SOLID participatory research from Finland: Enhancing on-farm forage protein production

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Summary

As part of SOLID WP1, on-farm research actions took place in Eastern Finland in 2013 and 2014 in order to increase the protein self-sufficiency of organic dairy farms. A mixture of red clover and grasses was studied as it is the most common sward composition for silage in organic farms. The aims of the on-farm trials were 1) To study the effect of grass topping on the clover content and forage protein production in the first silage cut and 2) To study the effect of the autumn application of slurry on the protein content of the companion grass and forage protein production in the first silage cut of the following spring. Topping and autumn slurry application were studied in two and four organic fields, respectively. Besides research questions, two different methods of conducting on-farm research were tested. Trials involved the use of farm scale machines and small plot measures of 0.25 m^2 taken by a researcher.

In the topping trial the exceptionally warm growing season in 2013 resulted in more vigorous and rapid early growth of red clover than usually. The difference in height between red clover and grasses was not great enough in early growth stage in May to top grass without damaging red clover. Time between topping and the first harvest was too short (less than two weeks) for red clover to develop and to increase protein content of the forage. Topping did not increase clover content of the first silage cut but rather on the contrary. However, the organic dairy farmers gained by one cut from un-topped organic red clover-grass a valuable yield of 4800, 3270, 560 and 380 kg ha^{-1} dry matter, digestible organic matter, crude protein and metabolizable protein, respectively.

In the trial of autumn slurry application three fields received 20 t ha^{-1} digestate of organic cattle slurry directly injected into the red clover-grass. The fourth field received 20 t ha^{-1} aerated organic cattle slurry broadcasting on soil surface. Slurry application in autumn increased crude protein content of grass (116 *vs*. 125 g kg^{-1} DM) and total crude protein yield (397 *vs*. 455 kg ha^{-1}) in the first silage cut of the following year. Concentration of soil nitrogen differed according to field due to soil type but no difference between treatment areas was found before the start of the trial. Effect of slurry application both on soil nitrate and ammonium nitrogen was clearly observed after five weeks of application. The effect could still be detected in soil soluble nitrogen the following spring. With slurry digestate 62 kg ha^{-1} soluble nitrogen was applied at the depth of four cm. Soil soluble nitrogen of 14 kg ha^{-1} at the ploughing layer was estimated to mineralize in spring. At the first silage cut 47 and 73 kg N ha^{-1} in grass and in total red clover grass yield, respectively, was harvested.

The conclusion from the results was the same despite the harvesting method although yield of large scale harvesting averaged 72 % of that from small plot sampling in all farm trials. Under scarcity of funds for research on organic production, on-farm research is a valuable tool to develop the sector. The most important phases in the on-farm research process were the discussions with farmers, advisors and researchers to define the questions before, and to conclude from results and experiences after the experimental work.

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1 Aims and Research question

As part of SOLID WP1, on-farm research actions took place in Finland in 2013 and 2014 in order to increase the protein self-sufficiency of organic dairy farms. This specific topic rose up in workshops held before the on-farm trials. It was also recognized to be an important issue in the other parts of Europe as indicated e.g. by the results obtained in farmer surveys conducted in SOLID WP5 (Deliverable 5.2).

There was lack of relevant research results under Northern conditions in this topic for organic farmers. The topic was studied by conducting on-farm trials. All participating farms were organic and located in Eastern Finland.

The aims of the on-farm trials were as follows:

1) To study the effect of topping of organic red clover-grass in first cut on the clover content and dry matter production of the ley and
2) To study the effect of the autumn application of slurry on growth of organic red clover-grass during the following spring

Besides research questions, two different methods of conducting on-farm research were tested on Finnish organic farms. The yield of clover-grass sward was measured by the farmer using his own machinery and by small plot measures of 0.25 m^2 taken by a researcher.

2 Background

2.1 Research Background

A mixture of red clover (Trifolium pratense L.) and grasses (Phleum pratense L., Festuca pratensis L.) in the silage is the most common forage in Finnish organic dairy and beef farms, but the protein content of the first cut is often low because of low clover content (Rinne & Nykänen, 2000; Nykänen, 2008).

Organic farmers of the SME Company *Juvan Luomu Ltd* were concerned about the low clover content in the first cut of red clover-grass to produce adequate protein content in the first cut silage. In general the first silage cut is the main forage batch in Finland. Besides high dry matter yield the high forage quality was strongly appreciated by organic farmers. In spring there is plenty of solar radiation with adequate soil moisture after snow melt. In early summer the growth rate of swards is the greatest over the growing season (Rinne and Nykänen, 2000).

TOPPING

Proportion of clover is lower in primary growth compared to regrowth (Rinne and Nykänen, 2000). The background of the topic was the unsatisfactorily low clover content in the first cut of red clover-grass to produce adequate protein content in the first cut organic silage. In the early stages of red clover growth, bud growth is driven by stored assimilates and firstly produced leaves are small to intercept light causing slow early growth rate of red clover (Black et al., 2009).

In Eastern Finland, vegetative phase of grass species convert to generative phase with stem elongation in early May (Virkajärvi and Järvenranta, 2001), which should enable grass topping early enough. The aim of grass topping was to give more space and time for red clover to develop and produce higher proportion of red clover into the first silage yield. The grass topping was hypothesized to suppress grass growth in relation to clover in the red clover-grass mixture.

MANURE USE IN AUTUMN

Organic farmers had also a target to increase the protein content of the companion grass of the red clover-grass mixture by autumn slurry application. The idea was to find means to have more soluble nitrogen available in soil for companion grass in early spring. In spring, fields often could be too wet for heavy machines and working time is too scarce to spread slurry by farmers. In autumn with low temperatures, ammonia emissions from slurry remained low (Nykänen-Kurki *et al.*, 1998). Sustainable manure management in general is under discussion (Luostarinen, 2013).

2.2 Farm Background

On-farm research is an attractive method for farmers to test suitable farming practices in their own environment. In cooperation with scientists, the topics can be formulated taking wider views and theoretical background into account.

In Finland as well as in many other countries, on-farm research has become more and more common. The reasons are many-fold. One of them is that agricultural research stations have been closed down due to economic constraints. Instead, applied field trials have been carried out in cooperation with farmers.

There could be a range of types of doing on-farm research. An important part is to involve the farmers in the research process. The involvement of farmers could vary from on-farm trials that are designed and carried out by researchers on farms, through to research in which farmers set the agenda, designed the assessment methods and carried out the assessments themselves. It is important that the outcome measures are of meaning and high value both to researchers and farmers (Lockeretz and Anderson, 1993).

Farmers involved here were well motivated to participate. They initiated the research questions and they were eager to carry out field management with their own machines in cooperation with measures by research scientists.

The main interest for the participating farmers was to increase the protein production on-farm by increasing the protein content of the red clover-grass forage. The farmers believe that by topping the grass during early spring growth, clover could get a relative advantage and the proportion of clover in primary growth could be increased.

In autumn, farmers have more working time to spread slurry than in spring. They had previous promising experiences about slurry application in autumn to benefit red clover grass growth the following spring.

Both on-farm research actions reported here aimed at increasing the self-sufficiency of organic farms in their protein feeding of cattle by developing the cultivation practices of the forage production. The results of the on-farm trials have previously been presented by Kurki and Nykänen (2014) and Nykänen et al. (2014).

3 Methodology and data collection

3.1 Location of the farms

The participating organic farms were situated nearby Juva, Eastern Finland (61°53′ N, 27°51′ E, 98 m above sea level).

3.2 Description of the on-farm Trials

The aims of this research were addressed with two separate trials. In the first trial, the effect of topping red clover grass to increase clover content of the organic red clover-grass was tested. The second trial tested the effect of manure application in autumn to increase the grass nitrogen content of the organic red clover-grass.

3.2.1 Trial 1: Topping of red clover-grass in early spring to increase clover content

This trial was a combination of small plot measurements and use of farm scale harvester by the farmer. The aim was to increase the protein content of the first cut of an organic mixed red clover (*Trifolium pratense* L.) and grass (*Phleum pratense* L., *Festuca pratensis* L.) silage on the organic farm. The trial included an early spring topping of grass to suppress grass growth in relation to red clover. This should give more time for red clover to develop and produce a higher proportion of red clover into the first silage harvest.

The topping trial was carried out on two different fields on the same farm. The fields were of moraine soils, which were quite warm with good water conditions. The soil type was coarser fine sand with moderate soil fertility (extraction with HAAc), and the pH (water) value and organic C content averaged 6.6 and 8.3 %, respectively.

The growing period started on 29 April in 2013 in Eastern Finland, which was in the normal range over the past 30 years. The spring was warmer than normally (Table 1).

Table 1. Mean temperature and monthly precipitation in 2013 in Eastern Finland.

	May		June	
	2013	1981-2010	2013	1981-2013
Mean temperature, ^oC	12.6	9.5	17.8	14.0
Monthly precipitation, mm	35	40	63	70

Each field was divided into two parts: In one part topping was carried out on May 31 by Lely Splendimo 550 P disc mowing machine (Figure 1) while the other part was left untreated.

In the previous year 20 t ha^{-1} digestate of organic cattle slurry fermented by Juva's Bioson Ltd was directly injected into the red clover-grass after the first silage cut. The soluble nitrogen and the total nitrogen content of the slurry was 3.2 and 5.3 kg ton^{-1}, respectively. In slurry, 64 and 106 kg ha^{-2} soluble nitrogen and total nitrogen, respectively, were applied. In the spring of topping no fertilization was applied.

The botanical composition, dry matter yield and height of clover and grasses including timothy apex height were measured at the time of topping by a researcher. The dry matter yield, botanical composition and crude protein content as well as the digestibility were determined in the first silage cut on 12 June 2013. The grass samples were analysed in the commercial laboratory of Valio Ltd by NIR. The yield of the first silage cut was measured both by small plot hand sampling (0.25 m^2) with five replicates and by John Deere 7250i farm scale harvester, with which yield of each treatment was weighed from 4 080 to 5 220 m^2 depending on the field (Figure 1). Statistical analyses were performed by SAS GLM procedure.

Figure 1. Lely Splendimo 550 P disc mowing machine and John Deere 7250i harvester were used in the topping farm trial in Eastern Finland. Photos: P. Kurki.

3.2.2 Trial 2: Manure use in autumn to increase grass nitrogen content

The manure trial was a combination of small plot measurements and was carried out on three organic farms; in one of the farms two fields were used so as a total of four fields was included in the trial. The swards were organic red clover (*Trifolium pratense* L.) and grass (*Phleum pratense* L., *Festuca pratensis* L.) mixtures for silage production. The trial involved use of farm scale machines for manure spreading and harvesting. For the trial the fields were divided into two parts: In the other part organic slurry was applied while the other part was left untreated.

Table 2. Mean temperature and monthly precipitation sum over the period August 2013 - June 2014 in comparison with the average values of the period 1981-2010 in Eastern Finland.

	Mean temperature ^oC		Precipitation mm	
	2013-2014	1981-2011	2013-2014	1981-2011
July	16.3	16.7	61	77
August	15.8	14.3	108	76
September	10.6	9.0	60	54
October	5.1	3.8	83	66
November	1.7	-1.7	84	56
December	-0.8	-5.9	56	52
January	-10.3	-8.1	20	49
February	-1.3	-8.2	26	35
March	0.8	-3.4	21	36
April	3.9	2.7	12	32
May	9.9	9.5	115	40
June	12.9	14.0	84	70
Mean / Sum	5.4	3.6	730	643

Three out of four fields were on moraine soils (Fields from 1 to 3), which were quite warm with good water conditions. The soil type of these three fields was coarser fine sand – fine sand with moderate soil fertility (extraction with HAAc) as pH (water) value and organic C content averaged 6.4 and 8 %, respectively. The fourth field (Field 4) was of a half-bog soil with moderate soil fertility (extraction with HAAc), in which pH (water) value and organic C content averaged 6.1 and 50 %, respectively.

The growth season ended 13 October 2013 which was in the normal range over the past 30 years. The autumn and winter was clearly warmer than normally (Table 2). Instead of a typical five months snow cover, it was exceptional short and thin (< 25 cm) appearing only in January - February. Similarly the soil frost stayed as short period as the snow cover.

The manure used was organic cattle slurry. The fields from 1 to 3 with moraine soils received 20 t ha^{-1} digestate of organic cattle slurry fermented by Juva's Bioson Ltd. The slurry was directly injected into the red clover grass on 25-27 September 2013 by Joskin Solodisk 6880 slurry tanker with direct injection unit of 7 m carrying 32 solodisks at disk distance of 22 cm for injection (Figure 2). The soluble nitrogen and the total nitrogen content of the slurry digestate was 3.1 and 5.3 kg ton^{-1}, respectively. In digestate of organic slurry, 62 and 106 kg ha^{-2} soluble nitrogen and total nitrogen, respectively, was applied.

The field 4 with half-bog soil was applied broadcasting 20 t ha^{-1} aerated organic cattle slurry on soil surface as such on 28 August 2013 by tanker of Koikkala's Machine and Iron. The soluble nitrogen and the total nitrogen content of the slurry was 2.5 and 4.0 kg ton^{-1}, respectively. In slurry, 50 and 80 kg ha^{-2} soluble nitrogen and total nitrogen, respectively, was applied.

Figure 2. The slurry was injected directly into the sward by Joskin slurry tanker in the manure farm trial in Eastern Finland. Photos: A. Laamanen.

The soil nitrogen content in autumn and in spring was determined at two depths, 0-25 cm and 25-50 cm (Figure 3). Soil samples were frozen before analyses. Ammonium and nitrate nitrogen extracted by 2 M KCl and determined spectrophotometrically by autoanalyzer at the laboratory of Luke in Jokioinen, Finland.

The botanical composition, dry matter yield and nitrogen content as well as the digestibility were determined in the following spring from first silage cut. The grass samples were analysed in the commercial laboratory of Valio Ltd by NIR. The cutting date varied from 11 June to 20 June in 2014 due to rainy weather. The yield of the first silage cut was measured both by small plot hand sampling (0.25 m^2) with five replicates (Figure 3) and by John Deere 7250i farm scale harvester, with which yield of each treatment was weighed from 2 200 to 4 000 m^2 depending on the field.

Statistical analyses were performed by SAS GLM procedure.

Figure 3. Soil and small plot samplings in the farm trial in Eastern Finland. Photos: P. Kurki.

3.3 Time scale

Different questions were addressed at different times**.** Trial number 1) Topping of red clover-grass in early spring to increase clover content was carried out in May - June 2013. Trial number 2) Manure use in autumn to increase grass nitrogen content in the following spring was started in August 2013 and studied until June 2014.

4 Results and Discussion

4.1 Trial 1: Topping of red clover-grass in early spring to increase clover content

The environmental temperature during the growing season in 2013 was higher in view of the average season temperature (Figure 4) resulting in more vigorous and rapid early growth of red clover than usually.

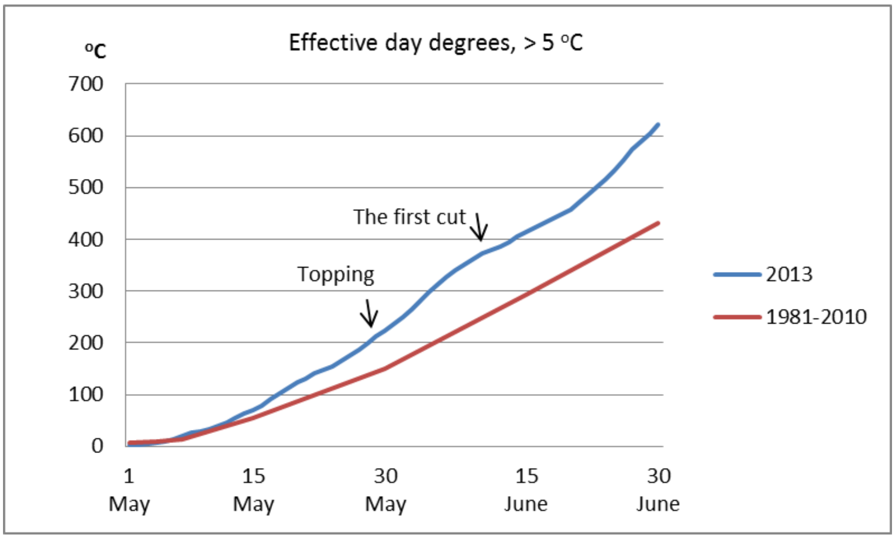

Figure 4. Effective day degrees (>5 °C) in spring in Eastern Finland.

Growth of grasses started in the beginning of May when daily mean temperature was above 0 °C. Growth of grasses is correlated highly with day degrees (> 0 °C), which averaged 390 and 620 °C at topping and at harvest, respectively. Although red clover growth started later than that of grasses, high temperature was more beneficial for red clover growth than for that of grasses. However, growth of red clover is correlated better with effective day degrees (> 5 °C) than with day degrees (> 0 °C). Effective day degrees (> 5 °C) averaged 240 and 400 °C at topping and at harvest, respectively.

The difference in height between red clover, timothy and meadow fescue was not great enough in early growth stage in May to top grass and it was not possible to remove timothy apex without damaging red clover with mowing machine. It was decided to do the topping at the height of 30 cm in both fields (Figure 5). Topping was carried out when height of grass averaged 40 and 47 cm in the first and the second field, respectively. The apex height of timothy averaged 8 and 20 cm in the same fields, respectively and the height of red clover averaged 26 and 30 cm, respectively. Often in May difference in height between grass and red clover stands is greater than that in 2013. Red clover content averaged 21 % in all fields at topping.

Figure 5. Topping at the height of 30 cm. Photos P. Kurki.

Time between topping and the first harvest was less than two weeks, which was too short time for red clover to develop and to increase protein content of the forage. Topping did not increase clover content of the first silage cut but rather on the contrary. Total dry matter production was decreased due to topping (4800 *vs*. 3870 kg ha^{-1}, P=0.025) as well as clover dry matter yield (837 *vs*. 478 kg ha^{-1}, P=0.02) and nitrogen yield (88 *vs*. 70 kg ha^{-1}, P=0.024). Forage quality data did not differ between treatments or fields but high quality values were met (Table 3).

Too short growing time between topping and harvest could be seen also in heights of red clover-grass swards. Grass height was decreased due to topping (80 *vs*. 68 cm) in the first silage cut. Topping damaged red clover in the second field, where red clover development was ahead and height had averaged topping height (30 cm) at the time of topping. In the second field red clover height averaged 56 and 67 cm with and without topping, respectively. No difference in red clover heights (on average 54 cm) was found between treatments in the first field. The same phenomenon could be seen in red clover yield results.

Organic dairy farmers succeeded well with forage production. They gained by one cut from un-topped organic red clover-grass yield of 4800, 3270, 560 and 380 kg ha^{-1} dry matter, digestible organic matter, crude protein and metabolizable protein, respectively. By that cut on average 52,300 MJ ha^{-1} metabolizable energy was harvested.

Tiller production of timothy was investigated in spring in order to identify the best possible period to apply the topping. Virkajärvi (2003) reported that timothy tiller production differed from that of other forage grass species. In accordance with those previous results both generative tillers and elongated vegetative tillers were recognized. At harvest 90 % of timothy tillers were generative rest remaining elongated vegetative ones. Those tillers have erect growth habit, which means good ability to intercept light and produce a high dry matter yield.

At the harvest 60 % of generative tillers were heading and the rest was still developing indicating a harvest time as commonly recommended. Red clover was at the growth stage of green flower-bud. All together growth stage of organic red clover-grass mixture was a most optimal in consideration of forage quality as it could be seen in forage quality results (Table 3). These results were supported by results on organic crop rotation based on red clover leys (Nykänen, 2008).

Table 3. Effect of topping two weeks before harvesting on red clover-grass yield and quality.

	n	Topped	Not topped	SEM	P-value
Dry matter content, g per kg	20	188	182	4.6	0.397
Red clover content, g per kg DM	20	119	167	2.95	0.266
Dry matter yield, kg per ha					
Grasses	20	3377	3957	215.0	0.074
Red clover	20	478	837	166.5	0.146
Total dry matter including weeds	20	3868	4798	268.4	0.025
Nitrogen yield, kg per ha					
Grasses	20	53.4	63.3	2.84	0.026
Red clover	20	14.1	24.5	4.87	0.149
Total dry matter including weeds	20	69.8	88.0	5.20	0.024
Feed analysis from mixed samples including weeds, g/kg DM (ARTTURI®)					
Ash	20	79	78	1.2	0.689
Crude protein	20	114	116	5.2	0.840
Water soluble carbohydrates	20	116	125	3.5	0.078
Neutral detergent fibre (NDF)	20	560	542	12.3	0.318
Indigestible NDF	20	84.8	83.4	2.67	0.715
D-value*	20	675	681	3.4	0.249
Metabolizable energy, MJ/kg DM	20	10.8	10.9	0.06	0.285
Metabolizable protein**	20	77.8	78.5	0.85	0.568
Protein balance in the rumen**	20	-3.1	-2.6	4.19	0.934

SEM = Standard error of the mean.

*Digestible organic matter in dry matter. **Calculated according to Luke (2015).

4.2 Trial 2: Manure use in autumn to increase grass nitrogen content

On the three organic farms with moraine soils dry matter of red clover-grass leys averaged 1200 kg ha^{-1} before slurry digestate was injected into the soil depth of three to four cm in late September (Figure 6). Three weeks later most of slurry was filtered into the soil. In the fourth farm with half-bog soil slurry had been broadcasted into ley surface in late August and dry matter averaged 2200 kg ha^{-1}. Due to warm autumn in 2013 some growth of leys was still occurring in October, three weeks after slurry application (Figure 7). Although autumn temperatures were too warm with high risk not to achieve a proper cold hardening of plants for winter no remarkable winter damage was found and all red clover-grass leys were well established the following spring. Slurry application in autumn increased crude protein content of grass (116 *vs*. 125 g kg^{-1} DM, $P<0.001$) and total crude protein yield (397 *vs*. 455 kg ha^{-1}, $P=0.021$) in the first silage cut of the following year (Table 4). Although more soluble nitrogen was available in the soil it did not decrease the proportion of red clover in the leys.

Figure 6. The ley after slurry digestate injection of 20 t ha^{-1} and three weeks later. Photos: P. Kurki.

Figure 7. Red clover- grass in October 2013 and the same ley in the beginning of the following June. Photos: P. Kurki.

Before slurry application in the autumn soil nitrate nitrogen, ammonium nitrogen and soluble nitrogen (sum of nitrate and ammonium nitrogen) content averaged 0.7, 7.4 and 8.1 mg l^{-1} soil at top layer of 0-25 cm, respectively (Table 5). After harvest the following summer soil nitrogen figures were again at this level. These figures are typical for Finnish mineral soils with red clover grass production before fertilization and after harvest (Nykänen-Kurki *et al.*, 1998).

Table 4. Effect of autumn slurry application on clover grass production in the following spring.

	n	With slurry	No slurry	SEM	P-value
Nitrogen yield, kg ha^{-1}					
Red clover	40	25.8	23.3	2.96	0.562
Grasses	40	47.0	40.3	2.73	0.091
Red clover + grasses	40	72.7	63.6	2.67	0.021
Crude protein yield, kg ha^{-1} in clover + grasses	40	455	397	16.7	0.021
Dry matter yield, kg ha^{-1}					
Red clover	40	725	698	89.0	0.833
Grasses	40	2373	2180	136.6	0.326
Red clover + grasses	40	3098	2879	107.1	0.157
Total (includes unsown species)	40	3433	3244	108.2	0.226
Crude protein concentration, g kg^{-1} DM					
Red clover	40	225	218	3.5	0.195
Grasses	40	125	116	2.1	<0.001
Proportion of red clover	40	0.215	0.217	0.0278	0.968
Proportion of unsown species	40	0.095	0.106	0.0121	0.514

Concentration of soil nitrogen differed according to field ($P<0.001$) due to soil type but no difference between treatment areas was found before start of the trial. Effect of slurry application both on soil nitrate and ammonium nitrogen ($P<0.001$ and P=0.002, respectively) was clearly observed after five weeks of application (Table 5). The effect could still be detected ($P=0.044$) in soil soluble nitrogen the following spring although natural mineralization of nutrients also occurred. These soil nitrogen results confirmed the effect of autumn slurry application to increase grass nitrogen content of the following spring and *vice versa*.

Soil layer of 0-25 cm (depth of ploughing) contained 25 million litre soil ha^{-1}. At that layer 2, 18 and 20 kg ha^{-1} nitrate nitrogen, ammonium nitrogen and soluble nitrogen, respectively, was determined before slurry application. Over 90 % of soil nitrogen was ammonium nitrogen. Considering the soil layer of 0-50 cm on average 25 kg ha^{-1} soluble nitrogen was measured before starting the trial.

With slurry digestate by Bioson Ltd 62 kg ha^{-1} soluble nitrogen was applied at the depth of four cm. Soil soluble nitrogen at the ploughing layer was enhanced on average by 15 kg ha^{-1} in five weeks. In consideration of results on untreated field 14 kg ha^{-1} soluble nitrogen was estimated to mineralize in spring. At the first silage cut 47 and 73 kg N ha^{-1} in grass and in total red clover grass yield, respectively, was harvested. Biological nitrogen fixation and nutrient cycling underground in rooting system was not estimated. Grasses and red clover are capable to catch nutrients much deeper than at the depth of 50 cm (Kutschera and Lichtenegger, 2010).

These results were in accordance with preliminary results by Virkajärvi and Räty (2014) who found no significant difference between summer and autumn direct injection applications of slurry on total nitrogen leaching in lysimeter field trials that included two surface runoff collector ditches. Instead, a risk for surface runoff of phosphorus was found with autumn application in spite of direct injection. In this trial phosphorus runoff was not investigated.

Table 5. Soil nitrate nitrogen, ammonium nitrogen and soluble nitrogen concentration.

	n	With slurry	No slurry	SEM	P-value
Soil depth of 0-25 cm					
Nitrate N, mg l^{-1} soil					
September before slurry	30	0.7	0.8	0.11	0.526
October five weeks after slurry	40	3.2	0.8	0.35	<0.001
May after winter	40	2.3	2.1	0.33	0.745
June after silage harvest	30	0.8	0.9	0.88	0.698
Ammonium N, mg l^{-1} soil					
September before slurry	30	7.4	7.4	0.35	0.988
October five weeks after slurry	40	9.8	6.2	0.76	0.002
May after winter	40	11.3	10.7	0.42	0.373
June after silage harvest	30	8.7	8.8	0.31	0.872
Soluble N, mg l^{-1} soil					
September before slurry	30	8.1	8.2	0.41	0.879
October five weeks after slurry	40	13.0	6.9	0.90	0.001
May after winter	40	13.5	12.8	0.62	0.044
June after silage harvest	30	9.6	9.7	0.34	0.806
Soil depth of 25-50 cm					
Nitrate N, mg l^{-1} soil					
September before slurry	30	0.2	0.2	0.06	0.735
May after winter	38	3.7	2.2	0.64	0.087
Ammonium N, mg l^{-1} soil					
September before slurry	30	2.0	1.9	0.11	0.976
May after winter	38	7.3	5.3	1.06	0.171
Soluble N, mg l^{-1} soil					
September before slurry	30	2.1	2.2	0.13	0.897
May after winter	38	11.0	7.5	1.65	0.124

Government Decree on the restriction of discharges from agriculture and horticulture was renewed in 2014 and it was valid since 1 April 2015 (Government Decree 1250/2014). Government Decree concerns all manure and organic fertilizer products. From 15 September to 31 October only direct injection is allowed. No distribution between 1 November and 31 March is allowed. After 1 September application of maximum 35 kg ha^{-1} soluble nitrogen of organic origin is allowed. It means that for example not more than 10 t ha^{-1} of slurry digestate by Bioson Ltd could be applied in autumn, which is already at the limitation of economical profitability.

4.3 On-farm trials as a scientific research means

One of the challenges in conducting on-farm trials was to collect reliable quantitative data. In both trials reported here, the yield of the swards was estimated both by taking 0.25 m^2 samples manually as typically done in research work, and by using a forage harvester equipped with scales, which was owned by the farmer (Figure 8).

Both methods seemed to work adequately, and the treatments ranked similarly with both methods. Yield of large scale harvesting averaged 72 % of that from small plot sampling in all farm trials, but the difference was constant between fields and treatments indicating successful on-farm trial management (Figure 9).

Thus the conclusion from the results was the same despite the harvesting method although yield data was at the different level according to measuring method. The machinery harvest areas were large enough to decrease variability and reliable estimates of the yield in absolute terms were obtained. The difference between small plot and farm scale measurements has been recognised also earlier, and in accordance with these results a scaling factor of 0.7 has been used in converting small plot results into a farm scale.

Figure 8. The area for John Deere 7250i farm scale harvesting was marked clearly. Photos: P. Kurki.

Under scarcity of funds for research on organic production, on-farm research was a valuable tool to develop the sector. The most important phases in the on-farm research process were the discussions before and after the experimental work. Discussions took place together with farmers, advisors and researchers to define the questions, and to conclude from results and experiences afterwards. Successful cooperation of networking farmers, advisors and researchers was shown in these cases. Targets to get more information for the farmers themselves and to disseminate to other farmers by professional magazines, Internet and open field days by trials were met.

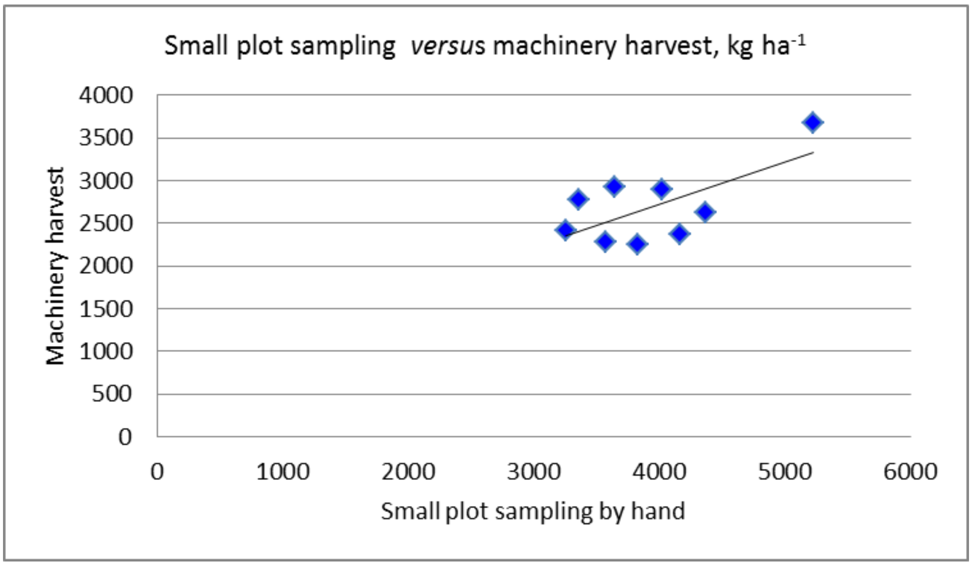

Figure 9. Effect of harvest method on estimation of dry matter production.

The annual variation in weather conditions is a challenge in all agricultural research as was also evident from particularly the topping trial reported here. The results might have been different in a cooler spring, and repetition over several years would give more definitive answers to most questions related to forage production.

There was no preference for different ways of doing on-farm research based on these cases. More important was to find the best way to answer the actual needs and questions. The interest of the farmer was the key point, when there was a need to do extra actions by him. In many cases on-farm research was a rapid way to give practical answers and increase both organic production and common knowledge in the topic.

This kind of work was valuable also for science. It allows to conduct trials on variable soils and environments, which are directly relevant to practice, but the need of replication and cost of visiting the farms may become relatively large. Observations and measurements in the small plots could be randomized and replicated sufficiently to decrease variation and meet scientific demands for statistical analyses. If there was a chance to introduce a number of farmers with large-scale fields and farm-scale harvesting machinery to participate, validity of the study increased as well.

5 Conclusions/Recommendations

The optimal timing for topping of grass to enhance red clover contribution in the first silage cut could not be discovered and more research will be needed to evaluate this adequately. However, valuable information on organic red clover-grass dry matter production and forage quality on farm level was achieved.

Autumn slurry application increased grass protein contribution in the first silage cut in the following spring. Management with direct injection into red clover-grass ley was successfully established. Risk of nitrogen leaching seemed to be low but role of phosphorus could not be investigated. Environmental aspects need more discussion for example related to phosphorus cycle.

Observational actions were most suitable to be conducted by a researcher or an advisor in the small plots, but the overall yields of fields or larger plots were better to harvest with farm-scale machines. On the basis of the experiences from the trials in Finland on-farm experiments had a lot to offer both to farmers and to researchers as an efficient tool to carry out research on good cultivation practices.

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