Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios

A.S. Lithourgidis a,*, I.B. Vasilakoglou b, K.V. Dhimac, C.A. Dordas d, M.D. Yiakoulaki e

a Department of Agronomy, Aristotle University Farm of Thessaloniki, 57001 Thermi, Greece
b Technological and Educational Institute of Larissa, Laboratory of Weed Science, 41110 Larissa, Greece
c Technological and Educational Institute of Thessaloniki, Laboratory of Agronomy, 54101 Echedoros, Greece
d Laboratory of Agronomy, Faculty of Agriculture, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
e Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

Received 14 October 2005; received in revised form 29 March 2006; accepted 29 March 2006

Abstract

Mixtures of annual forage legumes with winter cereals for forage production are used extensively in the Mediterranean region. Common vetch (Vicia sativa L.), oat (Avena sativa L.), and triticale (×Triticosecale Wittmack) monocultures as well as mixtures of common vetch with each of the above cereals, in two seeding ratios (55:45 and 65:35), were used to investigate forage yield and quality as well as the effect of intercropping on growth rate of the three species used in the mixtures. Oat and triticale monocultures as well as both common vetch–oat mixtures provided greater forage yield than mixtures of common vetch with triticale and monoculture common vetch. Total relative yield exceeded unity in common vetch–oat (65:35) indicating that at this seeding rate there was an advantage of intercropping in using the environmental resources. Growth rate of common vetch, oat, and triticale in mixtures was lower than that in monocultures. Crude protein content was highest in monoculture common vetch followed by common vetch–oat (65:35). However, quality characteristics such as lignin content, neutral detergent fiber, total digestible nutrients and to a much smaller degree the acid detergent fiber, digestible dry matter, dry matter intake and relative feed value were affected by intercropping. Highest forage quality was achieved when common vetch was grown as a monoculture or when at a high proportion in mixtures, especially with oat. The results showed that mixture of common vetch with oat at the 65:35 seeding ratio achieved a higher forage yield and protein content than the other mixtures studied.

Keywords: Common vetch; Crude protein; Forage; Growth rate; Intercropping; Oat; Triticale

1. Introduction

Traditionally, in the Mediterranean region, mixtures of certain annual legumes with winter cereals are used extensively for forage production (Anil et al., 1998; Qamar et al., 1999; Papastylianou, 2004). Common vetch (Vicia sativa L.), an annual legume with climbing growth habit and high levels of protein, is usually grown in mixtures with small grain cereals for hay or forage production. These mixtures improve growth conditions and forage harvesting (Anil et al., 1998).

Monocultures of common vetch or cereals do not provide satisfactory results for forage production (Osman and Nersoyan, 1986). Common vetch is low-yielding, particularly in areas with low rainfall (Hadjichristodoulou, 1978) and hinders harvest because it normally lays on the soil surface (Robinson, 1969). On the other hand, small grain cereals provide high yields in terms of dry weight but they produce forage with low protein (Lawes and Jones, 1971).
Forage quality of cereal hay is usually lower than that required to meet satisfactory production levels for many categories of livestock. 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 (Robinson, 1969; Thompson et al., 1992). Other benefits of mixtures include greater uptake of water and nutrients, enhanced weed suppression, and increased soil conservation (Stern, 1993; Ranells and Wagger, 1997; Anil et al., 1998; Vasilakoglou et al., 2005).

Cereal species, seeding ratios, and competition between mixture components may affect yield and quality of forage produced by mixtures (Droushiotis, 1989; Papastylianou, 1990; Caballero et al., 1995). Caballero and Goicoechea (1986) and Thomson et al. (1990) reported that the most suitable cereal for mixtures with common vetch is oat (Avena sativa L.), whereas Thomson et al. (1992) and Roberts et al. (1989) reported that barley (Hordeum vulgare L.) and wheat (Triticum aestivum L.), respectively, are the most suitable cereals for mixtures. However, Anil et al. (1998) reported that triticale (×Triticeosecale Wittmack) can be used as an alternative cereal for mixtures with common vetch. Various seeding ratios (ranging from 2 to 8 kg for cereals and 5 to 12 kg for common vetch) have been suggested for intercropping common vetch with cereals (Caballero and Goicoechea, 1986). Competition normally reduces yield of mixtures compared with cereal monocultures (Caballero et al., 1995), although higher yields have been reported when competition between the two species of the mixture was lower than competition within the same species (Vandermeer, 1990).

Despite the fact that competition is one of the factors that can affect forage yield and quality there are no reports on the effect of different cereals and different seeding rates on the growth rate of legume–cereal mixtures. Competition can also have a significant impact on growth rate of the three species used in the mixtures at the two seeding rates.

### 2. Materials and methods

#### 2.1. Study site

A field experiment was conducted during the 2003–2004 and 2004–2005 growing seasons at the University Farm of Thessaloniki in northern Greece (22°59’6.17”E, 40°32’9.32”N). The experiment was established in a sandy loam (SL) soil (Typic Xerorthent) with pH 7.0, organic matter content 0.99%, N-NO3 5.7 ppm, P (Olsen) 7.8 ppm and K 156.6 ppm (0 to 30 cm depth). The previous crop was winter wheat, which was harvested in mid June of 2003. Wheat straw was baled and removed after harvest. The same field was used in both years. Climatic data during the two growing seasons of the experimentation are given in Table 1.

#### 2.2. Crop management and experimental design

Seedbed preparation included ploughing, disk harrowing, and cultivation. Nitrogen and P2O5 at 80 and 40 kg ha⁻¹, respectively, were incorporated as diammomium phosphate (20–10–0) into the soil before sowing. Common vetch (cv. Melissa) and two winter cereal (oat and triticale) monocultures as well as mixtures of common vetch with each of the above cereals in two seeding ratios (55:45 and 65:35) based on seed numbers, were sown within the last week of November of both growing seasons at a seeding rate of 170 kg ha⁻¹. The two cereals were oat (cv. Pallini) and triticale (cv. Thisvi). In all plots, crops were planted with a farmer’s equipment (16-row sowing machine, Model 400, Co., Bekam, Greece). The row spacing was 16 cm and the seeds were mixed and sown together. Vetch had been grown in the field recently and natural nodulation occurred. Satisfactory nodulation was verified by visual examination of root systems. The experimental design was a randomized complete block with seven treatments (three monocultures and four mixtures of common vetch with cereals) replicated four times. Plot size was 5 m × 20 m. Treatments were separated by a 2 m buffer zone.

### Table 1

Monthly total rainfall and mean air temperature during the two growing seasons of experimentation at Thessaloniki, Greece

<table>
<thead>
<tr>
<th>Month</th>
<th>Total monthly rainfall (mm)</th>
<th>Mean monthly temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>67.5</td>
<td>31.5</td>
</tr>
<tr>
<td>November</td>
<td>32.5</td>
<td>36.0</td>
</tr>
<tr>
<td>December</td>
<td>26.5</td>
<td>30.0</td>
</tr>
<tr>
<td>January</td>
<td>98.5</td>
<td>43.0</td>
</tr>
<tr>
<td>February</td>
<td>9.5</td>
<td>20.0</td>
</tr>
<tr>
<td>March</td>
<td>13.0</td>
<td>54.0</td>
</tr>
<tr>
<td>April</td>
<td>53.0</td>
<td>5.0</td>
</tr>
<tr>
<td>May</td>
<td>31.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
2.3. Yield measurements

Cereals and common vetch were harvested in a randomly selected 1 m² area of each plot at four growth stages: 0, 3, 6, and 9 weeks after tillering (WAT) of cereals. Plants were cut to ground level with manual shears and separated by hand for determination of fresh weight of each species. Forage yield was determined by harvesting 3 m × 10 m of each plot with a flail forage harvester, approximately 6–8 cm above the soil surface. Plants in monocultures and in mixtures were harvested at the pod-setting stage of common vetch (approximately at milk stage of cereals) about mid May of each growing season. At that time, samples from a randomly selected 1 m² area of each plot were cut to ground level and separated by hand for the determination of common vetch percentage in each mixture. The samples (0.5 kg biomass for each species from each plot) were dried at 65 °C for 72 h to determine the relative water content. Forage yield was calculated on a 650 g kg⁻¹ water basis; the standard moisture content for harvesting for silage.

Relative yields of the three species were calculated as a ratio of yields in mixture to yield in monoculture. The RYT (the sum of both relative yields) was used as the criterion for mixed stand advantage as both common vetch and cereal were desired species. The value of unity is the critical value for RYT. When the RYT value is greater than one it means that the intercropping favoured the growth and yield of that species. In contrast, when the RYT value is lower than one, then intercropping negatively affected the growth and yield of the plants grown in mixtures (Mead and Willey, 1980; Caballero et al., 1995). The RYT was calculated as:

relative yield total (RYT) = RYvet + RYcereal,

\[ RY_{vet} = \frac{Y_m X_{cv}}{Y_v}, \quad RY_{cereal} = \frac{Y_m X_{cv}}{Y_c} \]

where \( Y_m \) is the dry matter yield of mixture, \( Y_v \) and \( Y_c \) the dry matter yields of common vetch and cereal, respectively, as sole crops, \( X_{cv} \) the actual dry matter proportion of common vetch (as measured at harvest) in mixture with cereal, and \( X_{cv} \) is the actual proportion of cereal in mixture with common vetch.

2.4. Quality measurements

For forage quality at harvest, a second set of random samples of 1 kg biomass from each plot was taken. Samples were dried in the oven for 72 h at 65 °C and prepared for chemical analysis. The samples were ground with a Wiley mill to pass a 1 mm screen and analyzed for quality components. Total N was determined using the Kjeldahl method (Bremner, 1965) 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 (NEₚ) were estimated according to the following equations adapted from Horrocks and Vallentine (1999):

\[ TDN = (-1.291 \times ADF) + 101.35, \]
\[ DMI = 120/\%NDF \text{ dry matter basis,} \]
\[ DDM = 88.9 - (0.779 \times \%ADF, \text{ dry matter basis),} \]
\[ RFV = \%DDM \times \%DMI \times 0.775, \]
\[ NEₚ = (1.044 - (0.0119 \times \%ADF)) \times 2.205 \]

2.5. Regression and statistical analyses

Fresh weight data for cereals and common vetch from each treatment were plotted against time. Linear, quadratic, hyperbolic, and logarithmic equations were tested for their suitability to describe the relationship between fresh weight response and time. The equation with the highest coefficient of determination (\( r^2 \)) value was judged to be the most appropriate. In these regression equations, fresh weight (Mg ha⁻¹) was the dependent variable (\( y \)) and time (WAT) the independent variable (\( x \)). MSTAT-C and SPSS (version 10) programs were used to conduct the analyses of variance (ANOVA) and the regression analysis, respectively (MSTAT-C, 1988; SPSS, 1998). Treatment mean differences were separated by the least significant difference (LSD) test at the 0.05 probability level. Because the analyses of variance for forage yield and quality indicated no treatment × experimental time interaction, the values are reported as means of the two growing seasons.

3. Results and discussion

3.1. Growth rate of species

The analyses of variance (ANOVA) for common vetch or cereal fresh weight data indicated that there were significant differences among treatments, but there was no treatment by growing season interaction. Thus, treatment means averaged across growing seasons are presented (Fig. 1). Common vetch and cereals fresh weight increased from 0 to 6 WAT but decreased from 6 to 9 WAT. The \( r^2 \) comparisons among the models tested showed that the quadratic regression equations (\( y = a + bx - cx^2 \)) had the best fit for fresh weight of cereals or common vetch over time (WAT). Estimated values \( a \) (intercept) and slope \( b \) (growth rate) for fresh weight of the three crops were greater when they grew in monocultures than in mixtures (Fig. 1). In cereals, intercept and slope \( b \) values decreased with increasing common vetch percentage in mixtures. In contrast, intercept and slope \( b \) for common vetch increased, in most cases, as common vetch ratio increased. Also, intercept and slope \( b \) of monoculture
oat or in mixture with common vetch were higher than those of common vetch or triticale. However, growth rate of common vetch was affected less when it was grown in mixture with triticale (values 4.14 and 4.09 for slope \( b \) in the two mixtures of common vetch with triticale, respectively), than when it was grown with oat (values 2.96 and 3.40 for slope \( b \), respectively) (Fig. 1).

Triticale and oat showed greater growth rate when they grew in monocultures than when mixed with common vetch. This could be attributed to competition by common vetch (Caballero et al., 1995; Assefa and Ledin, 2001; Velazquez-Beltran et al., 2002). The smaller effect of triticale on growth rate of common vetch than that of oat, however, could be explained by the lower competitive ability of triticale compared to that of oat (Dhima and Eleftherohorinos, 2001).

### 3.2. Forage yield

The analyses of variance for forage yield data indicated that there was no treatment by growing season interaction. Thus, treatment means averaged across growing seasons are presented (Table 2). The greatest forage yield was obtained from oat planted as monoculture. Common vetch yield did not differ significantly from that of the two mixtures of common vetch with triticale, but it was significantly lower than that of the two mixtures of common vetch with oat. In addition, forage yield was not affected by the increase of common vetch ratio in mixtures. However, forage yields of all mixtures were lower than yields of each cereal in monoculture (Table 2). Similarly, other researchers reported that forage yields in mixtures of common vetch with oat were not affected by seeding ratios (Robinson, 1969; Assefa and Ledin, 2001; Velazquez-Beltran et al., 2002).

### Table 2

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed ratios</th>
<th>Dry matter yield (Mg ha(^{-1}))</th>
<th>Forage yield (Mg ha(^{-1}))</th>
<th>Vetch contribution (%)</th>
<th>Relative yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vetch</td>
<td>100</td>
<td>7.17</td>
<td>20.49</td>
<td>100.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Triticale</td>
<td>100</td>
<td>10.76</td>
<td>30.74</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Vetch:triticale</td>
<td>55:45</td>
<td>7.70</td>
<td>22.00</td>
<td>42.85</td>
<td>0.46</td>
</tr>
<tr>
<td>Vetch:triticale</td>
<td>65:35</td>
<td>7.74</td>
<td>22.12</td>
<td>62.44</td>
<td>0.67</td>
</tr>
<tr>
<td>Oat</td>
<td>100</td>
<td>11.62</td>
<td>33.23</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Vetch:oat</td>
<td>55:45</td>
<td>9.58</td>
<td>27.37</td>
<td>28.02</td>
<td>0.37</td>
</tr>
<tr>
<td>Vetch:oat</td>
<td>65:35</td>
<td>9.22</td>
<td>26.34</td>
<td>45.44</td>
<td>0.58</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>0.85</td>
<td>2.42</td>
<td>3.86</td>
<td>0.06</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Means are averaged over two growing seasons (2003–2004 and 2004–2005) and four replicates.
Giacomini et al., 2003). In contrast, Roberts et al. (1989) found that DM decreased with increasing common vetch ratios in mixtures with wheat. In many cases, it has been reported that yields of mixtures of legumes and cereals were intermediate or even lower than yields of monocultures due to competition between species (Vandermeer, 1990; Caballero et al., 1995; Assefa and Ledin, 2001; Velazquez-Beltran et al., 2002). In mixtures of common vetch with triticale, forage yield was lower by 18% than that in mixtures of common vetch with oat. In addition, both mixtures of common vetch with triticale produced about 8% more forage yield than the monoculture common vetch, but about 28% less than the monoculture triticale. Both mixtures of common vetch with oat (55:45 and 65:35 seeding ratios), however, produced about 34 and 29%, respectively, more forage yield than the monoculture common vetch, but about 18 and 21%, respectively, less than the monoculture oat (Table 2). Similarly, Caballero et al. (1995) reported that mixtures of common vetch with oat produced 34% more forage yield than common vetch alone, but 57% less than monoculture oat. However, Giacomini et al. (2003) reported that yield of mixtures was similar to that of oat and greater than that of monoculture common vetch.

Dry matter yields of mixtures were not affected by seeding ratio of common vetch but proportions of common vetch decreased as the percentage of cereal seed increased in the mixtures (Table 2). In particular, there was a decrease of 31.4% (from 62.4 to 42.9%) of common vetch contribution when seeding ratio of triticale increased from 35 to 45% in mixtures of common vetch with triticale. This decrease was much higher than the expected (about 15%) for the common vetch in the mixture. A similar trend was observed in mixtures of common vetch with oat as there was a corresponding decrease of about 38% (from 45.4 to 28.0%). The observed decrease of common vetch contribution to DM of the mixtures could be attributed to competition between the two species when grown together (Willey, 1979; Willey and Rao, 1980; Roberts et al., 1989; Anil et al., 1998).

The RYT of the mixtures exhibited an increasing trend as common vetch proportion increased (Table 2). Moreover, the greatest RYT (1.09) was calculated in the common vetch–oat mixture at the 65:35 seeding ratio. This indicates that 9% more area would be required for a sole cropping system to equal the yield from an intercropping system (Midy et al., 2005). In this case, RYT exceeded unity, which indicates an advantage from intercropping over monocultures in terms of using the environmental resources for plant growth (Mead and Willey, 1980). These findings are in agreement with those of Caballero et al. (1995) who reported a mixed stand advantage at lower oat seeding proportions. On the other hand, monocultures production showed a significant yield advantage over mixtures of common vetch with triticale, but no significant advantage over the mixture of common vetch with oat at the 55:45 seeding ratio (Table 2). Relative yield of common vetch was lower in common vetch–oat mixtures as compared with that of common vetch–triticale mixtures at the same seeding ratios. In addition, the relative yield of oat in mixtures with vetch was higher than that of triticale. This was probably because of the lower common vetch contribution in mixtures of common vetch with oat than in mixtures of common vetch with triticale.

### 3.3. Forage quality

Crude protein content of forage is one of the most important criteria for forage quality evaluation (Caballero et al., 1995; Assefa and Ledin, 2001). In all mixtures, the CP content increased as common vetch seeding proportion increased (Table 3). Monoculture common vetch had the highest CP content (139.3 g kg\(^{-1}\) of DM), followed by the mixture of common vetch with oat (65:35) (119.1 g kg\(^{-1}\) of DM), and the two mixtures of common vetch with triticale (109.2 and 103.1 g kg\(^{-1}\) of DM, respectively) (Table 3). In contrast, triticale and oat monocultures had the lowest CP (63.2 and 78.4 g kg\(^{-1}\) of DM, respectively). These results are in agreement with those reported by Caballero et al. (1995) and Giacomini et al. (2003). In addition, Jannink et al. (1996) found that vetch mixture had much higher CP content than pea and oat alone.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed ratios</th>
<th>Crude (g kg(^{-1}) DM)</th>
<th>Protein (g kg ha(^{-1}))</th>
<th>Lignin (g kg(^{-1}) DM)</th>
<th>NDF (g kg(^{-1}) DM)</th>
<th>ADF (g kg(^{-1}) DM)</th>
<th>TDN (g kg(^{-1}) DM)</th>
<th>DDM (g kg(^{-1}) DM)</th>
<th>DMI (g kg(^{-1}) of body weight)</th>
<th>RFV (%)</th>
<th>NE(_{1}) (Mcal kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vetch</td>
<td>100</td>
<td>139.3</td>
<td>1000</td>
<td>68.5</td>
<td>443.1</td>
<td>365.8</td>
<td>441.45</td>
<td>604.0</td>
<td>27.1</td>
<td>126.85</td>
<td>1.341</td>
</tr>
<tr>
<td>Triticale</td>
<td>100</td>
<td>63.2</td>
<td>680</td>
<td>49.8</td>
<td>357.9</td>
<td>360.2</td>
<td>548.48</td>
<td>608.4</td>
<td>33.5</td>
<td>157.95</td>
<td>1.356</td>
</tr>
<tr>
<td>Vetch:triticale</td>
<td>55:45</td>
<td>103.1</td>
<td>790</td>
<td>55.8</td>
<td>402.8</td>
<td>362.8</td>
<td>545.12</td>
<td>606.3</td>
<td>29.8</td>
<td>140.02</td>
<td>1.349</td>
</tr>
<tr>
<td>Vetch:triticale</td>
<td>65:35</td>
<td>109.2</td>
<td>850</td>
<td>63.9</td>
<td>455.8</td>
<td>380.9</td>
<td>521.76</td>
<td>592.3</td>
<td>26.3</td>
<td>120.72</td>
<td>1.300</td>
</tr>
<tr>
<td>Oat</td>
<td>100</td>
<td>78.4</td>
<td>910</td>
<td>36.4</td>
<td>345.3</td>
<td>367.5</td>
<td>539.05</td>
<td>602.7</td>
<td>34.7</td>
<td>162.08</td>
<td>1.336</td>
</tr>
<tr>
<td>Vetch:oat</td>
<td>55:45</td>
<td>91.4</td>
<td>880</td>
<td>55.5</td>
<td>367.7</td>
<td>387.0</td>
<td>513.88</td>
<td>587.5</td>
<td>32.6</td>
<td>148.43</td>
<td>1.285</td>
</tr>
<tr>
<td>Vetch:oat</td>
<td>65:35</td>
<td>119.1</td>
<td>1100</td>
<td>55.8</td>
<td>401.7</td>
<td>351.4</td>
<td>494.90</td>
<td>615.2</td>
<td>29.9</td>
<td>142.08</td>
<td>1.378</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>9.1</td>
<td>50</td>
<td>6.3</td>
<td>30.7</td>
<td>26.3</td>
<td>38.32</td>
<td>42.1</td>
<td>2.1</td>
<td>11.71</td>
<td>0.112</td>
<td></td>
</tr>
</tbody>
</table>

Means are averaged over two growing seasons (2003–2004 and 2004–2005) and four replicates.
Crude protein expressed on an area basis was affected by the presence of common vetch, which contains more CP than the cereals used in this study (Table 3). The highest CP values per ha was for the mixture of common vetch–oat (65:35) (1100 kg ha\(^{-1}\)) followed by monoculture common vetch (1000 kg ha\(^{-1}\)) (Table 3). Although, the mixture of common vetch–oat (65:35) had lower CP content than monoculture common vetch, it gave the highest CP per ha than all crops because of its higher forage yield (Tables 2 and 3). The CP per ha was the lowest for monoculture triticale (680 kg ha\(^{-1}\)) and the mixture of common vetch–triticale (55:45) (790 kg ha\(^{-1}\)). In addition, higher CP per ha was found in oat than in triticale because of the higher amount of protein and larger biomass that oat produced compared with triticale (Table 3). Similar data have been reported by others where legumes included in the intercropping system significantly increased the CP protein that was harvested per ha (Caballero et al., 1996; Haj-Ayed et al., 2000; Assefa and Ledin, 2001; Kuusela et al., 2004). A similar trend, to that of CP content per ha was observed for the total N uptake (data not shown). Expressing protein per area, which combines the CP content and the total biomass produced is a valuable measure; it is important to know the total protein that can be harvested in a forage crop in livestock enterprises since CP is one of the most important quality characteristics.

Other important quality characteristics for forages are the concentrations of NDF and ADF (Caballero et al., 1995; Assefa and Ledin, 2001). In this experiment a similar trend to that of CP content was observed for NDF; it increased as the common vetch seeding proportion increased in mixtures (Table 3). Oat and triticale monocultures as well as the common vetch–oat (55:45) mixture had the lowest values of NDF, whereas the highest value was observed in the mixture of common vetch–triticale (65:35) and in monoculture common vetch. Monoculture common vetch had higher NDF concentration than cereals, which contradicts most other studies (Caballero et al., 1995; Assefa and Ledin, 2001). 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. In the case of ADF much smaller differences were observed. There were no significant differences between most of the treatments; the only significant differences were between mixtures of common vetch with oat at 65:35 and 55:45 seeding ratios and also between mixture of common vetch with oat at the 65:35 seeding ratio and mixture of common vetch with triticale at the same seeding ratio (Table 3). The actual values for ADF found in this study and the lack of significant differences in most cases agree with previous studies (Caballero et al., 1995; Velazquez-Beltran et al., 2002).

Lignin content was lower in both cereal monocultures than in the monoculture common vetch (Table 3). As the ratio of common vetch increased in mixtures there was an increase in the lignin content between the different mixtures. The highest lignin content was in monoculture common vetch and in common vetch–triticale (65:35) mixture, whereas in the other mixtures it was around 56 g kg\(^{-1}\) DM (Table 3). In contrast, oat had the lowest lignin content of all treatments (36.4 g kg\(^{-1}\) DM). This change in lignin concentration is because cell walls of cereals contain less lignin than cell walls of dicots such as common vetch (Buchanan et al., 2000; Carpita and McCann, 2000). A similar trend was also observed by others (Caballero et al., 1995, 1996).

Triticale and oat monocultures had higher TDN than monoculture common vetch, and they decreased as the common vetch seeding proportion increased in mixtures (Table 3). Similar values and trends were reported by Carr et al. (2004) for oat and barley which had higher TDN than pea. The TDN refers to the nutrients that are available for livestock and are related to the ADF concentration of the forage. As ADF increases there is a decline in TDN which means that animals are not able to utilize the nutrients that are present in the forage. The lowest values for TDN in common vetch are attributed to the high amount of ADF and also to the high lignin content (Table 3).

The presence of common vetch did not affect DDM as there were much smaller differences among treatments (Table 3). In addition, DMI was higher in the cereals monoculture and in the mixture of common vetch–oat (55:45) followed by common vetch–oat (65:35) and common vetch–triticale (55:45) mixtures (Table 3). The NDF is used to predict DMI and is negatively correlated with DMI, which means that when NDF is high the quality and the DMI are low (Horrocks and Vallentine, 1999).

A similar trend was observed for the RFV and the NE\(_f\). The RFV was much higher in cereals than in common vetch monoculture and in their mixtures (Table 3). The RFV is an index that is used to predict the intake and energy value of the forages and it is derived from the DDM and DMI. Forage with an RFV value >151 is considered prime (Horrocks and Vallentine, 1999). In the present experiments, the RFV value was higher than 151 in the case of triticale and oat monocultures which agrees with the other quality characteristics (ADF, NDF, DDM, DMI, TDN). However, triticale and oat monocultures had lower CP content than monoculture common vetch and their mixtures with common vetch (Table 3). In addition, the common vetch–oat mixtures and the common vetch–triticale mixtures (55:45) had RFV values near 151 (their values did not differ significantly from 151). Moreover, these mixtures had more CP content than cereal monocultures. Intercropping did not affect NE\(_f\) (Table 3). Similarly, Lauriault and Kirksey (2004) found that mixtures of pea with rye and barley had no effect on NE\(_f\).

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. High forage yield is very important for producers but for livestock enterprises it is also important to produce high quality forages. In this study, it was found that high forage yield and good quality characteristics for animal nutrition could be obtained from the mixture of vetch with oat at
65:35 seeding ratio which combines higher forage yield than the common vetch monoculture and better quality characteristics (as shown by most quality indices examined) than the cereal monocultures.

4. Conclusions

The results of this study clearly indicate that intercropping vetch with oat and triticale at different seeding ratios affects the growth rate of the individual species in mixtures as well as the forage yield and quality. Forage yield was higher in cereals monocultures as well as in mixtures of common vetch with oat compared with mixtures of common vetch with triticale and monoculture common vetch. The relative yield of individual species and mixtures was affected by intercropping and it was increased with increasing common vetch ratio. The RYT exceeded unity only in the mixture of common vetch with oat at the 65:35 seeding ratio indicating that at this seeding rate there was an advantage of intercropping for exploiting the environmental resources. The growth rate of common vetch and cereals was lower when they were grown in mixtures than in monocultures, especially in mixtures of common vetch with oat, probably because of competition among species. The greater benefit for forage quality was found when common vetch was grown in a monoculture or in mixtures with cereals. The mixture of common vetch with oat at the 65:35 seeding ratio gave higher forage yield than mixtures of common vetch with triticale and the highest CP content of all mixtures.

Acknowledgements

The authors are grateful to Professors N. Fotiadis and A. Gagianas, Faculty of Agriculture, Aristotle University of Thessaloniki, for their critical review of the manuscript.

References


