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EFFECTS OF FERTILISATION AND HARVESTING STAGES ON FORAGE YIELD AND QUALITY OF SAINFOIN (*ONOBRYCHIS SATIVA* L.)

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Abstract

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This study aimed to determine the effects of five phosphorus rates (0, 30, 60, 90 and 120 kg ha^{-1}) and three harvesting stages (beginning of flowering, full flowering, and seed filling) on forage yield and quality of sainfoin (*Onobrychis sativa* L.). Dry matter (DM) yield, crude protein (CP), N, P, K, Ca, Mg, acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined. Phosphorus rates and harvesting stages significantly affected most of the components determined in sainfoin. Phosphorus applications increased DM yield, CP, N, P, Ca and Mg contents but decreased K, tetany ratio (K: (Ca + Mg)), ADF and NDF. Harvesting at the late stages caused a reduction in forage quality. Contents of CP, N, P, K, Mg and tetany ratios decreased with advancing growth while DM yield, Ca, ADF and NDF contents increased. According to results of this research, 90 kg ha^{-1} phosphorous fertiliser and harvesting at the beginning of flowering are recommended for high herbage quality in sainfoin.

Key words: acid detergent fibre; dry matter; neutral detergent fibre; sainfoin

Introduction

Sainfoin (*Onobrychis sativa* L.) is an important forage legume for Turkey. It is a native, widely grown perennial legume well adapted to the highland farming system under the dryland conditions of Central and Eastern Anatolia. Sainfoin is a very palatable forage plant, and has the advantage of not inducing bloating as an animal feed over alfalfa (Elci et al., 1995). It has the advantage of root growth to a greater depth than most annual legumes. The roots penetrate through the deeper layers of the soil and supply a great amount of organic matter when plants are under the soil. This organic matter is very important, particularly under dryland conditions due to the difficult of producing large amounts of vegetation. Moreover, sainfoin is beneficial in agricultural rotations under Anatolian conditions. It is valuable for erosion control and grows well in intercropping systems with forage grasses. Honey bees visit sainfoin flowers very frequently, collecting pollen grains and nectar, producing honey with special aroma and taste. Additionally, sainfoin flowers set large numbers of seeds (Jensen and Sharp, 1968; Turk and Celik, 2006). The nutrient contents of the forage have an important role in animal feeding. The factors influencing the nutritive value of forage are many, and the degree to which they are interrelated may vary considerably from one area to another.

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These factors may include, alone or in combination, plant type, climate, season, weather, soil type and fertility, soil moisture, leaf to stem ratio, and physiological and morphological characteristics, and may change depending on whether the plants are annuals perennials, grasses or legumes. Phosphorus fertilisation affects dry matter yield and chemical composition of legume forage (Bell et al., 2001). Turk et al. (2007) reported that P fertilisation increased DM yield, CP, P, Ca and Mg contents, but it decreased K, tetany ratio (K: (Ca + Mg)), ADF and NDF contents. Nutrient composition levels are not necessarily the only criterion in evaluating the nutritive value of plants (Stobbs, 1975; Cook and Harris, 1979). The stage of growth seems to be the most important factor affecting the chemical composition and digestibility of forage. In general, forages are highly succulent and palatable in early growth. Most plants decline in nutrient composition with advancing maturation (Blaser et al., 1986; Tan et al., 2003; Rebole et al., 2004). A mineral deficiency or excess in diet may affect the health of animals adversely. Grass tetany, an important disease of livestock, is caused by mineral imbalance in feeds. The risk of grass tetany is increased at a K: (Ca + Mg) ratio of 2.2 or higher (Elkins et al., 1977; Crawford et al., 1998). The aim of this research was to determine the effects of P and harvesting stages on dry matter yield forage quality and nutritional value of sainfoin.

Materials and Methods

The research was performed at Isparta (37°45′N, 30°33′E, elevation 1035 m) located in the Mediterranean region of Turkey, during the 2007–09 growing seasons. The climatic data are given Table 1 for the experimental area.

The major soil characteristics, based on the method described by Rowell (1996) were as follows: the soil texture was clay-loam, organic matter was 1.2% by the Walkley-Black method; total salt was 0.34%; lime was 5.8%; sulphur was 15 mg kg^{-1}; extractable P by 0.5N $NaHCO_3$ extraction was 3.6 mg kg^{-1}; exchangeable K by 1N NH_4OAc was 105 mg kg^{-1}; pH was 7.1 in soil saturation extract. Soil type was a calcareous fulvisol.

The experiments were established in a randomised complete block design with three replications in November in 2007. Five different phosphorus rates (0, 30, 60, 90 and 120 kg P ha^{-1} per annum) and three different harvesting stages (beginning of flowering, full flowering, and seed filling) were applied. Seeding rate was 120 kg ha^{-1}. Individual plot size was 1.8×5 m = 9 m^2. Phosphorus was broadcast as triple superphosphate (46% P_2O_5) during sowing in November. Nitrogen was uniformly applied 30 kg ha^{-1} to all plots as ammonium nitrate. No irrigation was applied. Weeds were removed by hoeing as needed. There were no significant problems with pests and diseases during the course of the study.

Dry matter (DM) yield, N, P, K, Ca, Mg, acid detergent fibre (ADF), neutral detergent fibre (NDF) contents and tetany ratios were investigated in samples taken from quadrates (1 m^2). All plants were cut approximately 5 cm above the level of the soil with sickle. Samples taken from each plot were dried at room temperature then dried in an oven at 65°C till they reached constant weight.

After cooling and weighing, the samples were ground for mineral contents analyses. Nitrogen content was calculated by the Kjeldahl method (Kacar, 1972); K, Ca, Mg, contents of samples was determined using an atomic spectrophotometer after digesting the samples with $HClO_4$:HNO_3 (1:4); P content was determined by vanadomolybdophosphoric yellow colour method (Kacar and Kovanci, 1982). Tetany ratios (K: (Ca + Mg)) were calculated on a milliequivalent basis (Cherney and Marten, 1982). The ANKOM Fibre Analyser was used for NDF and ADF analysis. ANKOM F57 filter bags were used for ADF and NDF analysis in this study.

The data from 2008 and 2009 were analysed together using the Proc GLM (SAS 1998). Means were separated by LSD at the 5% level of significance.

Table 1
Some climatic values of study area

Precipitation, L m²													
Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2007											91.1	84.5	175.6
2008	10	15	34.2	51.1	13.3	4.4	2.6	35.7	20.4	31.2	60.7	5	293.6
2009	124.7	70.3	55.2	40.4	66.6	26.8							384
1975-2008	64.2	54.9	52.9	58.8	46	27.8	12.8	12.9	15.4	38	51.5	70.9	506.1
Temperature, °C													
Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
2007											7.6	2.6	5.1
2008	-0.1	1.4	8.9	12.1	15.4	21.7	24.5	25.3	19.4	12.8	9	3.7	12.84
2009	3.4	4	5.5	11	15	20.9							9.97
1975-2009	1.8	2.6	5.9	10.6	15.5	20.1	23.5	22.9	18.3	12.8	7	3.1	12.01

Results

Phosphorus applications had significant effects on DM yield, CP, N, P, K, Ca, Mg, tetany ratio, ADF and NDF contents ($P < 0.01$). The highest DM yield was obtained from 90 kg ha^{-1} P rates (7.61 t ha^{-1}), while the lowest DM yield (3.90 t ha^{-1}) was obtained from the control plot (Table 2). Increasing P rate resulted in an increase in CP and N contents. The highest CP (19.79%) and N (3.17%) content were obtained from 90 kg ha^{-1} P treatment. However, application of more than 90 kg ha^{-1} of P decreased the CP and N contents. P applications decreased K, tetany ratio, ADF and NDF contents while they increased P, Ca and Mg contents.

The effects of harvesting stages on DM yield, CP, N, P, K, Ca, Mg, tetany ratio, ADF and NDF contents of sainfoin were highly significant ($P < 0.01$). The DM yield, and Ca, ADF and NDF contents increased, while CP, N, P, K, Mg and tetany ratio decreased with advancing stages (Table 2).

Discussion

Phosphorus levels significantly increased forage yield and quality components of sainfoin. Our results confirm those of Albayrak et al. (2009), Turk et al. (2007), Celik (1980) Roath and Graham (1968). Bell et al. (2001) reported that P is the most important fertiliser nutrient required for growing narbon vetch, with N ranked next most important.

Crude protein and N content of sainfoin increased as phosphorus fertilisation increased. These confirm the results of other researchers (Miskovic et al., 1977; Celik, 1980; Comakli and Tas, 1996). Phosphorus treatments significantly increased P, Ca and Mg, while it decreased K, ADF and NDF content. Comakli and Tas (1996), found that P fertilisation increased P, Ca and Mg contents and decreased K content of some vetch species. These results are quite similar to our results.

Grass tetany is associated with Mg deficiency in the blood of animals. The risk of grass tetany is increased at a K:Ca + Mg ratio of 2.2 or higher (Crawford et al. 1998). Grass tetany values, which changed from 0.66 to 1.48 with increasing P rates, in this research were less than the critical level. This could be explained by the decrease in content of K and increase of the contents of Ca and Mg with phosphorus fertilisation.

Table 2
Dry matter yield and chemical composition of sainfoin as affected by phosphorus fertilization and harvesting stages

	DM, t ha^{-1}	CP, %	N, %	P, %	K, %	Ca, %	Mg, %	Tetany K/Ca+Mg	ADF, %	NDF, %
Phosphorus doses, kg ha^{-1}										
0	3.90 e	15.67 d	2.51 d	0.17 e	2.47 a	1.52 c	0.26 d	1.48 a	37.02 a	48.86 a
30	4.90 d	18.64 c	2.98 c	0.22 d	2.21 b	1.59 c	0.35 c	1.22 b	32.18 b	42.48 b
60	5.95 c	19.35 b	3.10 b	0.25 c	2.01 c	1.82 b	0.45 b	0.92 c	30.37 c	40.09 c
90	7.61 a	19.79 a	3.17 a	0.33 b	1.67 d	1.99 a	0.56 a	0.66 e	28.71 d	37.89 d
120	6.75 b	18.56 c	2.97 c	0.37 a	1.58 e	1.64 c	0.47 b	0.78 d	28.30 d	37.35 d
LSD (%5)	0.27	0.41	0.07	0.016	0.05	0.152	0.048	0.063	0.62	0.82
Harvesting stages										
BF	5.09 c	19.85 a	3.18 a	0.30 a	2.18 a	1.28 c	0.46 a	1.35 a	28.62 c	37.78 c
FF	5.90 b	18.24 b	2.92 b	0.26 b	1.97 b	1.66 b	0.42 b	0.96 b	31.50 b	41.58 b
SF	6.47 a	17.13 c	2.74 c	0.23 c	1.82 c	2.20 a	0.37 c	0.72 c	33.82 a	44.65 a
LSD (%5)	0.21	0.32	0.051	0.012	0.04	0.037	0.04	0.05	0.48	0.63
Significance										
P	**	**	**	**	**	**	**	**	**	**
HS	**	**	**	**	**	**	**	**	**	**
PXHS	ns	**	**	ns	*	**	ns	ns	**	**

BF: Beginning of Flowering, FF: Full Flowering, SF: Seed Filling

1 : Means followed by the same letter was not significantly different at 0.05 level using LSD test,

*,** : F-test significant at $P \leq 0.05$, and $P \leq 0.01$, respectively. ns - not significant

In this study, the DM yield significantly increased at advanced harvest stages. As plants begin to concentrate DM in pods and seeds, an enhanced forage yield with advancing maturity is consistent with results of several researchers (Munoz et al., 1983; Hintz et al., 1992; Osborne and Riedell, 2006).

Crude protein, N, P, K and Mg contents decreased with advancing stages, while Ca, ADF and NDF contents increased in the present study. Besides N, and hence protein, most minerals also decline with advancing plant development, including K and P (Rauzi et al., 1969). Maturity stage at harvest is the most important factor determining forage quality. Because P, Ca, Mg and K contents of forage decreased with delayed cutting, forage quality declined with advancing maturity (Blaser et al., 1986; Tan and Serin, 1996; Georgieva and Kertikov, 2006). Tan et al. (2003) reported that the contents of K, Mg, Ca and P decreased (29.31–22.04, 3.48–2.85, 12.83–11.58 and 1.50–1.19 g kg^{-1}, respectively) as plant age increased. These results are in agreement with our results, except for Ca content. The changes in element content with maturity are related to the increasing stem to leaf ratio. Leaves are richer in mineral nutrients than stems (Tan et al., 1997) and the proportion of leaves declines to maturity because of senescence of the lower leaves or damage by diseases (Albrecht and Marvin, 1995). Phosphorus content normally parallels that of protein in regard to seasonal changes. P and Mg both decreased significantly with advancing season (Stoddart, 1941; Oelberg, 1956). Calcium, in contrast, generally increases as the season advances (Savage and Heller, 1947). The fact that Ca content increased with maturity was explained on the basis of the increased amount of cellular material which is composed principally of this element.

The American National Research Council (NRC 1984) recommends that forage crops should contain 3.1 g kg^{-1} Ca, 6.5 g kg^{-1} K concentration for beef cattle. Tajeda et al. (1985) reported that forage crops should contain at least 0.3% of Ca, 0.2% of Mg, 0.8% of K for ruminants.

According to results of chemical properties of this research, nutritional quality values of sainfoin were higher than all the recommended standard values for ruminants.

There is no grass tetany risk in sainfoin in spite of advanced plant maturity. Grass tetany values changed from 1.35 to 0.72 with maturity. Tan and Serin (1996) found that K: Ca + Mg ratio is reliable in pure vetch hay.

The contents of ADF and NDF increased by delayed harvest time. ADF and NDF fractions were higher seed filing stage than before flowering stage. This could be explained by the decrease in proportion of leaves and increase of the proportion of stems with advanced maturity. The trend in ADF and NDF contents in regard to stage of maturity is normally the reverse of protein (Oelberg, 1956; Rebole et al., 2004).

Conclusions

Sainfoin has adequate mineral content for ruminant animal requirements for production in the Mediterranean conditions of Turkey. Increasing P rates resulted in increased forage yield and quality. The highest DM yield, CP, and N was obtained from 90 ha^{-1} P rates. The highest P content was obtained from 120 kg ha^{-1} P rates, while the highest K content was obtained from control plot. As P rate increased from 0 to 120 kg ha^{-1}, ADF, NDF and tetany ratio decreased. Forage yield and quality changed by harvesting stages. Delaying harvest resulted in increased DM yield and decreased forage quality.

Results further showed that sainfoin has mineral content well above the suggested requirement limits for dairy cattle.

At the end of the 2 year research conducted in Mediterranean conditions of Turkey, 90 kg ha^{-1} phosphorous fertiliser and harvesting at the beginning of flowering are recommended for high herbage quality in sainfoin.

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