DOI: 10.46793/SBT30.05VS

RED CLOVER IN AGRICULTURAL PRODUCTION SYSTEMS

Vladeta Stevović[1], Dalibor Tomić [1], Dragan Đurović[1], Đorđe Lazarević[2], Igor Đurđić[3] Milomirka Madić[1], Nenad Pavlović[1], Miloš Marjanović[1]

Abstract: Legumes can make a very significant contribution to sustainable crop production systems. Red clover (*Trifolium pratense* L.) has a potential contribution to sustainable production, due to its impact on increasing soil fertility. It is characterized by high biomass yields of excellent quality, high protein content and a high degree of nitrogen fixation. Since the middle of the last century, the area under red clover has been constantly decreasing globally, mainly due to cheap synthetic nitrogen fertilizers. However, interest in growing this legume is growing, due to the increase in the price of mineral fertilizers, especially recently, as well as the need to produce bulky animal feed on one's own farm. It is also very important in many organic production systems. The paper analyzes the importance of red clover in agricultural production systems, with the aim of reducing the negative impact of agriculture on the environment.

Keywords: crop rotation, forage, nitrogen fixation, red clover, sustainable agriculture

Introduction

Red clover is the second most important perennial forage legume in the world, both in terms of area sown, which is immediately behind alfalfa, and in terms of seed production/sale and number of varieties (Boller et al., 2010). This forage legume has a long history of cultivation in Europe, where, in addition to pure crops, it is also grown in mixtures with grasses, especially in short-term grasslands. Red clover has played an important role in the change, in the past period, of the highly prevalent, unsustainable systems of animal feed production. As a component of new production systems, it has been the basis for a significant increase in total agricultural production (Kjærgaard, 1995). The main change in these systems was based on the replacement of three-field by four-field crop rotations, in which fallow was replaced by red clover. This has,

[1]University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, Čačak, Serbia (vladeta@kg.ac.rs)
[2] Institute for Forage Crops, Globoder bb., 37251, Serbia
[3]Faculty of Agriculture, University of East Sarajevo, East Sarajevo, Bosnia and Herzegovina

among other things, led to an increase in soil fertility and an increase in the yield of certain cultivated plants, for example, small grains, the yields of which have increased by more than two times (Grigg, 1992).

The most important properties of red clover are: easy establishment of crops, high seedling vigor, rapid growth, high forage quality and improved soil properties after the period of exploitation. High genetic plasticity and adaptability enable almost global cultivation of red clover (McKenna et al., 2018). A very favorable feature of this species is that with plant aging, the quality of forage does not decline as quickly as with grasses. Therefore, mixtures of red clover and grasses can be used as fresh or conserved forage for ruminants for a longer period of time, without significant loss of quality (Dewhurst et al., 2009).

Since the middle of the last century, the area under red clover has been steadily decreasing globally, mainly due to cheap synthetic nitrogen fertilizers. Interest in growing this leguminous plant is rising, due to the increase in the price of mineral fertilizers, especially recently, as well as the need to produce bulky forage on one's own farm (Stevović et al., 2020).

Red clover is mainly used for making hay or silage for feeding ruminants. It can also be used as a component of pastures, but this will certainly reduce its production potential, because red clover does not tolerate grazing as well as, for example, white clover. In addition to forage production, red clover can also be used as a green manure plant. As a forage crop, it leaves significant amounts of nitrogen for the next crop.

The aim of the paper was to analyze the importance of red clover in different agricultural production systems, in purpose of reducing the negative impact of agriculture on the environment.

The role of red clover in improving soil fertility

In order to contribute to sustainable agricultural production, leguminous species, such as red clover, must be included in crop rotations. The very narrow crop rotation of two cultivated plant species – maize and winter wheat, which is used on the largest part of arable land in the Republic of Serbia, should be expanded by growing some leguminous plant species. Even in areas where the crop rotation includes three cultivated plant species (maize – soybean – winter wheat), the introduction of red clover crop is proposed (Wyngaarden et al., 2015; Loucks, 2017). Increased divergence of cultivated plants, i.e. crops, leads to an increase in the total yield and better resistance of the system to various environmental pressures – drought, diseases, nutrient uptake from the soil, humidity (Gaudin et al., 2015).

Red clover is characterized by a very high nitrogen fixation capacity; according to Carlsson and Huss-Danell (2003), the amount of nitrogen fixed in the above-ground part at the annual level can exceed 350 kg ha^{-1}. In a mixture of red clover and grass, about 80% of the nitrogen in the forage originates from nitrogen fixation (Carlsson and Huss-Danell, 2003).

The need for inoculation of red clover seeds usually does not exist, because most of our soils contain effective rhizobia in sufficient numbers. In mixtures containing red clover, the transfer of fixed nitrogen to non-legume plants is lower than in mixtures with white clover (Høgh-Jensen and Schjoerring 2000), and higher than in mixtures with alfalfa (Frankow-Lindberg and Dahlin, 2013). This transfer increases during the growing season, and according to data from Høgh-Jensen and Schjoerring (2000) and Dahlin and Stenberg (2010), it can exceed 70 kg ha^{-1} per year. Since red clover is a short-lived species (two to three years), it is often included as a legume in short-term grasslands on arable land, where it leaves significant amounts of nitrogen for the next crop.

Growing red clover in mixtures with grasses

In addition to pure crops, red clover is also widely grown in mixtures with grasses. This production method usually achieves higher forage yields, better weed control, and lower disease incidence (Frankow-Lindberg et al. 2009; Tomić et al. 2012). In addition, nitrogen leaching from the soil is much lower in mixtures of red clover and grasses than in pure red clover crops (Frankow-Lindberg and Dahlin, 2013). The recommended ratio of red clover seed to grass depends on the primary purpose. When the primary goal is maximum protein yield, red clover should dominate the mixture. To achieve this, the amount of red clover seed is usually standardized at 12–15 kg ha^{-1} and grass at 4–5 kg ha^{-1} (Frame et al., 1998). Smaller amounts of red clover seed, or larger amounts of grass seed, are usually applied to lawns, that are intensively fertilized with mineral nitrogen (Tomić et al., 2014). In order to increase and stabilize the share of legumes in the mixture, and thus the longevity of the lawn, another legume, most often white clover, can be added to the red clover (Frankow-Lindberg et al., 2009).

The amount of fixed nitrogen in red clover-grass mixtures is an important parameter in the standardization of mineral nitrogen (Nyfeler et al., 2009). Recent studies have shown, that in most cases, nitrogen is not needed for the next growth after mowing. The amounts of nitrogen added at the beginning of the growing season depend mostly on the presence of red clover in the mixture, and are always negatively correlated. However, during this period it is usually difficult to determine the proportion of red clover, on the basis of which the required amounts of nitrogen would be normalized, which otherwise has the strongest impact on forage yield in the first cut (Frankow-Lindberg, 2017).

The grass component in the mixture with red clover is most often timothy grass (*Phleum pratense* L.), due to its low competitive ability. In addition to this species, for certain agro-ecological conditions and production purposes, meadow fescue (*Festuca pratensis* Huds.), perennial ryegrass (*Lolium perene* L.), less often Italian ryegrass (*Lolium multiflorum* Lam.) (Tomić et al., 2012), hybrid ryegrass (*Festucololium*) or false oat-grass (*Arrhenatherum elatius* L.) (Tomić et al., 2018).

The role of red clover in the diet of domestic animals

Red clover forage is a high-quality feed, not only for ruminants (Dewhurst et al., 2009), but also for pigs (Reverter et al., 1999) and fish (Turan, 2006). Its forage is rich in proteins and minerals; ruminants willingly consume it due to the mechanical properties of its tissue, which differ from those of grass, because its forage is much easier to grind in the rumen and passes through it faster than grass forage (Dewhurst et al., 2009).

Unlike most other legumes, red clover forage contains the enzyme polyphenol oxidase, which during forage digestion provides a number of positive properties, such as reduced nitrogen (ammonia) emissions to the external environment during protein breakdown in the rumen (Parveen et al., 2010), as well as improved milk and meat quality. This enzyme is responsible for the synthesis of quinone, a compound that binds to proteins, thereby reducing protein degradation during the silage fermentation process. This improves silage quality and reduces nitrogen losses during fermentation (Lazarević et al., 2023). Polyphenol oxidase also reduces protein breakdown in the rumen (Parveen et al., 2010), which leads to increased nitrogen uptake efficiency in ruminants fed red clover, compared to animals fed white clover (Dewhurst et al., 2009). This enzyme reduces the biohydrogenation reaction of polyunsaturated fatty acids in the rumen (Van Ranst et al., 2011), thereby increasing the content of α-linolenic acid in the milk of cows fed red clover silage, compared to animals fed grass silage (Dewhurst et al., 2009). Milk from cows fed red clover silage contains low concentrations of the isoflavone equol, which may positively affect the health of consumers of such milk (Tham et al., 1998). An unfavorable feature of red clover is the presence of isoflavones (especially formononetin) in the feed, which exert an estrogenic effect, which is assumed to negatively affect the fertility of sheep (Dewhurst et al., 2009).

Red clover feed can be part of the pig diet, however, its higher proportion in the diet may lead to a decrease in protein digestibility compared to a classic grain-based diet (Andersson and Lindberg, 1997). However, protein digestibility in the small intestine is slightly lower (Reverter et al., 1999), indicating that this feed is still an excellent source of protein for monogastric animals.

Conclusion

Red clover has played a significant role in changing the previously widespread, unsustainable systems of animal feed production; as a component of new systems, it represents the basis for a significant increase in overall agricultural production.

Mixtures of red clover and grass can be used as fresh or conserved feed for ruminants for a long period of time, without significant loss of quality.

Unlike most other legumes, red clover forage contains the enzyme polyphenol oxidase, which during the digestion of forage gives a number of positive properties, such as reduced nitrogen (ammonia) emissions into the external environment during the breakdown of proteins in the rumen, as well as improved milk and meat quality.

Interest in growing red clover is rising due to the increase in the price of mineral fertilizers, especially recently, as well as the need for the production of bulky animal feed on one's own farm and its importance in many organic production systems.

Acknowledgement

The research presented in this article is part of Projects Ref. No. 451-03-66/2024-03/200088 and 451-03-66/2024-03/200217 was funded by the Ministry of Science, Technological Development and Innovation, Republic of Serbia.

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