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Effects of Applying Nitrogen on Yield of Silage Maize Grown after Forage Legumes

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ABSTRACT

In a 2-year study, it was determined how winter planting various forage legumes (Hungarian vetch, narbon vetch and forage pea) before applying nitrogen (0, 5, 10, 15 and 20 kg N da^{-1}) affected the yield components of silage maize grown afterward. Fallow was applied for control treatment. The results showed that among the forage legumes cultivated from October to May, forage peas afforded the highest fresh weight (4279 kg da^{-1}) and the dry matter ratio (20.50%). However, narbon vetch affected all other yield components of silage maize except dry matter ratio more positively than the other legumes and increased the green yield by 30.3% compared yields achieved in control plots. The dry matter ratio of silage maize was higher in plots grown with Hungarian vetch and forage pea plots because of their later sowing and harvest times. Later, applying nitrogen positively affected the green yields of silage maize by up to 15 kg N da^{-1}. Such results readily apply to cultivating crops with high nitrogen demands (e.g., maize) in soils with low organic matter content. It was concluded that narbon vetch as a previous crop should be advised for silage maize and top-dressing of 15 kg N da^{-1} could be beneficial for increasing green maize yield.

Research Article

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Keywords
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Baklagil Yem Bitkilerinden Sonra Yetiştirilen Silajlık Mısırın Verimi Üzerine Azot Uygulamalarının Etkileri

ÖZET

İki yıllık bu çalışmada, kışlık olarak ekilen farklı baklagil yem bitkileri (Macar fiği, koca fiğ ve yem bezelyesi) ve azot uygulamalarının (0, 5, 10, 15 ve 20 kg N da^{-1}) daha sonra ekilen silajlık mısırın verim bileşenlerini nasıl etkilediği belirlenmiştir. Nadas, kontrol uygulaması olarak kullanılmıştır. Araştırma sonuçlarına göre ekim-mayıs ayları arasında yetiştirilen baklagil yem bitkileri arasında en yüksek yaş ot verimi (4279 kg da^{-1}) ve kuru madde oranı (% 20.50) yem bezelyesinden elde edilmiştir. Bununla birlikte, koca fiğ kuru madde oranı hariç silajlık mısırın tüm verim bileşenlerini diğer baklagillerden daha olumlu etkilemiş ve kontrol parsellerine göre mısırın yeşil ot verimini % 30,3 oranında arttırmıştır. Silajlık mısırın kuru madde oranı geç ekilen ve hasat edilen Macar fiği ve yem bezelyesi parsellerinde daha yüksek çıkmıştır. Azotlu gübre uygulaması, silajlık mısırın yeşil ot verimini 15 kg da^{-1}'a kadar olumlu etkilemiştir. Bu tür sonuçlar, organik madde seviyesi düşük ve N talebi yüksek olan mısır gibi bitkilerin yetiştirilmesine uygun topraklar için oldukça önemlidir. Bu çalışmada, silajlık mısır için ön bitki olarak koca fiğin tavsiye edilmesi gerektiği ve üst gübre olarak 15 kg N da^{-1} uygulamasının mısırın yeşil veriminin arttırılmasında yararlı olabileceği sonucuna varılmıştır.

Araştırma Makalesi

Makale Tarihçesi
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Anahtar Kelimeler
Koca fiğ
Macar fiği
Yem bezelyesi
Yeşil ot verimi
Silajlık mısır

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INTRODUCTION

Using chemical fertilizers and pesticides to enhance yields per unit area in crop production has caused the physical, chemical, and biological degradation of soils.

In response, methods of sustainable agriculture have recently emphasized reducing the use of inorganic chemicals in a bid to protect the environment. Among such methods, incorporating crops that improve soil fertility in cropping systems can further contribute to agricultural sustainability.

For improving the soil in crop rotations, forage legumes rank among the best crops, particularly due to their tap-root and nitrogen fixation. Forage legumes with such nitrogen-fixing properties reduce the amount of nitrogen required by subsequent cash crops as well as benefit at different depths of the soil. Forage legumes also positively affect soil organic matter and biological activity, both via green manuring or root and leaf residues (Fageria et al., 2005).

A common way of including forage legumes in cropping systems is by replacing the winter fallow (Dabney et al., 2001). In that process, cold-tolerant forage legumes can be sown in autumn to afford them sufficient time to form rosettes before winter, such that they can grow rapidly in spring and leave the soil before summer cash crops are sown.

Forage peas, vetches, and grass peas are widely used in crop rotation systems, largely because they rapidly decompose and contribute high volumes of organic matter to the soil (Fageria et al., 2005; Gatiboni et al., 2011; Sieversa and Cook, 2018). Addressing those crop species, researchers have conducted some studies on integrating narbon and Hungarian vetches in cropping systems as cover crops. Among them, Ozyazıcı and Manga (2000) obtained higher grain yields of maize after incorporating common and narbon vetches in the soil, which respectively increased yields by 51.7% and 50.0%. Somewhat more recently, Gül et al (2008) found that silage maize did not respond to the application of more than 12 kg N da^{-1} following the cultivation of Hungarian vetch instead of leaving the land fallow. In other studies, forage peas have also positively affected cash crop yields when used as cover crops (Bahl et al., 2000; Skoufogianni et al., 2013; Marsh, 2014; Cicek et al., 2014; Liebman et al., 2018).

In this study, it was investigated how different applications of nitrogen affected the yield components of silage maize following the cultivation of cold-tolerant forage legumes (i.e., forage peas, narbon vetch, and Hungarian vetch) in the continental climate of central Turkey.

MATERIAL and METHODS

The field experiments of this 2-year study were conducted in the 2016–2017 and 2017–2018 growing seasons in Eskişehir, Turkey, at 390 45' 23' N, 300 28' 40'' E, and 798 m above sea level. That central region of Turkey, dominated by a continental climate, has an average total rainfall of 331 mm per year, an average temperature of 11.2 °C, and an average relative humidity of 73.2% (Table 1). In the years in which it was performed this field experiments, however, rainfall greatly exceeded the average precipitation in the region. The soil of the experiment site is clayey-loam, pH: 7.90 and 1.68% organic matter.

In the experiments, with split plots in a randomized block design with four replications, the main plots hosted the pre-applications (i.e., control, *Pisum arvense* cv. Töre, *Vicia narbonensis* cv. Balkan, and *Vicia pannonica* cv. Budak), whereas the subplots received five different applications of nitrogen, in amounts of 0, 5, 10, 15, and 20 kg da^{-1}.

Table 1. Climatic data at the experimental fields in 2016, 2017 and 2018 years
Çizelge 1. Deneme alanının 2016, 2017 ve 2018 yıllarına ait iklim verileri

	Rainfall (mm) *Yağış*				Temperature (°C) *Sıcaklık*				Relative humidity (%) *Nispi nem*			
	2016	2017	2018	Long-term *Uzun yıllar*	2016	2017	2018	Long-term *Uzun yıllar*	2016	2017	2018	Long-term *Uzun yıllar*
January	81.4	33.0	37.2	44.4	0.0	-2.0	1.6	0.0	87.3	87.1	86.4	84.0
February	32.8	9.2	39.8	27.2	6.6	1.9	5.8	1.9	81.1	78.3	82.3	79.3
March	40.6	16.2	46.4	31.1	7.5	7.6	9.2	6.0	70.3	68.7	73.5	73.0
April	30.6	62.0	12.6	29.5	12.9	9.6	13.8	10.2	64.5	66.9	61.6	70.1
May	44.4	50.8	62.2	42.6	14.1	14.4	16.8	15.0	74.2	73.2	74.8	69.8
June	7.0	44.8	46.6	34.7	21.0	19.1	19.9	19.4	62.1	73.4	69.5	66.9
July	12.0	13.4	46.0	5.2	22.8	23.1	22.3	22.4	58.3	59.5	65.5	62.1
August	26.4	31.4	12.6	17.7	22.8	22.0	22.9	22.4	66.0	67.3	63.5	64.1
September	31.1	2.6	2.8	18.0	17.8	19.6	18.6	17.7	67.1	57.0	65.5	68.1
October	8.0	46.4	29.2	36.6	12.4	10.8	13.3	12.0	73.4	72.9	77.4	76.5
November	27.8	28.2	18.0	22.0	5.3	5.5	7.6	6.1	69.6	85.4	82.5	80.4
December	23.8	36.4	42.2	22.0	-1.1	3.9	2.3	1.7	84.4	86.5	91.0	84.6
Mean/Total	365.9	374.4	395.6	331.0	11.8	11.2	12.84	11.2	71.52	73.01	74.45	73.2

(All data were provided by Turkish State Meteorological Service)

In each year of the study, forage legumes were sown in an arrangement of 30 × 5 cm from October 1 to 15. When the lower pods began to fill, the Balkan variety was mown on May 15, whereas the Töre and Budak varieties were mowed on May 25. Before mowing, four samples were collected from an area of 1 m^2 in order to determine the fresh weight and dry matter ratio.

Silage maize (cv. Truva) was sown in control plots at the beginning of May as well as in plots cultivated with forage legumes within 1 week after harvest in an arrangement of 70 × 14 cm. When the crops were 50 cm tall, N fertilizer (i.e., urea) was applied as top dressing to the plants. Considering drip flow rates and decreasing moisture levels with crop water consumption at the effective root depth, irrigation was performed 8 times for 12 h during the growing season.

Silage maize was harvested when the ears' milk line reached 50% (i.e., 115–120 d after sowing). Once stems and ears were separated and weighed, the separated parts were passed through a shredder and left to dry at 70 °C for 72 h. Chlorophyll content was measured with the help of chlorophyll meters (SPAD-502 Plus).

The results were analyzed in MSTAT software and the means were compared with Duncan's test. Correlation analysis was performed in SPSS version 16.0.

RESULTS and DISCUSSION

The fresh weight of forage legumes ranged from 3326 to 4279 kg da^{-1} (Table 2). Forage peas had the highest fresh weight and dry matter ratios, and Hungarian vetch exhibited a similar dry matter ratio (19.24%) despite its low fresh weight. The lowest dry matter ratio was obtained from narbon vetch (15.85%). The dry matter yield obtained with forage peas confirms the findings of Uzun et al. (2012) and Ateş and Tekeli (2017).

Table 2. The fresh weight and dry hay rate of preceding crops
Çizelge 2. Ön bitkilerin yeşil ot ağırlığı ve kuru ot oranı

Preceding crops *Ön bitkiler*	Fresh weight (kg da^{-1}) *Yaş ağırlık*			Dry matter (%) *Kuru madde*		
	2017	2018	*Mean*	2017	2018	*Mean*
P. arvense (cv.Töre)	4558^{a†}	4000^{c}	4279^{a}	20.09	20.92	20.50^{a}
V. pannonica (cv.Budak)	3410^{e}	3243^{f}	3326^{b}	19.38	19.10	19.24^{a}
V. narbonensis (cv.Balkan)	3634^{d}	4166^{b}	3900^{a}	14.41	17.28	15.85^{b}
Mean	*3867*	*3803*		*17.96*	*19.10*	

†: Letters show different groups at 5% level

Table 3 presents the mean values of the yield components, all of which for silage maize except for stem thickness varied from year to year. In 2017, ear ratio, dry matter ratio, and SPAD values were greater, whereas plant height and green yield were higher in 2018. Generally, however, pre-applications positively affected the yield components of maize except for ear ratio. Narbon vetch increased green yields by 30.3% compared to yields in the control application, a result that paralleled SPAD and stem thickness values. In terms of dry matter ratio, the Hungarian vetch and forage peas sown and harvested relatively late had higher values than the control and narbon vetch plots. Top dressing fertilization exceeding 15 kg da^{-1} did not positively affect green yield values.

Forage legumes that fix nitrogen with *Rhizobium* sp. bacteria increase the yield of subsequent cash crops (Peoples et al., 1995; Fageria et al., 2005; Briggs et al., 2005; Parr et al., 2011; Liebman et al., 2018). These findings regarding the high yield potential of narbon vetch confirm the results of Özyazıcı and Manga (2000). In their study, sowing common and narbon vetches as cover crops and incorporating them in soil increased subsequent maize yields by 50%.

Forage legumes also produced a greater accumulation of dry matter in silage maize than the control application. However, the dry matter ratio of silage maize was higher in Hungarian vetch and forage pea plots, most likely due to the delayed harvest date. Such findings also likely stemmed from the decreased air temperature at the time of harvest in the region. Miedema et al. (1987) observed that the dry matter content of maize tended to increase in low temperatures, presumably because low night temperatures decrease respiration and increase the accumulation of dry matter.

Increased doses of nitrogen positively affected yield, although no significant difference surfaced between doses of 15 kg da^{-1} and higher doses. Generally, the most effective dose for grain and silage yield in maize is 20 kg da^{-1} (Gül et al., 2008; Buriro et al., 2014; Kavut et al., 2015). From another angle, these findings support the results of Özyazıcı and Manga (2000), who observed no statistically significant difference between doses of 10 kg da^{-1} and 20 kg da^{-1} in maize yields.

Generally, forage legumes increased the stem thickness in maize compared to the control application, and the highest stem thickness was obtained by applying 10–15 kg N da^{-1} to the cultivated silage maize on narbon vetch plot (Figure 1). In contrary to this finding, İdikut et al. (2009) indicated that stem thickness of maize increased with increasing nitrogen doses, but not affected by the interaction of pre-applications x nitrogen doses.

Increasing doses of fertilizer instead of the pre-applications increased the ear ratio, which peaked with the application of 15-20 kg N da^{-1} to the narbon vetch plots. However, no significant difference emerged between 15-20 kg N da^{-1} doses of the application and the control application (Figure 2).

Similarly, Turgut et al. (2005) reported that the effect of pre-applications x nitrogen doses interaction on ear ratio of maize was significant and common vetch with the application of 24 kg N da-1 gave the best response for ear ratio.

The highest dry matter ratio (32.33%) occurred when no fertilizer was applied to the forage pea plots. However, no significant difference surfaced between that value and the values obtained by applying 0 or 20 kg N da^{-1} to Hungarian vetch plots, which were 32.01% and 31.51%, respectively (Figure 3).

Last among the findings, the relationships between green yield and plant height, stem thickness, ear ratio, and SPAD values were positive and significant (Table 4), whereas the relationship between green yield and dry matter ratio was significant but negative.

CONCLUSIONS

Despite numerous studies on integrating forage legumes into crop rotation systems and the crops' contributions to sustainable agriculture, few studies have addressed sowing Hungarian and narbon vetches in hard winter conditions and their effects upon the yield components of silage maize grown afterward. In this study, the highest green yield of silage maize was obtained by sowing the narbon vetch as a pre-plant, followed by applying 15 kg N da^{-1} to the maize. Such rotations enriched the nitrogen content of the soils and the quality of roughage required by animals. In that way, bare soils during the winter can be evaluated efficiently and cost-effectively without limiting the vegetation period of the subsequent plants.

Table 3. Analysis of variance and differences between mean values of silage maize grown on various nitrogen and pre-applications at 2017 and 2018 years.

Çizelge 3. 2017 ve 2018 yıllarında silajlık mısırın çeşitli azot dozları ve ön uygulamalar altında yetiştirilmesiyle elde edilen değerlerin varyans analiz sonuçları ve ortalama değerler arasındaki farklar.

Factors	Plant Height (m) *Bitki boyu*	Stem thickness (mm) *Sap kalınlığı*	Ear ratio (%) *Koçan oranı*	Green yield (kg da^{-1}) *Yeşil ot verimi*	Dry matter ratio (%) *Kuru madde oranı*	Spad value *Spad değeri*
Years *(Yıllar)*						
2017	3.23^{b†}	24.94	37.00^{a}	11142^{b}	30.68^{a}	49.38^{a}
2018	3.50^{a}	25.80	34.02^{b}	12501^{a}	28.23^{b}	37.29^{b}
Pre-applications *(Ön uygulamalar)*						
Control	3.22^{b}	23.34^{c}	35.22	10102^{d}	27.25^{d}	37.22^{d}
V. pannonica	3.40^{a}	24.45^{b}	35.71	11690^{c}	31.07^{a}	43.47^{c}
P. arvense	3.44^{a}	25.05^{b}	35.12	12320^{b}	30.27^{b}	45.32^{b}
V. narbonensis	3.40^{a}	28.63^{a}	36.00	13173^{a}	29.25^{c}	47.33^{a}
Nitrogen doses (kg da^{-1}) *(Azot dozları)*						
0	3.32^{b}	24.78	33.03^{c}	10689^{c}	29.68	38.59^{d}
5	3.39^{a}	25.44	35.16^{b}	11614^{b}	29.16	41.89^{c}
10	3.34^{ab}	25.47	35.26^{b}	11727^{b}	29.26	43.00^{c}
15	3.38^{ab}	25.79	37.18^{a}	12509^{a}	29.65	45.53^{b}
20	3.40^{a}	25.36	36.93^{a}	12568^{a}	29.54	47.67^{a}
Analysis of variance *(Varyans analizi)*						
Year (Y)	**	ns	**	**	**	**
Pre-applications (PA)	**	**	ns	**	**	**
Nit. doses (N)	*	ns	**	**	ns	**
PA x N	ns	*	**	ns	**	ns
Y x PA x N	ns	ns	*	ns	**	**
CV (%)	5.05	8.90	3.75	9.30	3.69	6.63

*, **: significant level of 5% and 1%, respectively, ns: non-significant. †: letters show different groups at 5% level.

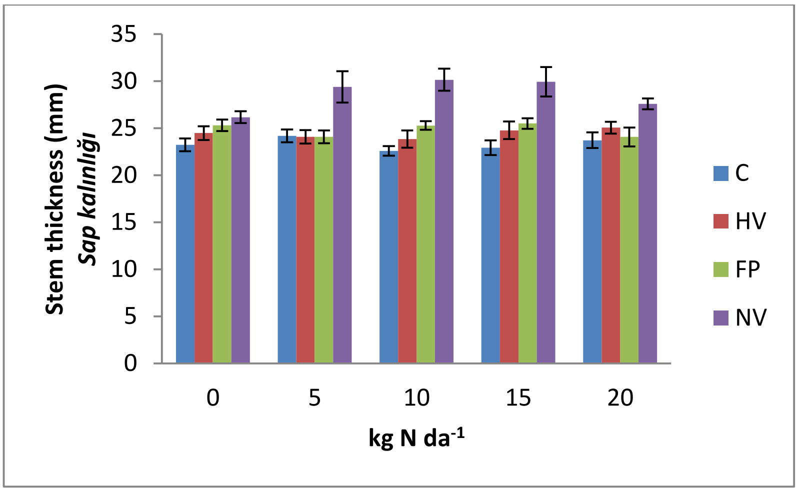

Figure 1. Stem thickness of maize after various N fertilization and pre-applications [(Control, Hungarian vetch, forage pea and narbon vetch) (Vertical bars indicate mean values ± s.e. at $P < 0.05$)].

Şekil 1. Çeşitli N gübrelemesi ve ön uygulamalardan sonra mısırın sap kalınlığı [(Kontrol, Macar fiği, yem bezelyesi ve koca fiğ) (Dikey çubuklar, P <0.05'te ortalama değerler ± standart hata'yı gösterir)].

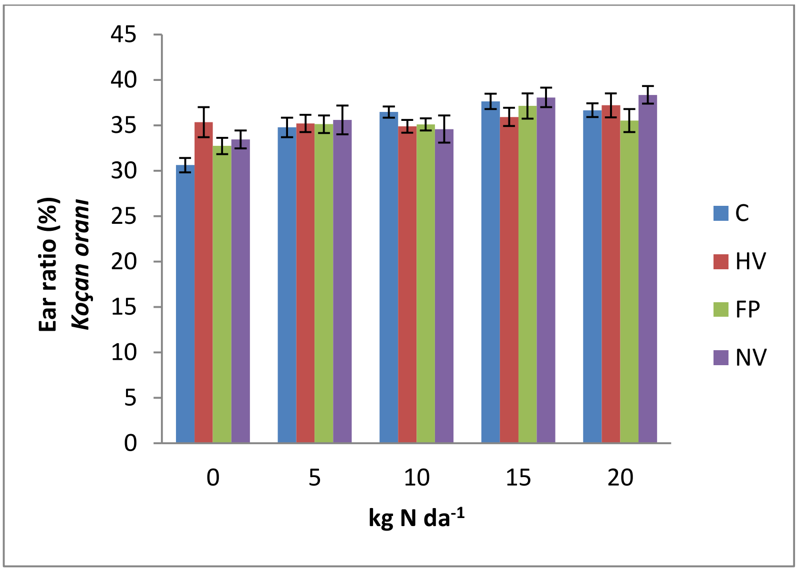

Figure 2. Ear ratio of maize after various N fertilization and pre-applications (Control, Hungarian vetch, Forage pea and narbon vetch) (Vertical bars indicate mean values ± s.e. at $P < 0.05$).

Şekil 2. Çeşitli N gübrelemesi ve ön uygulamalardan sonra mısırın koçan oranı [(Kontrol, Macar fiği, yem bezelyesi ve koca fiğ) (Dikey çubuklar, P <0.05'te ortalama değerler ± standart hata'yı gösterir)].

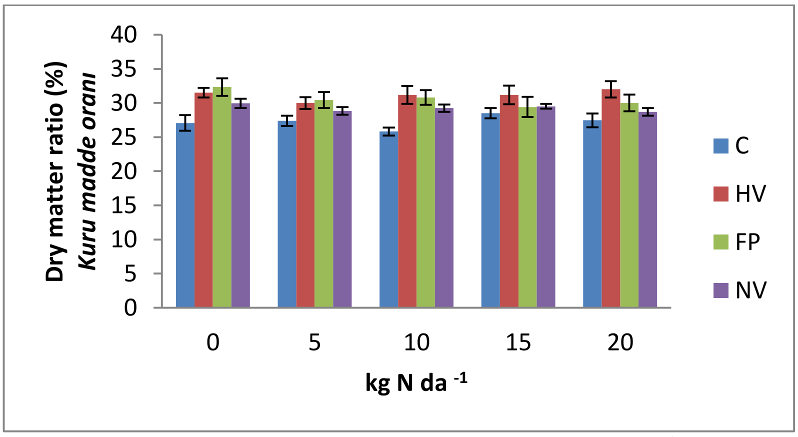

Figure 3. Dry matter ratio of maize after various N fertilization and pre-applications (Control, Hungarian vetch, Forage pea and narbon vetch) (Vertical bars indicate mean values ± s.e. at $P < 0.05$).

Şekil 3. Çeşitli N gübrelemesi ve ön uygulamalardan sonra mısırın kuru madde oranı [(Kontrol, Macar fiği, yem bezelyesi ve koca fiğ) (Dikey çubuklar, P <0.05'te ortalama değerler ± standart hata'yı gösterir)].

Table 4. The correlation between the investigated characters.
Çizelge 4. İncelenen karakterler arasındaki korelasyon

Result of correlation test *Korelasyon testi sonuçları*	Plant height *Bitki boyu*	Stem thickness *Sap kalınlığı*	Green yield *Yeşil ot verimi*	Ear ratio *Koçan oranı*	Dry matter ratio *Kuru madde oranı*	Spad value *Spad değeri*
Plant height *Bitki boyu*	1					
Stem thickness *Sap kalınlığı*	0.377**	1				
Green yield *Yeşil ot verimi*	0.511**	0.702**	1			
Ear ratio *Koçan oranı*	-0.105ns	0.168ns	0.459**	1		
Dry matter ratio *Kuru madde oranı*	-0.375**	-0.314**	-0.248*	0.283*	1	
Spad value *Spad değeri*	0.486**	0.516**	0.733**	0.368**	-0.14ns	1

*, **: significant level of 5% and 1%, respectively, ns: non-significant.

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Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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