12 Mixtures of Legumes for Forage Production

Branko Ćupina,[1]* Aleksandar Mikić,[2] Đorđe Krstić,[1] Svetlana Vujić,[1] Lana Zorić,[1] Vuk Đorđević[2] and Pero Erić[1]

[1]*University of Novi Sad, Novi Sad, Serbia;* [2]*Institute of Field and Vegetable Crops, Novi Sad, Serbia*

Abstract

In Europe, legumes are mostly grown as single species or in mixtures with cereals or grasses. As an alternative cropping strategy, mixtures of legumes for forage have been developed in Serbia. This novel approach can be applied in many other temperate regions of Europe. This chapter provides an overview of these cropping systems, their use and their development. Carefully designed mixtures of forage crop species offer advantages over the component species grown separately. These advantages include higher yield, enhanced weed control and reduced soil erosion. In addition, the use of legumes in forage mixtures has benefits for feed quality due to the high protein content of the legume. This chapter examines the use of annual legumes mixed with perennial legumes to boost first-year yields in particular. Our research has shown that an annual forage legume can provide a yield benefit when sown as the companion crop during the establishment phase of a perennial legume. This research also shows that including field pea as a companion crop significantly increased overall dry matter yields and reduced weeds in red clover stands. Similar research is in progress for the establishment of lucerne (*Medicago sativa* L.) and sainfoin (*Onobrychis viciifolia* Scop.). We also examined the intercropping of annual temperate legumes with each other for forage production, and found that all mixtures out-yielded their components grown as pure stands. The evidence in the literature that explains this is reviewed.

Introduction

The cropping systems described here were developed in Serbia, where agricultural production systems range from specialized arable cropping and livestock raising in relevant regions, to traditional mixed farming systems. A combination

*cupinab@polj.uns.ac.rs

of livestock raising and fruit and/or wine growing is common. The farming systems in the fertile northern areas (Vojvodina) and central parts of the country are dominated by intensive arable cropping and dairy farming. In the less fertile and predominantly mountainous regions of southern Serbia, the diverse farming systems are based on vegetables, vineyards, and forage crops to support the livestock.

Legumes are incorporated into Serbian cereal cropping systems as green manures, intercrops and rotational crops. They contribute high-quality organic matter to the soil and are effective in breaking the disease cycles of cereal crops.

Many farms in Vojvodina province have been affected by soil degradation. Inherently fertile soils such as the chernozem (black) soils have suffered a significant reduction in organic matter, in some cases as much as 50% (Ćupina *et al*., 2011a). Farmers are trying to reverse this process by using crop rotation, and especially by including legumes that are mostly sown as a winter cover crops and are used as green manure or as forage (Fig. 12.1).

Of the 3.3 million ha of arable land in Serbia, 8% is used for forage crop production. Lucerne (alfalfa; *Medicago sativa* L.) is the most important forage crop grown on 180,000 ha. Red clover (*Trifolium pratense* L.) is grown on 80,000 ha and annual legumes on over 30,000 ha. Intercropping of annual legumes (field pea, *Pisum sativum* L. and vetches, *Vicia* spp.) and cereals (mostly oat, *Avena sativa* L.) is found typically on farms that have livestock, and the practice is particularly important on relatively small farms (Erić *et al*., 2010).

Intercropping

Intercropping is the growing of two or more crops in the same field at the same time (Willey, 1979). Combinations of crops that do not fix nitrogen and legumes are regarded as a most effective (Corre-Hellou *et al*., 2006). This is due to the stimulating effect of the non-legume on the biological nitrogen (N) fixation in the legume (Hauggaard-Nielsen and Jensen, 2005; Temperton *et al*., 2007; Zarea *et al*., 2008; Fustec *et al*., 2010). The focus of this chapter, however, is the intercropping of legumes with legumes for forage purposes. If the components are

(A)

(B)

Fig. 12.1. Vetches and a mixture of vetches and wheat used as cover crops: cutting regime (A) and mulching regime (B). (Photo credit: B. Ćupina.)

carefully selected, intercrops of legumes have potential advantages compared with sole crops. These include: (i) increased forage yield and enhanced weed control (Avola *et al*., 2008); (ii) decreased soil erosion (Wiersma *et al*., 1999); and (iii) reduced incidences of pests and diseases (Trenbath, 1993; Altieri, 1999; Malézieux *et al*., 2009). Intercropping exploits the benefits of diversity, interactions between species, and other natural regulation mechanisms (Vandermeer *et al*., 1998) to use the available resources more efficiently than sole crops (Anil *et al*., 1998).

Intercropping of annual and perennial crops can be applied to forage crops in Europe in four main forms (Zemenchik *et al*., 2000; Koivisto, 2002; Thorsted *et al*., 2002). These are as follows.

1. Two or more annual forages sown together.
2. An annual companion crop used to establish a perennial forage crop (Fig. 12.2).
3. Annual forages sown into an existing perennial stand to boost short-term yields.
4. Perennial legumes sown between the rows of an annual arable crop, such as maize.

Temperate perennial forage legumes, such as red clover, lucerne and sainfoin (*Onobrychis viciifolia* Scop.), are established either in late summer and early autumn, or in spring. Due to their small seed size, perennial legumes are sown shallow, so are especially susceptible to drought during the germination and establishment phase. A spring-sown perennial forage crop frequently has a significantly lower yield in the year of establishment in comparison to the autumn-sown one, partly because of weeds (Ćupina *et al*., 2000, 2004). To overcome this, farmers in Europe have traditionally established perennial forage crops using a companion crop (Klesnil, 1980; Matejkova, 1982; Tesar and Marble, 1988; Zollinger and Meyer, 1996), often a cereal, such as oat. This practice usually increases the total forage yield, enhances the forage quality and reduces the weed invasion (Fig. 12.3) (Vandermeer *et al*., 1998). Nevertheless, using a companion crop in the establishment of a perennial forage legume has its limitations, since the annual companion species may also compete to the detriment of the perennial (Tesar and Marble, 1988), especially where oat or another cereal is used. For this

(A) (B)

Fig. 12.2. Two approaches to intercropping legumes. (A) Field pea used as a nurse crop for red clover. (B) A mixture of white lupin and field pea. (Photo credits: Đ. Krstić (A) and S. Vujić (B).)

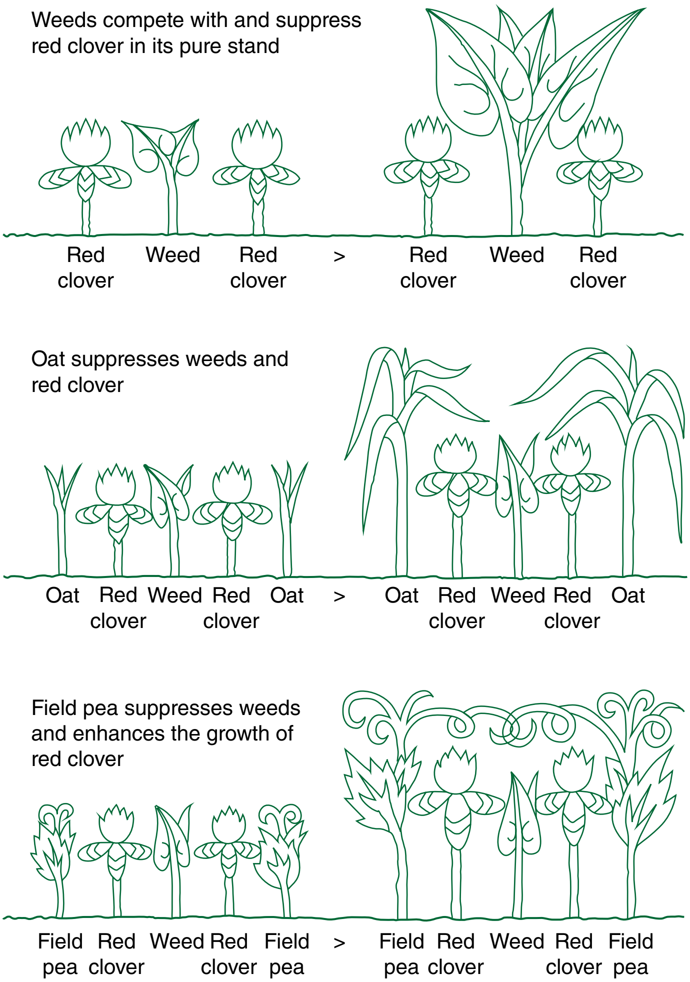

Fig. 12.3. Different ways of using nurse crops in the establishment of perennial legumes with their effects. (From Ćupina *et al*., 2011d.)

reason, an alternative and economically reliable scheme has been suggested, where an annual legume, such as pea, is used (Fig. 12.3).

The success of using an annual companion crop in establishing a perennial forage legume depends on the capacity of the perennial to develop in the shade of the annual (Tan *et al*., 2004). Competition for light has a direct impact on the morphology and physiology of the perennial species that lies lower in the canopy (Bedoussac and Justes, 2010).

Our research has focused on using pea as a companion species in particular. The light intensity at the level of the perennial forage legume under the pea companion crop is consistently higher compared with that under other companion crops that have a more robust growth habit (Simmons *et al*., 1995). Semi-leafless (afila) pea cultivars in particular increase the total capture of photosynthetically active radiation (PAR), so they are considered to be more appropriate for intercropping (Heath and Hebblethwaite, 1985).

Developing and Managing Mixtures of Legumes – the Fundamentals

Optimizing the growth of a mixture of perennial and annual forage species depends on finely balancing the benefits of the additional biomass and weed control provided by the annual with the negative effects of shading on the perennial. To achieve this, an understanding of the physiological responses within the stand is useful.

It is well established that leaves adapt to the light environment. Anatomical variation induced by the light environment has consequences for photosynthesis, as better development of palisade tissue in sun leaves gives a high photosynthetic capacity (Dickison, 2000). Leaves grown in the shade have lower photosynthetic saturation points than those developed in full sun (Björkman, 1981; Taiz and Zeiger, 2002). This fundamental effect provides the basis for the benefits of intercropping, enabling shaded plants to survive shading and respond positively through new leaf development when the shading companion crop is removed.

This general effect of shading on photosynthetic responses can be observed in specific intercrops. In a red clover or lucerne–pea mixture, reduced light intensity retards the growth and leaf area development of the clover (Heichel *et al*., 1988). This effect increases as the number of pea plants of either leafy or semi-leafless cultivars above the clover or lucerne increases (Krstić *et al*., 2005a, b). The leaves and other plant parts receiving only diffuse light often have a higher chlorophyll content than those exposed to direct light. Thus, the contents of both chlorophyll a and b were lower in the sole crops of lucerne (10 mg/g) and red clover (12 mg/g) than in their intercrops with field pea (18 mg/g). This increased chlorophyll concentration enables the perennial crop to benefit from the protection of the pea while still establishing effectively in shade. Furthermore, we have observed that differences in plant architecture and morphology of the intercropped field pea cultivars did not induce significant differences in lucerne leaf anatomical parameters (Zorić *et al*., 2012).

The overall effect is that establishing lucerne or red clover with a companion crop of field pea increases the total capture of solar radiation, increasing overall crop yields.

It is noteworthy that most of the perennial plant rosette remains after the first cut of a perennial forage legume. This part enables the plant to recover faster than the covering nurse crop (Krstić *et al*., 2005b). This means that harvesting favours the perennial over the annual, further reinforcing the benefits of this type of intercropping.

The results of our research in the conditions of Serbia confirm that lucerne, from both anatomical and morphological aspects, may be successfully established and cultivated with a companion crop of field pea, regardless of its leaf type, in an environment-friendly way, thus providing various farming systems with reliable ecological services (Zorić *et al*., 2012).

Optimizing Interspecific Interactions when Establishing Perennial Forage Crops

Effect of pea cultivar

Careful selection of the companion pea cultivar is important in optimizing pea–perennial crop mixtures in some circumstances. Leafy field pea cultivars are susceptible to lodging, so they introduce a high risk of suppressing the growth of the undersown perennial forage crop to the detriment of the overall crop yield (Faulkner, 1985; Gilliland and Johnston, 1992). However, in a 3-year field study carried out in Serbia (Ćupina *et al.*, 2010b), two pea cultivars with different leaf types, namely leafy cv. 'Javor' and semi-leafless cv. 'Jezero', did not differ significantly as cover for red clover. The crops also had similar forage yields, with no consistent differences in 2 establishment years, confirming the previous results (Koivisto, 2002).

Optimizing plant populations

Using the optimum seed rate for the nurse (cover) species is central to establishing the optimum balance with perennial crop (Tan *et al.*, 2004). A high population of the companion crop increases first-year forage yields and suppresses weeds, but can adversely affect the longer-term potential of the perennial crop. Lower companion seed rates may not be sufficient to suppress weeds, but provide the intercrop canopy with more solar radiation and better air movement (Tesar and Marble, 1988; Horrocks and Vallentine, 1999). Given these trade-offs, it is recommended that the seeding rate of the companion crop (in viable seeds/m^2) should not exceed half of the seeding rate of the perennial crop.

Early first cutting reduces competition from the cover crop. In the case of using peas, this means cutting at the early pod-filling stage (Vough *et al.*, 1995).

Ćupina *et al.* (2010b) reported that the highest annual forage dry matter yield (7.66 t/ha) and the lowest weed cover in the first cut of the newly established red clover (5.9%) were obtained where clover was mixed with the highest sowing rate of field pea tested (90 plants/m^2) (Fig. 12.4). From an economic perspective, a lower pea plant population of 60 plants/m^2 may be more appropriate. In the same experiment, the highest forage yields in the first year were obtained from red clover intercropped with oat. However, forage digestibility in ruminants is an important parameter which in these conditions ranges from 70% to 80% in field pea and 50–60% in oat (Smith *et al.*, 1972; Obračević, 1990). Additionally, field pea has morphological and biological characteristics that make it more suitable than oat for use as a companion crop for red clover in both the establishment and the first full harvest years. In the second and subsequent years, perennial legumes that were grown with pea had a better regeneration rate and thus higher total annual yield.

By contributing to the forage yield in the first cut, the annual companion crop contributes to the average annual forage yield. Generally, the use of an annual

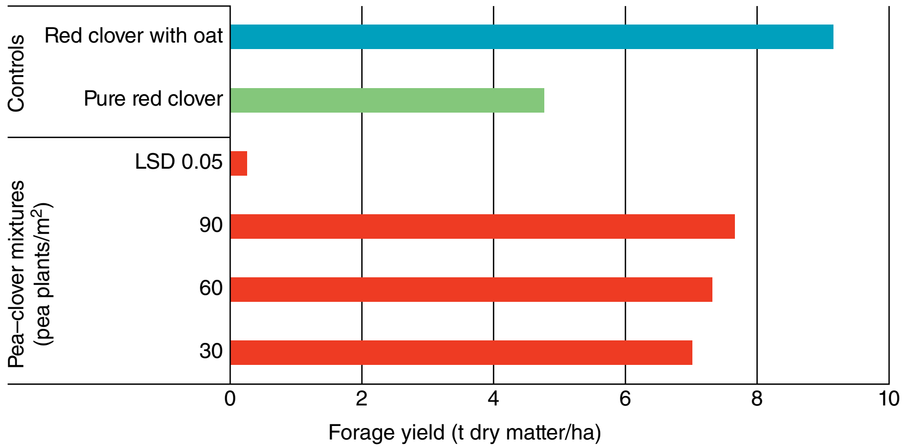

Fig. 12.4. Forage yields of red clover and mixtures of red clover with oats and pea. The three pea–clover mixtures with different pea plant populations (sowing rate of 30 pea plants/m^2, 60 plants/m^2 and 90 plants/m^2) are compared with a pure stand of red clover and red clover mixed with oat. LSD, Least significant difference. (From Ćupina *et al*., 2010c.)

legume as a companion crop instead of oat results in a lower proportion of the first-year yield coming from the first cut. On average, the proportion of the first cut in the annual yield may range from 50% to about 70% where pea is the companion crop, which is similar to the proportion of first cuts in pure stands. In comparison, where oat is used, a larger proportion of the first-year forage yield is in the first cut. The first-cut yield of lucerne intercropped with oat in the establishment year may comprise between 70% and nearly 100% of the total first-year yield. The reason is that oat intercropped with a perennial forage legume often reduces the forage yields in subsequent cuts during the establishment year (Lanini *et al*., 1991).

Mixtures of Annual Legumes

Compared with the intercropping of legumes with cereals, grasses and brassicas, reports of the intercropping of annual legumes species are rare. White lupin (*Lupinus albus* L.) used phosphorus more effectively when intercropped with soybean (*Glycine max* L.) than on its own (Braum and Helmke, 1995). Similarly, intercropping soybean and pigeon pea (*Cajanus cajan* L.) may mitigate the effects of an unpredictable drought (Ghosh *et al*., 2006a). Annual legume species rich in bioactive compounds, such as fenugreek (*Trigonella foenum-graecum* L.), are efficient in reducing the infection of faba bean by broomrape (*Orobanche crenata* Forssk.) (Evidente *et al*., 2007; Fernández-Aparicio *et al*., 2011). However, intercropping annual legumes with each other may cause undesirable effects, such as competition for nutrients that may reduce the growth of one legume, as in the case of intercropping pigeon pea with soybean, due to nitrogen deficiency (Ghosh *et al*., 2006b).

We have developed the intercropping of annual legumes for both forage and grain production (Ćupina *et al.*, 2011c). This began with an evaluation of several hundred accessions of numerous cool- and warm-season annual legume species of diverse geographic and genetic origin and status in the collection maintained in Novi Sad. The goal was to assess the potential of components in various two-way combinations as intercrops for forage and grain production (Antanasović *et al.*, 2011). The main conclusions of this research are illustrated in Fig. 12.5.

Annual legumes such as vetches with lodging stems suppress weeds, but forage yields are low because of the degradation of lower leaves. In contrast, faba bean (*Vicia faba* L.) is susceptible to weed infestation as a sole crop. Mixing these combines the good standing ability of the faba bean with weed suppression from the vetch. Intercropping using an incompatible mixture reduces yield by giving

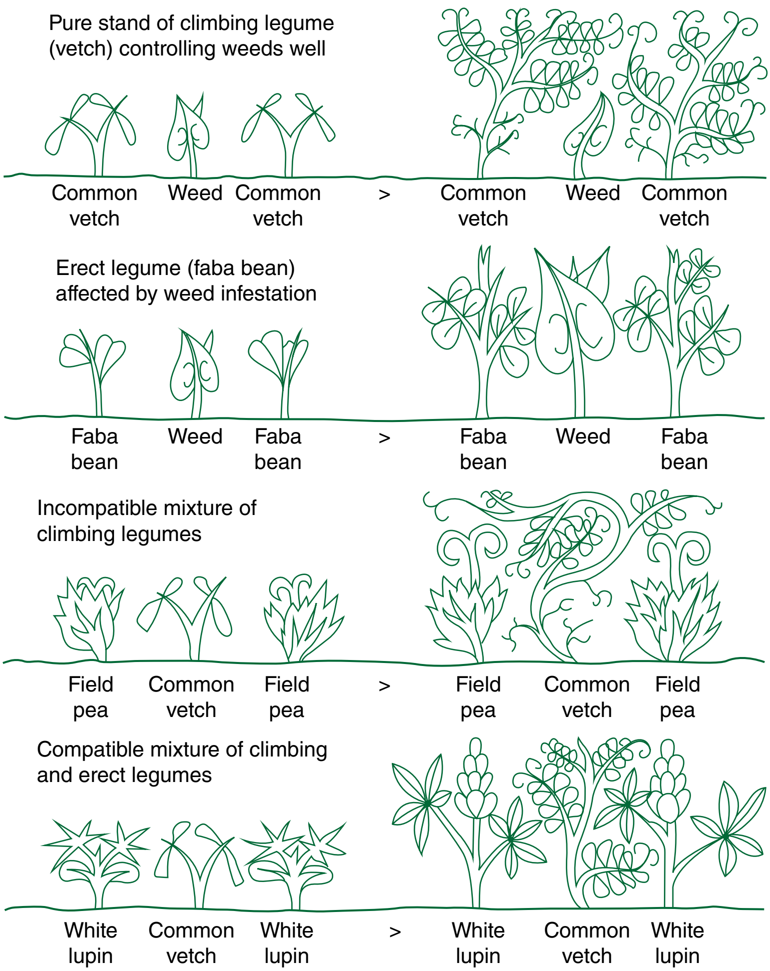

Fig. 12.5. Different approaches to intercropping annual legumes with each other. (From Ćupina *et al.*, 2011d.)

advantage to one component, such as common vetch (*Vicia sativa* L.), while severely affecting another one, such as semi-leafless pea. A compatible, functional and reliable intercropping is one such as white lupin and common vetch, providing the best possible conditions and effects.

On the basis of the results of our experiments and wider knowledge, we have established four basic requirements for a successful intercropping of two annual legume species for forage production (Ćupina *et al.*, 2011d).

1. Components should have the same optimum sowing time.
2. Components should have similar heights.
3. Components should have similar full flowering times to achieve a balance between forage yield and its quality.
4. One component needs to have a good standing ability (supporting crop) to complement the component that is more susceptible to lodging.

Annual Legume Forage Intercrops for Farm Use

From these requirements, we have examined the performance of three main groups of the annual legume intercrops that are expected to over-yield (Mikić *et al.*, 2012):

- autumn- and spring-sown 'tall' cool-season annuals;
- autumn- and spring-sown 'short' cool-season annuals; and
- early and late maturing warm-season annuals.

Each component of the two-way mixtures was included at 50% of its pure-stand seeding rate.

'Tall' cool-season annuals

For our autumn sowings, faba bean was the supporting crop, while forage pea, common vetch, Hungarian vetch (*Vicia pannonica* Crantz) and hairy vetch (*Vicia villosa* Roth) were the supported crops (Fig. 12.6). For spring sowing, faba bean and white lupin were the supporting crops, while forage pea, common vetch and grass pea (*Lathyrus sativus* L.) were the supported crops.

The performance of an intercrop is expressed using the land equivalent ratio (LER). This is the yield of the intercrop compared with the yield of the components grown separately on the same area of land, expressed as a ratio. An LER of 1.1 means that the intercrop had a 10% higher yield than the total of the components grown separately. Intercropping autumn-sown faba bean with common vetch proved especially effective with both contributing similarly to the total forage dry matter yield and an LER of 1.42 (Ćupina *et al.*, 2011d). These experiments also evaluated a range of seeding-rate relationships: 50%/50%, 75%/25% and 25%/75%. The intercrops of 50% faba bean with 50% of grass pea, and 75% white lupin with 25% grass pea had the best agronomic performance, with LERs for green forage yield of 1.44 and 1.21, respectively (Ćupina *et al.*, 2009). The

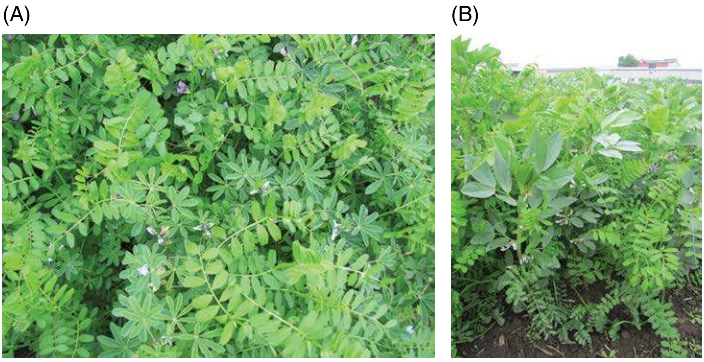

Fig. 12.6. Examples of intercropping 'tall' cool-season legumes: (A) autumn sowing – white lupin with common vetch; (B) spring sowing – faba bean with common vetch. (From Mikić *et al*., 2012.)

intercrops of white lupin with common vetch resulted in high values of LER for green forage yield in all three ratios, averaging 1.28 (Ćupina *et al*., 2011b).

'Short' cool-season annuals

'Short' cool-season annual forage legumes have short stems with fewer nodes, often determinate stem growth and more uniform stages of growth and development. In our experiments, the autumn-sown option comprised semi-leafless pea as the supporting crop and leafy pea and bitter vetch (*Vicia ervilia* (L.) Willd.) as the supported crop. The spring-sown option was leafy pea with lentil (*Lens culinaris* Medik.) serving as the supported crop.

Semi-leafless pea allows good light penetration into the stand, providing favourable conditions for weed growth, which is countered by the presence of the companion. Mixing these two types of pea increased forage yield (Table 12.1) (Ćupina *et al*., 2010a). The intercrops of autumn-sown semi-leafless pea with bitter vetch had an LER for forage dry matter yield of only 0.91, whereas that of spring-sown semi-leafless pea with lentil had an LER for forage dry matter yield of 1.09 (Mikić *et al*., 2012).

Warm-season annuals

Warm-season annual forage legumes are sown in late spring. In our trials, early- and late-maturing mixtures were tested. In the early-maturing group, soybean belonging to the 00 maturity group was the supporting crop, while several *Vigna* species, namely mung bean (*Vigna radiata* L.), adzuki bean (*Vigna angularis* (Willd.) Ohwi & Osashi) and black gram (*Vigna mungo* L.) were the supported crops. Within the late-maturing group, soybean belonging to a late-maturity group and pigeon pea served as supporting crops, while cowpea (*Vigna unguiculata* (L.) and hyacinth bean (*Lablab purpureus* (L.) were the supported crops (Mikić *et al*., 2012).

Table 12.1. Forage dry matter yields (t/ha) and corresponding land equivalent ratios (LER) in intercrops of pea cultivars with different leaf types at Rimski Šančevi during 2008–2010. (From Ćupina *et al*., 2010a.)

		Forage dry matter yield (t/ha)			
Season	Treatment	Supporting component	Supported component	Total	LER for forage dry matter
Winter	'Dove', pure stand	6.8	0.0	6.8	1.00
	'Frijaune', pure stand	0.0	7.8	7.8	1.00
	'Dove' + 'Frijaune'	5.1	3.0	8.1	1.13
Spring	'Jezero', pure stand	6.3	0.0	6.3	1.00
	'Javor', pure stand	0.0	6.4	6.4	1.00
	'Jezero' + 'Javor'	2.9	3.6	6.5	1.03
$LSD_{0.01}$[a]			0.8		0.08

[a]LSD, Least significant difference.

A schematic of the responses in these mixtures is depicted in Fig. 12.7. Regardless of its maturity group, a soybean crop provides favourable conditions for weed development and thus regularly requires intensive weed control measures. In contrast, cowpea and hyacinth bean are notoriously prone to lodging. Both develop a mass of creeping cover able to counter weed species but these may suffer losses of lower biomass and may be difficult to harvest due to lodging. When intercropped, soybean carries the cowpea or lablab plants preserving their protein-rich leaves combined with a significant benefit from essentially reduced weed infestation.

In the preliminary trials with intercrops of warm-season annual forage legumes carried out at Rimski Šančevi and Zemun Polje near Belgrade, almost all proved as economically reliable and superior to the pure stands (Mikić *et al*., 2010). Intercropping pigeon pea with hyacinth bean performed particularly well, with an LER for forage dry matter yield of 1.10. Additional data indicate that the performance of the intercrops of soybean belonging to the 00 maturity group with adzuki bean and black gram were better than the one with mung bean, with an LER for forage dry matter yield of 1.07 and 1.11, respectively (Mikić *et al*., 2012).

Conclusions

An annual legume used as the companion crop in the establishment of the perennial forage crop can increase total forage yields. The superiority of intercropping over pure stands is attributed generally to variations between species in morphological characteristics resulting in more efficient capture of resources. In addition, field pea as a companion crop contributes to improving forage quality and digestibility.

We conclude that legumes can be intercropped together successfully. It is emphasized that such intercrops do not increase the costs of crop establishment.

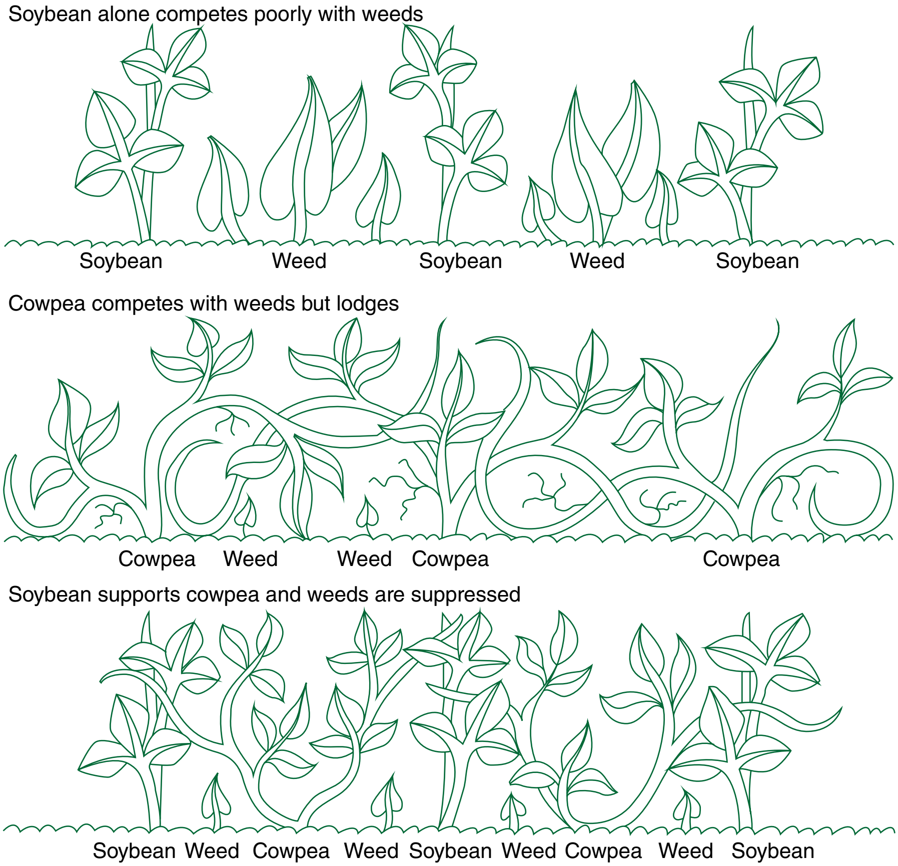

Fig. 12.7. Model of intercropping warm-season legumes. (From Mikić *et al*., 2012.)

At the same time, when both components in an intercrop are legumes, the crude protein content in forage dry matter remains high and does not decrease as happens in the case of intercropping with cereals. All three presented models of annual forage legume intercrops are characterized by short growing seasons and thus are able to fit easily into various cropping systems. Producing forage in such intercrops does not require the application of either synthetic nitrogen fertilizer, since both components are legumes, or herbicides, due to an enhanced weed control, and thus confirms its value as a true environment-friendly service.

There remain questions to address including: (i) the optimum ratios for individual intercrops; (ii) the impact of intercropping on forage yield components; (iii) possible correlations between total forage yields and their LER values; (iv) the chemical composition of the forage dry matter in the intercrop components; and (v) various underground aspects, with particular regard to microbiology and allelopathy. Reliable seed production of the intercropping-specific annual forage legume cultivars is also required in order to secure their successful use in general production.

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