and soil fertility. Plant species differ in their requirement of boron for growth. Marschner (1995) reported that a considerable amount of the total boron content of plant is complexed in cis-diol configuration in the cell walls and graminaceous species are lower boron requirement compared with dicotyledonous related to lower amounts of compounds with cis-diol config in the cell walls. Therefore, the differences between boron applications may be insignificant.

Table 2. Effect of foliar boron fertilization on plant height and stem diameter of maize

Treatment	Plant Height (cm)			Stem Diameter (mm)		
	2015	2016	2015-2016	2015	2016	2015-2016
Application times						
V2	256	246	250	18.7	21.8	20.3
V4	254	250	252	18.7	21.7	20.2
V2+V4	255	248	251	18.6	22.2	20.4
LSD	ns		ns	ns		ns
Boron dosages						
0	253	250	252	18.6	22.0	20.3
4	254	247	251	18.7	22.2	20.4
6	256	247	251	18.7	21.7	20.2
8	257	248	252	18.7	21.8	20.2
LSD	ns		ns	ns		ns
CV(%)	1.87			6.45		

ns: not significant

Higher silage and hay yields obtained at all boron applications in comparison with control, whereas boron application times had similar effects. Boron applications had increases 10-15% in silage yields and 7-12% in hay yields according to control. The highest silage yield (68430 kg ha⁻¹) and hay yield (21580 kg ha⁻¹) obtained at the highest boron application dose, but also statistically similar results were observed at all boron application doses. These results indicated that boron applications had positive effects on maize silage and hay yields even in low amounts. Yilmaz et al. (2003) determined similar silage yield values, whereas Atis et al. (2013) obtained higher yields in the same ecological location. Torun

(1999) reported that lower silage yields obtained at Samsun ecological conditions in comparison with our results. Shabaz et al. (2015) reported that boron applications enhanced biological yield of maize significantly. Nawaz et al. (2017) stated that fresh and dry matter yield of sorghum were increased with increases in boron doses. Kaur and Nelson (2015) indicated that the highest grain yields obtained at 2.24 kg ha⁻¹ boron application at V4-V6 growth stage of maize. Also, Konuskan (2018) reported that boron applications enhanced grain yield of maize at early vegetative growth stages.

Table 3. Effect of foliar boron fertilization on silage yield and hay yield of maize

Treatment	Silage Yield (kg ha ⁻¹)			Hay Yield (kg ha ⁻¹)		
	2015	2016	2015-2016	2015	2016	2015-2016
Application times						
V2	71020	59770	65400	20970	21330	21150
V4	71530	55830	63680	20390	19490	19940
V2+V4	72080	60490	66290	20620	21070	20840
LSD	ns		ns	ns		ns
Boron dosages						
0	64230	54680	59460 b**	18640	19930	19290 b*
4	72600	61130	66870 a	20290	21790	21040 a
6	73730	57740	65730 a	21470	19880	20670 ab
8	75600	61240	68430 a	22240	20910	21580 a
LSD	ns		3035	ns		1485
CV(%)	6.89			10.64		

*,** significant P<0.05, P<0.01 levels, respectively; ns: not significant

Boron applications had not significant effects on leaf, stem and cob ratios of silages. Cob ratios ranged from 61.8% to 63.2% in different boron applications in this

study. High cob ratio is a desired characteristic for quality maize silage and these values are quite higher than some other research results. Ileri et al. (2018) reported that

cob ratios of maize silage ranged from 33.8% to 42.5% according to genotypes. Keskin et al. (2017) determined that 36%-45.6% cob ratios for different silage maize

genotypes. Nazli et al. (2019) revealed that cob ratios of maize silage differed from 20% to 80% according to genotype and harvesting time.

Table 4. Effect of foliar boron fertilization on leaf ratio and stem ratio and cob ratio of maize

Treatment	Leaf Ratio (%)			Stem Ratio (%)			Cob ratio (%)		
	2015	2016	2015-16	2015	2016	2015-16	2015	2016	2015-16
Application times									
V2	13.5	15.3	14.4	23.7	22.5	23.1	62.7	61.9	62.3
V4	13.6	16.0	14.8	23.7	20.9	22.3	62.5	62.9	62.8
V2+V4	14.0	16.4	15.2	23.7	20.3	22.1	62.2	63.3	62.8
LSD	ns		ns	ns			ns		
Boron dosages									
0	13.6	16.0	14.8	23.6	20.6	22.1	62.7	63.4	63.1
4	13.8	16.4	15.1	23.5	19.6	21.5	62.6	63.8	63.2
6	13.5	15.3	14.4	23.8	22.4	23.1	62.6	62.2	62.4
8	14.0	15.9	14.9	24.1	22.3	23.2	62.1	61.5	61.8
LSD	ns		ns	ns	ns		ns		
CV (%)	10.77			9.9			3.80		

ns: not significant

Boron application times and doses effects on neutral detergent fiber (NDF) contents of maize were not statistically significant and NDF contents ranged from 35.7% to 37.0% in this study. These values are quite low in comparison with desired maize silage NDF contents of 35% to 55% for good quality maize silage (Chahine et al. 2009). The NDF content of maize silage is affected by hybrid, ecological conditions, fertilization and maturity at harvest. Johnson et al. (2001) reported NDF contents of silage maize ranged between 36.3% and 57.3%. Filya (2004) reported that ADF and NDF contents of maize tended to increase with advanced plant maturity. This is related to the increase in the proportion of grains with

low NDF and ADF contents (Johnson et al., 2001; Filya, 2004). Acid Detergent Fiber (ADF) contents of maize silage ranged from 18.1% to 19.6% and slightly increased in high boron dose in this study. Ileri et al.(2018) reported that 22%-26.7% ADF content for different maize genotypes. Furthermore, our results are very low considering desired ADF contents of 20% to 33% for good quality maize silage (Chahine et al. 2009). NDF and ADF values are closely related to grain content of maize silage and decreases with high grain ratios of silage. In our study, NDF and ADF contents are quite low and desirable characteristics for quality maize silages.

Table 5. Effect of foliar boron fertilization on NDF and ADF contents of maize

Treatment	NDF (%)			ADF (%)		
	2015	2016	2015-16	2015	2016	2015-16
Application times						
V2	37.6	35.3	36.4	18.4	18.8	18.6
V4	38.1	34.3	36.2	19.0	18.8	18.9
V2+V4	38.4	35.0	36.7	19.0	18.9	18.9
LSD	ns		ns	ns		
Boron dosages						
0	37.7	35.1	36.4	18.5	18.8	18.7 ab
4	37.1	34.2	35.7	18.2	17.9	18.1 b
6	38.6	34.8	36.7	19.6	19.5	19.6 a
8	38.6	35.4	37.0	18.9	19.2	19.1 a
LSD	ns		ns	ns		0.96
CV(%)	6.24			7.59		

*, ** significant P<0.05, P<0.01 levels, respectively; ns: not significant

CONCLUSIONS

The results of this study showed that boron applications enhanced silage and hay yield of maize and similar results were observed at 4, 6 and 8 kg ha⁻¹ boron fertilizer applications, whereas application times had similar effects on yield. High boron applications slightly increased NDF and ADF contents of maize silage, but also these values are rather low and quality parameters were not affected. As a result of this study, we recommend that 4 kg ha⁻¹ boron fertilizer applications at early vegetative stages of maize for high silage yield and quality.

ÖZET

Amaç: Bu çalışma, Doğu Akdeniz ekolojik koşullarında, mısırın farklı vejetatif gelişme dönemlerinde uygulanan bor miktarlarının mısırın silaj verimi ve kalitesi üzerine etkilerini belirlemek için yapılmıştır.

Yöntem ve Bulgular: Mısırın erken vejetatif gelişme dönemlerinde (V2, V4, V2V4), farklı borlu gübre dozları (0, 4, 6, 8 kg ha⁻¹. Disodyum oktaborat tetrahidrat(ETİDOT-67 (Na₂B₈O₁₃4H₂O)) uygulanmış ve mısırın hasıl verimi ve kalitesine etkileri incelenmiştir. Yapılan çalışma sonucunda, tüm bor uygulamalarında kontrole göre daha yüksek silaj ve kuru ot verimleri gözlemlenmiş ve en yüksek verimler (68.43 ton ha⁻¹ silaj ve 21.58 ton ha⁻¹ kuru madde verimi) 8 kg ha⁻¹ bor dozunda elde edilirken, diğer bor uygulama dozlarında da istatistiksel olarak benzer sonuçlar elde edilmiştir. Uygulama zamanlarında en yüksek verim V2 + V4 gelişme döneminde belirlenmiş olmakla birlikte, uygulama zamanları arasındaki fark istatistiksel olarak önemli bulunmamıştır.

Genel Yorum: Yüksek silaj verimi kalitesi için mısırın erken vejetatif gelişme dönemlerinde 4 kg ha⁻¹ bor uygulanması önerilmektedir.

Çalışmanın Önemi ve Etkisi: Şimdiye kadar mısırın hasıl ve silaj verimi ile kalite özellikleri üzerine bor gübrelemesinin etkileri konusunda sınırlı araştırmalar yapılmıştır. Bu çalışma ile mısırın erken vejetatif gelişme döneminde bor uygulamasının etkileri ortaya koymuştur. Ayrıca, bu çalışmanın daha sonraki çalışmalar için kaynak olması beklenmektedir.

Anahtar Kelimeler: ADF, Bor, mısır, NDF, silaj verimi.

CONFLICT OF INTEREST

The authors declare no conflict of interest for this study.

AUTHORS' CONTRIBUTIONS

The contribution of the authors is equal.

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