

Full Length Research Paper

Common vetch-wheat intercropping: Haylage yield and quality depending on sowing rates

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The winter-sowing genotypes of common vetch (*Vicia sativa* L.) are very susceptible to lodging and therefore are sown in mixtures with small grains that serve as supporting crops. In order to determine an optimum ratio of vetch and wheat (*Triticum aestivum* L.) components in their mixture, a four-year trial (autumn 2005 to spring 2009) was carried out, aiming at the yield and quality of winter vetch haylage. The sowing rate of winter vetch was 120 kg ha⁻¹, while the sowing rate of winter wheat was 0, 15, 20, 25 and 30 kg ha⁻¹. An increased proportion of the cereal in its mixture with vetch significantly decreased the stand lodging, have a positive influence on forage yield, but haylage quality is of a poorer quality. Quality characteristics such as crude protein and lignin content, total digestible nutrients, dry matter intake and relative feed value were highest in monoculture common vetch followed by mixture with the lowest rate of wheat. Neutral detergent fiber content was positively affected by intercropping. There were no significant differences among treatments for acid detergent fiber content, digestible dry matter and net energy for lactation. The most favorable balance between the haylage yield and quality, as well as the highest crude protein yield (1482 kg ha⁻¹), was achieved with the mixture of 120 kg ha⁻¹ of the vetch seed and 15 kg ha⁻¹ of wheat.

Key words: Common vetch, crude protein, forage quality, haylage, mixture, nutritive value.

INTRODUCTION

Winter form of common vetch (*Vicia sativa* L.), is an annual legume crop rich in protein that is traditionally used in the regions of South east Europe as high quality roughage, that is, green forage or hay. Recently, it was increasingly used in the form of haylage, due to numerous advantages of conservation it has (Seven and Cerci, 2006). Also, the enhanced quality of the conserved forage allowed a greater milk yield and a reduction in the winter feeding costs. Carefully managing the haylage during storage prevented the risk of clostridial or other bacterial contamination in the milk and produced cheeses (Borreani et al., 2007).

However, vetch has a vine growing habit and if sown as monocrop, it lodges heavily (Caballero et al., 1995). As a result, forage yield and quality start to decrease due to the decomposition of herbage

(Gulcan et al., 1988; Aydin and Tosun, 1991;). Due to this, it is sown with winter-sown small grains, such as oats (*Avena sativa* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.) and triticale (x *Triticosecale* Wittmack). In mixtures, companion cereals provide structural support for common vetch growth, improve light interception and facilitate mechanical harvest, whereas common vetch in mixtures improves the quality of forage (Roberts et al., 1989; Caballero et al., 1995; Lithourgidis et al., 2006). So far, there has been no report on what cereal is the best companion crop for vetch (Caballero and Goicoechea, 1986; Thompson et al., 1992). Roberts et al. (1989) reported that the most suitable cereal for mixtures with common vetch is wheat. Due to a problematic response to low temperatures in oats in Serbia, it was wheat that was most often used as a companion crop for winter vetch.

Although numerous studies have examined the effects of varying seeding ratios (Aydogdu and Acikgoz, 1995; Tukul et al., 1997; Karadag and Buyukburc, 2003; Lithourgidis et al., 2006; Tuna and Orak, 2007; Kokten

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et al., 2009), the optimum seeding rates for these combinations are not well-defined. The conclusions these authors have drawn are highly influenced by the climatic conditions on which their testing was carried out. Common vetch produces low yields, particularly in areas with low rainfall (Hadjichristodoulou, 1978) and seriously hinders harvest because of lodging in areas with high rainfall (Robinson, 1969; Caballero et al., 1995).

For the prevailing agro-ecological conditions of Serbia, Miskovic (1986) recommends that the sowing rates are 150 kg ha⁻¹ for common vetch and 30 to 35 kg ha⁻¹ for cereals. However, it has been demonstrated that these sowing rates are too high for the contemporary agriculture. By this reason, the objective of this study was to compare the haylage yield and quality of mixed stands of vetch and wheat obtained when several seeding rates of wheat were combined with constant seeding ratio of vetch.

MATERIALS AND METHODS

Field experiment

A field experiment was conducted during four growing seasons (2005/06, 2006/07, 2007/08 and 2008/09) at the experimental field of the Institute of Field and Vegetable Crops, Novi Sad, in northern Serbia (45°20'N, 19°51'E). The area has a continental semiarid to semi humid climate, the long-term average temperature from October to May is 6.87°C, and sum of precipitation is 359.6 mm. The experiment was established in a loamy soil with pH 7.2, and organic matter content of 2.82%, N-NO₃ 17.2 mg kg⁻¹, P₂O₅ 20.7 mg kg⁻¹ and K₂O 29.1 mg kg⁻¹ (0 to 30 cm depth). Nitrogen and P₂O₅ at 15 and 78 kg ha⁻¹, respectively, were incorporated as mono-ammonium phosphate (10–52–0) into the soil before ploughing. In all the years, the previous crop was oilseed rape, with harvest residues chopped and incorporated into the soil.

The experimental design was a randomized complete block with five treatments (vetch monoculture and four mixtures of common vetch with wheat) replicated four times. The sowing rate of vetch in all treatments was 120 kg ha⁻¹, while the sowing rates of wheat were 0 kg ha⁻¹ (SRW₀), 15 kg ha⁻¹ (SRW₁₅), 20 kg ha⁻¹ (SRW₂₀), 25 kg ha⁻¹ (SRW₂₅) and 30 kg ha⁻¹ (SRW₃₀). The plot size was 60 m² (5 x 12 m) and the treatments were separated by a 2 m buffer zone.

The seeds of vetch and wheat were mixed before the sowing which was done in the first day of October in all four years, using Amazone AD 253 Special seed drill made in Germany and with 12.5 cm between rows traditionally practiced in Serbia (Miskovic, 1986; Mihailovic et al., 2006). Mean seed weights were 50.2 and 39.8 g per 1000 seeds for common vetch and wheat, respectively. Usual modern agronomic practices of vetch production were applied.

Yield measurements

The cutting and chopping of the forage were done by hand with a scythe in the stage of first pods forming (the last day of May) and on the area of 10 m² in the middle of each plot. The cut biomass was dried *in situ* until it had a moisture content of 55% (Plue and Haley, 1988; Dordevic and Dinic, 2003; Cavallarin et al., 2005), when the haylage yield was measured. Samples of 1 kg biomass from each plot were dried at 65°C for 72 h in order to determine the dry matter content.

Quality measurements

The cut and dried biomass was placed in a silo trench without inoculants. After 60 days of fermenting (Van Ranst et al., 2009), the haylage samples of 400 g each were taken, with an analysis of the basic quality parameters. Total N was determined using the Kjeldahl method and crude protein (CP) was calculated by multiplying the N content by 6.25 (AOAC, 1980). Neutral and acid detergent fiber (NDF and ADF) and acid detergent lignin (ADL) were determined using the procedure by Goering and van Soest (1970). Total digestible nutrients (TDN), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV) and net energy for lactation (NE_L) were estimated according to the following equations adapted from Horrocks and Vallentine (1999):

$$\text{TDN} = 73.5 + 0.62(\% \text{CP}) - 0.71 (\% \text{ADF})$$

$$\text{DDM} (\%) = 88.9 - (\% \text{ADF} \times 0.779)$$

$$\text{DMI} (\% \text{DM}) = 120 : \% \text{NDF}$$

$$\text{RFV} = (\% \text{DDM} \times \% \text{DMI}) : 1.29$$

$$\text{NE}_L = (1.044 - (0.0119 \times \% \text{ADF})) \times 2.205$$

Data analysis

The results were processed by the analysis of variance (ANOVA). The treatment mean differences were separated by the least significant difference (LSD) test at the 0.05 probability level. For the entire statistical analysis, the MSTAT-C software was used (MSTAT-C 1988). Due to the fact that the analyses of variance for haylage yield and quality indicated no treatment x experimental time interaction, the values are reported as means of the four growing seasons.

RESULTS

The influence of the wheat sowing rate on the vetch haylage yield was significant (Table 1). The highest vetch haylage yield (18938 kg ha⁻¹) was achieved in the treatment with the highest wheat sowing rate. By decreasing the wheat sowing rate, the haylage yield was also decreased, that is, from 9.4% in SRW₂₅ to 35.4% in the vetch monocrop. There were no significant differences in the vetch haylage yield between the treatments SRW₁₅ and SRW₂₀. An identical trend, to that of haylage yield was observed for the dry matter yield (Table 1). The influence of the wheat sowing rate on the vetch proportion in the total yield was significant for all treatments (Table 1).

The highest CP content was in the vetch monocrop (251.8 g kg⁻¹ DM) with the lowest wheat sowing rate (223.1 g kg⁻¹ DM), with no significant differences between these two treatments (Table 2). With a further increase of the wheat sowing rate, there was a significantly lower CP content in dry matter. The decrease of the CP content varied from 30.8% with SRW₂₀ to 59.0% with SRW₃₀. The influence of the wheat sowing rate on CP yield was significant in all treatments. The highest yield was achieved with SRW₁₅ (1482 kg ha⁻¹). The decrease of CP

Table 1. Haylage yield, dry matter yield and vetch contribution of monoculture and mixtures of common vetch with wheat*.

Treatment	Haylage yield (kg ha ⁻¹)	Dry matter yield (kg ha ⁻¹)	Vetch proportion in the total yield (%)
SRW ₀	12240 ^d	5430 ^d	100.00 ^a
SRW ₁₅	14970 ^c	6641 ^c	80.66 ^b
SRW ₂₀	15366 ^c	6816 ^c	74.27 ^c
SRW ₂₅	17151 ^b	7718 ^b	62.91 ^d
SRW ₃₀	18938 ^a	8400 ^a	56.12 ^e
Average	15733	7001	74.79
LSD 0.05	1378	623	3.73

*Values within the columns followed by the same letter do not differ significantly at the 0.05 level of probability according to least significant difference (LSD) test.

Table 2. Crude protein (CP) content, crude protein yield, neutral acid detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) in haylage of monoculture and mixtures of common vetch with wheat*.

Treatment	CP (g kg ⁻¹ DM)	CP yield (kg ha ⁻¹)	NDF (g kg ⁻¹ DM)	ADF (g kg ⁻¹ DM)	ADL (g kg ⁻¹ DM)
SRW ₀	251.8 ^a	1367 ^b	421.2 ^d	356.3 ^a	98.9 ^a
SRW ₁₅	223.1 ^a	1482 ^a	448.4 ^{cd}	362.0 ^a	93.3 ^{ab}
SRW ₂₀	174.3 ^b	1188 ^c	466.9 ^c	371.9 ^a	89.2 ^b
SRW ₂₅	123.4 ^c	952 ^d	521.3 ^b	355.4 ^a	64.6 ^c
SRW ₃₀	103.2 ^d	867 ^e	564.7 ^a	352.1 ^a	61.7 ^c
Average	175.2	1171	484.5	359.5	81.5
LSD 0.05	13.8	69	37.5	25.6	9.3

*Values within columns followed by the same letter do not differ significantly at the 0.05 level of probability according to least significant difference (LSD) test.

yield ranged between 7.8% in the vetch monocrop to 41.5% in the treatment with the highest wheat sowing rate.

The highest NDF content (564.7 g kg⁻¹ DM) was in the treatment with the highest wheat sowing rate (Table 2). The decrease of the wheat sowing rate caused the decrease of NDF content, from 7.7% with SRW₂₅ to 25.4% in the vetch monocrop. At the same time, there were significant differences in NDF content either between the treatments SRW₂₀ and SRW₁₅, or between the treatments SRW₁₅ and SRW₀. The average ADF content in the vetch haylage was 359.5 g kg⁻¹ DM, with no significant differences between the treatments. The lignin content was highest in the vetch monocrop (98.9 g kg⁻¹ DM). The increase in the wheat sowing rate above 20 kg ha⁻¹ caused a significant decrease in the lignin content, from 9.2 to 37.6% (Table 2).

The highest TDN was determined in the vetch monocrop (Table 3). There were no significant differences in the TDN content between the treatments SRW₀ and SRW₁₅. The increase of the wheat sowing rate above 15 kg ha⁻¹ caused a significant decrease of the TDN content

in haylage, from 9.3 to 14.0%, in comparison with SRW₀. The average DDM was 608.9 g kg⁻¹ DM, with no significant differences between the treatments (Table 3).

The highest DMI was in the vetch monocrop and the lowest wheat sowing rate, 28.5 and 26.8 g kg⁻¹ of BW, respectively. In comparison with the vetch monocrop, the values of the other treatments were significantly lower, from 9.8 to 25.3% (Table 3). The highest RFV was determined in the vetch monocrop and the lowest wheat sowing rate, 135.04 and 126.07%, respectively. In comparison with the vetch monocrop, the values of the other treatments were significantly lower. The average NE_L was 1.359 Mcal kg⁻¹ without significant differences between the treatments (Table 3).

DISCUSSION

The increase of the cereal in its mixture with vetch significantly increased the yields of both haylage and DM, which agrees with the results of Roberts et al. (1989) who found that DM decreased with increasing common vetch

Table 3. Total digestible nutrients (TDN), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV) and net energy for lactation (NE_L) of the haylage of monoculture and mixtures of common vetch with wheat*.

Treatment	TDN (g kg ⁻¹ DM)	DDM (g kg ⁻¹ DM)	DMI (g kg ⁻¹ of body weight)	RFV (%)	NE _L (Mcal kg ⁻¹)
SRW ₀	638.1 ^a	611.4 ^a	28.5 ^a	135.04 ^a	1.367 ^a
SRW ₁₅	616.3 ^{ab}	607.0 ^a	26.8 ^{ab}	126.07 ^{ab}	1.352 ^a
SRW ₂₀	579.0 ^{bc}	599.3 ^a	25.7 ^b	119.37 ^b	1.326 ^a
SRW ₂₅	559.2 ^c	612.1 ^a	23.0 ^c	109.11 ^c	1.369 ^a
SRW ₃₀	549.0 ^c	614.7 ^a	21.3 ^c	101.47 ^c	1.378 ^a
Average	588.3	608.9	25.0	118.21	1.359
LSD 0.05	43.7	38.6	1.7	9.31	0.114

*Values within columns followed by the same letter do not differ significantly at the 0.05 level of probability according to least significant difference (LSD) test.

ratios in mixtures with wheat. Caballero et al. (1995) determined that the mixtures produced 34% more dry matter than monocrop of vetch, but 57% less than oat monocrop. Unlike our results, Kokten et al. (2009) determined the lowest DM yield in the mixture of 20% vetch and 80% triticale and the highest DM yield in the mixture of 80% vetch and 20% triticale.

Vetch monocrop had the highest crude protein content. In all mixtures, the CP content decreased as cereal proportion increased, which responds with the results of numerous authors (Roberts et al., 1989; Caballero et al., 1995; Balabanli and Turk, 2006; Lithourgidis et al., 2006; Kokten et al., 2009). Karadag and Buyukburc (2003) determined that the CP content was 19.22% in a vetch monocrop and 9.77% in an oat monocrop.

However, CP yield is one of the most important criteria for forage evaluation. Although the mixture of vetch and wheat (SRW₁₅) had lower CP content than monocrop of vetch, it gave the highest CP yield than all crops because of its higher haylage yield (Tables 1 and 2). Similarly, Lithourgidis et al. (2006) showed that the highest CP yield was in the mixture of common vetch–oat (1100 kg ha⁻¹) followed by monoculture common vetch (1000 kg ha⁻¹). According to Lauk and Lauk (2006), the extra gains in protein yield obtained from mixed crops as compared to wheat monocultures were 100 to 500 kg ha⁻¹. Unlike our results, Tuna and Orak (2007) recommended the mixture of 25% vetch and 75% oat, on the basis of solely DM yield (6.5 t ha⁻¹). In addition, Tukul et al. (1997) determined the lowest CP yield (0.54 t ha⁻¹) in pure vetch sowing and the highest CP yield (0.98 t ha⁻¹) in a triticale monocrop. The lowest NDF concentration was in vetch monocrop and the increase of the wheat sowing rate caused increase of NDF content, which is in agreement with most studies (Caballero et al., 1995; Castro et al., 2000; Assefa and Ledin, 2001). However, Lithourgidis et al. (2006) showed that the monoculture of common vetch had higher NDF concentration. This can be attributed to the different cultivar used in this study and possibly to the different growth stage of common vetch at harvest as compared with the other studies. After testing the wheat

monocrop silage quality, Siefers and Bolsen (1997) determined a relatively low forage quality as evidenced by high NDF and ADF percentages (higher than 60% NDF and 40% ADF contents).

In the case of ADF, much smaller differences were observed. The actual values for ADF found in this study and the lack of significant differences agree with other studies (Caballero et al., 1995; Castro et al., 2000; Lithourgidis et al., 2006).

The increase in wheat sowing rate decreased the lignin content and increased the NDF content in DM (Table 2). This may be explained by significant differences between chemical composition in wheat and vetch dry matter. According to Lopez et al. (2005), the wheat DM has NDF content higher for 25% and lignin content lower for 96% in comparison with the vetch DM. The results obtained respond with those from other studies (Caballero et al., 1995, 2001; Rebole et al., 2004; Lithourgidis et al., 2006).

The vetch monocrop and SRW₁₅ had higher TDN than all other mixtures (Table 3). Similar values and trends were reported by others where legumes included in the intercropping system significantly increased the TDN (Osman and Nersoyan, 1986; Roberts et al., 1989). Having tested the ruminal degradability of DM and CP, Mahida et al. (2000), concluded that the vetch proportion in hay was positively correlated with effective degradability (ED) of DM and ED of CP. However, Lithourgidis et al. (2006) showed that triticale and oat monocultures had higher TDN than monoculture common vetch, and TDN decreased as the common vetch seeding proportion increased in the mixtures. The differences in this research were as a result of various methods used to determine TDN.

A similar trend was observed for the DMI and RFV. The RFV was much higher in vetch monocrop and SRW₁₅ than in other mixtures, which is consistent with results of Hackman et al. (2008). According to Dunham (1998), the best use of RFV is for selecting forages to be used in rations which require high nutrient density such as high producing dairy cows. Using alfalfa with a RFV less than 140 should not be considered for early lactation

COWS.

However, alfalfa with a RFV of 125 to 140 could be fed to dairy cows in late lactation. Lower RFV alfalfa could be adequate for growing heifers.

The different content of common vetch did not affect DDM and NE_L as there were no significant differences among treatments, which is in agreement with results of Lithourgidis et al. (2006).

Conclusion

For forage crops, it is important to produce greater forage yields per hectare, higher nutritional quality (percentage composition of selected nutrients) or combined nutrient yields. On the basis of the results obtained from this research, it can be concluded that the most favorable balance between haylage yield and quality, as well as the highest CP yield (1482 kg ha^{-1}), was achieved by sowing the mixture of 120 kg ha^{-1} of vetch and 15 kg ha^{-1} of wheat, thus recommending this combination to the farmers for the agro-ecological conditions of South east Europe.

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