

## Oats (*Avena sativa*) — common vetch (*Vicia sativa*) mixtures grown on a low-input basis for a sustainable agriculture

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### Abstract

A 2-year field study was conducted from 2001 to 2003 using common vetch (*Vicia sativa*) and oats (*Avena sativa*) in mixtures and pure stands, on a low-input basis, to investigate the effects of mixed cropping on yield and quality of forage as well as land equivalent ratio (LER) and competitive ratio (CR) of the component crops. Mean dry matter yield of pure oats was 6.07 t/ha and that of pure vetch was 4.14 t/ha ( $P < 0.05$ ), with the highest yield (6.32 t/ha) in the 45:55 oats:vetch mixture. Crude protein (CP) concentration in harvested dry matter increased as level of vetch in the mixture increased, with 8.5% CP in pure oats and 22.3% in pure vetch. CP yield peaked (1.1 t/ha) in the 45:55 oats:vetch mixture. Common vetch was a more competitive crop than oats in all mixtures except for 25:75 and 15:85 oats:vetch mixtures. It appears that a 45:55 mixture with low fertiliser level would produce as much forage as pure oats but of a higher quality than oats.

### Introduction

Intercropping of winter cereals with annual legumes is extensively used in the Mediterranean region for forage production under rain-fed conditions (Lithourgidis *et al.* 2006). Advantages of mixed cropping include higher feed quality owing to the higher crude protein (CP) concentration of legumes (Umuna *et al.* 1995), increased biomass yield (Lithourgidis *et al.* 2006), reduced

use of non-renewable resources through reduced N fertiliser use, a consistent production pattern, improved soil fertility (Banik and Bagchi 1993; Lopez-Bellido Garrido and Lopez-Bellido 2001) and improved livestock production (Umuna *et al.* 1995). Mixed cropping of cereals with forage legumes can improve both quantity (Mpairwe *et al.* 2003) and quality of fodder over a pure cereal crop (Umuna *et al.* 1997; Mpairwe *et al.* 2003).

The annual legume common vetch (*Vicia sativa*) can be grown successfully in the rain-fed arable lands of the Mediterranean basin during winter. In coastal regions, mixed hays of vetch and small-grain cereals are used to cover the forage deficit for small ruminants during summer and winter (Caballero *et al.* 1996). Caballero and Goicoechea (1986) suggested that oats (*Avena sativa*) was the most suitable companion cereal crop for vetch species, while Thomson *et al.* (1990) preferred barley (*Hordeum vulgare*) and Roberts *et al.* (1989) preferred wheat (*Triticum aestivum*). Despite its relatively low CP concentration, oats is regarded as an important forage crop because of both high yields and high carbohydrate levels. In the mixtures, oats can provide support for climbing vetch, improve light interception through the canopy and facilitate mechanical harvesting, reducing rotting of vetch hay (Roberts *et al.* 1989; Thomson *et al.* 1990).

Although several indices such as land equivalent ratio (LER), competitive ratio (CR), relative crowding coefficient (K), aggressivity and actual yield loss have been developed to measure competition in and advantages of intercropping, LER and CR are most commonly used. The LER value shows the relative amount of land under pure stands to produce the same yield as the mixture. The mixture is more efficient in terms of land use if the LER value is  $> 1$ . CR can be a better index than K and aggressivity to measure competitive ability of component crops (Dhima *et al.* 2007).

The main aim of this study was to determine the effects of different proportions of oats and vetch in sowing mixtures on botan-

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ical composition at harvest, forage yield, forage quality, land use efficiency and competition between the species in the Mediterranean coastal basin.

## Materials and methods

### *Field experiments*

The experiments were conducted at the Research Station of Agriculture Faculty of Kahramanmaraş Sutcu Imam University, Turkey (37°38'N, 36°37'E; elevation 540 m asl) under rain-fed conditions during the 2001–2002 and 2002–2003 growing seasons. The experimental soils were loamy in texture, had a neutral pH (7.14) and were low in organic matter (0.6%), salt content (0.03%) and available P (15.8 mg/kg) and rich in available K (31.2 mg/kg). Climatic data for the research area are given in Table 1.

Common vetch cv. Kubilay 82 and a medium-maturing oats cultivar Checota were used. The experiments were arranged in a complete randomised block design with 3 replications in each growing season. The experimental structure was a replacement series (RS), consisting of pure stands and a number of different sowing mixtures of the 2 species with similar total density (Conolly *et al.* 2001). Seeding rates for the pure stands were 100 and 180 kg/ha for common vetch and oats, respectively, while seeding rates for the mixtures were proportional to the pure stand seeding rates. Oats:common vetch ratios in mixtures at sowing were 85:15, 75:25, 55:45, 45:55, 25:75 and 15:85. All stands were grown on a low-input basis with 25 kg/ha N and P at planting. Since native strains of rhizobia in the soil produced effective nodulation on vetch, seeds were not inoculated with any strains of rhizobia at planting. Plants were

grown under rain-fed conditions with no control of weeds, diseases or insects. All seeds were planted by hand in rows 15 cm apart and covered with about 3 cm of soil (Caballero *et al.* 1995). Each plot was 15 m<sup>2</sup> and contained 20 rows. Harvest area was 9.6 m<sup>2</sup> after eliminating border effects (removing 2 rows on each side and plants up to 0.5 m from each end of the plots). The crops were sown on November 2, 2001 and November 18, 2002 and harvested on April 25, 2002 and May 3, 2003. At harvest, oats was at the early dough stage, while common vetch was at 20% flowering stage (Assefa and Ledin 2001). Harvest dates in both years did not postpone sowing of the following crop.

### *Botanical composition and yield measurements*

Forage yield was determined by harvesting the crops by hand approximately 6–7 cm above the soil surface and weighing the fresh material. Samples (5 kg) of green forage were separated into legume, cereal and volunteer species to determine botanical composition and the sub-samples were dried in a forced-draught oven to constant weight to determine dry matter (DM) percentage. DM yields were calculated.

### *Quality measurements*

A second set of forage samples (1.5 kg) from each plot was taken for forage quality measurements. These samples were dried in the forced-draught oven at 65°C for 72 h and then ground to pass a 1 mm screen. Nitrogen concentration was estimated by the Kjeldahl method (AOAC 1980) and CP yields were determined. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were

**Table 1.** Mean monthly temperature and monthly rainfall during the study and medium-term data (20 years).

| Months | Temperature (°C) |        |             | Rainfall (mm) |        |             |
|--------|------------------|--------|-------------|---------------|--------|-------------|
|        | 2001–2           | 2002–3 | Medium-term | 2001–2        | 2002–3 | Medium-term |
| Oct    | 19.8             | 20.3   | 18.9        | 36            | 24     | 56          |
| Nov    | 10.4             | 13.5   | 12.0        | 56            | 76     | 59          |
| Dec    | 6.9              | 4.2    | 6.5         | 258           | 78     | 119         |
| Jan    | 3.5              | 7.1    | 4.3         | 130           | 120    | 135         |
| Feb    | 9.8              | 3.8    | 6.3         | 64            | 214    | 110         |
| Mar    | 12.5             | 8.0    | 10.4        | 82            | 146    | 90          |
| Apr    | 14.0             | 15.0   | 14.9        | 124           | 89     | 68          |
| May    | 19.6             | 14.1   | 19.9        | 29            | 30     | 35          |

determined by the method of Goering and van Soest (1970).

### Intercropping indices

The LER value, which is widely used as an indicator of productivity or land use efficiency developed for the RS design (De Wit and van den Bergh 1965; Conolly *et al.* 2001), was determined by the formula:

$$\text{LER} = (Y_{\text{vm}}/Y_{\text{vp}}) + (Y_{\text{om}}/Y_{\text{op}})$$

where  $Y_{\text{vp}}$  and  $Y_{\text{op}}$  are yields of common vetch and oats in pure stands, respectively, and  $Y_{\text{vm}}$  and  $Y_{\text{om}}$  are yields of common vetch and oats in mixtures.

The competitive ratio (CR) is a method for assessing inter-specific competition between components of mixtures, giving an estimate of the competitive ability of the component crops (Dhima *et al.* 2007). The CR was calculated according to the following formula:

$$\text{CR}_{\text{vo}} = (Y_{\text{vm}}/Y_{\text{om}})(R_{\text{o}}/R_{\text{v}})$$

$$\text{CR}_{\text{ov}} = (Y_{\text{om}}/Y_{\text{vm}})(R_{\text{v}}/R_{\text{o}})$$

where  $\text{CR}_{\text{vo}}$  and  $\text{CR}_{\text{ov}}$  are competitive ratios of common vetch over oats and oats over common vetch in mixtures, respectively, and  $R_{\text{v}}$  and  $R_{\text{o}}$  are the original proportions of common vetch and oats at sowing.

### Data analysis

Results from the 2 years were combined and analysed as a complete randomised block design by using the SAS statistical package program (SAS Institute Inc. 1994).

## Results

Neither of the companion crops in the experimental area showed significant damage from frost in either year, although mean temperatures in January 2002 and February and March 2003 were lower than medium-term data (Table 1). There was no evidence of wilting in either year.

Maximum dry matter (DM) yields exceeded 6 t/ha (pure oats and 45:55 oats:vetch). Yields were not significantly affected as vetch percentage at sowing increased to 55%, but declined progressively thereafter with lowest yields of 4.1 t/ha for pure vetch (Table 2). Legume percentage in the dry forage reflected the sowing ratios. Since volunteer species represented less than 2% (DM basis) of available forage and none was harmful for ruminants, they were not taken into consideration in statistical analyses.

Crude protein concentration increased progressively as legume percentage at sowing and in the harvested DM increased ( $P < 0.05$ ), with the highest levels for pure vetch (22.9% CP). Pure oats contained 8.5% CP. Crude protein yields peaked at 1.1 t/ha for the 45:55 oats:vetch mixture. NDF concentrations declined significantly as the percentage of vetch in the forage increased.

LERs ranged from 0.92 to 1.33 for 85:15 and 45:55 oats:common vetch mixtures, respectively. Data indicated that the only mixtures to show yield advantages over comparable proportions of pure stands were 55:45 and 45:55 oats:common vetch mixtures, where the mixtures would produce 13% and 32% more feed, respectively, than pure stands.

**Table 2.** Dry matter yields of pure and mixed stands of oats and common vetch, land equivalent ratios (LER) and competitive ratios (CR) for the two crops.

| Mixture rate<br>oats:vetch | Total DM<br>yield (t/ha) | Vetch in<br>dry forage (%) | Vetch DM<br>yield (t/ha) | Oats DM<br>yield (t/ha) | LER    | $\text{CR}_{\text{vo}}$ | $\text{CR}_{\text{ov}}$ |
|----------------------------|--------------------------|----------------------------|--------------------------|-------------------------|--------|-------------------------|-------------------------|
| Pure oats                  | 6.07 ab                  | —                          | —                        | 6.07 a                  | 1.00 c | —                       | —                       |
| 85:15                      | 5.38 b                   | 10.9 f                     | 0.58 f                   | 4.80 b                  | 0.92 c | 0.69 ab                 | 1.48 bc                 |
| 75:25                      | 5.47 b                   | 26.8 e                     | 1.46 e                   | 4.00 bc                 | 1.01 c | 1.10 a                  | 0.92 d                  |
| 55:45                      | 5.74 ab                  | 42.0 d                     | 2.41 d                   | 3.33 cd                 | 1.13 b | 0.98 ab                 | 1.24 cd                 |
| 45:55                      | 6.32 a                   | 58.4 c                     | 3.69 ab                  | 2.63 d                  | 1.33 a | 1.17 a                  | 0.88 d                  |
| 25:75                      | 4.54 c                   | 62.3 c                     | 2.83 cd                  | 1.71 e                  | 0.97 c | 0.55 b                  | 1.82 ab                 |
| 15:85                      | 4.53 c                   | 73.4 b                     | 3.33 bc                  | 1.20 e                  | 1.00 c | 0.49 b                  | 2.05 a                  |
| Pure vetch                 | 4.14 c                   | 100.00 a                   | 4.14 a                   | —                       | 1.00 c | —                       | —                       |
| LSD ( $P < 0.05$ )         | 0.73                     | 10.12                      | 0.72                     | 0.83                    | 0.096  | 0.49                    | 0.55                    |

## Discussion

This study has shown that mixtures of oats and common vetch can be grown successfully in Mediterranean regions with minimal inputs. While DM yields of mixtures generally exceeded those of pure vetch, no combination produced significantly more than pure oats. Overall, the mixtures outyielded pure vetch by a mean of 29%, but produced 12% less than pure oats. Lithourgidis *et al.* (2006) also reported that yields of mixtures were similar to that of pure oats and greater than that of pure common vetch, while Ross *et al.* (2005) reported that forage yield of oat-berseem clover intercrops was 50–100% higher than yields of pure berseem clover under two-cut harvesting in Montana. While Caballero *et al.* (1995) showed yields of oats-vetch mixtures were 34% higher than pure vetch, they found mixtures yielded 36% less than pure oats. It is significant that most researchers agree that intercrops use natural resources such as light (Ghanbari-Bonjar and Lee 2003), nutrients and water (Ahlawat *et al.* 1985) more efficiently than pure stands, which can reduce competition between species (Ghanbari-Bonjar and Lee 2003), resulting in higher DM production in intercropping systems.

The proportion of common vetch in dry forage was very similar to the proportion of common vetch in the seed mixture at sowing up to 55% vetch but was below the sowing proportion at 75 and 85% levels. This contrasts with the findings of Caballero *et al.* (1996), where the proportion of vetch in vetch-oats hay was lower than expected from sowing rates of 50% or less common vetch, because oats was more competitive than common vetch. They recommended that common vetch should represent at least 70% of seed in a mixture if 50% vetch in dry forage was

an objective. However, our results suggest that including more than 55% of vetch seed in a mixture with oats at planting in this environment will result in more than 50% vetch in DM at harvest.

CP concentrations in the available forage increased linearly as the proportion of vetch in the sowing mixture increased, while NDF concentrations declined, reflecting the increasing legume percentage in the harvested forage. Caballero *et al.* (1996) reported that sowing rates of 25% or more of common vetch resulted in CP concentrations above 130 g/kg DM in forage, which is considered optimal for growth of ruminants (NRC 1976). Our results support this statement. CP yields peaked in the 45:55 oats:vetch mixture, reflecting the higher forage yields on this treatment.

Our data indicate little advantage in terms of forage yield of these mixtures over comparable proportions of pure stands of the component crops, the advantages occurring only for 55:45 and 45:55 oats:vetch mixtures. Dhima *et al.* (2007) also reported yield advantages in terms of total LER for common vetch-wheat mixtures (1.05) at a 55:45 seeding ratio and for common vetch-oat mixtures (1.09) at a 65:35 seeding ratio. Similarly, Lithourgidis *et al.* (2006) obtained a LER value of 1.09 for a 65:35 mixture. However, Banik *et al.* (2000) reported that wheat-chickpea mixtures were less productive than pure stands.

Competitive ratios indicated little consistency in competitiveness between the two crops. Vetch was slightly more competitive than oats in the 75:25 and 45:55 oats:vetch mixtures, as the percentage of common vetch in the harvested material was higher than the proportion of seed sown. However, oats was slightly more competitive than vetch for 85:15 and 55:45 mixtures and much more competitive than vetch for 25:75 and 15:85 mixtures. There is no simple explanation.

**Table 3.** CP, NDF and ADF concentrations and CP yields of pure and mixed stands of oats and common vetch.

| Mixture rate<br>oats:vetch | CP concentration<br>(g/kg) | CP yield<br>(kg/ha) | NDF<br>(g/kg) | ADF<br>(g/kg) |
|----------------------------|----------------------------|---------------------|---------------|---------------|
| Pure oats                  | 84.8 d                     | 515 e               | 533 ab        | 390           |
| 85:15                      | 99.4 cd                    | 535 de              | 555 a         | 379           |
| 75:25                      | 134.0 bc                   | 733 cd              | 504 abc       | 352           |
| 55:45                      | 152.8 b                    | 877 bc              | 476 bc        | 384           |
| 45:55                      | 173.7 b                    | 1098 a              | 445 cde       | 374           |
| 25:75                      | 164.8 b                    | 748 c               | 428 de        | 377           |
| 15:85                      | 218.5 a                    | 990 ab              | 385 e         | 363           |
| Pure vetch                 | 222.9 a                    | 923 abc             | 406 e         | 325           |
| LSD (P<0.05)               | 41.7                       | 203.5               | 6.2           | NS            |

Inter-specific competition in any intercropping system is complex and variable as species are competing for so many factors, e.g. light (Ross *et al.* 2005), nutrients and soil water (Ahlawat *et al.* 1985). Crop species (Ghanbari-Bonjar and Lee 2003) and even cultivars can affect the outcome. Woolypod vetch was found to be more compatible with late-maturing oats than with medium-maturing varieties (Assefa and Ledin 2001). The present experiment showed that growing oats and common vetch in mixtures on a low-input basis, especially in terms of N fertilisation, favoured the growth of common vetch at proportions up to 45:55 oats:vetch as yields were higher than expected from a proportional area of pure vetch as reported by Assefa and Ledin (2001). However, oats growth was lower than expected in 85:15 and 75:25 oats:vetch mixtures but above expected levels in 25:75 and 15:85 mixtures. Low soil nitrogen could have limited the competitive ability of oats in the mixtures containing high proportions of oats (Assefa and Ledin 2001; Chen *et al.* 2004), while fixation of atmospheric nitrogen as vetch proportion at sowing increased might have resulted in more N being available to plants in these treatments, with less inter-specific competition for soil N.

## Conclusions

The results of this experiment suggested that sowing 50:50 mixtures of oats:common vetch in Mediterranean regions with minimal N fertiliser could produce as much forage as pure oats, while forage quality in terms of CP yield and concentration would be far superior to oats. Forage quality would be adequate to support high levels of animal production, e.g. organic milk or meat production. An added benefit would be the improvement in soil fertility through fixing of atmospheric nitrogen by the legume, but this needs to be confirmed by soil analyses.

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(Received for publication March 13, 2008; accepted February 12, 2009)