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Sustainable production of barley and wheat by intercropping common vetch

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Abstract – Intercropping legumes with cereals for forage production is a sustainable technique showing several environmental benefits. We studied yields, quality and the growth rate of a 2-year experiment including (1) sole crops of common vetch, barley and winter wheat, and (2) intercrops of common vetch with barley and winter wheat using seeding ratios of 55:45 and 65:35. Our results show that the greatest dry matter yields were obtained with wheat and barley sole crops. The lowest yield was obtained with common vetch sole crop. The intercrops produced about 13–30% more dry matter than the common vetch sole crop, but 12–23% less than cereal sole crops. Further, the growth rate of common vetch and cereals was greater when species were grown as sole crops than in intercrops. Quality components indicated an advantage for the sole crop of common vetch followed by its intercrop with barley at the 65:35 seeding ratio, which exhibited higher crude protein yield than the sole crop of cereals and the other intercrops. The results of this study indicate that common vetch intercrops with barley or winter wheat produced higher dry matter than common vetch sole crop. In addition, the intercrop of common vetch with barley (65:35) provided higher forage quality than the other intercrops. Our study highlights that vetch-cereal intercropping can be used as an alternative cropping system which combines sustainability due to N fixation from common vetch, and high yield and forage quality.

cereal / crude protein / growth rate / legume

1. INTRODUCTION

Intercropping of most annual legumes with winter cereals is extensively used as a cropping practice for forage production in many countries (Qamar et al., 1999; Clergue et al., 2005). One of the legumes that is used extensively in intercropping systems in the Mediterranean region is common vetch (*Vicia sativa* L.), an annual legume with a climbing growth habit, which contains high levels of protein and is grown in intercropping with small grain cereals for hay or forage production (Anil et al., 1998; Lithourgidis et al., 2006).

Intercropping of vetch with annual grasses has the advantages of increasing soil conservation, enhancing weed suppression (Anil et al., 1998; Avci and Akar, 2006), and providing better lodging resistance (Assefa and Ledin, 2001), yield stability (Lithourgidis et al., 2006), hay curing and forage preservation over common vetch, and may also increase protein yield (Roberts et al., 1989), and the length of the optimum harvest period over grasses (Qamar et al., 1999). However, intercropping of vetch with cereals has the disadvantages of including extra work in preparing and planting seeds, and they lack tolerance to herbicides as mixed crops (Anil et al., 1998).

There are several factors that can affect yield and quality of the intercropping systems such as cereal species, seeding ratios and interspecific competition (Caballero et al., 1995; Chen

et al., 2004). It is not clear which cereal species is the best for intercropping since there are conflicting reports. From previous studies it was found that barley (*Hordeum vulgare* L.) produced higher quality forage than oat (*Avena sativa* L.), triticale (\times *Triticosecale* Wittmack) or wheat (*Triticum aestivum* L.) (Thompson et al., 1992; Qamar et al., 1999). On the other hand, Thomson et al. (1990) reported that the most suitable cereal for intercropping with common vetch is oat. However, Roberts et al. (1989) proposed that wheat is the most suitable cereal for intercropping. Different seeding ratios, ranging from 20 to 80 kg ha⁻¹ for cereals and 50 to 120 kg ha⁻¹ for common vetch, have been proposed for intercropping common vetch with cereals (Osman and Nersoyan, 1986; Caballero et al., 1995).

Interspecific competition can often reduce yields of intercropping compared with cereal sole cropping, although higher yields have been reported when interspecific competition was lower than intraspecific competition (Vandermeer, 1990). Interspecific competition is usually mediated through competition for soil water, available nutrients and solar radiation (Buxton and Fales, 1993; Rodrigo et al., 2005). Interspecific competition can also have a significant impact on the growth rate of the different species which are used in intercropping. Despite the fact that competition is one of the factors which can affect forage yield and quality, there are few reports about the effect of different cereals and different seeding rates on the growth rate of different cereal-legume intercrops.

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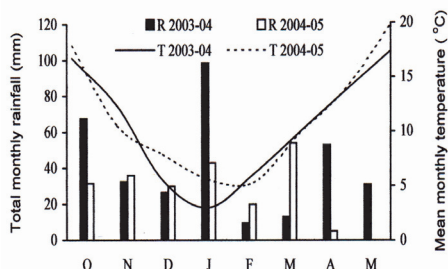


Figure 1. Monthly total rainfall and mean air temperature during the two growing seasons of experimentation. R: rainfall, T: temperature.

The objectives of this study were (i) to evaluate common vetch and two cereal sole crops (barley and wheat) as well as common vetch-cereal intercrops at two seeding ratios (55:45 and 65:35) for forage yield (expressed as dry matter) and quality, and (ii) to estimate the effect of intercropping on the growth rate of the three species used in the intercrops at the two seeding rates.

2. MATERIALS AND METHODS

2.1. Establishment of the experiment

The experiments were carried out at the University Farm of the Aristotle University of Thessaloniki in northern Greece during the 2003–2004 and 2004–2005 growing seasons. The experiment was established in a sandy loam 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 total monthly rainfall and average temperature for each growing season are shown in Figure 1.

The previous crop was winter wheat, which was harvested in mid-June of 2003. Common vetch (cv. Melissa) and two cereal sole crops, winter wheat (cv. Yecora) and double-row barley (cv. Thessaloniki), as well as common vetch-cereal intercrops with each of the above cereals, at two seeding ratios (55:45 and 65:35), were sown during the last week of November of each growing season at a seeding rate of 170 kg ha⁻¹. The crop was fertilized with 80 and 40 kg ha⁻¹ of N and P₂O₅, respectively. The experiment was established using a completely randomized block design with seven treatments and four replications. The experimental plots were 5 m × 20 m, separated by a 2-m buffer zone.

2.2. Forage production

Forage yield (expressed as dry matter) was determined by harvesting 3 m by 10 m of each plot with a flair-type forage harvester. The sole crops and intercrops were harvested at the pod-setting stage of common vetch (approximately at the milk stage of cereals), in mid-May. At that time, random samples from 1-m² areas of each plot were cut to ground level and separated by hand for determination of the percentage of common vetch in each mixture. The samples (0.5 kg biomass of each

species) were dried in the oven at 70 °C for 72 h to determine the relative water content. Total nitrogen accumulation was estimated by multiplying the total nitrogen concentration of the dry matter by the total dry matter.

The advantage of intercropping was calculated according to Mead and Willey (1980). The relative yield total (RYT) values were used as indicators for advantages or disadvantages of intercropping as compared with the respective sole crops. The value of unity is the critical value for total relative yield. When the total relative yield value is greater than one, it means that the intercropping favored the growth and yield of the species, and vice versa. The total relative yield was calculated as:

$$\text{Relative yield total (RYT)} = (\text{RY}_{\text{vetch}} + \text{RY}_{\text{cereal}})$$

$$\text{RY}_{\text{vetch}} = [(Y_m X_{vc})/Y_v] \text{ and } \text{RY}_{\text{cereal}} = [(Y_m X_{cv})/Y_c]$$

where Y_m is the dry matter yield of the intercrop, Y_v and Y_c are the dry matter yields of common vetch and cereal, respectively, as sole crops, and X_{vc} and X_{cv} are the actual dry matter proportion of common vetch and cereal, respectively, in intercrop.

2.3. Growth rate

Wheat, barley and common vetch were harvested from a 1-m² random area of each plot at four growth stages of the plants: 0, 3, 6 and 9 weeks after tillering of the cereals. Plants were separated by hand for determination of the fresh weight of each species. Fresh weight data for cereals and common vetch were regressed against time. The equation with the highest coefficient of determination (r^2) was judged to be the most appropriate.

2.4. Forage quality

At harvest, a second set of random samples of 1 kg biomass from each plot was taken and dried in the oven for 72 h at 70 °C. Then the samples were ground with a Wiley mill to pass through a 1-mm screen and analyzed for quality components. Total N was determined using the Kjeldahl method and crude protein (CP) was calculated by multiplying by 6.25 (AOAC, 1980). Other quality characteristics such as neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined using the procedure by Goering and Van Soest (1970). Hemicellulose content was estimated as the difference between neutral detergent fiber and acid detergent fiber. Net energy for lactation (NE_l) was estimated according to the following equation adapted from Horrocks and Vallentine (1999): $\text{NE}_l = [1.044 - (0.0119 \times \% \text{ADF})] \times 2.205$.

2.5. Statistical analysis

The MSTAT and SPSS (version 10) programs were used to conduct the regression analysis and the analysis of variance (ANOVA), respectively. Treatment mean differences were separated by the least significant difference (LSD) test at the 0.05 probability level. Because the analysis of variance for forage yield and quality indicated no treatment × experimental time interaction, the values are reported as means of the two growing seasons.

Table I. Dry matter, nitrogen accumulation, vetch contribution (%) and relative yields of sole crops and intercrops of common vetch with winter wheat or barley at two seeding ratios. Means are averaged over two growing seasons with four replications.

| Crop | Seed ratios | Dry matter (Mg ha ⁻¹) | N accumulation (kg ha ⁻¹) | Vetch contribution (%) | Relative Yield | | |
|---------------------|-------------|-----------------------------------|---------------------------------------|------------------------|---------------------|----------------------|------|
| | | | | | RY _{vetch} | RY _{cereal} | RYT |
| Wheat | 100 | 10.67 | 133.5 | 0.00 | 0.00 | 1.00 | 1.00 |
| Vetch:wheat | 55:45 | 8.95 | 137.9 | 51.99 | 0.65 | 0.40 | 1.05 |
| Vetch:wheat | 65:35 | 7.37 | 120.8 | 60.70 | 0.62 | 0.27 | 0.89 |
| Barley | 100 | 10.53 | 151.2 | 0.00 | 0.00 | 1.00 | 1.00 |
| Vetch:barley | 55:45 | 9.24 | 143.2 | 25.96 | 0.33 | 0.65 | 0.98 |
| Vetch:barley | 65:35 | 8.07 | 157.6 | 42.86 | 0.48 | 0.44 | 0.92 |
| Vetch | 100 | 7.12 | 159.8 | 100.00 | 1.00 | 0.00 | 1.00 |
| LSD _{0.05} | | 0.87 | 7.9 | 4.61 | 0.05 | 0.03 | 0.03 |

3. RESULTS AND DISCUSSION

3.1. Forage production

Forage yield, expressed as dry matter, differed significantly among sole crops and intercrops (Tab. I). The greatest dry matter was obtained with wheat and barley in sole cropping, whereas the lowest was obtained with the common vetch sole crop and the common vetch-wheat intercrop (65:35). In addition, the dry matter yield of most intercrops was intermediate compared with yields of sole crops, and decreased when the common vetch seeding rate increased in the intercropping (Tab. I). In particular, both common vetch-barley intercrops (55:45 and 65:35) produced about 29.9% and 13.3% more dry matter, respectively, than the sole crop of common vetch, but about 12.2% and 23.4% less than the barley sole crop. In addition, the common vetch-wheat intercrop (55:45) produced about 25.7% more dry matter than the common vetch sole crop. Similarly, Caballero et al. (1995) reported that yields decreased with increasing common vetch ratios in the common vetch-oat intercrops, whereas they were intermediate compared with yields of sole crops. In contrast, Lithourgidis et al. (2006) reported that yield of common vetch intercrops with oat or triticale was not affected by seeding ratios; it was greater than or equal to the common vetch sole crop.

The relative yield of common vetch was lower in vetch-barley intercrops as compared with common vetch-wheat intercrops (Tab. I). In addition, the relative yield of barley in intercrops was higher than that of wheat. Probably, this was because of the lower common vetch contribution in common vetch-barley intercrops than in common vetch-wheat intercrops (Tab. I). The greatest total relative yield (1.05) was calculated in the common vetch-wheat intercrop at the 55:45 seeding ratio. In this case, the total relative yield value exceeded unity, which indicates an advantage of intercropping over sole cropping in terms of using the environmental resources for plant growth (Mead and Willey, 1980; Chen et al., 2004). However, sole crops showed a yield advantage over intercrops of common vetch with wheat or barley at the 65:35 seeding ratio, but no significant advantage over the common vetch-barley (55:45) intercrop.

Nitrogen accumulation is a measure of how much nitrogen is taken up and accumulated by the crop and also how much is removed from the field with harvest. Nitrogen accumulation had the highest value for the sole crop of common vetch and

the common vetch-barley intercrop (65:35), followed by the sole crop of barley (Tab. I). The lowest amount of nitrogen was in the common vetch-wheat intercrop (65:35), followed by the wheat sole crop and common vetch-wheat intercrop (55:45). Although common vetch provided the lowest dry matter yield (Tab. I), it accumulated the highest amount of nitrogen. This is because common vetch contains more protein than the cereals used in this study (Tab. II). These data agree with Jannink et al. (1996), who found that vetch had much higher nitrogen uptake than pea and oat alone. In addition, common vetch is one of the legumes used for green manure because of the high nitrogen uptake, which results in higher organic N deposition in the soil (Stern, 1993).

3.2. Growth rate

Regression equations for fresh weight of wheat, barley and common vetch with time indicated that the quadratic equation provided the best fit (Fig. 2). In most cases, fresh weight of common vetch and cereals increased with increasing duration of interference. The estimated values *a* (intercept) and *b* (slope) for fresh weight of the three crops were greater when they grew as sole crops than in intercrops (Fig. 2). Moreover, in most cases, there was a decrease in the values *a* and *b* for cereals as the common vetch percentage increased in the intercrops. In contrast, *a* and *b* for common vetch increased as the common vetch ratio increased. Also, the initial growth (*a*) and growth rate (slope *b*) of barley as a sole crop or in intercrops with common vetch were higher than those of common vetch or wheat. On the other hand, the growth rate of common vetch was affected less when it was grown in intercrops with barley (*b* values 2.33 and 3.88 for the two common vetch-barley intercrops, respectively), than when it was grown with wheat (*b* values 3.18 and 4.87, respectively).

The fact that wheat and barley showed greater growth rates when they grew as sole crops than in intercrops could be attributed to cereal competition with common vetch (Assefa and Ledin, 2001; Lithourgidis et al., 2006). Moreover, the lower effect of wheat on the growth rate of common vetch than that of barley, and the lowest dry matter proportion of common vetch in intercrops with barley (Tab. I) could be attributed to the fact that barley is a more competitive species than wheat (Dhima and Eleftherohorinos, 2001).

Table II. Forage quality of sole crops and intercrops of common vetch with winter wheat or barley at two seeding ratios. Means are averaged over two growing seasons with four replications. Where: NDF is neutral detergent fiber, ADF is acid detergent fiber and NE_l is net energy for lactation.

| Crop | Seed ratios | Crude (g kg ⁻¹ DM) | Protein (kg ha ⁻¹) | Lignin (g kg ⁻¹ DM) | NDF (g kg ⁻¹ DM) | ADF (g kg ⁻¹ DM) | Hemicellulose (g kg ⁻¹ DM) | NE _l (mcal kg ⁻¹) |
|---------------------|-------------|----------------------------------|-----------------------------------|-----------------------------------|--------------------------------|--------------------------------|--|---|
| Wheat | 100 | 78.2 | 834 | 44.2 | 423 | 299 | 124 | 1.517 |
| Vetch:wheat | 55:45 | 96.3 | 862 | 54.7 | 444 | 325 | 118 | 1.449 |
| Vetch:wheat | 65:35 | 102.5 | 755 | 61.2 | 428 | 309 | 119 | 1.491 |
| Barley | 100 | 89.7 | 945 | 33.4 | 422 | 293 | 129 | 1.533 |
| Vetch:barley | 55:45 | 96.9 | 895 | 43.1 | 414 | 304 | 110 | 1.504 |
| Vetch:barley | 65:35 | 122.1 | 985 | 50.3 | 429 | 319 | 110 | 1.465 |
| Vetch | 100 | 140.3 | 999 | 67.4 | 430 | 304 | 116 | 1.504 |
| LSD _{0.05} | | 8.4 | 49 | 5.4 | ns | ns | ns | ns |

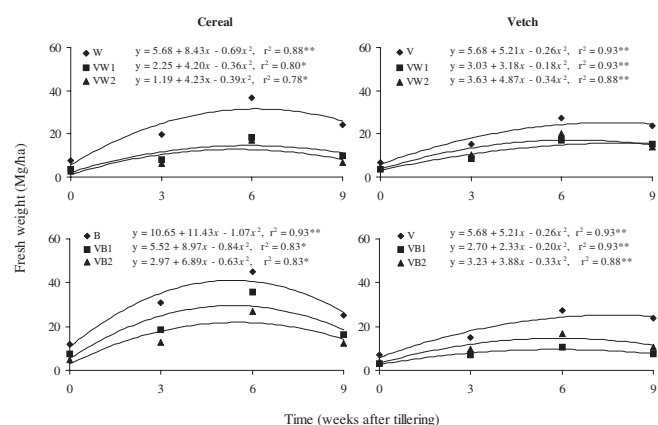


Figure 2. Temporal pattern in fresh weight of sole crops and intercrops of common vetch with winter wheat or barley at two seeding ratios. Means are averaged over two growing seasons and four replications. Lines describe quadratic regression equations ($y = a + bx + cx^2$), (*, ** significant at the 0.05 and 0.01 probability levels, respectively). W: wheat, VW1: common vetch-wheat (55:45), VW2: common vetch-wheat (65:35), B: barley, VB1: common vetch-barley (55:45), VB2: common vetch-barley (65:35), V: common vetch.

3.3. Forage quality

Crude protein content is one of the most important criteria for forage quality evaluation (Haj-Ayed et al., 2000). The highest crude protein was achieved when common vetch was grown as a sole crop. In all intercrops, with the exception of common vetch-barley (55:45), protein content was higher than that of cereal sole crops (Tab. II). Moreover, intercrops had higher protein content where the seeding ratios of common vetch increased in the intercrop. In particular, the highest crude protein content was observed in the common vetch sole crop (140.3 g kg⁻¹ dry matter) followed by the common vetch-barley intercrop (65:35). In contrast, the sole crop of wheat had the lowest protein content (78.2 g kg⁻¹ dry matter) followed by the sole crop of barley and the common vetch with barley and wheat intercrops (55:45). Similarly, Osman and Nersoyan (1986) and Caballero et al. (1995) reported that the highest crude protein was recorded when the legume was

grown as a sole crop or formed a high proportion in intercrops with cereals.

In most cases, a similar trend was observed for the crude protein when it was expressed on a per area basis (Tab. II). The lowest amount was for the intercrop of common vetch with wheat at the 65:35 seeding ratio (755 kg ha⁻¹) followed by wheat as a sole crop and the common vetch-wheat intercrop (55:45). Moreover, the highest values were found for the common vetch sole crop (999 kg ha⁻¹) and the common vetch-barley intercrop (65:35), followed by the barley sole crop (Tab. II). Although dry matter yield was similar for the two cereals (Tab. I), mean yield per hectare in terms of total protein was higher for barley, because of the higher amount of protein which barley contained in dry matter compared with wheat (Tab. II).

Lignin content was much higher for the common vetch sole crop (67.4 g kg⁻¹ dry matter) than for the cereal sole crops (33.4 and 44.2 g kg⁻¹ dry matter in barley and wheat, respectively), and it decreased with an increasing cereal ratio in the intercrop. This difference in lignin concentration was because the cell walls of cereals contain a lower amount of lignin than the cell walls of dicots such as common vetch (Carpita and McCann, 2000).

The concentrations of neutral detergent fiber and acid detergent fiber are another important quality characteristic for forage, which are affected by intercropping. The increasing common vetch proportion in forage was usually associated with an increase in cell contents and a decrease in neutral detergent fiber (Caballero et al., 1995; Haj-Ayed et al., 2000). However, in this study there were no significant differences between sole crops and their intercrops for neutral detergent fiber, acid detergent fiber or hemicellulose contents (Tab. II). This can be attributed to the different cultivars used in this study and possibly to the different stages of maturity at harvest or to the different weather conditions during maturity (Roberts et al., 1989; Assefa and Ledin, 2001; Lauriault and Kirksey, 2004). In agreement with our findings, Velazquez-Beltran et al. (2002) reported that there were no differences in acid detergent fiber composition among sole crop of oat, common vetch-oat and common vetch-oat-maize intercrops.

The net energy for lactation was not affected by intercropping (Tab. II). Similarly, Lauriault and Kirksey (2004) found

that intercrops of pea with rye and barley had no effect on NE_1 , but intercrops of pea with oat, wheat or triticale had greater NE_1 than forage of the respective cereal sole crops.

For forage intercrops it is important to produce greater forage yields per hectare with higher nutritional quality. High forage yield is very important for the producers, but for livestock enterprises it is also important to produce high quality forages. In addition, cereal-legume intercropping may be a valuable tool to assist farmers with efficient N management while providing residue cover and biological N accumulation. The benefit of this research is to provide information for farmers for which intercropping is better regarding total yield and high forage quality for livestock. Intercrop of common vetch with barley at a 65:35 seeding ratio can be used, as it has a higher nutrition value and comparable high yield. On the other hand, the results from this experiment provide a base of information for additional research on grass-legume intercropping as an alternative cropping system.

4. CONCLUSION

The present study demonstrates that intercropping of common vetch with barley or wheat affects dry matter yield, the growth rate of the individual species, and also forage quality. The net effect of cereals in the intercrops was to produce about 13 to 30% more dry matter than the sole crop of common vetch. Because the quality of cereal forage is lower than that of common vetch, wheat or barley forages could be mixed with common vetch to increase crude protein content with no negative effects on other quality components. In addition, the growth rate of common vetch, wheat and barley was lower when they were grown together than in sole cropping because of competition between species.

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REFERENCES

- Anil L., Park J., Phipps R.H., Miller F.A. (1998) Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK, *Grass Forage Sci.* 53, 301–317.
- Assefa G., Ledin I. (2001) Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in sole crops and mixtures, *Anim. Feed Sci. Tech.* 92, 95–111.
- Association of Official Analytical Chemists (AOAC) (1980) *Official Methods of Analysis*, 11th ed., AOAC, Washington, DC.
- Avci M., Akar T. (2006) Ecological production of dryland hairy vetch by mechanical control, *Agron. Sustain. Dev.* 26, 29–34.
- Buxton C.L., Fales S.L. (1993) Plant environment and quality, in: Fahey G.C. Jr et al. (Eds.), *Forage quality, evaluation and utilization*. ASA, CSSA and SSSA Publishing, Madison, WI, USA, pp. 92–116.
- Caballero R., Goicoechea E.L., Hernaiz P.J. (1995) Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of common vetch, *Field Crop. Res.* 41, 135–140.
- Carpita N., McCann M. (2000) The Cell Wall, in: Buchanan B.B., Gruissem W., Jones R.L. (Eds.), *Biochemistry and Molecular Biology of Plants*, American Society of Plant Biologists, Maryland, USA, pp. 52–108.
- Chen C., Westcott M., Neill K., Wichman D., Knox M. (2004) Row configuration and nitrogen application for barley-pea intercropping in Montana, *Agron. J.* 96, 1730–1738.
- Clergue B., Amiaud B., Pervanchon F., Lasserre-Joulin F., Plantureux S. (2005) Biodiversity: function and assessment in agricultural areas, A review, *Agron. Sustain. Dev.* 25, 1–15.
- Dhima K.V., Eleftherohorinos I.G. (2001) Influence of nitrogen on competition between winter cereals and sterile oat, *Weed Sci.* 49, 77–82.
- Goering H.K., Van Soest P.J. (1970) *Forage fiber analysis: Apparatus Reagents, Procedures, and Some Applications*, Agric. Handbook 379. U.S. Gov. Print. Office, Washington DC, USA, pp. 3979–3991.
- Haj-Ayed M., Gonzalez J., Caballero R., Alvir M.R. (2000) Nutritive value of on-farm common vetch-oat hays. II. Ruminant degradation of dry matter and crude protein, *Ann. Zootech.* 49, 391–398.
- Horrocks R.D., Vallentine J.F. (1999) *Harvested forages*, Academic Press, London, UK, pp. 17–47.
- Jannink J.-L., Leibman M., Merrick L.C. (1996) Biomass production and nitrogen accumulation in pea, oat, and vetch green manure mixtures, *Agron. J.* 88, 231–240.
- Laurialt L.M., Kirksey R.E. (2004) Yield and nutritive value of irrigated winter cereal forage grass-legume intercrops in the southern high plain, USA, *Agron. J.* 96, 352–358.
- Lithourgidis A.S., Vasilakoglou I.B., Dhima K.V., Dordas C.A., Yiakoulaki M.D. (2006) Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios, *Field Crop. Res.* 99, 106–113.
- Mead R., Willey R.W. (1980) The concept of a land equivalent ratio and advantages in yields for intercropping, *Exp. Agr.* 16, 217–228.
- Osman A.E., Nersoyan N. (1986) Effect of the proportion of species on the yield and quality of forage mixtures, and on the yield of barley in the following year, *Exp. Agr.* 22, 345–351.
- Qamar I.A., Keatinge J.D.H., Mohammad N., Ali A., Khan M.A. (1999) Introduction and management of common vetch/barley forage mixtures in the rainfed areas of Pakistan. 3. Residual effects on following cereal crops, *Aust. J. Agr. Res.* 50, 21–27.
- Roberts C.A., Moore K.J., Johnson K.D. (1989) Forage quality and yield of wheat-common vetch at different stages of maturity and common vetch seeding rate, *Agron. J.* 81, 57–60.
- Rodrigo V.H., Stirling C.M., Teklehaimanot Z., Samarasekera R.K., Pathirana P.D. (2005) Interplanting banana at high densities with immature rubber crop for improved water use, *Agron. Sustain. Dev.* 25, 45–54.
- Stern W.R. (1993) Nitrogen fixation and transfer in intercrop systems, *Field Crop. Res.* 34, 335–356.
- Thompson D.J., Stout D.G., Moore T. (1992) Forage production by four annual cropping sequences emphasizing barley irrigation in southern interior British Columbia, *Can. J. Plant Sci.* 72, 181–185.
- Thomson E.F., Rihawi S., Nersoyan N. (1990) Nutritive value and yields of some forage legumes and barley harvested as immature herbage, hay and straw in North-West Syria, *Exp. Agr.* 26, 49–56.
- Vandermeer J.H. (1990) *Intercropping*. Agroecology, McGraw-Hill Publishing, New York, USA, pp. 481–516.
- Velazquez-Beltran L.G., Felipe-Perez Y.E., Arriaga-Jordan C.M. (2002) Common vetch (*Vicia sativa*) for improving the nutrition of working equids in campesino systems on hill slopes in central Mexico, *Trop. Anim. Health Pro.* 34, 169–179.