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Impact of the seeding and nitrogen fertilizer rates of spring wheat that is used as a cover crop on the yielding ability of tetraploid red clover stand established at different seeding rates

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Abstract. In the years 2013–2014, a field trial was conducted at the Estonian Crop Research Institute in order to investigate a possibility of using spring wheat as a cover crop in the establishment of red clover seed field. In the trial the cover crop had four different seeding and fertilization rates. Two tetraploid red clover cultivars, 'Varte' (early) and 'Ilte' (late), were seeded at rates 2, 4, 6 and 8 kg PLS per hectare in four replications. In the year of sowing the height and density of generative tillers of spring wheat, the grain yield and its quality, the number of red clover plants per m², and the seed yield of red clover and its quality in the 1st year of harvest were determined. Economic feasibility was calculated based on the prices valid at the time of trial conduction. The trial confirmed that while establishing a red clover seed field, it is possible to replace the earlier recommended six-rowed early barley cultivars with early spring wheat cultivars. It is expedient to reduce the seeding rate and nitrogen fertilizer rate of cover crop by one third. The optimum seeding rate of tetraploid red clover cultivars was 4–6 kg PLS ha^{-1}.

Keywords: cover crop, seeding and fertilization rates of cover crop, tetraploid red clover, seeding rate, seed yield, economic feasibility.

INTRODUCTION

The seed yield of red clover, the main leguminous forage plant in Estonia, depends on the type of cultivar, the weather conditions during growth, abundance of pollinators as well as the used cultivation methods. As a rule, it is recommended to establish a red clover seed field by seeding under a cover crop, which enables the seed producer to get yield (income) in the year of sowing, the pressure of annual weeds on the young clover stand is smaller and the cover crop protects clover sprouts during the 1st half of summer against unfavourable weather conditions. But at the same time the cover crop has also a negative impact: higher competition for light, plant nutrients and humidity. To reduce the negative effects, it is recommended to use early six-rowed barley cultivars as a cover crop; after harvesting the cover crop there will be more time for clover sprouts to recover before the end of vegetation period. It is also recommended to reduce the seeding and nitrogen fertilizer rates of cover crop (Jaama, 1986; Undersander et al., 2014).

Due to global warming the period free from nocturnal frosts in Estonia has become longer by 17 days in the past 30 years (Sepp, 2015). At the same time early two-rowed barley and spring wheat cultivars with shorter straw and good standing ability have become available on the market. These facts leave us with the question whether six-rowed barley cultivars with a relatively poor standing ability are still needed for the establishment of clover seed field, or can they be replaced by other spring cereals.

Previously barley has been dominating among the cereals grown in Estonia. In recent years, due to economic considerations, the area under wheat has considerably grown (exceeding that of barley), which has also increased the interest among producers towards spring wheat as a possible cover crop for red clover.

The research carried out in Norway has indicated that thanks to the adoption of new cereal varieties with a better standing ability, it is not necessary to reduce the seeding and nitrogen fertilizer rates of cover crop any more (Aamlid & Havstad, 2011).

In Estonia it has been recommended to establish seed fields of red clover at the seeding rate of 6–16 kg ha^{-1} (Kotkas, 1969; Rand, 1992; Bender, 2006). Foreign sources also suggest very different seeding rates, but as a rule, these recommendations remain below ours. They usually are between 2–4.5 kg ha^{-1} (Bowely et al.,1985; Bouet & Sicard, 1998; Huebner, 2016). In case of a broader row space it is recommended to sow only 0.5–0.75 kg ha^{-1} (Clifford & Anderson, 1980; Rinker & Rampton, 1985). However, it is said that in practice the seeding rate for seed fields is still 6–13 kg ha^{-1} (Bowely et al., 1985; Rinker & Rampton, 1985; Marshall et al., 1998; Huebner, 2016). In Latvia, the seeding rate of red clover seed fields in case of narrow row space is 8–10 kg ha^{-1} (Jansone, 2008), in Norway 2–4 kg ha^{-1} (Aamlid & Havstad, 2011; Aamlid, 2016). As a rule, the literature does not indicate whether the sowing rate recommendations concern tetraploid or diploid cultivars. However, there is a significant difference in 1000 seed weight: for diploid cultivars it is 1.4–1.9 g and for tetraploid cultivars 2.5–3.2 g. With the same seeding rate we sow considerably less seeds of tetraploid cultivars.

The seed yield of tetraploid cultivars is considered to be approximately 40% lower than that of diploid cultivars (Sjödin & Ellerström, 1986). In Norway, according to the statistics bureau, the average seed yield of tetraploid cultivars was 164 kg ha^{-1}, that of diploid cultivars 247 kg ha^{-1}. The same indices for Sweden were respectively 225 and 300 kg ha^{-1} (Amdahl et al., 2016). Very little information is available in literature on how the method of seed field establishment and cultivation affect the seed yield of red clover cultivars.

As in Estonia the cultivation methods for red clover seed production have not been studied for several decades, a field trial was established in Jõgeva in 2013 in order to investigate and specify the following issues:

1) Is it possible to replace six-rowed early barley, recommended as cover crop for red clover, with early cultivars of spring wheat;

2) How the applied seeding and nitrogen fertilizer rates affect the yield of cover crop and its quality;

3) What is the impact of cover crop background on the formation of red clover stand and the seed yield of the 1st year of harvest;

4) What is the optimum seeding rate for the establishment of seed field of tetraploid red clover;

5) How the cover crop background and the seeding rate of red clover affect the monetary value of production in total of the sowing and harvest year, and what is the profitability expressed as a ratio.

MATERIALS AND METHODS

In the field trial that was established with the aim to get answers to the above-mentioned questions the early spring wheat cultivar 'Mooni' was used as the cover crop. The trial had the following background variants:

1) The seeding rate of cover crop was reduced (66% out of the normal rate), the nitrogen fertilizer rate was reduced (66% of the normal rate) – control variant;

2) The seeding rate of cover crop was not reduced (100%), the nitrogen fertilizer rate was reduced (66% of the normal rate);

3) The seeding rate of cover crop was not reduced (100%), the nitrogen fertilizer rate was not reduced (100%);

4) The seeding rate of cover crop was reduced (66% of the normal rate), the nitrogen fertilizer rate was not reduced (100%).

The variants were calculated on the basis of the seeding rate of spring wheat that was 600 live seeds per m² (100%), and the nitrogen fertilizer rate N 120 kg ha^{-1} (100%).

In all four cover crop variants the following seeding rates of red clover were studied: 2, 4, 6 and 8 kg ha^{-1}. The early tetraploid cultivar 'Varte' and the late tetraploid cultivar 'Ilte' were used in the trial. The trial plots had a completely randomized design and there were four replications.

The trial was established on a calcaric cambisol (K_0), which according to analysis data had the following content of plant nutrients: P 179, K 162, Ca 1,392 and Mg 56 mg per kg soil. The soil contained 2.0% of organic carbon, the soil reaction pH was $_{KCL}$5.4.

Phosphor and potassium fertilizers were applied to the trial plots manually (P 19, K 67 kg ha^{-1}), nitrogen fertilizer was applied as ammonium salpeter before the last soil tillage prior to sowing using a Saxonia drill. Later the trial was not fertilized. Cover crop was sown on the 30th of April, undersowing was done on the 2nd of May (planter Hege 80). To control short-lived dicotyledonous weeds, the trial area was sprayed with the herbicide MCPA 750 at the rate 1.0 l ha^{-1}.

In the year of establishment the number of generative tillers of cover crop per area unit (0.5 x 0.5 m, in 4 replications) was counted, and their height during flowering was measured (in 16 replications). The spring wheat 'Mooni' ripened and was harvested on the 10th of August. The yield was determined with the trial plot combine Hege 140. Cereal samples were dried, sorted and weighed. In the laboratory of the Estonian Crop Research Institute the following quality parameters of the yield were determined: volume weight, 1,000 seed weight, crude protein content, gluten content and gluten index.

In the year of sowing, prior to the end of vegetation period, the number of red clover plants per area unit (0.5 x 0.5 m, in 4 replications) was determined. In the harvest year of red clover seed (2014), the cultivar 'Varte' was harvested on the 20th of August, the cultivar 'Ilte' on the 2nd and 3rd of September. The combine Hege 125 C was used for harvesting. Seeds were dried, treated in the brush machine Westrup-400 and final cleaning was done with the Kamas-Westrup laboratory cleaner LALS. Seed germination and 1,000 seed weight were determined in the laboratory three months after combine harvesting.

The trials were located in the vicinity of an apiary (ca 300 m) with 8 beehives.

Statistical analysis of trial results was performed with the programme AGROBASE 20 TM.

Meteorological conditions of trial years

In the year of trial establishment (2013) air temperatures were above normal in May, June and July; in June, July and August precipitation was lower than normal (Table 1). These factors accelerated the ripening of spring wheat, but slowed down the growth and development of undersown clover plants. After the harvest of cover crop, the red clover plants had 79 days for recovering before the end of the vegetation period.

Table 1. Temperature and precipitation compared with meteorological average

Month	Average daily air temperature, °C			Precipitation, mm		
	2013	2014	Average*	2013	2014	Average*
May	14.3	11.5	10.3	84	64	50
June	17.7	13.1	14.5	38	158	67
July	17.6	19.2	16.8	35	48	80
August	16.7	16.6	15.3	70	114	89
September	10.9	11.5	10.5	32	28	66
October	6.6	5.2	5.4	58	49	65

* − average of the years 1922−2012.

Weather conditions in the year of red clover seed harvest (2014) were contradictory. May was warmer than normal (temperature was above 25 °C in 8 days). It was followed by an unusually cool June. On four occasions (on the June 24, 26, 27 and 28) frost was registered on the surface of plant stand. On the 17th of June snow and on the 23rd of June hail was falling. Early red clover started flowering on the 15th of June, but the work of pollinators was stopped until the end of month due to unfavourable weather conditions. The weather improved in July. Air temperature above the average of many years as well as a small amount of precipitation favoured the work of pollinators. From the viewpoint of red clover seed production the weather remained favourable until the 23rd of August after which frequent rains started. On the 23rd and 24th of August there was a heavy hail fall. It was possible to harvest the seed yield of early red clover in favourable conditions, the ripening of seeds of late red clover coincided with the rain period. Part of seeds were damaged due to germination in flower heads in the field.

RESULTS AND DISCUSSION

Spring wheat 'Mooni' as cover crop

The spring wheat 'Mooni' sown as cover crop grew 91–98 cm tall in the research area (Table 2). The reduction of seeding rate did not change the length of generative tillers. The reduction of nitrogen fertilizer rate by one third decreased the length of generative tillers by 3–4 cm. The difference was statistically reliable.

Table 2. Height of plants and density of generative tillers of the spring wheat 'Mooni'

	Cover crop background			
Seeding rate 400 live seeds m^2, N 80 kg ha^{-1}	Seeding rate 600 live seeds m^2, N 80 kg ha^{-1}	Seeding rate 600 live seeds m^2, N 120 kg ha^{-1}	Seeding rate 400 live seeds m^2, N 120 kg ha^{-1}	LSD 0.05
	Undersown early red clover 'Varte'			
	Height of plants, cm			
91	89	93	98	3
	Number of generative tillers, pcs m^2			
430	617	654	516	38
	Undersown late red clover 'Ilte'			
	Height of plants, cm			
93	93	96	96	2
	Number of generative tillers, pcs m^2			
448	627	644	474	42

The number of spring wheat's generative tillers per area unit was affected both by the seeding and nitrogen fertilizer rates. The nitrogen fertilizer rate had a bigger effect on the density of spring wheat. Spring wheat was sparsest in the trial variant, in which both the seeding rate and nitrogen fertilizer rate were reduced by one third compared to those used in production. In this variant 430–448 generative tillers were counted on square meter.

In our trial in 2013, we received contradictory yield data of the spring wheat 'Mooni' (Table 3). Increasing the seeding rate from 400 live seeds to 600 live seeds per m^2 reduced the grain yield by 143–147 kg ha^{-1}. The decrease in yield was not statistically reliable, but as the tendency was the same for the both undersown red clover cultivars, it must have been caused by weather conditions. This particular year with high temperatures and sufficient soil humidity had very favourable conditions for tillering, which probably eliminated the advantages of bigger seeding rate. At the nitrogen background N 80 kg ha^{-1} increasing of seeding rate somewhat increased the grain yield's volume weight, but reduced the 1,000 seed weight. In the part of experiment, where the early red clover 'Varte' was undersown, these changes werestatistically reliable, with the undersown cultivar 'Ilte' the changes remained within the limit of trial error. The reduction of the seeding rate of spring wheat 'Mooni' changed neither the contents of crude protein and gluten nor the gluten index. At the nitrogen background N 120 kg ha^{-1} the reduction of the seeding rate of spring wheat 'Mooni' did not change the grain yield.

As predicted, the increase of nitrogen fertilizer rate invoked bigger changes in trial data. The grain yield increased depending on the variant by 229–281 kg ha^{-1}. The crude protein and gluten contents of the yield were reliably higher than those of the yield grown at lower nitrogen background. In our trial the nitrogen rates did not affect the volume weight, 1,000 seed weight and gluten index.

The goal of spring wheat production should be the use of the yield for human consumption. Of the yield's quality parameters the relatively low protein content reduced the selling price. When 80 kg ha^{-1} of nitrogen was applied, the yield's protein content was slightly above 10%, which corresponds to the 5th category of food wheat's quality. In variants with full nitrogen rates the protein content was 12%. This raised the quality of yield to category III. The difference in selling price compared to category V was 14 euros per ton. At lower nitrogen backgrounds also the gluten content was problematic. Due to the gluten content the yield's quality class varied between categories IV–V. The full rate of nitrogen fertilizer raised the gluten content to a level (over 26%), which could have allowed to sell the yield as food wheat of categories I or II.

Table 3. Yield of spring wheat 'Mooni' and its quality in 2013

No	Seeding and N fertilizer rates of spring wheat	Yield, kg ha^{-1}	Volume weight, g l^{-1}	1,000 s. weight, g	Crude protein, %	Gluten content, %	Gluten index
		Undersown early red clover 'Varte'					
1	400 live seeds m^2, N 80 kg ha^{-1}	3,474	805	72.93	10.33	21.83	60.3
2	600 live seeds m^2, N 80 kg ha^{-1}	3,331	823	70,59	10.32	22.18	59.5
3	600 live seeds m^2, N 120 kg ha^{-1}	3,703	808	69.50	12.20	27.95	49.5
4	400 live seeds m^2, N 120 kg ha^{-1}	3,707	800	71.34	11.87	26.97	51.7
		Undersown late red clover 'Ilte'					
5	400 live seeds m^2, N 80 kg ha^{-1}	3,610	807	71.04	10.60	22.73	54.3
6	600 live seeds m^2, N 80 kg ha^{-1}	3,463	813	70.31	10.37	21.70	59.0
7	600 live seeds m^2, N 120 kg ha^{-1}	3,891	810	69.57	12.72	28.75	50.7
8	400 live seeds m^2, N 120 kg ha^{-1}	3,866	797	70.13	12.67	28.83	50.5
	LSD 0.05	211	9	2.03	0.72	2.12	5.0

Table 4 presents the densities of undersown red clover stands counted on the 30th of October 2013, i.e. at the end of the vegetation period of the sowing year. The data indicate that the number of plants per area unit depended more on the seeding rate of red clover and less on the differences in the seeding and fertilizer rates of the cover crop. The big value of LSD indicates that the density of red clover stands varied a lot even within the same seeding rate. There were both sparser and denser stands. It could depend on uneven sowing or heterogeneous moisture and light conditions under the cover crop.

According to literature, to obtain a good red clover seed yield it is sufficient to have at least 17 plants per square meter (Clifford & Anderson, 1980). In our research this level was achieved with all red clover seeding rates at all cover crop backgrounds except one – when cover crop was sown at full rate, nitrogen fertilizer was applied at the rate used in production and red clover was undersown at a smaller rate (2 kg ha^{-1}).

Table 4. Densities of red clover, sown under the spring wheat 'Mooni', stands in the autumn of the seeding year, plants pcs m^2

Clover seeding rate, kg ha^{-1}	Cover crop background				LSD 0.05
	400 live seeds m^2, N 80 kg ha^{-1}	600 live seeds m^2, N 80 kg ha^{-1}	600 live seeds m^2, N 120 kg ha^{-1}	400 live seeds m^2, N 120 kg ha^{-1}	
	Early red clover 'Varte'				
2	28	21	10	28	15
4	35	30	30	48	9
6	44	54	45	58	12
7	62	73	42	59	12
LSD 0.05	12	14	12	13	
	Late red clover 'Ilte'				
2	28	18	31	20	16
4	38	42	29	40	27
6	49	60	54	43	15
8	68	43	46	62	15
LSD 0.05	13	21	26	16	

Seed yield of red clover

The seeding and fertilizer rates of spring wheat had a relatively low impact on the seed yield of the undersown red clover 'Varte' (Table 5). The decrease in seed yield was statistically reliable only in the variant, in which the cover crop was sown at full seeding rate and fertilized at the nitrogen rate used in production, red clover was sown at the rate of 8 kg ha^{-1}.

Table 5. The effect of seeding and fertilizer rates of spring wheat 'Mooni' and that of seeding rate of the undersown red clover on the seed yield of the cultivar 'Varte' in 2014, kg ha^{-1}

Red clover seeding rate kg ha^{-1}	Cover crop background				LSD 0.05
	400 live seeds m^2 N 80 kg ha^{-1}	600 live seeds m^2, N 80 kg ha^{-1}	600 live seeds m^2, N 120 kg ha^{-1}	400 live seeds m^2, N 120 kg ha^{-1}	
2	316	310	290	311	56
4	325	306	312	319	50
6	340	329	319	325	82
8	366	302	283	305	73
LSD 0.05	53	45	54	62	
	Effect of cover crop background on the seed yield of undersown red clover 'Varte'				
2	100.0	98.1	91.9	98.5	
4	100.0	94.1	96.1	98.1	
6	100.0	96.8	93.6	95.6	
8	100.0	82.5	77.2	83.1	
	Effect of increase in the red clover 'Varte' seeding rate on the seed yield				
2	100.0	100	100.0	100.0	
4	102.9	98.8	107.7	102.4	
6	107.7	106.3	109.8	104.5	
8	116.0	97.5	97.4	97.9	

Increasing the seeding rate of the undersown red clover 'Varte' from 2 kg to 6 kg per ha increased the seed yield of the first harvest year, but the 4.5–9–8% increase was not statistically reliable.

The late red clover 'Ilte' sown under spring wheat gave a relatively good seed yield (Table 6). The seed yield varied between 332.8–406.3 kg ha^{-1} depending on the seeding and fertilizer rates of cover crop and on the seeding rate of red clover. When the seeding rate and nitrogen fertilizer rate of cover crop were not reduced, the seed yield of the late red clover 'Ilte' decreased in the first year of harvest by 8.9–10.1%. However, at the high value of LSD this decrease in seed yield was not statistically reliable. The seed yield of red clover 'Ilte' was highest in all variants of cover crop background, when the seeding rate of 4 kg ha^{-1} had been used for undersowing.

Table 6. The effect of seeding and fertilizer rates of spring wheat 'Mooni' and that of seeding rate of the undersown red clover on the seed yield of the cultivar 'Ilte' in 2014, kg ha^{-1}

Red clover seeding rate kg ha^{-1}	Cover crop background				PD 0.05
	400 live seeds m^2 N 80 kg ha^{-1}	600 live seeds m^2, N 80 kg ha^{-1}	600 live seeds m^2, N 120 kg ha^{-1}	400 live seeds m^2, N 120 kg ha^{-1}	
2	375	370	337	360	61
4	406	395	372	378	71
6	388	380	355	378	57
8	366	366	333	371	63
LSD 0.05	34	66	81	43	
	Effect of cover crop background on the seed yield of undersown red clover 'Ilte'				
2	100.0	98.7	89.9	96.1	
4	100.0	97.1	91.4	93.0	
6	100.0	98.0	91.5	97.5	
8	100.0	100.2	91.1	101.5	
	Effect of increase in the red clover 'Ilte' seeding rate on the seed yield				
2	100.0	100.0	100.0	100.0	
4	108.5	106.7	110.3	104.9	
6	103.5	102.8	105.3	105.0	
8	97.6	99.1	98.8	103.1	

In the year of sowing the seeding and fertilizer rates of cover crop and the seeding rate of red clover affected neither clover's 1,000 seed weight nor germinability. For the cultivar 'Varte' these indices were between 2.857–2.989 g and 96–99%, for 'Ilte' respectively 2.813–2.949 g and 97–99%. The germinability of late red clover seed was somewhat surprising as the yield was affected in the field before harvest by continuous rain and seeds germinated partially in flower heads of heavily lodged stand.

Economic calculations

Of production inputs in the year of sowing major costs were related to phosphorous-potassium complex fertilizer (price 350 € t^{-1}), ammonium salpeter (300 € t^{-1}), spring wheat seed (C1 category 0.53 € kg^{-1}) and red clover seed (E category 10 € kg^{-1}). When the seeding rate of spring wheat was 600 live seeds per m² and the nitrogen fertilizer was applied at the rate of N 120 kg ha^{-1}, the inputs needed for the establishment of seed field cost 421.2 € ha^{-1} (Table 7).

Table 7. Economic result in 2013–2014 at the red clover seeding rate of 4 kg ha^{-1}

Cover crop background	Production input cost € ha^{-1}	Income from production sales € ha^{-1}	%	Ratio
	'Varte'			
Spring wheat 66%, N 66%	342.2	2,534	100	7.4
Spring wheat 100%, N 66%	385.2	2,396	94.5	6.2
Spring wheat 100%, N 100%	421.2	2,546	100.5	6.0
Spring wheat 66%, N 100%	378.2	2,563	101.1	6.8
	'Ilte'			
Spring wheat 66%, N 66%	342.2	3,042	100	8.9
Spring wheat 100%, N 66%	385.2	2,928	96.3	7.6
Spring wheat 100%, N 100%	421.2	2,934	96.4	7.0
Spring wheat 66%, N 100%	378.2	2,972	97.7	7.9

The reduction of spring wheat's seeding rate by one third reduced the establishment costs by 11.4%, the reduction of nitrogen fertilizer rate by one third by 9.3% and the reduction of both by 23.1%.

Based on the price level of 2015, the spring wheat yield could be sold for food consumption depending on the quality either as quality class III (182 € t^{-1}), IV (175 € t^{-1}) or V (168 € t^{-1}), the yield of red clover tetraploid cultivars as C_1 category seed at the price 6 € kg^{-1}. Spring wheat could not be classified into higher quality (and price) category due to low protein content, particularly in trial variants with the reduced nitrogen fertilizer rate.

Considering the cost of production inputs for the establishment of seed field, and the monetary value of production in the year of establishment and the first year of harvest, sowing of spring wheat as cover crop at reduced seeding and nitrogen fertilizer rates was economically more justified (Table 7).

CONCLUSIONS

Based on the trial results, the following can be concluded.

1. It is possible to establish a seed field of red clover by sowing it under early spring wheat varieties;
2. When weather conditions during tillering are favourable, the reduction of cover crop's seeding rate affects the density and yield of cover crop relatively little. This method enhances the development of red clover plants sown under cover crop and increases the seed yield in the first year of harvest by 3–6%;
3. The rate of nitrogen fertilizer has a significant effect on the density, grain yield and quality of yield of spring wheat. The nitrogen fertilizer rate applied to the cover crop had an impact on the development of red clover stand. The negative effect was evident in the density of clover stand, in the development of plants and strength of growth, and in the first year of harvest in the decrease of seed yield under sparser cover crop by 2–7%, under cover crop sown at full seeding rate even by 22%;
4. The seeding rate of tetraploid red clover between 2–8 kg ha^{-1} affected the seed yield relatively little. Better results were obtained with variants in which the seeding rate was 6 kg ha^{-1} for 'Varte' and 4 kg ha^{-1} for 'Ilte'. Based on the trial results we recommend

to use seeding rates 4–6 kg ha^{-1} for the establishment of seed fields of tetraploid red clover cultivars;

5. The seeding and fertilization rates of spring wheat and the seeding rate of undersown red clover did not affect the 1,000 seed weight and germinability of tetraploid cultivars 'Varte' and 'Ilte';

6. The red clover cultivars 'Varte' and 'Ilte' have a good seed yielding ability. 'Varte' yielded up to 366, 'Ilte' 406 kg ha^{-1};

7. Economically was justified to establish seed fields of both red clover cultivars under spring wheat by reducing the seeding and nitrogen fertilizer rates of cover crop by one third.

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REFERENCES

Aamlid, T.S. 2016. Frøavl av rødkløver. Dyrkingsveiledning Mai 2016 (http://froavl.bioforsk.no) (accessed on 2016/12/10). (in Norwegian).

Aamlid, T.S. & Havstad, L.T. 2011. Seed production of red clover. http://www.seemneliit.ee/wp-content/uploads/2011/12/Trygve_red-clover-2011.pdf (accessed on 2013/10/15)

Amdahl, H., Aamlid, T.S., Ergon, A., Marum, P., Kovi, M.R., Alsheikh, M. & Rognli, O.A. 2016. Seed yield potential in tetraploid red clover. *Proceedings of the 16th Nordic herbage seed production seminar*. NJF seminar 491. 20-22 June 2016, Grimstad, Norway, pp. 17−21.

Bender, A. 2006. Forage legumes. In: Bender, A (ed.). *Establishment and exploitation of various types of grasslands I.* Publishing House of Tartu University, Jõgeva, pp. 130−233 (in Estonian).

Bouet, S. & Sicard, G. 1998. Trifolium pratense in France. In: Fairey, D. T. & Hampton, J. G. (eds.). *Forage seed production 1. temperate species*. Wallingford, New York, pp. 377−383.

Bowely, S.R., Upford, R.A. & Wright, H. 1985. Producing red clover seed in Ontario. http://www.uoguelph.ca/plant/perfornance_recommendations/ofcc/pdf (accessed on 2016/12/15)

Clifford, P.T.P. & Anderson, A.C. 1980. Red clover seed production - research and practice. In: North, P. (ed.). Herbage seed production. Grasslands research and practice. Ser. 1. N.Z. Grassland Assoc., pp. 76−79.

Huebner, G. 2016. Red clover seed production. http://www.forageseed.net/index.php?option=com_content&view=article&id=152:red-clover-seed-production (accessed on 2016/12/15)

Jaama, E. 1986. Agricultural engineering of perennial grass crop. In: Reimets, E. (ed.). *Plant cultivation*. Valgus, Tallinn, pp. 225−242. (in Estonian).

Jansone, B. 2008. Red clover. In: Jansone, B. (ed.). *Guide Book in the Seed Production of forage Grasses*. Skriveri, pp. 22−53. (in Latvian).

Kotkas, H. 1969. Seed production of red and alsike clover. In: Toomre, R. (ed.). *Agricultural engineering of perennial grass crop*. Valgus, Tallinn, pp. 213−237 (in Estonian).

Marshall, A.H., Steiner, J.J., Niemeläinen, O. & Hacquet, J. 1998. Legume seed crop management. In: Fairey, D. T. & Hampton, J.G. (eds.). *Forage seed production 1. temperate species*. Wallingford, New York, pp. 127–152.

Rand, H. 1992. Herbage seed production. In: Older, H. (ed.). Grassland for farming. Saku – Tallinn – Tartu, pp. 44−74 (in Estonian).

Rinker, C.M. & Rampton, H.H. 1985. Seed production. In: Taylor, N. L. (ed.). *Clover Science and Technology*. Wisconsin, pp. 417−443.

Sepp, M. 2015. Climatological aspects of climat change adaptation. In: Roose, A. (ed.). *Climate Change Adaptation in Estonia – Prepared for Force Majeure?* Publicationes Instituti Geographici Universitatis Tartuensis 112. Tartu, pp. 20−37 (in Estonian).

Sjödin, J. & Ellerström, S. 1986. Autopolyploid forage crops. In: Olsson, G. (ed.). *Svalöf 1886–1986. Research and Results in Plant Breeding*. Stockholm, Sweden, pp. 102−113.

Undersander, D., Smith, R.R., Kelling, K., Doll, J., Wolf, G., Welding, G.J., Peter, S.J., Hoffman, P. & Shaver, R. 2014. Red clover. Establishment, Management und Utilization. http://learningstore.uwex.edu/assets/pdfs/A3492.pdf (accessed on 2016/12/15).