Agronomy Research **7**(Special issue II), 684–690, 2009

Biomass production and feeding value of whole-crop cereal-legume silages

A. Nykänen[1], L. Jauhiainen[2] and M. Rinne[3]

[1] MTT Agrifood Research Finland, Plant Production Research, Lönnrotinkatu 3, FIN-50100 Mikkeli, Finland; e-mail: arja.nykanen@mtt.fi
[2] MTT Agrifood Research Finland, Method Services, FIN-31600 Jokioinen, Finland
[3] MTT Agrifood Research Finland, Animal Production Research, FIN-31600 Jokioinen, Finland

Abstract. In eastern Finland, 12 mixtures of spring wheat, spring barley, spring oats and/or rye with vetches and/or peas were evaluated in field experiments from 2005 to 2007 for their dry matter (DM) production, crude protein (CP) concentration and digestibility using three different harvesting times. Spring wheat-pea and spring wheat-vetch-rye mixtures produced the highest DM yields (5,000–6,000 kg ha^{-1}) while the lowest yields were found with spring oats-vetch (4,000 kg ha^{-1} DM). The highest CP concentrations were found in vetches (200 g kg^{-1} DM) and lowest in spring cereals (90–120 g kg^{-1} DM). Organic matter digestibility was highest in peas (700–750 g kg^{-1}) and lowest in spring rye and wheat (550–610 g kg^{-1}). It is suggested that decisions concerning when to harvest legume-cereal mixtures for forage could be based on the maturity stage of the cereal, because changes in digestibility and CP concentration are slow in legumes during the potential harvesting period.

Key words: barley, dry matter yield, forage digestibility, oats, pea, rye, vetch, wheat

INTRODUCTION

In the Nordic countries the winter-feeding in organic milk and meat production is based on silage made from perennial clover-grass mixtures. Over-wintering of perennial swards can be a problem on farms and the area available for manure spreading is limited. Cultivation of cereals for whole-crop silage can solve these problems. Production of peas has focused on growing these crops for seed, but they can be cultivated for forage crops as well, especially in northern Europe's short growing season. Peas can be grown as pure stands, but there is the risk of lodging, especially with leafed varieties (Salawu et al., 2001; Koivisto et al., 2003). With the right choice of cultivars, mixed cropping of peas and cereals can keep the stand upright as well as improve the biomass production (Salawu et al., 2001). Experience with cultivation of legume-cereal mixtures for silage in Finland is limited (Pursiainen & Tuori 2006; 2008) and there have been no studies on different mixtures for this purpose.

Growing time and stage of maturity at harvest greatly affect the forage yield and quality (Åman & Graham, 1987; Mustafa & Seguin, 2004). Growing time can be expressed as accumulated growing degree days (GDD) over a base temperature of 5ºC, or as crop age in days. In the case of grain legumes, the yields of seeds and pods are important to the yield quality, in addition to leaves and stems (Salawu et al., 2001).

When fed to dairy cows, whole-crop cereals increase the utilisation of nitrogen (N) and DM intake, but they have been found to be only moderately digestible and result in marginal improvements in milk production (Ahvenjärvi et al., 2006). For legumes, high rates of intake and ruminal fermentation have been found (Mustafa et al. 2000). It has been shown that ruminants tend to eat more of mixed than single forage rations (Huhtanen et al. 2007) and that animal production can be improved when energy- and protein-rich crops are intercropped and used as feed (Salawu et al., 2000).

The aim of this study was to examine changes in the yield and nutritional characteristics of mixtures of cereals and legumes for whole crop silage for three growing seasons in Finland. In addition, how the nutritional characteristics of each plant species developed during the growing season in relation to GDD was studied.

MATERIALS AND METHODS

Field experiments were carried out in Juva in eastern Finland (61°5'N 27°5'E) on a sandy soil (Dystric Regosol) with moderate organic matter (OM) concentration. The nutrient status was good or moderate according to the Finnish soil classification system (Vuorinen & Mäkitie, 1955). The fields had been cultivated using organic farming methods for 20 years. The experimental years 2005, 2006 and 2007 were in July and August 0.6–2.5 degrees warmer than the long-term average. In that area, the average precipitation from May to August is 250 mm. In 2006 the precipitation was 150 mm whereas the growing seasons in 2005 and in 2007 were quite wet with rainfall varying from 350 mm to 390 mm. Altogether 12 different mixtures were tested for whole crop silage in plots of 15 m^2. The mixtures consisted of spring wheat (*Triticum aestivum* L., cv. 'Amaretto'), spring barley (*Hordeum vulgare* L., cv. 'Polartop'), spring oats (*Avena sativa* L., cv. 'Roope'), spring rye (*Secale cereale* L. cv. Juuso) or winter rye (cv. 'Riihi') with common vetch (*Vicia sativa*, cv. 'Ebena'), hairy vetch (*Vicia villosa*, cv. 'Hungavillosa') and/or pea (*Pisum sativum* L.) (Table 1). In the mixtures, three different pea cultivars were also tested. 'Timo' is a long-straw variety with light purple flowers, 'Nitouche' is a white-flowering semi-leafless pea, while 'Algarve' is intermediate between these two. Italian ryegrass was sown as a catch crop.

Table 1. The seed amounts (kg ha^{-1}) of the different plant species in the mixtures and the cultivation year of each mixture in field experiments.

Acronym	Wheat	Oats	Barley	Rye	Pea	Vetch	Ryegrass	Year
M	60	60			30^{T}	40^{E}	10	2005
M1	60	60			30^{A}	40^{EH}	10	2006, 2007
M2	30	30			15^{A}	20^{EH}	10	2006, 2007
WP^{T}	180				50^{T}			2005, 2006
WP^{N}	180				50^{N}			2005,2006
WP^{A}	180				30^{A}			2007
WP^{A2}	100				80^{A}			2007
WVR^{J}	120			60^{J}		40		2006,2007
WVR^{R}	120			60^{R}		40		2007
BP			180		50^{N}			2005,2006
OV		180				40		2006,2007

^{J} = rye cv. 'Juuso', ^{R} = rye cv. 'Riihi', ^{T} = pea cv. 'Timo', ^{A} = pea cv. 'Algarve', ^{N} = pea cv. 'Nitouche', ^{EH} = in 2006 half of the vetch was hairy vetch.

The plots were fertilised with 30 Mg ha^{-1} cow slurry. The mixtures were sown in May with a plot drill and harvested at three harvesting times from July to August (Table 2) with a Haldrup harvester. The total fresh matter yield of the plot was weighed and a sample for DM determination was taken and dried at 105ºC for 16 hours. Before harvesting, two 0.25 m^2 samples from each plot were taken for plant composition determination. Different plant species were separated by hand, weighed, chopped, dried at 60ºC for 16 hours and milled with a 1 mm sieve for chemical analyses.

Table 2. Sowing and harvesting dates, growing time (days) and growing degree days (GDD, ºC, calculated as 5ºC base temperature) of the crops in different cuts in the experimental years.

Year	Cut	Sowing date	Harvest date	Growing time	GDD
2005	1	26 May	27 July	61	636
	2		8 August	71	765
	3		22 August	85	916
2006	1	25 May	12 July	48	496
	2		26 July	61	650
	3		4 August	67	721
2007	1	6 June	31 July	54	452
	2		6 August	60	519
	3		13 August	67	622

The total N concentration in the plant samples was determined with the *Kjeldahl* method (AOAC method 984.13) and multiplied by 6.25 to obtain the crude protein concentration. The *in vitro* OM digestibility (OMD) was determined using a modification of the pepsin-cellulase method described by Nousiainen et al. (2003). The results were calculated with forage-type specific correction equations to convert the *in vitro* values into those determined for sheep with maintenance level feeding (Huhtanen et al., 2006). The whole-crop equation was used for cereals and the legume equation for vetches and peas.

The field experiments were done with a split-plot-design, where 'mixture' was the main plot and 'cutting time' was the sub-plot with four replicates. The set of mixtures varied from year to year. The statistical model used takes into account the variation between years and therefore estimates for all mixtures are comparable. A mixed model approach was used to analyse the data. The fixed effects were cutting time, mixture and their interaction. Random effects were year, block within year and interactions of year*mixture, block*year*mixture, year*cutting time and year*mixture*cutting time. Analyses were performed using SAS/MIXED software (SAS 2004).

RESULTS AND DISCUSSION

The highest DM yields, around 5,000 kg ha^{-1}, were found when spring wheat was mixed with peas or vetch and rye (Table 3). In those mixtures the proportion of spring wheat varied from 60% to 80%. The lowest DM yield was produced by the mixture of oats and vetch. The DM yields increased 1,500–2,000 kg ha^{-1} during the final two weeks of the growth period, resulting yields of 6,000 kg ha^{-1}, which is comparable to the average yields of perennial clover-grass leys in organic farming in Finland (Nykänen 2008).

Table 3. Dry matter (DM) yields (kg ha^{-1}), yields as feed units (FU-yield, FU ha^{-1}), organic matter digestibility (OMD, g kg^{-1}), crude protein (CP, g kg^{-1} DM) and N amount of the yield (N-yield, kg N ha^{-1}) of the mixtures. Mixture acronyms refer to table 1. Values with different superscripts differ (P<0.05) from each other. (Standard errors in parentheses).

Mixture	*n*	Yield	FU-yield	OMD	CP	N-yield
M	12	4 680^{abc} (512)	4 290^{b} (435)	668^{bc} (29)	158^{c} (9)	120^{d} (14)
M1	24	4 480^{ab} (462)	4 000^{b} (378)	659^{bc} (24)	148^{c} (7)	105^{bcd} (12)
M2	24	4 470^{ab} (462)	4 030^{ab} (378)	666^{bc} (24)	143^{c} (7)	101^{bcd} (12)
WP^{T}	24	4 800^{bc} (461)	4 230^{b} (376)	645^{abc} (23)	124^{ab} (7)	95^{abc} (12)
WP^{N}	24	5 200^{c} (461)	4 460^{b} (376)	630^{ab} (23)	108^{a} (7)	88^{ab} (12)
WP^{A}	12	5 090^{bc} (509)	4 400^{b} (431)	637^{abc} (29)	110^{a} (9)	87^{ab} (14)
WP^{A2}	12	5 040^{bc} (509)	4 550^{b} (431)	661^{bc} (29)	121^{ab} (9)	95^{abc} (14)
WVR^{J}	24	5 320^{c} (462)	4 330^{b} (378)	591^{a} (24)	107^{a} (7)	93^{ab} (12)
WVR^{R}	12	4 940^{bc} (509)	4 350^{b} (431)	648^{abc} (29)	144^{c} (9)	112^{cd} (14)
BP	24	4 560^{ab} (462)	4 210^{ab} (378)	677^{bc} (24)	117^{a} (7)	84^{a} (12)
OV	24	4 100^{a} (461)	3 650^{a} (377)	658^{bc} (23)	161^{c} (7)	106^{bcd} (12)

The botanical composition did not change remarkably when growth proceeded (data not shown). The proportion of peas in mixtures varied from 10% to 25% and the proportion of vetches varied from 20% to 40% in DM. The amount of weeds varied from 5% to 20% being smallest in mixtures with vetches and wheat.

Mixture containing spring rye (WVR^{J}) produced the highest DM yield, but the nutritive value was the lowest, since spring rye matures very fast. The OMD varied from 630 to 680 g kg^{-1}, being highest in mixtures of barley-pea (BP), wheat-pea with higher amount of pea in seed mixture (WP^{A2}) and diversified mixtures (M-M2) (Table 3). These values are considered too low for dairy cows and beef bulls. Rondahl et al. (2006) used remarkably higher pea amounts in seed mixture (200 kg ha^{-1}) resulting high OMD (740–820 g kg^{-1}) and CP (165–176 g kg^{-1}) in a pea-oats whole-crop silage. Differences between feed unit yields (FU-yield) were evened out because of the effect of OMD. Mixtures containing vetches had relatively high CP concentrations (120–140 g kg^{-1} DM), which also resulted in higher N amounts (N-yield) in mixtures.

Table 4. The Organic matter digestibility (OMD, g kg^{-1}) and crude protein (CP, g kg^{-1} DM) content of the different crops as an average of all mixtures and cutting times. Values with different superscripts differ (P<0.05) from each other. S.E. indicates the standard error.

Crop, cultivar	*n*	OMD	S.E.	CP	S.E.
Pea, 'Timo'	33	719^{f}	12.7	179^{f}	3.9
Pea, 'Algarve'	32	750^{g}	12.8	161^{e}	4.4
Pea, ,Nitouche'	44	713^{f}	12.5	147^{d}	3.6
Common vetch, 'Ebena'	93	688^{e}	12.2	205^{h}	3.0
Hairy vetch, 'Hungavillosa'	12	678de	14.2	239^{i}	5.6
Spring wheat	45	611^{b}	12.5	103^{b}	3.5
Spring barley	24	670^{d}	13.1	113^{c}	4.4
Spring oats	81	641^{c}	12.2	109^{bc}	3.1
Spring rye, 'Juuso'	23	548^{a}	13.1	73^{a}	4.4
Winter rye, 'Riihi'	12	755^{g}	14.2	192^{g}	5.8

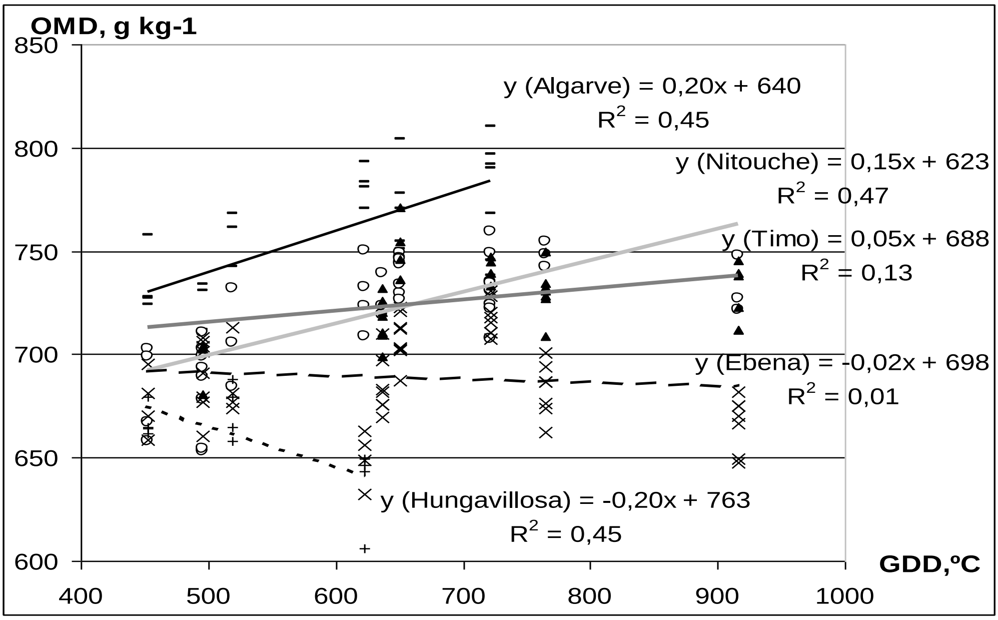

Fig. 1. Development of the organic matter digestibility (OMD g kg-^{1}) of peas (Algarve (–), Nitouche (○), Timo (▲)) and vetches (Ebena (×), Hungavillosa (+)) cultivars according to growing degree days (GDD, ºC).

The highest OMD was found in peas (710–800 g kg^{-1}) and especially in the 'Algarve' cultivar, a type, which is intermediate between the other cultivars (Table 4; Fig. 1). Vetches and spring barley had an OMD of 670 g kg^{-1}, while the other spring cereals had the lowest values (550–610 g kg^{-1}). Pursiainen & Tuori (2008) reported OMD values of 751, 716 and 670 g kg^{-1} for pea, common vetch and spring wheat, which were higher than our values even though the growing period was slightly longer in their experiment.

CP concentrations varied greatly in our experiments and the highest values were found in vetches (200–240 g kg^{-1} DM) and the lowest in spring cereals (70–110 g kg^{-1} DM). Pursiainen & Tuori (2006; 2008) observed lower CP concentration for common vetch, similar or higher for pea and higher for barley in their experiments, which might be a result of different varieties and their conventional farming method compared to our organic method.

During the last two to three weeks, the OMD of peas increased while it decreased in hairy vetch (Fig. 1). It was also noticed that the OMD of spring barley increased slightly while the other spring cereals matured more quickly (data not shown). The CP concentration decreased with all other crops except peas (data not shown). Other authors have also concluded that the nutritive characteristics of peas develop slowly compared to spring cereals (Salawu et al. 2001; Borreani et al., 2007). The changes in nutritive values of plants during the growing period can be explained partly by the maturity-induced changes in the composition of plant parts, and changes in grain (pod)-straw ratio.

CONCLUSIONS

The most productive mixtures for cereal-legume whole-crop silage in organic farming are mixtures, which contain spring wheat and peas. The highest CP concentrations were found in vetches and the highest OMD in peas. The development of these nutritive values is quite slow and the optimal harvesting point for whole-crop silage of mixtures of legumes and cereals can be determined based on the developmental stage of the cereals and the target for the yield.

ACKNOWLEDGEMENTS. We are most thankful to the field and laboratory staff for their great contribution in the analysis of the numerous samples. We also thank the Employment and Economic Development Centre of South-Savo for financing this study.

REFERENCES

Ahvenjärvi, S., Joki-Tokola, E., Vanhatalo, A., Jaakkola, S. & Huhtanen, P. 2006. Effects of replacing grass silage with barley silage in dairy cow diets. *Journal of Dairy Science* **89,** 1678−1687.

Åman, P. & Graham H. 1987. Whole-crop peas. I. Changes in botanical and chemical composition and rumen in vitro degradability during maturation. *Animal Feed Science and Technolog,* **17**, 15−31.

Borreani, G., Peiretti, PG. & Tabacco, E. 2007. Effect of harvest time on yield and pre-harvest quality of semi-leafless grain peas (*Pisum sativum* L.) as whole-crop forage. *Field Crops Research* **100**, 1–9.

Huhtanen, P., Nousiainen, J. & Rinne, M. 2006. Recent developments in forage evaluation with special reference to practical applications. *Agricultural and Food Science* **15,** 293−323.

Huhtanen, P., Rinne, M. & Nousiainen, J. 2007. Evaluation of the factors affecting silage intake of dairy cows: a revision of the relative silage dry-matter intake index. *Anima,* **1,** 758−770.

Koivisto, JM., Benjamin, LR., Lane GPF. & Davies, WP. 2003. Forage potential of semi-leafless grain peas. *Grass and Forage Science* **58**, 220−223.

Mustafa, AF., Christensen, DA. & McKinnon, JJ. 2000. Effect of pea, barley, and alfalfa silage on ruminal nutrient degradability and performance of dairy cows. *Journal of Dairy Science* **83**, 2859−2865.

Mustafa, AF. & Seguin,P. 2004. Chemical composition and in-vitro digestibility of whole-crop pea-cereal mixture silages grown in South-western Quebec. *Journal of Agronomy and Crop Science* **190**, 416−421.

Nousiainen, J., Rinne, M., Hellämäki, M., & Huhtanen, P. 2003. Prediction of the digestibility of the primary growth of grass silages harvested at different stages of maturity from chemical composition and pepsin-cellulase solubility. *Animal Feed Science and Technology* **103,** 97-111.

Nykänen, A. 2008. Nitrogen dynamics of organic farming in a crop rotation based on red clover (Trifolium pratense) leys. *Agrifood Research Reports* **121**, 60p. (Diss.). http://www.mtt.fi/met/pdf/met121.pdf

Pursiainen, P. & Tuori, M. 2006. Replacing grass silage with pea-barley intercrop silage in the feeding of the dairy cow. *Agricultural and Food science* **15**, 235−251.

Pursiainen, P. & Tuori, M. 2008. Effect of ensiling field bean, field pea and common vetch in different proportions with whole-crop wheat using formic acid or an inoculant on fermentation characteristics. *Grass and Forage Science* **63**, 60−78.

Rondahl, T., Bertilsson, J., Lindgren, E. & Martinsson, K. 2006. Effects of stage of maturity and conservation strategy on fermentation, feed intake and digestibility of whole-crop pea-oat silage used in dairy production. *Acta Agriculturae Scandinavica Section A*, **56**, 137−147.

Salawu, MB., Adesogan, AT. & Dewhurst, RJ. 2000. Milk production from dairy cows offered pea-wheat bi-crops containing different ratio of peas to wheat and harvested at two maturity stages. *Proceedings of the British Society of Animal Science* **150**.

Salawu, MB., Adesogan, AT., Weston, CN. & Williams, SP. 2001. Dry matter yield and nutritive value of pea/wheat bi-crops differing in maturity at harvest, pea to wheat ratio and pea variety. *Animal Feed Science and Technology* **94**, 77−87.

SAS 2004. *SAS/STAT 9.1 User's Guide.* Cary, NC: SAS Institute Inc. 5121p.

Vuorinen, J. & Mäkitie, O. 1955. The method of soil testing in use in Finland. *Agrogeological Publications* **63,** 1−44.