ratar. povrt.

original scientific paper / originalni naučni članak
Ratar. Povrt. 2016, 53(2): 46-52
doi:10.5937/ratpov53-10119

Direct Undersowing of Degraded Stands with Annual and Perennial Legumes in the Northern Bulgaria

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Summary: The possibility of annual and perennial legume crops to be used for undersowing of degraded pasture stands and alfalfa seed production stands was studied in the conditions of the Northern Bulgaria. The direct undersowing of degraded pasture stands was done after harvest with these legumes: birdsfoot trefoil (*Lotus corniculatus* L.), red clover (*Trifolium pratense* L.), black medick (*Medicago lupulina* L.), arrowleaf clover (*Trifolium vesiculosum Savi*), and common vetch (*Vicia sativa* L.). The undersowing of degraded seed production stands of alfalfa was done in autumn of the fourth year of using with subterranean clover (*Tr. subterraneum ssp. brachycalicinum* cv. Antas). Red clover showed the best results in terms of suitability for the direct undersowing of degraded pasture stands. Subterranean clover could be used for the direct undersowing of the degraded alfalfa seed production stands due to its self-seeding ability.
Key words: direct undersowing, degradation, legumes, alfalfa, pastures, arrowleaf clover, subterranean clover

Introduction

The permanent changes having occurred in the last ten-year period in the climate (increase of average annual temperatures, long droughts in spring and summer, increase of CO_2 concentration in the atmosphere) present a serious risk to the agricultural crops (Mannetje, 2006; Gornall et al., 2010; Aranjueloa et al., 2014). They have a negative impact on the species composition, productivity and quality of dry matter, as well as their durability. Climate change requires adaptation of forage crops and mixtures to the changed conditions and greater efficiency of resource use (Lelièvre & Volaire, 2009).

Direct undersowing is used to recover and/or prolong the persistence of the degraded pastures and meadows. It is applied in degraded stands, where the legume components are dropped due to the short duration, less adaptability to over use, adverse soil and climatic conditions, or other factors. By including legumes crops through this method, it is expected that it prolongs the durability of the stands, enhance the productivity and quality of the forage (Springer, 1997).

When selecting the legume for the direct undersowing, it is necessary to provide for its adaptability to the habitat, for which it is intended, the sowing rate as well as the regime of use of the stands (Abusuwar et al., 1993; Riday, 2008). For areas with a temperate climate mostly used legume crops for this purpose are clovers (*Trifolium* spp.), birdsfoot trefoil (*Lotus* spp.) and alfalfa (*Medicago* spp.) (Entz et al., 2007; Escaray et al., 2012).

Arrowleaf clover is an annual legume crops with winter type of development. It is characterized by high productivity and excellent quality of the forage (Ovalle et al., 2010; Naydenova et al., 2014). This legume is used successfully for undersowing of couch grass pastures in the United States (Han et al., 2012; Freeman et al., 2014).

Red clover (*Trifolium pratense* L.) is defined as a legume with the greatest potential to meet the objectives of the direct undersowing, due to the rapid initial growth of seedlings in the conditions of competition, tolerance of shade and good compatibility with the most common types of forage grasses (Riday, 2008; Mihovski, 2009; Naydenova et al., 2013).

Black medick (*Medicago lupulina* L.) is water-saving and easily-maintained turf legume with high protein and low fibre content and it is suitable for grazing (Cao et al., 2003).

At present, crops that can provide self-sowing and persist continuously in the stands become of practical importance (Carneiro, 1999; Nichols et al., 2012; Bartholomew, 2014). Such is subterranean clover (*Trifolium subterraneum* L.) - an annual drought resistant ephemeral legume with winter-spring type of development (Yakimova & Yancheva, 1986; Piano et al., 1996). As a nitrogen-fixing crop it is a widespread component in the pastures and other grasslands of the

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temperate areas of Central and Northern Europe and America (Pecetti & Piano, 1998, 2002; Nichols et al., 2013). Studies with this crops over the past years show that it has a practical application for the climatic conditions of Bulgaria (Vasilev, 2006; Vasilev & Vasilev, 2012a; Vasilev & Vasilev, 2012b; Vasileva et al., 2011, 2015; Vasileva, 2015; Ilieva et al., 2015). The effective utilization of autumn-winter soil moisture, successful seed formation and self-sowing at the end of spring allow to the subterranean clover to avoid summer droughts (Piano et al., 1996; Porqueddu et al., 2003).

The objective of this work was to assess the results of direct undersowing of degraded pasture stands and degraded alfalfa seed production stands with annual and perennial legume crops in the conditions of Northern Bulgaria.

Materials and Methods

Experimental work was carried out on two locations in Bulgaria as follows:

1. Direct undersowing of degraded pasture stands with adapted genotypes (varieties and local populations) annual and perennial legumes. Experimental work was carried out through undersowing of pasture stands, categorized as municipal land, used for unregulated grazing in the area of town of Pavlikeni (43°24' N, 53° 32' E, 144 m), Bulgaria. The field trial was laid down in the autumn of 2013 with an area of the experimental plot of size of 5 m², four replicated. Direct undersowing was done with the following types of legumes: birdsfoot trefoil (*Lotus corniculatus* L.), a local pasture ecotype; red clover (*Trifolium pratense* L.), cv. Nika 11; black medick (*Medicago lupulina* L.), local population (from the area of the town of Pavlikeni); arrowleaf clover (*Trifolium vesiculosum* Savi) wild population (from the area of Strandja) and common vetch (*Vicia sativa* L.), the selection line.

The sowing rate for birdsfoot trefoil, red clover, black medick, and arrowleaf clover was 2000 germinated seeds per m², and 400 germinated seeds per m² for common vetch. The sowing was done in the middle of October 2013 after the harvesting of the pasture stands. Plant samples of 0.25 m² were taken from the each replication and determined as follows: in the first year after undersowing (2014) – relative ratio of the legumes (%) (weight) (used for undersowing) during the spring growth (May) and autumn regrowth (October); during the second year after undersowing (2015) – relative ratio of legumes (%) during the spring growth (May), regrowth of the second cut (June) and autumn regrowth (October). The plant height of the legumes was measured (cm) during the spring growth (for red clover - during the formation of the first cut (May); for arrowleaf clover - at the beginning of July 2015 during the flowering).

2. Direct undersowing of degraded seed production stands of alfalfa with subterranean clover. Experimental work was carried out on the experimental field of the Institute on Forage Crops, Pleven (43°23'N, 24°37' E, 109 m), Bulgaria, on soil subtype leached chernozem. The long plots method was used, the size of the plot of 5 m² and 4 replications. Alfalfa seed production stands (cv. Pleven 6) was sown in 2007 and carried during the vegetation according to the common technology. In the autumn of the fourth year (2010) of exploitation, cross the lines undersowing was done with subterranean clover. *Tr. subterraneum ssp. brachycalicinum* (cv. Antas) was used and undersowing was done with 400 number of germinated seeds m^{-2}. Four cuts were obtained during the first and second year after undersowing (2011 and 2012), and three cuts during the last year (2013). Before the each cutting plant samples were taken from 0.25 m² and the relative ratio of the subterranean clover (%) was determined, as well the plant height (cm) was measured. The experimental data were processed statistically using SPSS software (2012).

Results and Discussion

1. Direct undersowing of degraded pasture stands with adapted genotypes (varieties and local populations) annual and perennial legumes. Growing season of 2014 was characterized by very wet conditions during summer months. The amount of rainfall was 578 l/m² vs. 367 l/m² in 50 year period (Table 1). In 2015, temperatures and rainfall did not deviate from the climatic norm for the area, with the exception of July, when high drought was observed.

The best results in the year after undersowing (2014) are obtained from the red clover and black medick (Figure 1). The highest relative ratio of common vetch was observed during the month of May (24.1%). No seedlings were recorded during the spring of the first experimental year for birdsfoot trefoil and arrowleaf clover. The ratio of red clover was above 90% and the ratio of the black medic above 50% in the end of vegetation.

Large ratio of red clover compared to other legumes in terms of direct undersowing was related to the biology characteristics of this species, namely the rapid growth of seedlings as well as tolerance to shading (Sheaffer et al., 2003; Riday et al., 2008). Gorski et al. (1984) and Oleszek et al. (1992) found allelopathic activity of black medick. According to the authors, black medick contains up to 2.5% of the dry matter hemolytic saponins, which exhibit allelopathic action against the grasses, suppressing germination and growth. We assume that this is the reason for the good results obtained from the undersowing in 2014.

In the second year after undersowing due to differences in the development of clovers, arrowleaf clover had small ratio in the stands in May, when the first cut of perennial grasses was formed. Arrowleaf clover presence was approximately 50% in June, when the second cut of red clover was formed (Table 2).

Table 1. Agrometeorological conditions for the period of 2013-2015

Months/years	2013		2014		2015	
	t	rainfall	t	rainfall	t	rainfall
	°C	l/m²	°C	l/m²	°C	l/m²
January	0.5	34.0	1.5	38.0	2.1	27.0
February	4.6	45.0	3.5	4.0	2.7	39.0
March	6.9	39.0	10.0	89.0	7.3	76.0
April	14.5	66.0	13.2	68.0	12.4	40.0
May	22.0	43.0	17.8	93.0	19.8	66.0
June	21.8	112.0	21.6	91.0	21.0	86.0
July	23.2	78.0	23.4	106.0	25.6	20.0
August	24.7	16.0	24.3	12.0	24.8	72.0
September	19.4	14.0	18.3	115.0	19.9	47.0
October	13.5	94.0	12.4	94.0	11.6	38.0
November	9.4	34.0	6.0	54.0	9.7	51.9
December	0.6	3.0	2.6	85.0		
Av/sum	13.4	578.0	12.9	849.0	14.3	562.9

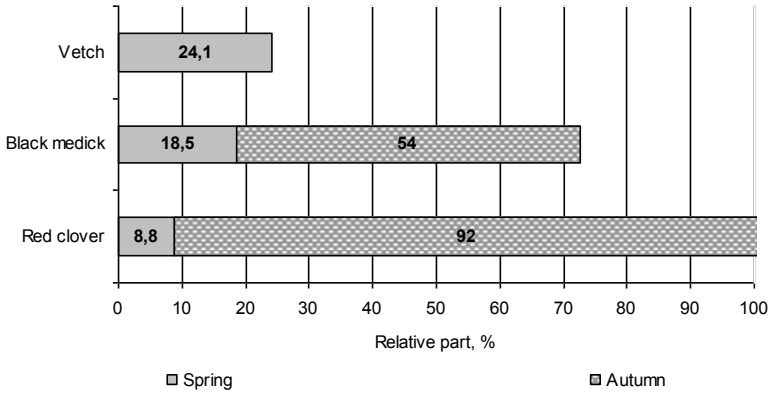

Figure 1. Relative ratio of legumes in the stands during the year after undersowing (2014)

Due to late sowing and winter type of development, arrowleaf clover appeared in the stands in the second growing season (2015) after the second wintering, which is an indicator of good storage of seeds in the soil seed bank. In the conditions of the Central Northern Bulgaria the seeds of arrowleaf clover showed good environmental adaptation. This biological characteristic could be used in practice.

For areas with Mediterranean climate, the selection of arrowleaf clover for hardiness of the seeds is leading, which allows its gradual emergence and thus self-supporting in the stands for several years, although it is an annual type (Loi et al., 2005). Subterranean clover has similar behaviour. Naydenova et al. (2014) found that this genotype of arrowleaf clover sown before September 10 germinates in autumn, overwinters successfully, has slowly spring development, but until July 10 to 15 develops dense stands, 50-60 cm tall, with a strong branched generative stems.

It is believed that the development of sown seeds of plants has been slow due to the existing competition. Considering the characteristic height/ length of the generative stems for red clover and arrowleaf clover, it is seen that these crops were considerably lower in comparison with the same when the stands were created by a standard method (Table 3). In contrast, black medick and common vetch (this breeding line), which is of wintering type, did not react to the undersowing by reducing the length of the generative stems.

Table 2. Relative ratio of legumes in the stands during the second year after undersowing (2015)

Undersown species	Spring growth	Second cut	Autumn regrowth
	May	June	October
Birdsfoot trefoil	0.0	0.0	0.0
Red clover	81.4	88.6	71.3
Black medick	0.0	0.0	0.0
Arrowleaf clover	27.6	48.5	0.0
Vetch	0.0	0.0	0.0

Table 3. Height of the plants during the spring growth (first cut) and pure stands created by standard technology (Naydenova et al., 2012; 2014)

Under sowed species	Height, cm		
	direct undersowing		standard technology
	2014	2015	
Red clover	28.85±1.20	34.45±3.39	70.2
Black medick	31.35±1.74	0.0	30.6
Arrowleaf clover	0.0	24.70±1.38	53.3
Vetch	55.60±1.90	0.0	54.5

To succeed in a type after undersowing, the sowing rate should be above a certain threshold, which is specific to the species as well to its habitat. Therefore it would be good if different sowing rates were studied. We assume that the sowing rate should be increased in vetch and birdsfoot trefoil. It does not neglect the fact that the used genotypes are most adapted to the conditions of the experiment, as they were selected exactly for those of Central North Bulgaria.

2. Direct undersowing of degraded seed production stands of alfalfa with subterranean clover. Agrometeorological conditions during the period of the experiment could be determined as unfavourable (Table 4). In the year after undersowing long dry period with extremely high temperatures was occurred. Unevenly distributed rainfall and long (duration 82 days) drought in summer are characteristics of the second experimental year.

Despite the unfavourable conditions experienced throughout the period, subterranean clover self-seeded successfully and its participation in the cuts is presented in Figure 2. In the first year after undersowing the ratio of subterranean clover in the first cut reached 22%. In the next cuts it was present but insignificant - there were self-seeded plants, but the their height was up to 5.3 cm (data not shown).

The participation of subterranean clover in the second year reached 10% in the first and second cuts. During the formation of third and fourth cuts of alfalfa, the agrometeorological conditions were extremely unfavourable for the development of all crops, due to the prolonged drought.

During the third year after undersowing from the three obtained cuts, subterranean clover participated in the stands of the first and second cuts. Its ratio was 6.8% in the first and 5.2% in the second cut.

The most developed plants were in the first cut, when they used autumn-winter moisture for germination (Table 5). During the third experimental year after undersowing, the plant height in the first cut varied from 13.7 cm to 17.5 cm.

In the second cut better developed plants were those from the second and third year after undersowing. This is related to the biology of the crops, as well as the agrometeorological conditions. Precipitation in late summer facilitated emergence of new self-seeded plants.

Table 4. Agrometeorological conditions for the period of 2011-2013

Months/years	2011		2012		2013	
	t	rainfall	t	rainfall	t	rainfall
	°C	l/m²	°C	l/m²	°C	l/m²
January	-1.0	32.8	-0.1	44.2	0.5	19.0
February	0.2	27.2	-5.2	17.8	3.9	60.9
March	6.1	25.7	8.5	7.6	6.3	39.6
April	11.4	28.2	14.8	46.3	14.0	50.8
May	16.8	79.8	17.4	85.2	19.5	63.7
June	21.4	33.6	24.1	40.3	21.3	112.4
July	23.5	50.2	27.8	1.4	22.7	105.8
August	23.6	41.3	25.8	35.6	24.9	20.2
September	22.0	0.0	21.1	21.0	18.4	15.8
October	11.1	50.2	15.0	56.0	12.2	59.2
November	7.6	0.4	8.1	4.0	8.7	29.1
December	3.9	28.6	-1.0	56.7	0.2	2.3
Av/sum	12.2	398.0	13.0	416.1	12.7	578.8

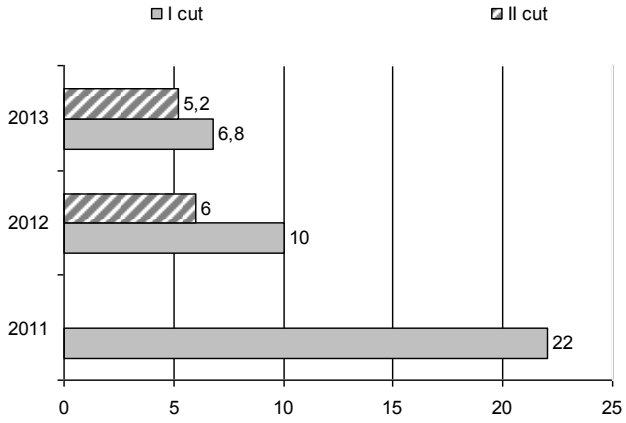

Figure 2. Relative ratio (%) of subterranean clover in under sowed degraded seed production stands of alfalfa

Table 5. Height of self-seeded subterranean clover plants (cm) in degraded seed production stands of alfalfa

Cuts	Plant height, cm		
	2011	2012	2013
I	17.5±0.4	16.6±0.61	13.7±2.31
II	5.3±1.1	10.7±0.58	10.7±0.58
III	4.0±1.6	0.0	0.0
IV	3.7±1.5	0.0	

±, STDEV

Conclusions

Red clover showed the best results regarding the suitability of the adapted genotypes (varieties and local populations) of annual and perennial legumes for direct undersowing of degraded pasture stands. Black medick and arrowleaf clover have potential importance as crops for undersowing, but the concretization of the technology is needed to ensure their presence in the stands for the years of period.

Subterranean clover can be used for direct undersowing of degraded seed production alfalfa stands. It is an annual leguminous species, but because of the biological ability for self-seeding, with the presence at the beginning and end of growing season, it behaves as a perennial type with extended durability of the stands.

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Direktno podsejavanje degradiranih parcela jednogodišnjim i višegodišnjim mahunarkama u severnoj Bugarskoj

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Sažetak: U uslovima severne Bugarske ispitivana je mogućnost korišćenja jednogodišnjih i višegodišnjih mahunarki za podsejavanje degradiranih pašnjaka i lucerišta za semensku proizvodnju. Degradirani pašnjaci su direktno podsejani nakon žetve sledećim mahunarkama: žuti zvezdan (*Lotus corniculatus* L.), crvena detelina (*Trifolium pratense* L.), obična vija (*Medicago lupulina* L.), gušava detelina (*Trifolium vesiculosum Savi*) i obična grahorica (*Vicia sativa* L.). Degradirana lucerišta za semensku proizvodnju su podsejana podzemnom detelinom (*Tr. subterraneum ssp. brachycalicinum* cv. Antas) u jesen četvrte godine korišćenja. Crvena detelina je pokazala najbolje rezultate što se tiče pogodnosti za direktno podsejavanje degradiranih pašnjaka. Podzemna detelina bi se mogla koristiti za direktno podsejavanje degradiranih lucerišta za semensku proizvodnju zbog sposobnosti da sama zaseje svoje seme.
Ključne reči: degradacija, direktno podsejavanje, gušava detelina, lucerka, mahunarke, pašnjak, podzemna detelina

Received: 14 January 2016, Accepted: 25 February 2016
Published online: 2 August 2016