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COVER CROPS FOR ENHANCED SUSTAINABILITY OF CROPPING SYSTEM IN TEMPERATE REGIONS

SUMMARY

The main aim of cover crops growing is protection of agro-ecological system. Increased usage of cover crops, particularly legumes and their mixtures can provide high quality food and feed, reduce the energy and greenhouse gas impacts of agriculture, improve soil fertility, reducing of nutrients leaching, prevention of soil erosion, reducing the needs for pesticides, water quality protection and help safe guard personal health. Benefits vary by location and season, but at least two or three occur with any cover crop. Cover crops are using to design new strategy that preserves farm natural resources while remaining profitable. Key to this approach is to see a farm as an agro ecosystem a dynamic relationship of the mineral, biological, weather and human resources involved in producing crops or livestock. This review aims to facilitate integration and progress in cover crops research and development in West Balkan countries, and the efficient tackling of problems, so that cover crops contribute to meeting environmental and health challenges.

Keywords: Cover crops, Ecosystem services, Greenhouse effect, Soil fertility.

INTRODUCTION

Increasing agricultural production is generally a desirable goal in the context of an increasing World human population (Carvalho, 2006). The intensification of agricultural practice during the second half of the XXth century, with more inputs (such as nitrogen, pesticides, irrigation) allowed significant yield improvement in most arable crops (Uphoff, 2002; Smith et al, 2007). However, at the same time, these types of farming systems, together with other human activities, have contributed to many negative environmental impacts leading to several risks or damages: greenhouse gas emissions, a consumption of fossil energy, the high use of pesticides and the use of increasing amounts of water for irrigation which contributes to the depletion of underground water (Potter et al, 1998). Arable crops are responsible of half of the world N2O emissions issued from human activities (Smith et al, 2007). Industrial nitrogen

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fertilisers are usually the major source (70 to 90%) of N2O emission linked to an agricultural product (Smart et al, 1999). A consumption of fossil energy, contributing to resource scarcity and this is also mainly linked to the use of more nitrogen fertilizers which represents more than 50% of the energy consumption in the farm systems based on arable crops. The high use of pesticides, leading to contamination of water, air and soils with risks of toxicity (Aubertot et al, 2006).

The use of cover crops is one measure that has been taken in agricultural production in order to increase environmental protection and to encourage sustainable use of natural resources (Dabney et al, 2001). The practice of cover cropping in some regions has gained importance in view of the decline of animal production and the related reduced availability of organic fertilizers. In the Vojvodina province, Serbia, fertile soils such as chernozem have suffered a significant reduction in humus content, in some cases as much as 50%, which justifies the introduction of cover cropping in commercial production (Cupina et al, 2011).

The integration of cover crops into cropping systems brings costs and benefits, both internal and external to the farm (Snapp et al, 2005). In annual cropping systems, cover crops are often included to maximize benefits such as biomass and nitrogen production. Cover crops can increase yields and at the same time, they can reduce costs, increase profits and even create new sources of income. Some studies showed that cover crops become more profitable as the price of nitrogen increases (Clark, 2007). Cover crops are using to design new strategy that preserves farm natural resources while remaining profitable.

Many cover crops offer harvest possibilities as forage, grazing or seed that work well in systems with multiple crop enterprises and livestock. Cover crops could be used also as green manures that are grown and tilled under to add nutrients and improve the soil. Smother crops are used to control weeds. Living mulches are planted around or beside cash crops for weed control. Catch crops are planted to ‘catch’ excess nutrients that might otherwise be leached from the soil (Sainju et al, 2001).

Cover crops offer many benefits to sustainable agriculture. According to Clark (2007) the main benefits of cover crops are:

- cut fertilizer costs
- reduce the need for herbicides and other pesticides
- improve yields by enhancing soil health
- prevent soil erosion
- conserve soil moisture
- protect water quality

By reducing reliance on agrichemicals for cash crop production, cover crops help protect the health of people. They also help address community health and ecological concerns arising from nonpoint source pollution attributed to farming activities. Benefits vary by location and season, but at least two or three occur with any cover crop (Clark, 2007).

RESULTS AND DISCUSSION

Cover crops in temperate regions?

In temperate regions there are suitable conditions for planting and growing annual cover crops after a cash crop is harvested in late summer/autumn and before the next cash crop is planted the following spring (Teasdale et al, 2007). Species from the family of grasses (*Poaceae*) and crucifers (*Brasicaceae*) are commonly used as winter cover crops. The dominant cover crop species in temperate grain systems are cold-tolerant species, such as cereal rye or rye grass (Tonitto, 2006). They are efficient in the uptake of residual nutrients from the soil (Kuo and Jellum, 2002). Cereal cover crops produce the largest amount of biomass and should be considered, when the goal is to rapidly build soil organic matter (Snapp et al, 2005). Most non-legume cover crops do not fix nitrogen, but they can affect soil nitrogen availability. Small grains can absorb large quantities of nitrogen from the soil, thereby reducing the potential for nitrate leaching. Because of the high carbon-to-nitrogen (C/N) ratio of grasses, their residues decompose slowly, and soil nitrogen availability may be substantially decreased following their incorporation into the soil. Several species in the *Brassicaceae* family also readily take up nitrogen. Due to lower C/N ratios, however, these species decompose and release their absorbed nitrogen into the soil more rapidly than grasses (Dean and Weil, 2009). If soil pests are a major yield limiting factor in cash crop production, then the use of brassica cover crops should be considered (Haramoto and Gallandt, 2005; Snapp et al, 2005).

Fast-growing cover crops such grasses and crucifers hold soil in place, reduce crusting and protect against erosion due to wind and rain (Sarrantonio, 2007b). They can be grown whenever the soil is left bare for part of a season. After harvest, more cover crops can be planted and provide cover throughout the winter. For example, common vetch, once established, forms an excellent living ground cover and a thick mulch after it dies (Wallace and Scott, 2008). Hairy vetch, or mixtures with rye or another small grain can reduce erosion, add N and organic matter to the system (Clark, 2007). Rye provides soil protection on sloping fields and holds soil loss to a tolerable level (Edwards et al, 1993). As a spring crop, barley holds soil strongly to minimize erosion during droughty conditions (Clark, 2007).

For ecological reasons, legumes (*Fabaceae*) are gaining increasing importance (Brandsaeter and Netland, 2000), since nitrogen use in arable lands is the cause of several major environmental problems, and since additional nitrogen is needed by all arable crops, except legumes. Legume cover crops can be easily included in a crop rotation and, in contrast to grasses and crucifers, contribute additional N to the nutrient cycle by symbiosis (Evans and Taylor, 1987; Thorup-Kristensen et al, 2003). Most of the symbiotic N is used for legume growth (Peoples et al, 1995) and is therefore accumulated in organic matter. Some of this N can be used later as animal feed in the form of protein in herbage (Kramberger et al, 2007) while the rest of the accumulated N can be taken up by subsequent crops after ploughing-in and mineralisation of the organic matter (Vaughan et al, 2000; Andraski and Bundy, 2005). Legume-cereal mixtures show great potential over a wide range of niches (Snapp et al, 2005). According to Sainju et al (2001) bi-culture legume-cereal cover cropping may enhance above and below ground biomass yield and C and N content. The increase in C and N supply to the soil has the potential to improve soil quality and crop productivity compared with monoculture cover crop species.

The absence of nitrogen fertilizer on the legume crop and the reduction of fertilizer amount required by the following crop, due to highly efficient nitrogen mineralisation, allows a significant reduction of fossil energy consumption and of greenhouse gas emissions. For example, in the Barrois region in France or Saxe-Anhalt in Germany, Nemecek et al (2008) showed a reduction of 50% for energy consumption of a pea crop compared with oilseed rape, wheat or barley crops, leading to an average reduction of 13% for a rotation which includes 20% of legumes; 50% for the greenhouse gas emissions for the pea crop compared with the other crops, and of 14% for a rotation including pea, compared with the rotation without pea; up to 18% for the acidification per hectare of the rotation including pea compared to the reference one without pea.

Effect of cover crops on subsequent crop

Use of cover crops has benefits for both the soil and the subsequent crop. After mineralisation of ploughed-in cover crops, accumulated N is available for subsequent crops in the field crop rotation. When a legume cover crop is incorporated into the soil, a substantial amount of nitrogen is usually mineralised within a few weeks. Nitrogen continues to mineralise in ensuing weeks as the organic matter decomposes (Snapp et al, 2005). Recently, emphasis has been placed on the uptake of soil mineral N which could otherwise be leached as NO_3 into deeper soil layers and ground water (Shipley et al, 1992; Logsdon et al, 2002), lost during nitrification as NO and N_2O, or denitrified as N_2 (Jenkinson, 2001). The contribution of symbiotically fixed N by winter legume cover crops to the nitrogen cycle in field rotation can exceed one hundred kilos N per hectare (Mueller and Thorup-Kristensen, 2001; Gselman and Kramberger, 2008) with beneficial effects on the succeeding crop in the rotation (Sainju and Singh, 2001; Hanly and Gregg, 2004). The succeeding crop recovery of N was estimated from 10-36% of total N in legume residues (Ranells and Wagger, 1996; Peoples et al, 2004; Tonitto et al, 2006).

In two year field experiment Cupina et al (2011) studied the effect of cover crops grown as green manure on the dynamics of NO_3-N in the soil, before and after ploughing-in of the cover crops. The additional goal of this trial was to assess the effect of the cover crops on the yield and quality of Sudan grass. Three sole cover crops and one mixture were included in the experiment, namely wheat-W, field pea-FP, mixture of field pea and wheat-FP/W and oilseed rape-OSR, as well as mineral fertilization treatments, namely 40 kg N ha^{-1} (N_1) and 80 kg N ha^{-1} (N_2) and an unfertilized control.

Cover crops and N treatment significantly affected the soil Nmin content. At the first two sampling dates-before cover crop sowing and at the beginning of the spring growing season of the cover crop, soil nitrate content was higher in the non-cropped treatments i.e. in the control (bare fallow) and the mineral fertilization treatments (Fig. 1). This can be explained by the fact that, when sampled, these treatments had no plants that could uptake N from the soil. The lowest soil Nmin content was in winter wheat and its mixture with field pea as a consequence of intensive N uptake by the plants. After the first and second cut of Sudan grass, results of soil sampling has shown that the treatment with winter field pea had the highest Nmin content. This is a result of intensive mineralization after the ploughing-in of the legume crop (Chavez et al, 2004; Boldrini et al, 2006) and it’s due to significant removal of N by the Sudan grass yield in other treatments. The lowest soil Nmin content was recorded in the treatments with winter wheat, crop mixture and the crucifer, which also had the lowest yields of Sudan grass. Significant correlation (*r* = 0.86**) was established between soil Nmin content at the end of the growing season (after the second cutting) and the total yield of Sudan grass. The correlation between soil NO_3-N content at the time of ploughing-in and the first cut on one side and yield on another were not statistically significant.

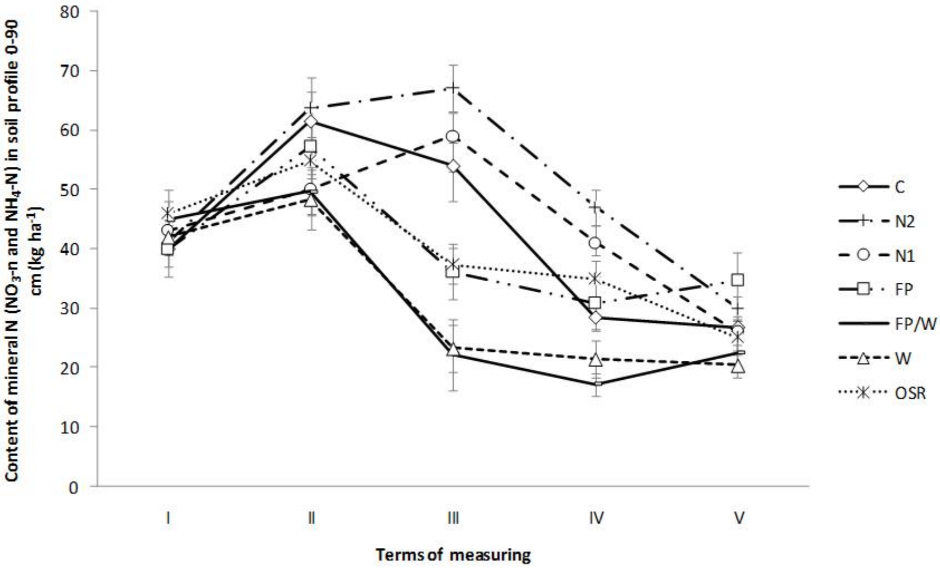

Figure 1. Dynamic of mineral nitrogen (NO_3-N and NH_4-N) in the soil during the trial period (average of 2005 and 2006). Bars represent standard error of means.

In the treatments with field pea and its mixture with wheat, the contents of symbiotically fixed N were 140.97 and 53.9 kg N ha^{-1}, respectively (Tab. 1). On the other hand, C/N ratio was the highest in treatment with OSR and lowest with field pea, which should be take into consideration in case of using cover crops for improving organic matter content.

Table 1. Effects of cover crop on the ploughed-in biomass dry matter yield (BDMY), content and the amount of in biomass accumulated N, C/N ratio and symbiotically fixed N

Parameter	Cover crops			
	W	FP	FP/W	OSR
N content (%)	1.79	3.24	2.57	1.10
C/N ratio	28	16	21	33
Symbiotically fixed N (kg ha^{-1})	-	140.97	53.93	-

Positive effect of symbiotically N fixation resulted in significantly higher apparent N remaining in the soil (ARNS) in treatment with legume. The highest nitrogen contribution was in the field pea (165.26 kg N ha^{-1}), while the control and N_1 had negative N balances

(- 59.48 kg N ha^{-1} and -25.40 kg N ha^{-1}, respectively) (Tab. 2).

Table 2. Nitrogen content in above ground Sudan grass yield (N yield), and apparent N remaining in the soil (ARNS) after Sudan grass harvesting as affected by cover crop and fertilization treatments (average 2005-2006)

Treatments/Cover crops	N yield (kg N ha^{-1})	ARNS (kg N ha^{-1})
W	106.65b	41.55c
FP	123.91a	165.26a
FP/W	108.10b	94.03b
OSR	112.61ab	0.37e
C	113.48ab	-59.48g
N1	110.27ab	-25.40f
N2	132.52a	29.0c

The yields of Sudan grass following the addition of N_2 and field pea cover crop were higher than the control, while they were on the same level as the control after cover crops of oilseed rape and the mixture of wheat-field pea. Wheat produced the lowest yield of Sudan grass, due to nitrogen deficiency after ploughing-in. The N_2 treatment had the highest crude protein content at the first cut and the lowest at the second cut (Tab 3).

Non-leguminous cover crops, which typically have low N content show little or no beneficial effects on the succeeding crops and in some cases the effects are even, negative (Kuo and Jellum, 2002). Raimbault et al (1990), Choi and Daimon (2008) reported that reasons for possible negative effects of cover crops on the succeeding crops in field rotation are also soil moisture depletion by cover crops in spring, while Munawar et al (1990) mentioned allelopathy. Water use by cover crops can adversely impact yields of subsequent dryland crops in semiarid areas (Dabney et al, 2001). Despite concerns about water use, many farmers are interested in cover crops because of the potential for improved nutrient cycling and biological N2 fixation. According to Fernando et al (2005) agricultural practices involving cover crops, such as species, fertilization, kill date, and tillage significantly affect subsequent crop yields. On the other hand, Andraski and Bundy (2005) found that beneficial cover crop effects were primarily the result of a rotation effect rather than direct N contributions from the cover crop. Cherr et al (2006) claim that the cover crops used may be substituted only for a relatively small portion of synthetic N rates. From this point of view the economic aspect of crop production should be taken into consideration.

Table 3. Effect of cover crops on Sudan grass DM yield (t ha^{-1}) and crude protein content (%) (Two-year average 2005-2006)

Treatment	Yield			Crude protein	
	First cut	Second cut	Total	First cut	Second cut
W	5.13 b	2.55 d	7.68 d	8.76 b	8.60 a
FP	5.64 ab	3.67 ab	9.32 a	8.51 b	8.12 ab
FP/W	4.83 b	3.39 b	8.23 c	8.52 b	7.91 bc
OSR	5.06 b	3.59 ab	8.66 b	8.00 b	8.41 ab
N1	5.09 b	2.99 c	8.08 c	8.66 b	8.40 ab
N2	5.77 a	3.85 a	9.62 a	9.68 a	7.55 c
C	5.37 ab	3.42 b	8.80 b	8.56 b	7.56 c
Average	5.06	3.35	8.63	8.67	8.08
2005	4.67 b	4.20 a	8.87 a	8.36 b	31.99 b
2006	5.87 a	2.49 b	8.37 b	8.98 a	34.43 a

Values followed by the same letter within columns are not significantly different ($P < 0.05$)

The field pea cover crop, achieved the highest dry matter (DM) and N yield. According to Snapp et al (2005) cereal cover crops produce the largest amount of biomass and should be considered when the goal is to rapidly build soil organic matter. But, for enhancing cash crop yields, legume cover crops are the most reliable means compared with fallow or other cover crop species.

As a conclusion Cupina et al (2011) reported that management decision concerning the use of cover crops should be based on the balance between farm profitability and environmental sustainability. The effect of cover crops on the Sudan grass yield and quality varied from positive (FP and FP/W) to negative (W). N mineralization should be regulated in accordance with the N demands of the subsequent crop. In animal production areas, cover crops can be an important source of quality forage or can be used for mulching. In such cases and in rotation with Sudan grass, cover crops should fulfil the following requirements: low-cost production, yield and quality, N uptake during periods critical for leaching and no negative effects on subsequent crops.

Agronomy practice of cover crops

For adequate establishing and use of cover crops it is necessary to identify a goal, a time and a place, as well as the desirable characteristics of cover crops.

Improper management of cover crops can lead to substantial yield loss of cover crop as well as subsequent cash crop (Wortman et al, 2012). Since cover crops have different functions, it is important to determine what the crop is expected to do. The main benefits of cover crops can be gained by careful selection of appropriate plant species (Guldan and Martin, 2003). Thus, fitting a cover crop into the sequence of a crop rotation must be taken into consideration. Fast-growing, drought-tolerant cover crops that require minimal management are preferred. Cover crops with fast germination and good seedling vigour are usually chosen because of their ability to compete with weeds (Olorunmaiye, 2010). Also, species with the potential to reduce pest populations should be chosen, while those that harbour harmful diseases or pests of the cash crops should be avoided (Dabney et al, 2001; Ilnicki and Enache, 1992).

Rotational fit. One of the biggest challenges of cover cropping is to fit cover crops into current rotations, or to develop new rotations that take full advantage of their benefits (Clark, 2007). Selection of cover crops is much easier when the crop rotation or cash crops have already been determined (Sarrantonio, 1994). It is well known that after brassica species, another one should not be grown. It is possible to plant hairy vetch or a grass-legume mixture in fall, terminate it the following spring at flowering, and plant sorghum-sudan grass (Cupina et al, 2011). The winter cover crop provides weed suppression and ground cover, and if it is a legume - significant amount of N is left in the soil for the subsequent crop.

Seeding time. Some cover crops grow well in the summer and others are great for autumn growth. In many regions it's need to seed winter covers at least six weeks before a hard frost. Winter cereals, especially rye, are an exception and can be planted a little later. If ground cover and N recycling needs are minimal, rye can be planted as late as the frost period for successful overwintering (Sarrantonio, 2007a). Any cover crop planted in the early spring or fall should be somewhat frost-hardy (Wallace and Scott, 2008). Fast-growing summer annuals provide erosion control, weed management, organic matter and perhaps some N. It is need overseeding a spring crop with a fast-growing summer grain such as sorghum-sudangrass or a warm-season legume such as cowpeas (Sarrantonio, 2007a). Cover crops with strong and deep taproots are good for breaking up hardpans and bringing up nutrients from deep in the soil. Extensive root systems (ray, raygrass) are good for catch crops. Winter cover crops hold potential to capture excess NO_3^- and reduce leaching by recycling nutrients (Brandi-Dohrn et al, 1997). The fibrous root systems of grasses and cereals add organic matter, as well as help control erosion and compaction (Table 4.) (Wallace and Scott, 2008).

Maintenance. Some cover crops may need weed control at first, or may need to be mowed to prevent them from going to seed while some cover crops are difficult to till in without mowing first (eg. annual grasses and vetches) (Wallace and Scott, 2008). The cover crop can't use too much water or tie up nutrients at key periods. Too much N might stimulate excessive leaf growth or prevent hardening off before winter. Cover crop which is easy to maintain, it should: be a perennial or reseeding annual, be low-growing, needing minimal management, use water efficiently, have a soil-improving root system, release some nutrients during the year. (Sarrantonio, 2007a).

Table 4. Properties and role of cover crops (Clark, 2000)

Plant species	Nitrogen (kg ha^{-1})	DM yield (t ha^{-1})	N scavenger	Soil builder	Erosion protection	Weed fighter	Quick growth	Lasting residue	Duration of growing season	Harvest value	
										F	G
Annual grasses	-	3-8	4	5	5	4	5	4	3	3	2
Ray	-	4-10	5	5	5	5	5	5	4	2	2
Sorghum sp.	-	8-12	5	4	5	4	5	4	5	5	1
Brassica sp.	-	4-10	3	3	2	4	5	3	4	5	2
Vetches	90-200	2,5-5	2	4	4	4	2	2	4	2	2
Field pea	90-150	4-5	2	3	4	3	4	2	3	5	4
Lupine	200-300	3-5	3	3	3	2	2	2	3	3	4
Red clover	70-150	2-6	3	4	3	4	3	2	3	5	3
White clover	80-120	2,5	2	3	4	4	2	2	5	4	3
Alfalfa	50-120	2-4	2	2	3	4	5	3	4	4	3

F-Forage, G-Grain

Legend: 1-very poor, 2-poor, 3-good, 4-very good, 5-excellent

Cover crop compatibility with another. Cover crops should provide weed control, either through smothering the weeds or by allelopathic suppression. Living mulches however, should not compete with crops (Wallace and Scott, 2008). Species mixtures for cover cropping show great potential over a wide range of niches. Selecting a single species is often popular among farmers due to the ease of planting, uniform development, and predictable termination efficacy of the cover crop (Creamer et al, 1995; Mirsky et al, 2009). However, often a combination of cover crops is better than planting one alone (Wallace and Scott, 2008). Multi-species mixtures may increase productivity, stability, resilience, and resource-use efficiency of the cover crop community (Tilman et al, 2001; Wortman et al, 2012). A mixture of legume and nonlegume species may maximize the benefits of biological N2 fixation and nutrient cycling, as legumes can increase N availability to other species in mixture leading to increased productivity (Kuo and Sainju, 1998; Mulder et al, 2002). With hairy vetch and a vetch/rye mixture, summer soil water conservation by the cover crop residue had a greater impact than spring moisture depletion by the growing cover crop in determining corn yield (Clark et al, 1997; Clark et al, 2007a). Companion seed a winter annual cover crop with a spring grain, or frost seed (broadcasting seed onto frozen ground) a cover into winter grains. Soil freezing and thawing pulls seed into the soil and helps germination (Sarrantonio, 2007a). Mixtures of small grains with winter peas and the vetches had C:N values from 13 to 34, but were generally under 25 to 30, the accepted threshold for avoiding net immobilization of N (Ranells and Wagger, 1997).

Cover crops for establishing perennial legumes

Klesnil et al (1980) and Matejkova (1982) claimed that pure crops of perennial legumes produced significantly lower forage yields than intercrops, as well as that their slow growth during establishment increased their vulnerability to weed invasion. However, intercropping with short-season crops, such as field pea (*Pisum sativum* L.) and vetches (*Vicia* spp.), significantly increased forage yield and quality and reduced incursion of weeds. In general, intercropping with perennial legumes is deemed to be an effective method of agricultural and, more specifically, forage production because it offers greater yield stability, higher yields, reduced weed competition, an increase in protein content within a mixed diet and a higher land-use efficiency (Anil et al, 1998). An annual forage crop, when sown as the companion, can provide an economic yield during the establishment of the perennial forage crop (Lanini et al, 1991; Joanne et al, 2001; Tan et al, 2004) and so producing a return in the seeding year (Sturgul et al, 1990; Chapko et al, 1991).

In the West Balkan Countries and beyond, it is small grains, primarily oats (*Avena sativa* L.) and barley (*Hordeum vulgare* L.), that are traditionally intercropped with perennial legumes, although these tend to be too fast-growing and therefore too competitive for the legume component (Ćupina et al, 2010b). Such companion crops compete with weeds, but also with the undersown species, reducing yield and in some cases the persistence of the stand (Tesar and Marble 1988; Nickel et al, 1990).

Annual legumes such as field pea and vetches are suitable for intercropping with perennial forage legumes because the crop can be harvested quickly and the canopy structure is not dense enough to cause suppressive shading. Because of its short growing season, field pea and vetches are suited to be harvested when the first (establishment) cut of perennial legumes is due (Koivisto, 2002). Cultivars of field pea with semi-leafless leaves and with short stems could be more adapted for intercropping since the light penetration is much stronger, providing better conditions for the initial growth of the undersown crop (Cupina et al, 2006). In addition, including peas in this arable mixture makes possible to improve forage quality and digestibility, that is, to increase the forage crude protein content and to decrease both neutral (NDF) and acid (ADF) detergent fiber (Chapko et al, 1991). To mitigate the effect of competition among the intercropped plants, it is recommended that the normal seeding rate of the companion crop be reduced (Lanini et al 1991; Vough et al, 1995; Ćupina et al, 2000), what requests that the optimum stand density (the number of plants of the companion crop per unit area) needs to be determined (Tan et al, 2004).

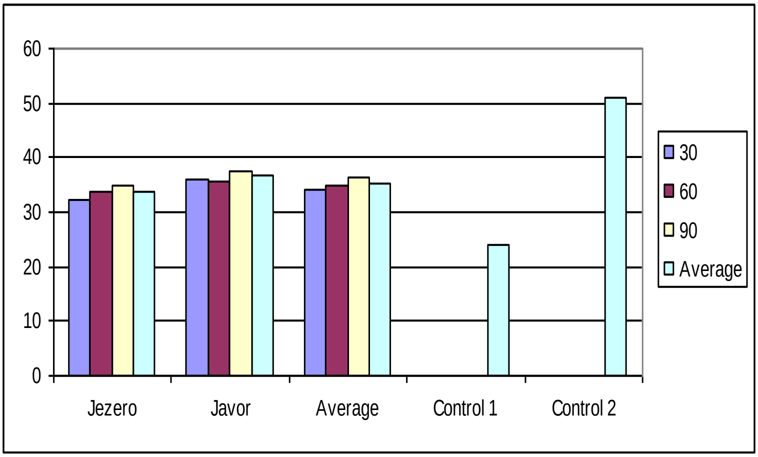

Figure 2. Effect of field pea cultivar and plant population density (30, 60 and 90 m^{-2}) on two-year average green forage yield (t ha^{-1}) when intercropped with red clover, with pure stand of red clover as control 1 and red clover + oat as control 2 (Cupina et al, 2010b)

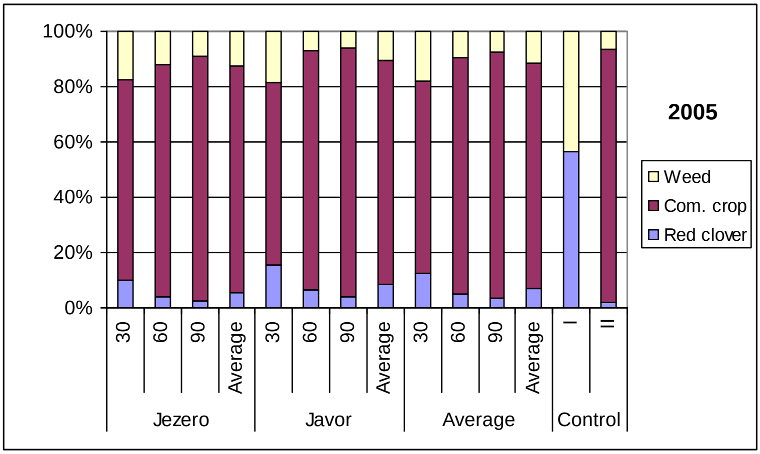

Figure 3. Weed proportion (%) in the first cutting of red clover intercropped with field pea (Cupina et al, 2010b)

Vough et al (1995) also recommended to cut the companion crop early for forage, as opposed to its use for grain, to reduce its competition with the undersown species. The second reason for using the companion crop for forage is to reduce the risk of lodging prior to a grain harvest (Tesar and Marble, 1988). Cupina et al (2010b) reported that the highest forage yields and the lowest weed proportions were obtained by the highest plant number (90 m^{-2}, Figure 3 and 4) of field pea as a cover crop. It should be noticed that the difference in the forage yields in the intercropping between 90 plants m^{-2} and 60 plants m^{-2} in the first cutting was not statistically significant (Figure 2). In the subsequent red clover cuttings, the difference decreases (first cut) (Figures 2), while the yield was equalized in the first year of utilization. Regarding the economic side, it could be recommended that in the wide production a lower seed rate (60 plants m^{-2}) of field pea companion crop is used. Those authors also reported that the highest forage yields were obtained in intercropping with oat as a control. However, according to Cupina et al (2006), yield performance is not the only criterion for determining the suitability of pea as a cover crop. The forage coefficient of digestibility in the diet of ruminants should be considered as important as yield performance. Smith et al (1972) and Obračević (1990) report that the digestibility coefficients of red clover, field pea and oat at the harvestable stage are 71%, 79% and 54%, respectively.

In the same trial, the authors reported that the pure red clover stand had the highest weed proportion while there were differences in weed proportion between field pea cultivars. The weed proportion, just like the red clover proportion, decreases with increasing the plant number of the companion crop (Figure 3). Lanini et al (1991) also found that using an oat companion crop also reduced the number of weeds in the alfalfa (*Medicago sativa* L.) by up to 50%, over a solo seeded control.

For intercropping, particularly with perennial legumes, it is important to check for possible negative effects on the undersown crop in the first cut, subsequent cuts and the total annual yield. Cupina et al (2006) reported that companion cropping contributed to the forage yield in the first cut and therefore to the total annual yield. In average, the proportion of the annual yield derived from the first cut ranged from 50% to 69% when field pea was included, 58% in the pure crop (two cuts) and as much as 79% when sown with oats (control variant). It is supported by Lanini et al (1991) who found that yield from the first cut of perennial forage legume (alfalfa) and oat mixture in the establishment year comprised from 71 to 98% of the annual yield. These authors also maintained that undersown crop yields at subsequent cuts during the establishment year were reduced by the oat companion crop. Thus, intercropping perennial legumes with field pea results in adequate yield in all cuttings which provides more organic matter and forage.

CONCLUSIONS

In conclusion, it is urgent to change cropping systems in temperate region in order to achieve the environmental requirements of a more durable development. However, the evolution of cropping systems requires the involvement of all the stakeholders and actors influencing agricultural practices. Thus the design new cropping systems requires the involvement of a diversity of actors and the implementation of participatory methods.

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GAJENJE MEDJUUSEVA U CILJU POVEĆANJA ODRŽIVOSTI BILJNE PROIZVODNJE U USLOVIMA UMERENOG KLIMATA

SAŽETAK

Osnovni cilj gajenja medjuuseva je zaštita agro-ekološkog sistema. Povećanje učešća medjuuseva, posebno leguminoza u biljnoj proizvodnji ima za cilj obezbedjenje zdrave hrane za čoveka i životinje. Značaj gajenja međuuseva ogleda se u: smanjuje potrošnja energije i efekta staklene bašte, smanjenju troškova đubrenja, čuvanju zemljišne vlage i sprečavanju ispiranja hraniva, popravci fizičkih, hemijskih i bioloških osobina zemljišta, sprečavanju erozije, smanjenju upotrebe pesticida, očuvanju kvaliteta vode i očuvanju životne sredine i zdravlja čoveka uopšte. Navedene koristi od međuuseva značajno zavise od konkretnih agroekoloških uslova proizvodnje. Međuusevi imaju izrazito važnu ulogu i javljaju se kao neizostavna karika u proizvodnji zdravstveno bezbedne hrane, uz očuvanje prirodnih resursa, pri čemu se istovremeno ostvaruje i profit. Ključni pristup za takvu koncepciju je vidjenje farme kao agroekosistema koji predstavlja dinamičan odnos zemljišnih, vremenskih, bioloških i ljudskih resursa uključenih u biljnu i stočarsku proizvodnju. Rad ima za cilj da se sagleda potencijal i značaj gajenja medjuuseva u regionu Zapadnog Balkana, kao i promociju njihovog uključivanja u sistem održive poljoprivrede.

Ključne riječi: Medjuusevi, ekosistem, efekat staklene bašte, plodnost zemljišta.