Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch

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Abstract

In the Mediterranean area, most annual legumes, such as common vetch (Vicia sativa L.) that have a scrambling habit, are sown with oat (Avena sativa L.) to improve growing conditions and forage harvesting. Although some studies have examined the effects of varying seeding ratios, the optimum seeding rates for those combinations are not well-defined. The objective of this study was to compare the yields from mixed stands of vetch (principal species) and oat (secondary species) obtained when several seeding rates of vetch were combined with various seeding ratios of the two species. A field study was conducted at two locations near Madrid in the 1981-82 and 1982-83 growing seasons. Both species were planted as monocrops and in mixtures. Ratios of the number of vetch to oat seed were 100:0; 90:10; 80:20; 70:30 and 60:40. Within each mixture, seeding rates of vetch were 60, 80, 100 and 120 kg ha⁻¹. The oat monocrop was seeded at 140 kg ha⁻¹. Plants were harvested at the pod-setting stage of vetch. Relative yield total (RYT) calculated as the sum of the relative dry matter yields of both species was used as the criterion for mixed stand advantage.

Mixtures produced 34% more dry matter than the monocrop of vetch, but 57% less than the oat monocrop. Dry matter yields of mixtures were not affected by seeding ratio or seeding rate of vetch but proportions of vetch dry matter decreased linearly as the percentage of oat seed in the mixture increased. The net effect of oat in the mixture was a linear increase in competition as oat density increased. Relative yield totals of mixtures with 90:10 or 80:20 ratios of vetch:oat seed exceeded unity.

Keywords: Competition; Intercropping; Mediterranean agriculture; Oats; Vetch

1. Introduction

Small grain cereals following fallow predominate the rainfed arable land of the Mediterranean basin (Caballero, 1993). Integrating winter annual legumes into crop rotations has been recommended as a means of reducing the use of nonrenewable resources (Hargrove, 1986; Heichel, 1987; Papastylianou and Danso, 1991) and maintaining consistent grain production (Osman and Nersoyan, 1986). Additionally, the availability of forage legumes allows ruminant production to be integrated into the farming system and relieve pressure on overgrazed and seasonally available range-

land (Munzur, 1989; Caballero et al., 1992).

Some annual legumes such as common vetch used for haymaking have a scrambling habit which results in rotting and harvesting difficulties when grown as monocrops. Additionally, in low rainfall areas, vetch cultivars that lack drought tolerance have smaller for-
age yields compared to small grain cereals cultivated for forage production (Hadjichristodoulou, 1978).

Mixtures of vetch and small grain cereals are often planted for haymaking. Other research (Caballero and Goicoechea, 1986) has shown oat to be the most suitable companion crop for common vetch and hairy vetch (Vicia villosa Roth) in the Castilian Plain. Oat provided support for the climbing vetches, improved light interception and facilitating mechanical harvesting. A balanced botanical composition is needed, however, because legumes are of paramount importance to the nutritive value of the forage mixture (Beever, 1989; Roberts et al., 1989; Thomson et al., 1990).

Overyielding in mixtures may occur when competition between species is less intense than between members of the same species. Population density can determine the amount of competition or facilitation in species mixtures (Vandermeer, 1990).

Most previous research on two-component mixtures has assessed the influence of varying seeding ratios, expressed as seed mass, at fixed seeding rates of the principal species (Droushiotis, 1989; Moreira, 1989; Ouknider and Jacquard, 1989; Papastylianou, 1990). The intercropping of sorghum (Sorghum bicolor L.) and pinto bean (Phaseolus vulgaris L.) has also been studied in a semi-arid environment, but at a fixed plant density of the secondary species (Carr et al., 1992).

Different seeding rates of the mixture components, 20 to 80 kg ha\(^{-1}\) of oat and 50 to 120 kg ha\(^{-1}\) of common vetch, have been recorded (Schoth and McKee, 1965; Hycka, 1974; Caballero, 1986). In a survey among 43 farmers in Castile-La Mancha, Caballero et al. (unpublished) recorded on-farm seeding rates of 108 ± 43 kg ha\(^{-1}\) of oat and 38 ± 30 kg ha\(^{-1}\) of oat in vetch–oat mixtures. Hay yields were unrelated to seeding rates, and vetch contributed to 41 ± 31% hay composition.

The objectives of the present experiment were to (i) determine whether mixtures with oat would alter vetch and total yield in a competitive or facilitative way related to the sowing proportions based on number of seeds, and (ii) assess whether the use of seeding rates of both species below current on-farm levels could lead to a balanced botanical composition and good forage quality and yields.

2. Material and methods

Field experiments were conducted under rainfed conditions during the 1981–82 and 1982–83 growing seasons at Viveros de Navalcarnero and La Poveda Field Stations, both near Madrid (40 km SW and 30 km E, respectively). Rainfall distributions during the growing seasons are shown in Table 1. Mean days with frost for both years were 61 and 67 in Navalcarnero and La Poveda, respectively. Soils at La Poveda have higher pH (7.7 vs 6.0), C/N ratio (9.2 vs 6.2), organic matter (1.7 vs 0.9%), available P (82 vs 20 mg kg\(^{-1}\)) and available K (122 vs 7 mg kg\(^{-1}\)) than those of Navalcarnero. Soil series are Typic Xerofluvent Entisol and Typic Haploxeralf Alfisol in La Poveda and Navalcarnero, respectively.

After plowing a barley stubble in October, 550 kg ha\(^{-1}\) of 8:15:15 (N:P\(_2\)O\(_5\):K\(_2\)O) compound fertilizer were applied to all plots. Linuron [\(N'-(3,4\)-dichlorophenyl]-N-methoxy-N-methylurea] at the rate of 0.875 kg ai ha\(^{-1}\) was applied pre-emergence for weed control. The experiments were arranged as a factorial combination of four levels of common vetch (principal species) seeding rates (60, 80, 100 and 120 kg ha\(^{-1}\)) and five levels of sowing proportions (0, 10, 20, 30 and 40%) of oat (secondary species) seed numbers. Corresponding oat seeding densities for each combination are shown in Table 2. Seed weights of the species were 56.6 and 35.1 mg seed\(^{-1}\) for vetch and oat, respectively.

<table>
<thead>
<tr>
<th>Month</th>
<th>1981–82a</th>
<th>1982–83b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navalcarnero</td>
<td>La Poveda</td>
<td>Navalcarnero</td>
</tr>
<tr>
<td>October</td>
<td>6.0</td>
<td>2.5</td>
</tr>
<tr>
<td>November</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>December</td>
<td>180.3</td>
<td>138.5</td>
</tr>
<tr>
<td>January</td>
<td>26.6</td>
<td>28.5</td>
</tr>
<tr>
<td>February</td>
<td>34.3</td>
<td>58.5</td>
</tr>
<tr>
<td>March</td>
<td>18.7</td>
<td>26.5</td>
</tr>
<tr>
<td>April</td>
<td>12.8</td>
<td>43.3</td>
</tr>
<tr>
<td>May</td>
<td>71.0</td>
<td>68.2</td>
</tr>
</tbody>
</table>

aCommon vetch–oat seeded on October 29 and harvested in May 15 of the following year.
bCommon vetch–oat seeded on November 8 and harvested in May 22 of the following year.
tively. Monocrop oat was included at the seeding rate of 140 kg ha\(^{-1}\) and randomized within the treatment structure. Plots (4 m by 20 m) were arranged in a randomized complete block design with three replications.

Seed of both species was hand-broadcast and covered by cross-passes of a cultivator and roller. In both growing seasons, monocrop and mixtures were sown on October 29 and November 8 and harvested in May 15 and May 22 of the following year, respectively. The monocrop of vetch and the mixtures were harvested at the pod-setting stage of vetch (grain with 20 to 30% dry weight). Monocrop oat was harvested at anthesis.

Spanish cultivars of oat (Cartuja) and common vetch (Común tolerada) were used.

Aboveground biomass was determined by harvesting 1.5 m by 15 m with a flail-type forage harvester. To determine botanical composition, plants in two 0.5-m × 0.5-m quadrats per plot were sickle-harvested, hand-separated and subsamples of each species dried 16 h at 105°C for dry matter (DM) determination.

Relative yields of both species were calculated as the ratio of yields in mixture to yields in monocrop. Relative yield total (RYT, the sum of both relative yields) was used as the criterion for mixed stand advantage as both vetch and oat were desired species. The value of unity is the critical value, with the intercrop favored above and the monocrops favored below that value (Mead and Willey, 1980; Vandermeer, 1990). Yield response of vetch affected by the density of oat was calculated as the difference in yield between mixtures and monocrops. The proportion of the vetch in the total yield was thus related to the densities of the two species.

Forage quality, measured as fiber detergent fraction (Goering and Van Soest, 1970) and total N (Technicon, 1977), was determined on subsamples of both species oven-dried for 22 h at 60°C followed by 2 h at 80°C and then milled to pass a 1-mm screen.

Analysis of variance techniques, as discussed by Hicks (1973), were used to assess statistical significance of treatment effects. Partial analyses were performed within locations between years, and within years between locations. Years and sites within years were combined into four year-location combinations and were considered random effects. Differences between means were compared using the LSD test at the 0.05 probability level.

### Table 2

<table>
<thead>
<tr>
<th>Vetch:oat seeding ratio</th>
<th>Common vetch seeding rates (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td>100:0</td>
<td>0</td>
</tr>
<tr>
<td>90:10</td>
<td>4.13</td>
</tr>
<tr>
<td>80:20</td>
<td>9.30</td>
</tr>
<tr>
<td>70:30</td>
<td>15.94</td>
</tr>
<tr>
<td>60:40</td>
<td>24.80</td>
</tr>
</tbody>
</table>

*Calculated as seed number. Common vetch and oat seed weights are 56.6 and 35.1 mg seed\(^{-1}\), respectively.

### 3. Results

Common vetch and oat cultivars exhibited winter hardiness without frost damage, and mean plant establishment was 90 and 92%, respectively. Differences among treatments were not significant.

Mean forage production of mixtures was not significantly affected by increasing seeding rate of vetch over the range used. Overall dry matter yields were 4.09, 4.12, 4.09 and 4.38 t ha\(^{-1}\) at vetch densities of 60, 80, 100 and 120 kg ha\(^{-1}\), respectively. Seeding rates of vetch did not influence botanical composition of mixtures. There was no significant vetch seeding rate \(\times\) sowing ratio interaction for composition, because the vetch contribution decreased at all vetch seeding rates as oat seeding proportion increased (Fig. 1). Differences between experimental sites were not
Table 3
Forage production and relative yields of monocrops and mixtures of common vetch and oat from four seeding ratios

<table>
<thead>
<tr>
<th>Vetch:oat seed ratio</th>
<th>Dry matter yield (t ha⁻¹)</th>
<th>Vetch contribution (%)</th>
<th>Relative yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vetch</td>
</tr>
<tr>
<td>Mono vetch</td>
<td>3.12</td>
<td>100.00</td>
<td>1.00</td>
</tr>
<tr>
<td>90:10</td>
<td>4.25</td>
<td>75.71</td>
<td>1.03</td>
</tr>
<tr>
<td>80:20</td>
<td>4.22</td>
<td>68.21</td>
<td>0.92</td>
</tr>
<tr>
<td>70:30</td>
<td>3.99</td>
<td>54.39</td>
<td>0.69</td>
</tr>
<tr>
<td>60:40</td>
<td>4.33</td>
<td>40.29</td>
<td>0.56</td>
</tr>
<tr>
<td>Mono oat</td>
<td>6.57</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.63</td>
<td>4.09</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*All values are means of location-year combinations and four common vetch seeding rates (60, 80, 100 and 120 kg ha⁻¹).

Fig. 2. Yield differential of common vetch at varying seeding rates and increasing seeding proportions of oat.

Table 4
Fiber and protein concentration (g kg⁻¹ DM) of monocrop species

<table>
<thead>
<tr>
<th>Species</th>
<th>NDF</th>
<th>ADF</th>
<th>ADL</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common vetch</td>
<td>381.1</td>
<td>295.7</td>
<td>81.3</td>
<td>195.7</td>
</tr>
<tr>
<td>Oat</td>
<td>557.6</td>
<td>320.4</td>
<td>47.4</td>
<td>69.7</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>19.1</td>
<td>14.3</td>
<td>2.4</td>
<td>8.8</td>
</tr>
</tbody>
</table>

*Mean of two duplicate samples, two years, and two locations.

**Common vetch and oat harvested at pod-setting and anthesis, respectively.

**NDF = Neutral detergent fiber, ADF = Acid detergent fiber, ADL = Acid detergent lignin, and CP = Crude protein.

significant. Although the seasons were different in total rainfall, small difference in spring rainfall contributed greatly to the pattern of results in the two years.

From the 90:10 to the 60:40 vetch:oat sowing ratios, mean vetch contribution to forage yield dropped by 54%, relative yield of vetch dropped by 46%, and relative yield of oat increased by 144% (Table 3). Monocrops of the two species differed significantly in herbage production, and both monocrops had significantly different mean total yields from the mixtures. Averaged together, the mixtures outyielded the monocrop of vetch by 34%, but were outyielded by the monocrop of oat by 57%.

Relative yield of vetch decreased and that of oat increased as oat seeding proportions increased. Relative yield total of the mixtures exhibited a decreasing trend as oat proportion increased. For mixtures with 10 and 20% oat, RYT exceeded unity, suggesting a mixed stand advantage at lower oat seeding proportions. This trend suggests potential for higher RYT with an even lower proportion of oat. Monocrop production showed no significant advantage over the mixtures (Table 3).

The difference between yields of vetch grown in the mixtures and monocrop vs. the seeding density of oat appear in Fig. 2. A significant seeding rate × seeding ratio interaction occurred because the switching effect was not the same at different seeding rates. At 10% oat, the 80-vetch seeding rate was positive and at 20% oat, the 120-vetch seeding rate was positive and the 60-, 80- and 100-vetch seeding rates were negative. At 30 and 40% oat, competition was present at any vetch seeding rate.

Quality components (Table 4) indicated an advantage for vetch, that exhibited lower neutral detergent fiber (NDF) and higher crude protein (CP) contents than oat. These differences may affect the total inges-
tion of protein because a negative relationship exists between NDF content and dry matter intake by ruminants (Rohweder et al., 1978).

4. Discussion

When two plants grow near one another, basic physiological principles suggest that they will compete for environmental resources regardless of facilitation. If competition and facilitation are both operative, the net effect could switch from positive to negative as a function of density (Vandermeer, 1990).

Our results suggest that the net response of common vetch to an increasing population density of oat had a threshold pattern with no facilitation at the lower seeding proportion of oat (10%), and an increasing level of competitive depression at oat seeding proportions over 20% in the mixture. The yields of mixtures were intermediate between the higher and the lower yielding monocrop species, which agrees with most accepted theoretical work on forage competition (De Wit and Van Den Bergh, 1965; Vandermeer, 1984). In vetch-cereal mixtures, our results are in agreement with those of Ouknider and Jacquard (1989) who did not find significant differences in DM yields between mixture treatments of 25:75; 50:50 or 75:25 sowing ratios and a fixed seeding rate of the principal species.

Our work suggests that adequate vetch contribution and forage quality (Moreira, 1989; Roberts et al., 1989) can be obtained only at low oat seeding proportions (10 or 20%). At oat seeding proportions above 30%, vetch contribution to forage yield fell below 50%, a value recommended as a minimum for quality hay (Caballero, 1986). Forage yields were not affected by vetch seeding rates within the range of 60 to 120 kg ha\(^{-1}\). Adequate contribution of vetch to forage yield is incompatible with high DM yield of oat. Yield of mixtures did not increase, however, within the range of 10 to 40% oat proportions.

In conclusion, the net effect of oat in the mixture was to increasing competition as oat density increased. The data suggest the possibility of greatest vetch yield with oat proportions below 10%. Forage yields of mixtures were not affected by seeding rates of common vetch well below those typically used in Central Spain. If high dry matter yield is the objective, the oat monocrop will be selected. High forage quality of the mixtures would require a very low seeding proportion of oat to increase vetch contribution to forage yield.

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References


