FERTILIZATION VALUE OF EARLY RED CLOVER, WASHINGTON LUPIN AND CRIMSON CLOVER AS GREEN MANURE CROPS

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Abstract
Field trials were carried out at Jõgeva Plant Breeding Institute in 2008 – 2011 to identify the possibilities of using early red clover (Trifolium pratense L.) ‘Jõgeva 433’ (diploid), Washington lupin (Lupinus polyphyllus Lind.) ‘Lupi’ and crimson clover (Trifolium incarnatum L.) as green manure. Fresh material of the above species was ploughed into the soil in autumn of the sowing year. Fertilizer value was quantified through yield and grain quality of spring wheat ‘Vinjett’ and barley ‘Inari’. The composition and amount of ploughed biomass were recorded. By the time of ploughing, Washington lupin had produced the most abundant biomass. From studied species crimson clover had the lowest fertilizer value – only by 6–7% extra yield of spring wheat in the following year. Crimson clover had no residual effect of fertilization in the second year. The fertilizer values of red clover and Washington lupin were approximately equal. Their effect on yield increase of spring wheat and barley lasted for three years, on grain quality for two years. Red clover, ploughed into the soil in the year of sowing, resulted in maximum spring wheat yield increase of 23.9%, compared with N 0 treatments; that of Washington lupin was 21.3%. The residual positive effect in the second year quantified as barley production increased by 6.2% in Washington lupin and 7.9% in red clover. The yield increase in the third year was 3.9% and 12.1%, respectively. Green manure increased the contents of crude protein and gluten in spring wheat and crude protein content in barley.

Key words: Washington lupin, red clover, crimson clover, green manure, fertilization value.

Introduction
After Estonia regained its independence, great changes have occurred in agriculture. Former collective and state farms were practicing both plant and animal husbandry in a single unit. Now, the numerous specialized plant producers have taken their place. Since manure has become scarce, alternatives must be found to preserve and enrich the humus content of soil. Attention has been paid to green manures. In north Estonia, soil is favourable for white sweet clover (Melilotus albus L.) cultivation (Kõrgas, 1963) while in the southern part, sandy and acid soil is more appropriate for red clover (Trifolium pratense L.). In the past, Washington lupin (Lupinus polyphyllus Lind.) was cultivated there. The species has caught the attention of researchers in neighbouring countries because of its great nitrogen fixation – 250–350 kg ha⁻¹ (Heinsoo et al., 1986; Kurlovich et al., 2007) and high protein concentration (Aniszewski, 1993). Washington lupin cultivars containing alkaloids are used as raw material in chemical industry, low alkaloid content lupin is used as protein-rich forage (Aniszewski, 1992; Kurlovich et al., 2008). Latvian researchers have reported that green biomass of Washington lupin is the appropriate raw material for biogas production (Dubrovskis et al., 2011). Lithuanian researchers have reported that high alkaloid Washington lupin has qualifications of good raw material for bioethanol production (Kryževiciene, 2006). In Russia, varieties ‘Pervenets’ and ‘Truvor’ (Kurlovich, 2002) and variety ‘SF/TA’ in Finland (Aniszewski, 1993) have been bred. Latvian national variety list includes a perspective domestic breed.

In 1990, to meet the local demand, Jõgeva Plant Breeding Institute initiated breeding of species, too. A perspective candidate variety was submitted to national testing in 2004. It passed the trials and was registered as the cultivar ‘Lupi’ in 2013. The main objective of the current research was to compare fertilization value of Washington lupin and early red clover. We also investigated possibilities of using crimson clover (Trifolium incarnatum L.) as a green manure crop. According to J. Frame (2005), the species is appreciated for its great nitrogen fixation ability (up to 155 kg nitrogen ha⁻¹) and is recommended in northern areas for green manure (Fovelands and Evers, 1995).

Materials and Methods
A field trial was established at the Jõgeva Plant Breeding Institute (58° 45’ N, 26° 24’ E) in the spring 2008. Early red clover ‘Jõgeva 433’ (diploid, seed rate 12 kg ha⁻¹, row space 15 cm), Washington lupin ‘Lupi’ (30 kg ha⁻¹ and 30 cm), and crimson clover (20 kg ha⁻¹ and 15 cm) were sown without a cover crop. Fertilizer value of ploughed in biomass was evaluated on the basis of yield and grain quality of spring wheat (Triticum aestivum) ‘Vinjett’ (2009) and barley (Hordeum vulgare) ‘Inari’ (2010, 2011). The field plots seeded with timothy (Phleum pratense) were used as a control (sown at the same time as green manure crops). Timothy plots were regularly mown with a lawn mower in the summer 2008. Green manure crops and timothy were ploughed in during the autumn of the year of sowing (2008). Ammonium nitrate was applied prior to the last tillage procedures.
before sowing the cereals. A nitrogen rate was 0, 60 and 120 kg ha⁻¹ in spring wheat and 0, 60 and 90 kg ha⁻¹ in barley. The treatments had five replications. The trial was conducted on calcareous cambisol (Ko), with following characteristics: pH KCl 5.8, P 27, K 67, Ca 2150, Mg 159 mg kg⁻¹ and C_\text{org} 24 g kg⁻¹. Phosphorus and potassium fertilizers were applied just once before the establishment of the trial (in 2008) at a rate of P 19 and K 67 kg ha⁻¹.

The whole formed biomass was ploughed in mid-October (on 15th October 2008) of the sowing year. Only roots and stubble of the timothy, equivalent to 3.18 t dry matter ha⁻¹, containing 7 g kg⁻¹ N, were ploughed in. Crimson clover (Italian origin), which was supposed to be a very late cultivar on the basis of shipping documents, proved to be an entirely early variety in Estonian conditions. Its seeds matured in the beginning of September, were harvested for seed and the straw was removed from the field. Roots and stubble of crimson clover were ploughed in (0.32 t dry matter ha⁻¹, 12.6 g kg⁻¹ nitrogen). Washington lupin had produced 12.98 t dry matter ha⁻¹ of which roots formed 6.27 t ha⁻¹, nitrogen content 23.5 g kg⁻¹; stems and leaves together 6.71 t ha⁻¹, nitrogen content 20.8 g kg⁻¹. Red clover produced 7.98 t dry matter ha⁻¹, of which roots 3.70 t ha⁻¹, nitrogen content 19.1 g kg⁻¹; stems and leaves combined 4.28 t ha⁻¹, nitrogen content 21.2 g kg⁻¹. Total amount of nitrogen ploughed into the soil with green manure was 287 kg in case of lupin, 161 kg in red clover and 4 kg nitrogen ha⁻¹ in crimson clover (Table 1).

In the first year (2009) of residual effect, Washington lupin and red clover ensured approximately equal increase of spring wheat yield compared to control variant (21.3 and 23.9%, respectively, Table 2). The yields were similar with fertilization treatment N 120 kg ha⁻¹. The 1000 kernel weight decreased in both cases compared to the control variant but the gluten content increased. As a result of residual effect of crimson clover, the spring wheat yield increased by 5.9%, which was statistically significant. All

### Results and Discussion

The vegetation period of 2008 was one month longer than long-term average, extremely rainy while air temperature was lower, and that established very favourable growing conditions for green manure crops. The vegetation period of 2009 was similar to long-term average of air temperature, amount and proportion of precipitation. Vegetation periods of 2010 and 2011 had a low precipitation level with high air temperature. In both years, barley matured extremely early in the trial. Microbiological activity of soil was inhibited because of the serious drought. It could have had an effect on the rank of green manure residual.

Aboveground biomass was determined using a forage plot harvester Hege 212. Samples of fresh material (approximately 1 kg) from each plot were taken to measure dry matter. After weighing, the samples were dried at 105 °C to a constant weight and the dry matter yield was calculated. The monoliths (surface 15x30 cm) from up to 25 cm in depth were taken to determine the root and stubble biomass. The roots were washed, then dried and weighed. Chemical analyses of biomass were conducted in the laboratory of Agricultural Research Centre. Nitrogen and carbon were determined by using TUMAS ISO/TC 16634-2:2009 method. To determine moisture content, Draminski Grain moisture meter PN-EN ISO 9001:2001 was used. Gluten content of spring wheat was measured by Glutomatic 2200.

The software AGROBASE 20™ was used for statistical data analysis. The significance of the differences of the variants was calculated using the LSD test.

### Table 1

<table>
<thead>
<tr>
<th>Biomass ploughed into the soil and its nitrogen content</th>
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<tr>
<td><strong>Dry matter t ha⁻¹</strong></td>
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<td><strong>Phleum pratense (control)</strong></td>
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<td><strong>Lupinus polyphyllus</strong></td>
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<td><strong>Lupinus polyphyllus</strong></td>
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*seed harvest*
seed quality properties were improved except gluten content, which remained below the control treatment. Grain yield of barley ‘Inari’, formed as a result of the residual effect of Washington lupin in the second year (2010), was by 6.2% higher than in the control treatment, although it was not statistically significant (Table 3). However, the concurrent increase of 1000 kernel weight and crude protein content was significant. The residual effect of red clover resulted in barley ‘Inari’ yield increase of 7.9%, which was also statistically significant. There were no major changes in grain quality. Starting from the second year (2010) there was no residual effect of crimson clover.

Residual fertilizer effect of red clover continued in the third year (2011). Grain yield of barley ‘Inari’ was by 12.1% higher than in the control treatment. The residual effect of Washington lupin expressed by the increase of grain yield in the third year (2011) was only 3.9% higher than in the control treatment, being statistically not significant. There was no residual effect on the quality in the third year (2011).

From the studied green manure crops, Washington lupin, sown without a spring cover crop, produced the highest amount (12.98 t ha\(^{-1}\)) of biomass by the end of the very long and favourable growing season, containing 287 kg of nitrogen. The respective values...
for red clover were 7.98 t ha$^{-1}$ and 161 kg at the same time. The residual fertilizer effect of the above species was comparable in the first year. They produced extra grain yield at nitrogen 120 kg ha$^{-1}$ compared to unfertilised treatment. The residual effect of Washington lupin was approved by the increase of wheat gluten content by 5.8%. In the second and third year, the residual effect of Washington lupin increased grain yield of barley, though not significantly. In the second year, 1000 kernel weight and protein content of barley increased. Significant positive residual effect of red clover to the yield of barley appeared even in the third year.

Most of nitrogen was ploughed in with the biomass of Washington lupin, but its advantage was not affirmed by the estimated fertilization value. The problem may lie in the fact that the roots of Washington lupin are vigorous, remain alive in the soil longer and do not decompose. Secondly, growing species has a weaker root system in comparison with perennials (red clover, timothy, Washington lupin). Its root system is formed mainly of fibrous roots. The crimson clover had finished its growth cycle for the middle of September and its ploughing took place in mid-October. For that time one part of the fibrous roots could have been decomposed in the soil during the intermediary one and a half month. Despite of modest amount of biomass, there was a significant residual effect to yield and quality of spring wheat after the first year. Yield increase was probably not solely the result of better nitrogen nutrition. Enhanced soil microbiological activity could also have an impact. The residual effect of fertilisation did not last till the second and third year in crimson clover.

Conclusions

Washington lupin has high nitrogen fixing ability. It can be used as a replacement of red clover in South-Estonian lighter texture acid soils as green manure. The replacement makes it possible to save red clover seeds for producing valuable forage for livestock. The fertilizer value of Washington lupin was similar to early red clover during the first two years of the residual effect. Spring wheat yield increased by 21.3% after Washington lupin and by 23.9% after red clover in the first year of the residual effect. During the second year of the residual effect, barley grain yield increased by 6.2% after Washington lupin and by 7.9% after red clover. During the third year of the residual effect, the fertilizing impact of Washington lupin decreased to 3.9%, while the fertilizer value of red clover was still 12.1%

Nevertheless, additional research to exploit its full properties is needed. The research should focus on the application of herbicides before ploughing and/or chopping the roots with tillage equipment. As long as the risk of the species turning into weed in following crops exists, it cannot be recommended to organic farmers.

Crimson clover reaches its full bloom by the middle of July. In Estonia, it can be cultivated as green manure for winter crops. Fertilizer value of crimson clover is lower compared to red clover, and residual effect is limited only to the first year. Also, it is necessary to continue trials with these species.

References

