

Legume-Livestock System as a Solution for Sustainable Agriculture: A Review

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Abstract. Legumes constitute one of the most important groups of crop production. They are particularly attractive for livestock production because of their unique ability to fix the atmospheric nitrogen biologically. This review presents the high potential of legume-based systems, by indicating their socio-economic and environmental benefits for sustainable agriculture and livestock production. Lower chemical nitrogen inputs, efficiency in crop rotation combined with higher yields, increased soil productivity, applicability in mixed farming systems as well as improvement of livestock production are considered as highly significant advantages associated with the cultivation of legumes. Despite these advantages and expectations, their cultivation meets some constraints which limit their potential. Further research and increasing knowledge are required, in order to overcome challenges at the production and market level.

Keywords: legumes; livestock production; sustainability; livestock-crop systems; circular economy.

1 Introduction

Legumes represent the second most important family of crops in economic terms after *Poaceae* (grass family), accounting for approximately 27% of the world’s crop production (Mlyneková, et., al., 2014). The family of legumes (*Fabaceae* or *Leguminosae*) includes several important plants, such as soybean, vetch, pea, chickpea, lentil, lupine, bean, alfalfa, clover and peanut. They are grown for human consumption or for animal nutrition, as coarse feed (forage) or seeds for concentrates. They are also cultivated as green fertilizer plants, as they are included in crop rotation systems and their residuals are integrated in order to increase soil productivity. The introduction of legumes in livestock production especially, has been an issue of high importance during the last two decades, as many researches in Europe have focused on the potential of legumes to contribute to sustainable and low-cost livestock production (Rochon, et., al., 2004).

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The pods of legumes are rich in carbohydrates and are known for their high nutritional value. Indeed, legumes contribute by about one-third to human direct protein intake worldwide (Mlyneková, et., al., 2014). The benefits from their consumption are accepted by different societies around the world and have been associated with longevity in the food cultures of many peoples such as the Japanese, the Swedes and in the Mediterranean (Darmadi-Blackberry, et., al., 2004). They constitute the main protein source in the diet of the population of developing countries, since proteins of animal origin are scarce and costly in these areas, and they are sometimes referred to as the “meat” of poor people (Nedumaran, et., al., 2015). Legumes are also steadily gaining higher significance in developed countries as well, as they are included in healthier diets and lifestyles.

In Greece, the adoption rate of legumes in farm production remains low. The most commonly cultivated legumes are chickpeas, lentils, peas and beans. The limited cultivated areas, in combination with the unavailability of seeds and varieties adapted to the specific conditions of each region imply deficient production, unable to cover domestic consumption and livestock needs. This leads to high imports of legumes for human consumption and soybean for livestock use. In 2017, Greece imported 649008 tons of soybean and soy flour (ELSTAT, 2017). Producers achieve low yields combined with high production costs, thus not valorizing the high potential of legumes, which is mainly associated with the beneficial climate and soil conditions of Greece.

The purpose of this study is to examine the importance of legumes at a socio-economic level by investigating their benefits for production systems. In particular, the review builds around the main issues concerning the production and use of legumes especially in livestock production as well as the possibilities to create sustainable legume-livestock systems.

2 Decrease in Nitrogen Inputs

The great importance of legumes, in relation to other types of crops, is based on their ability to fix the atmospheric nitrogen, so that their nitrogen needs can be partially or completely covered. This happens because of the symbiosis of legumes with *Rhizobium* bacteria. Because of this attribute, legumes can be used as a source of nitrogen in both natural and agricultural ecosystems (Mlyneková, et., al., 2014).

The unique ability of legumes to fix atmospheric nitrogen, implies their ability to grow satisfactorily in soils with low nitrogen availability. By fixing nitrogen, legumes could maintain and improve soil fertility, which results in the reduction of expenses for chemical fertilizers (Kebede, et., al., 2016). This is really important, considering that prices of chemical fertilizers are rapidly increasing in recent years and their use will be limited in the long term (Kebede, et., al., 2016). Cropping systems with legumes can reduce nitrogen fertilizer use by 38%, compared to systems without legumes (Reckling, et., al., 2016). Substitution of industrial nitrogen fertilizer by improved use of nitrogen fixed by legumes could be an important contribution to resource-efficient and environmental-friendly agricultural systems (Luscher, et., al., 2014).

3 Efficiency in Crop Rotation and Yield Advantage

The enrichment of soil with nitrogen can be beneficial in cases of crop rotation, since nitrogen can be used by the next crop installed after legumes. The importance of using legumes in different types of crop rotation systems has been known since ancient times in Ancient Greece, Egypt and China.

The inclusion of legumes in a well-planned crop rotation reduces insect, diseases and pest, improves organic matter levels and soil productivity and increases crop yield (Kebede, et., al., 2016). The fixed nitrogen leads to higher protein concentration in soil, which can also be recycled as a form of fertilizer (Kebede, et., al., 2016). As a result, subsequent crops do not require the use of chemical fertilizers, which implies economic and environmental benefits.

Except for their advantages in terms of sustainable production, legumes entail yield benefits in crop rotations. Under standard fertilization levels, cereals yield is on average 17% higher in legume-based rotation systems than in monocropping cultivations (Stagnari, et., al., 2017). Studies have also proven that wheat reports higher yields grown in rotation after legumes (Stagnari, et., al., 2017). It should also be mentioned that yield advantages of legumes depend on the climate conditions of a specific area, on the amount of fixed nitrogen, as well as on the species (Stagnari, et., al., 2017).

4 Benefits in Livestock Production

The most important advantage of legumes in livestock production is related to the use of soybean in animal nutrition. Soybean is the only legume whose acreage is continuously increasing in Europe, reaching 3.45 million ha in 2012, more than all the other legumes together (Rubiales & Mikic, 2015). However, the highest percentage of international soybean production comes from genetic modified plants. As a result, the European Union and national governments promote the cultivation of other legumes with subsidies (Rubiales & Mikic, 2015) as an alternative to soybean. In addition, soybean is only imported in Greece (Table 1) since it is not cultivated in a domestic level, which implies higher and uncertain production costs for livestock farms. As a result, the use of legumes to substitute soybean is considered important for countries like Greece.

Table 1. Soybean and soy flour imports 2015-2017 in Greece.

Year	2015		2016		2017	
Soybean Imports	Value (million €)	Quantity (thousand tons)	Value (million €)	Quantity (thousand tons)	Value (million €)	Quantity (thousand tons)
	116,3	302,0	115,7	315,5	118,9	317,8
Soy flour Imports	Value (million €)	Quantity (thousand tons)	Value (million €)	Quantity (thousand tons)	Value (million €)	Quantity (thousand tons)
	112,0	278,6	104,6	293,5	111,3	331,3
Total	228,3	580,6	220,3	609,0	230,2	649,1

Source: ELSTAT, 2017

Legumes were suggested as a sustainable solution for livestock production many years ago. It is expected that, by increasing the availability of legumes, livestock farms will benefit from a cheap and good quality protein source. In Greece, the use of legumes in livestock production is really important, considering that animal nutrition with legumes produced on-farm will be able to reduce production costs, as well as the dependence of farms on imported feedstuff.

There is also evidence that the inclusion of legumes in animal nutrition affects the quality of produced milk in a positive way. Legume silages and legume-dominated silages can increase milk production compared to pure grass silages (Luscher, et., al., 2014). Rations including legume silages led to high levels of performance of dairy cows, especially when legumes were of a high nutritive value. Similar results were reported for beef production (Luscher, et., al., 2014).

5 Legumes in Mixed Farming Systems and Circular Economy

The use of legumes in mixed farming systems is another significant factor associated with the advantages of legumes at the socio-economic level, as they can be used as forage in animal nutrition. Legumes species also represent excellent sources of green manure in sustainable agriculture and organic farming (Kebede, et., al., 2016). The contribution of legumes in mixed farming systems is recognized, since production costs can be reduced by using lower amount of coarse feed. This also implies that these systems pertain to circular economy principles, since they can operate as economic systems aimed at eliminating waste, via the circular use of their resources, forage and manure.

Indeed, mixed farming systems involve complementary interactions between crops and livestock, which means that legumes can be a basic component because of their unique characteristics. The use of manure for cropping as well as the use of crop residuals for livestock constitutes important interactions between livestock-crop systems (Kebede, et., al., 2016). The uncertainty of agricultural activities can also be reduced through mixed farming systems because of internalizing part of the input

requirements of farms due to the combination of livestock and crop enterprises (Kebede, et., al., 2016).

In general, the integration of the forage legumes instead of grass could contribute a more preferable option for livestock-crop systems. The possibility of nitrogen fixation, the continuity of feed supply, the increased crop productivity, the high coarse feed quality and the use of manure as fertilizer can secure a sustainable production (Kebede, et., al., 2016).

6 Challenges and Limitations

Legumes suffer from some limitations, which implies the need for further research in order to fully develop the opportunities they offer (Luscher, et., al., 2014). Besides the growing trends observed between 1974 and 2014, the cultivated areas of species such as pea, bean and lupine have declined worldwide (Stagnari, et., al., 2017). The average yield increase for most legumes was about 50%, which is still below the increases achieved by major cereal crops, which ranged between 130 to 160% (Rubiales & Mikic, 2015). Poor spring growth, unavailability of seeds, limited farmers' knowledge on the appropriate use of the fixed nitrogen and management of legumes in a whole cropping system, as well as animal health issues are the main reasons of concern about the viability of legume-based systems.

There are also limitations regarding their adoption by mixed farming systems. Nutrient management in livestock-crop systems remains a challenge, especially regarding nitrogen losses in managing manure (Reckling, et., al., 2016). The adoption of forage legumes is also restricted in some farms in many European countries (Reckling, et., al., 2016).

Market constraints are also of high significance. Although the global market is very well developed for soybean, supply chains and markets in general are inadequately prepared for the majority of legumes crops (Stagnari, et., al., 2017). There is also evidence that immediate profits are not delivered to producers from the introduction of legumes into a farming system because of the high diversification of legumes production trends around the world (Stagnari, et., al., 2017). This is the main reason why there is a high preference for cereals from farmers in Europe and they will need to be more convinced by future research that the cultivation of legumes has profitable potential. Low prices and few marketing channels affect legumes' commercialization in a negative way. Prices are currently lower than the actual feed value, which means that legumes produced in European countries have difficulties in the competition with other protein crops of the world market (Reckling, et., al., 2016). Undoubtedly, there are still a lot of challenges and constraints that need to be overcome for legumes to increase their reliability in production systems and their competitiveness in global markets.

7 Conclusions

The advantages of legumes are numerous and should become even more significant in the following years. The opportunities emerging from legume-based systems are important in socio-economic terms and environmental perspective. Due to their unique characteristics, they can secure more rational use of chemical fertilizers, increase in soil productivity, efficiency in crop rotations and benefits in livestock production. Their introduction in mixed farming systems has a high potential as well. However, legumes are still not competitive and widespread. In order to overcome possible constraints and limitations, their positive effects need to be communicated to advisors and farmers, and regional supply chains need to be developed in food markets (Reckling, et., al., 2016). Further research is required to increase attractiveness and confidence for producers. There is also a need for research on how to integrate them in mixed farming systems. Agronomic knowledge is required and has to be more widely available. Finally, agricultural policy measures have to be introduced and implemented specifically for legume-based systems, so that their economic and ecological benefits can be valorized.

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