

# The effect of incorporation time of different crops on the residual effect on spring cereals

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The effect of the time of incorporation of different green manures and barley residues on the grain yield of spring cereals in two successive seasons was studied in seven field trials. Annual hairy vetch (*Vicia villosa* Roth), red clover (*Trifolium pratense* L.), westerwold ryegrass (*Lolium multiflorum* Lam. var. *westerwoldicum*) and straw of spring barley (*Hordeum vulgare* L.) were incorporated into the soil by ploughing in early September, late October and the following May, and by reduced tillage in May. Spring barley was established in the following spring, and spring oats (*Avena sativa* L.) one year later.

In general the grain yield of spring barley after legumes was similar to that after barley, in spite of the fact that N fertilization was reduced by 40 kg ha<sup>-1</sup>. The two autumn ploughing treatments resulted in a good yield of spring barley more reliably than did the spring incorporations. Because delayed autumn ploughing did not decrease the grain yield, a delaying procedure can be recommended for its potential of decreasing nitrogen leaching. Spring ploughing could be used on all but clay soils. Incorporating ryegrass or red clover in spring by using reduced tillage often decreased the grain yield of barley. Timing of incorporation did not have a consistent effect on the grain yield of oats in the third experimental year.

*Key words:* *Avena sativa*, decomposition, green manures, *Hordeum vulgare*, legumes, *Lolium multiflorum*, mineralization, mulching, *Trifolium pratense*, *Vicia villosa*

## Introduction

The residual effect of a green manure crop is highly dependent on the species grown (Wallgren and Lindén 1991). Legumes are generally considered to leave high amounts of N for the succeeding crop (Badaruddin and Meyer 1990), although there are great differences between legume crops in this respect (Kirchmann and Marstorp 1991). In Finland, cool late autumn weather and cold winter can decrease the decomposition rate of plant material and nitrification of nitrogenous compounds in soil (Anderson 1960). However, mineralization processes has been found to occur at low temperatures, too (Müller and Sundman 1988, Van Schöll et al. 1997).

On the basis of experiments with several different green fallow crops, delayed ploughing in autumn was proposed mainly because of the reduced risk of N leaching (Känkänen 1993), which is in accordance with several other results (Haynes 1994). However, the measures needed to support good utilization of the green manure N by spring-sown crops in Finland are not fully understood. Delayed incorporation of green manure crops can be used to enhance synchronization of the release of N with the requirements of the succeeding crop. Incorporation of green manure crop in spring, immediately before the next crop is sown, may lead to too late N mineralization with respect to the need of the succeeding crop (Thorup-Kristensen 1996). Delaying incorporation of green manure crop in autumn can also affect the yield of the following crop: Sanderson and MacLeod (1994) found that potato planted in spring following lupin incorporated on 1 October had a higher tuber yield than did that following lupin incorporated on 1 September.

The method of incorporation of the crop residues can also affect the successive cereal grain yield, either because the N release from the incorporated plant material differs or there are other factors in the soil influencing yield, or both. Maillard and Vez (1991) noticed that cereal yield was higher when green manure was incorporat-

ed lightly into the soil rather than by regular ploughing into the 20–25 cm soil layer. Direct drilling of grain sorghum into clover surface mulch was not recommended by Lemon et al. (1990), because N availability was not synchronous with the needs of the succeeding plant.

The positive effect of N rich plant biomass on the succeeding cereal grain yield is often reduced with increasing N fertilization (Badaruddin and Meyer 1990, Lindén and Wallgren 1993). Further, Francis and Knight (1993) state that after different tillage methods, differences in yields can be compensated with different amount of fertilizer N.

The aim of the study was to investigate how the time of incorporation (early or late autumn ploughing, and spring incorporation by ploughing) of crops with different N content (hairy vetch, red clover and westerwold ryegrass, and straw of spring barley) affect the grain yield of the following spring cereal crop. Reduced tillage was added as an additional treatment as this practise is increasingly common in cereal cropping in Finland. The effects of different N fertilization rates of the following crop on the differences between the effects of other treatments was studied, too.

## Material and methods

Hairy vetch (*Vicia villosa* Roth), red clover (*Trifolium pratense* L.), westerwold ryegrass (*Lolium multiflorum* Lam. var. *westerwoldicum*) and straw residues of spring barley (*Hordeum vulgare* L.) were incorporated into the soil by ploughing in early autumn (beginning of September), late autumn (end of October) and spring (May) and by reduced tillage in spring. Incorporation times were determined according to normal practices in cereal farming in Finland, autumn ploughing period starting after crop harvest and ending when soil is frozen or too wet for ploughing. Time of spring tillage was determined according to soil moisture suitable for

sowing. The experimental sites, design, treatments and samplings are described in detail by Känkänen et al. (1998). Spring barley and oats (*Avena sativa* L.) were harvested with a combine harvester when ripe (1.5 m x 7 m per plot). After the grains had been dried in an air stream (+40°C) and sorted, the grain yield was measured and calculated as kg ha<sup>-1</sup> at 15% moisture.

Information on weather conditions during the experimental years is given in detail by Känkänen et al. (1998), and in Table 1.

The names of the trials are abbreviated as follows: Jokioinen 1991–1993 = J1, Jokioinen 1993–1995 = J2, Pälkäne 1991–1993 = P1, Pälkäne 1993–1995 = P2, Ylistaro 1991–1993 = Y1, Ylistaro 1993–1995 = Y2 and Toholampi 1991–1993 = T. The crop of the first experimental year (green manures and spring barley) is called precrop, the crop of the second experimental year (spring barley) is called 1st year test crop, and the crop of the third experimental year (oats) is called 2nd year test crop.

## Statistical methods

The data from the seven different field trials were analysed separately. The main effects of precrop, incorporation treatment and N fertilization, and their interactions, on the grain yield of 1st year test crop (spring barley) were tested statistically by analysis of variance according to the split-split-plot design. Replication was considered a random effect, whereas precrop, incorporation treatment and N fertilization were considered fixed effects. Precrop was analysed as a main plot factor, incorporation treatment as a subplot factor and N fertilization as a sub-subplot factor.

If significant interaction between N fertilization and other treatments were found, the differences of the effect of N fertilization in different treatment combinations were examined, else significant effects of the precrop and incorporation treatment and their interactions were examined over all N fertilization levels. If an interaction between the precrop and incorporation treat-

ment was found, the effects of incorporation treatments were determined separately for different precrops. The differences were examined in pairs, and the means were compared by t-type contrast examinations. When there was no interaction, but the main effect was due to the precrop or incorporation treatment, the paired comparisons were made by Tukey's honest significant difference (HSD) methods.

Before the analysis of variance was performed, the consistency of different examinations with the assumptions of equality of group variances were checked by Box-Cox diagnostic plots. In addition the normality assumption of errors was assessed by graphic methods. All analyses were performed by means of the SAS statistical package. MIXED (SAS 1992), UNIVARIATE (SAS 1990) and GPLOT (SAS 1991) procedures were used.

## Results

### Precrop yields

The dry matter yields of green manure crops varied, depending on site, year, species and sampling date (Table 2). In autumn, we measured 5000–8000 kg ha<sup>-1</sup> dry matter of hairy vetch. However, in the succeeding spring the detectable amount of dry matter in material left on the soil surface was only 2000–6000 kg ha<sup>-1</sup>. In red clover (total dry matter ranging from 1800 to 9500 kg ha<sup>-1</sup>), this was found at both Jokioinen and Toholampi in 1991–1992. A great proportion (as an average 50%) of the red clover dry matter was in roots, and the amount in red clover grown annually increased sharply between samplings before early (12–38%) and late autumn (49–65%) ploughing. In contrast, the dry matter yield of vetch was mainly in above-ground plant biomass. The dry matter yield of westerwold ryegrass ranged from 2500 to 7000 kg ha<sup>-1</sup>. The average N content of the above-ground plant biomass varied between trials from

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Table 1. Weather conditions at the experimental sites in experimental years (data provided by the Finnish Meteorological Institute) and in 1961–1990 (Finnish Meteorological Institute 1991).

	Mean air temperature, °C						Precipitation, mm					
	1991	1992	1993	1994	1995	1961–1990	1991	1992	1993	1994	1995	1961–1990
<i>Jokioinen</i>												
January	-3.6	-2.1	2.3	-4.8	-3.6	-7.5	69	50	56	52	46	36
February	-7.5	-2.7	-3.4	-13.9	-1.0	-7.4	16	31	16	1	58	24
March	-1.0	0.4	-0.9	-3.2	-0.3	3.5	31	43	29	54	45	25
April	3.4	1.3	3.3	5.0	2.7	2.4	14	48	29	33	47	32
May	7.2	11.4	13.5	7.8	8.7	9.4	29	7	1	34	87	35
June	12.1	15.6	11.4	12.1	16.7	14.3	69	25	56	66	121	47
July	16.6	16.0	15.6	19.0	15.3	15.8	55	47	107	1	53	80
August	16.2	14.3	12.9	15.1	15.1	14.2	92	107	136	54	65	83
September	9.1	11.2	5.7	10.0	10.3	9.4	80	59	13	105	45	65
October	5.4	-0.6	3.0	4.4	7.6	4.7	49	64	51	75	66	58
November	2.6	-1.8	-3.6	-1.0	-2.8	-0.4	81	63	3	24	47	55
December	-1.6	0.1	-3.4	-0.4	-8.5	-4.9	34	33	61	51	19	42
Year	4.9	5.3	4.3	4.2	5.0	3.9	619	577	558	551	698	582
<i>Pälkäne</i>												
January	-4.6	-2.9	-2.8	-5.8	-4.0	-8.2	40	37	41	50	52	36
February	-8.2	-3.1	-3.4	-14.6	-1.5	-8.0	13	39	16	2	58	25
March	-1.4	0.3	-0.9	-3.2	-0.4	-3.6	33	47	31	54	36	27
April	3.4	0.6	2.6	4.5	2.1	2.2	17	56	25	43	26	32
May	7.5	11.5	13.3	7.9	8.8	9.5	22	8	3	48	65	37
June	12.8	16.2	11.6	12.7	17.0	14.7	88	30	46	75	76	50
July	17.3	15.8	15.7	19.2	15.6	16.3	41	58	75	5	37	74
August	16.6	14.1	13.1	15.5	15.5	14.6	103	136	128	75	60	82
September	9.5	11.5	5.9	10.3	10.5	9.7	68	105	18	84	33	64
October	5.5	-0.6	3.0	4.3	7.5	4.7	36	67	59	75	51	58
November	2.5	-2.7	-4.0	-1.4	-2.9	-0.7	65	61	5	35	48	50
December	-2.1	-0.3	-4.0	-1.0	-9.5	-5.4	44	25	53	38	26	40
Year	4.9	5.0	4.2	4.0	4.9	3.8	570	669	501	583	568	574
<i>Ylistaro</i>												
January	-4.1	-2.9	-3.0	-6.7	-3.8	-8.6	25	43	40	25	19	31
February	-8.9	-2.6	-3.8	-13.8	-2.3	-8.4	14	31	14	1	39	21
March	-1.7	0.6	-0.8	-3.6	-0.1	-4.1	39	36	17	38	52	23
April	3.9	0.2	3.1	4.2	2.1	2.0	12	23	23	26	22	29
May	6.5	10.9	11.6	6.8	7.7	8.8	56	13	16	7	44	38
June	12.3	15.1	10.9	12.5	16.1	14.0	147	18	84	81	75	42
July	16.4	14.5	15.2	17.8	14.9	15.5	26	77	86	28	45	68
August	15.7	13.2	12.6	14.4	14.1	13.6	60	103	122	52	34	70
September	7.9	10.4	5.4	9.1	9.6	8.8	88	91	26	56	48	61
October	5.2	-2.6	2.5	3.1	6.8	4.1	38	62	78	83	42	50
November	2.2	-3.7	-3.1	-2.0	-3.7	-1.4	49	47	10	31	25	45
December	-2.0	0.2	-5.1	-0.8	-9.8	-6.2	25	41	51	25	12	35
Year	4.5	4.4	3.8	3.4	4.3	3.2	578	584	568	452	458	513
<i>Toholampi</i>												
January	-6.4	-4.1	-4.4		-10.5		32	55	62			35
February	-9.1	-4.6	-4.5		-10.0		18	29	20			24
March	-4.3	-1.8	-1.7		-5.3		34	51	27			28
April	2.6	1.9	2.0		0.9		24	12	26			30
May	5.5	10.0	10.8		8.1		38	10	20			38
June	11.6	10.2	10.4		13.4		108	15	17			49
July	15.6	15.2	15.8		15.4		35	138	70			67
August	14.8	12.2	12.5		13.1		61	107	82			79
September	6.9	9.6	4.7		7.8		110	99	34			59
October	4.1	-3.2	1.6		2.8		46	47	99			49
November	1.1	-5.0	-3.6		-2.9		65	75	7			48
December	-3.6	-0.6	-5.7		-7.9		33	48	76			38
Year	3.2	3.3	3.2		2.1		604	686	540			544

Table 2. Above-ground and root dry matter yield (kg ha<sup>-1</sup>) and N content (%; in parentheses) of green manure crops. J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, T = Toholampi 1991–1993.

	Above-ground dry matter			Root dry matter (0–20 cm)		
	Hairy vetch	Red clover	Westerwold ryegrass	Hairy vetch	Red clover	Westerwold ryegrass
<i>J1</i>						
Early autumn	6910 (3.1)	5280 (3.0)	4380 (0.9)	240 (1.5)	1960 (2.0)	880 (0.7)
Late autumn	7510 (3.1)	3510 (2.4)	3900 (1.2)	220 (1.9)	6030 (2.2)	1090 (0.9)
Spring	1850 (2.2)	1160 (3.0)	1950 (1.1)	280 (2.2)	660 (3.0)	680 (1.2)
Reduced tillage	2170 (2.3)	1180 (2.7)	2110 (0.9)	200 (2.6)	1770 (3.1)	1250 (0.8)
<i>J2</i>						
Early autumn	6170 (3.2)	2560 (3.2)	3160 (1.7)	710 (3.3)	1550 (2.4)	2150 (1.2)
Late autumn	4670 (4.0)	3410 (3.4)	3610 (1.9)	810 (2.4)	3240 (2.7)	1290 (1.4)
Spring	2000 (3.0)	2790 (3.4)	1810 (1.7)	250 (2.2)	2480 (3.0)	1310 (1.1)
Reduced tillage	3970 (2.7)	2080 (3.3)	2100 (1.8)	720 (2.0)	2210 (3.2)	1620 (1.0)
<i>P1</i>						
Early autumn	6330 (3.0)	2280 (2.0)	2760 (0.9)	780 (1.6)	1410 (1.0)	2730 (0.8)
Late autumn	6730 (2.9)	2650 (2.0)	2520 (1.0)	2110 (1.4)	4820 (1.6)	3110 (0.7)
Spring	3320 (2.5)	2720 (2.1)	3760 (0.8)	2250 (–)	3650 (–)	3200 (–)
Reduced tillage	4750 (2.4)	2290 (2.1)	3180 (0.7)	1890 (–)	4750 (–)	3000 (–)
<i>T</i>						
Early autumn	4490 (2.7)	2210 (1.6)	5390 (0.8)	240 (1.8)	290 (1.5)	750 (1.1)
Late autumn	4610 (3.3)	1750 (2.1)	1150 (1.0)	940 (1.2)	1520 (1.6)	1440 (1.1)
Spring	1800 (2.7)	710 (2.2)	1130 (1.3)	390 (1.5)	1860 (1.5)	2050 (1.4)
Reduced tillage	1680 (2.7)	900 (2.5)	1350 (1.2)	340 (1.5)	1720 (1.6)	2960 (1.1)

2.1 to 3.1%, 1.2 to 3.4%, 0.9 to 1.8% and 0.8 to 1.4% in vetch, red clover, ryegrass and barley straw, respectively. The respective root N content ranged from 1.5 to 3.0%, 1.3 to 2.8%, 0.8 to 1.7% and 1.1 to 1.9%. Total N yield ranged from 45 to 240, 40 to 220 and 25 to 90 kg ha<sup>-1</sup> in vetch, red clover and ryegrass, respectively. The amount of N in plant biomass is more closely presented in our earlier article (Känkänen et al. 1998). The amount of incorporated barley straw was determined only in two trials: the total N yield in autumn was 90 kg ha<sup>-1</sup> in P1 and 50 kg ha<sup>-1</sup> in T.

### Grain yield of 1st year test crop

The grain yield of the 1st year test crop (spring barley) differed markedly at the experimental

sites. The lowest (J1) and highest (Y1) average grain yield varied from 500 to 5100 kg ha<sup>-1</sup>. Unless otherwise mentioned, the differences between treatments are statistically significant at the level  $P < 0.05$  (Table 3). Grain yields presented below are calculated as the means over N fertilization levels, because N fertilization normally increased the grain yield in spite of other treatments. The few exceptions showing significant interaction are examined more closely later in the text.

The precrop affected the grain yield of the 1st year test crop in four trials (P1, P2, Y2, T); the poor grain yield after red clover in three of these trials was partly caused by decreased N fertilization. The incorporation treatment affected the grain yield of 1st year test crop in all trials except Y2. However, in trials P2, Y1 and T the effect of incorporation depended on the pre-crop.

Table 3. Statistical significances of the main effects of the treatments and their interactions on grain yield of 1st year test crop (spring barley) and 2nd year test crop (oats). Degrees of freedom of F test are in subscript after treatments. J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, Y2 = Ylistaro 1993–1995, T = Toholampi 1991–1993.

	J1	J2	P1	P2	Y1	Y2	T
<i>1st year test crop</i>							
Precrop <sub>3,6</sub>	0.89	0.56	0.03	<0.001	0.45	0.027	0.009
Incorporation <sub>3,24</sub>	<0.001	0.046	0.003	<0.001	0.17	0.29	<0.001
Precrop x incorporation <sub>9,24</sub>	0.71	0.9	0.52	0.002	0.027	0.85	0.033
N fertilization <sub>2,64</sub>	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Precrop x fertilization <sub>6,64</sub>	0.26	0.11	0.48	<0.001	0.46	0.17	0.052
Incorp. x fertilization <sub>6,64</sub>	0.47	0.57	0.52	0.012	0.39	0.77	0.16
Precr. x incorp. x fertil. <sub>18,64</sub>	0.38	0.88	0.28	0.95	0.63	0.69	0.033
<i>2nd year test crop</i>							
Precrop <sub>3,6</sub>	0.83	0.98	0.057	0.17	0.39	0.91	0.63
Incorporation <sub>3,24</sub>	0.11	0.39	0.14	0.33	0.052	0.11	0.003
Precrop x incorporation <sub>9,24</sub>	0.24	0.29	0.22	0.44	0.15	0.73	0.11
N fertilization <sub>2,64</sub>	0.024	0.003	0.58	0.65	0.26	0.96	0.16
Precrop x fertilization <sub>6,64</sub>	0.74	0.006	0.18	0.68	0.65	0.46	0.55
Incorp. x fertilization <sub>6,64</sub>	0.58	0.59	0.2	0.21	0.35	0.95	0.014
Precr. x incorp. x fertil. <sub>18,64</sub>	0.31	0.95	0.021	0.37	0.42	0.71	0.27

### *Effect of precrop*

The grain yield of the 1st year test crop showed that hairy vetch had the expected 40 kg ha<sup>-1</sup> N effect; in one trial (P1), this effect was even higher (Fig. 1). Although the increase in the yield of 1st year test crop after vetch was high compared with that after barley in J2, 1100 kg ha<sup>-1</sup>, the effect of the precrop was not statistically significant.

The differences between the grain yields of 1st year test crop after red clover and barley were small in three trials (J1, P1, Y1) in spite of 40 kg ha<sup>-1</sup> lower N fertilization after red clover (Fig. 1, Table 4). In three trials (P2, Y2, T), the grain yield of 1st year test crop was lower after red clover than after barley. In these trials also N yield of red clover was lower than in other trials, above ground N yield being 20–30 kg ha<sup>-1</sup> in the former trials and 50–90 kg ha<sup>-1</sup> in the latter. However, in trials P2 and T the differences between precrops varied, depending on the incorporation treatment (Table 4). The average grain yield of 1st year test crop after the 90 kg N ha<sup>-1</sup> above ground yield of red clover in J2 was more than 200 kg ha<sup>-1</sup> higher than that of after barley;

the difference was not statistically significant, however.

In one trial (P2), the average grain yield of 1st year test crop was clearly smaller after westerwold ryegrass than after barley, although the difference varied depending on the incorporation treatment. The average grain yield of 1st year test crop was, however, 500 kg ha<sup>-1</sup> higher after westerwold ryegrass than after barley in three trials (J2, Y1, T). The differences were not statistically significant.

### *Effect of incorporation treatment*

According to the grain yield of 1st year test crop, both ploughing dates in autumn were suitable at all experimental sites after all precrops (Fig. 2, Table 4), except in Y1, in which late autumn ploughing of westerwold ryegrass decreased the grain yield of 1st year test crop by an average of 550–840 kg ha<sup>-1</sup> as compared with the other incorporation treatments. After hairy vetch and barley a similar tendency was seen, but the difference (on average 300 kg ha<sup>-1</sup>) was not statistically significant (Table 4).

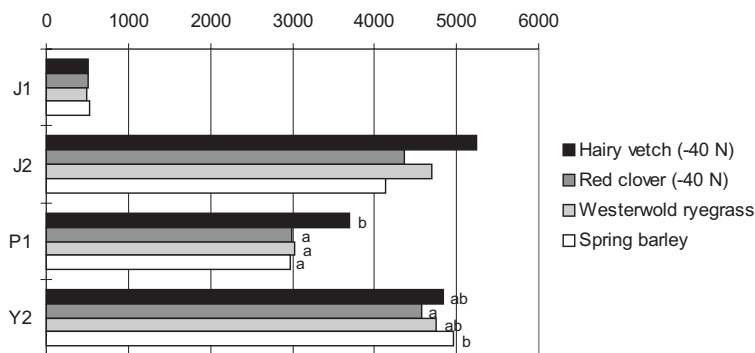


Fig. 1. The main effect of the precrop on grain yield of 1st year test crop (spring barley) in trials with no interactions between incorporation and precrop. The bars are based on means of all incorporation and N fertilization treatments, reduced by 40 kg ha<sup>-1</sup> after legumes (standard error of means, SEM: J1 = 41, J2 = 558, P1 = 352, Y2 = 187 kg ha<sup>-1</sup>). Within trials, yields followed by the same letter are not statistically different at level P<0.05. There was a statistically significant interaction between precrop and incorporation treatment in trial P2, Y1 and T; results presented in Table 4. J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, Y2 = Ylistaro 1993–1995, T = Toholampi 1991–1993.

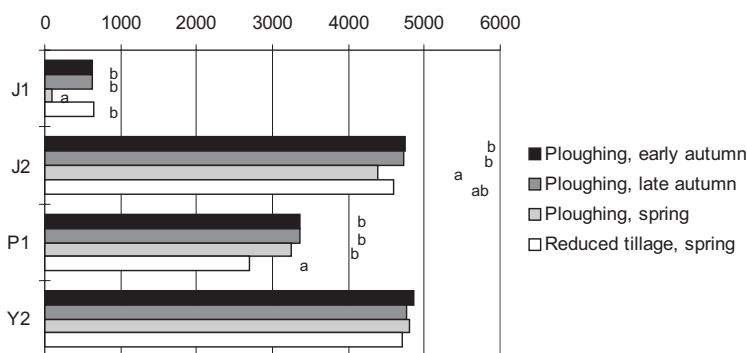


Fig. 2. The main effect of incorporation treatment on grain yield of 1st year test crop (spring barley) in trials with no interactions between incorporation and precrop. The bars are based on means of all precrops and N fertilization treatments, reduced by 40 kg ha<sup>-1</sup> after legumes (standard error of means, SEM: J1 = 41, J2 = 291, P1 = 348, Y2 = 184 kg ha<sup>-1</sup>). Within trials, yields followed by the same letter are not statistically different at level P<0.05. There was a statistically significant interaction between precrop and incorporation treatment in trial P2, Y1 and T; results presented in Table 4. J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, Y2 = Ylistaro 1993–1995, T = Toholampi 1991–1993.

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Table 4. Effect of incorporation treatment of different precrops on the succeeding 1st year test crop (spring barley) grain yield (kg ha<sup>-1</sup>) in trials with interactions between incorporation and precrop. The figures are means of N fertilization treatments, reduced by 40 kg ha<sup>-1</sup> after legumes. The main effect of precrop and incorporation is presented in 'average' columns and rows. P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, T = Toholampi 1991–1993.

	Hairy vetch	Red clover	Westerwold ryegrass	Spring barley	Average
<i>P2 (SEM 130)</i>					<i>(SEM 65)</i>
Early autumn	3100 <sup>ab</sup>	2210 <sup>b</sup>	2550 <sup>c</sup>	2940 <sup>b</sup>	2700 <sup>b</sup>
Late autumn	3280 <sup>b</sup>	2170 <sup>b</sup>	2460 <sup>bc</sup>	2610 <sup>a</sup>	2630 <sup>b</sup>
Spring	2970 <sup>a</sup>	1770 <sup>a</sup>	2200 <sup>ab</sup>	2790 <sup>ab</sup>	2430 <sup>a</sup>
Reduced tillage	3100 <sup>ab</sup>	1550 <sup>a</sup>	1960 <sup>a</sup>	2950 <sup>b</sup>	2390 <sup>a</sup>
<i>Average (SEM 137)</i>	<i>3110<sup>s</sup></i>	<i>1920<sup>f</sup></i>	<i>2290<sup>f</sup></i>	<i>2820<sup>s</sup></i>	
<i>Y1 (SEM 434)</i>					<i>(SEM 324)</i>
Early autumn	4920 <sup>a</sup>	4850 <sup>b</sup>	5550 <sup>b</sup>	5130 <sup>a</sup>	5110
Late autumn	4850 <sup>a</sup>	5150 <sup>b</sup>	5000 <sup>a</sup>	4670 <sup>a</sup>	4920
Spring	5270 <sup>a</sup>	4960 <sup>b</sup>	5650 <sup>b</sup>	4970 <sup>a</sup>	5210
Reduced tillage	5100 <sup>a</sup>	4340 <sup>a</sup>	5840 <sup>b</sup>	5130 <sup>a</sup>	5100
<i>Average (SEM 405)</i>	<i>5030</i>	<i>4830</i>	<i>5510</i>	<i>4980</i>	
<i>T (SEM 225)</i>					<i>(SEM 144)</i>
Early autumn	5080 <sup>b</sup>	3930 <sup>b</sup>	4830 <sup>ab</sup>	4760 <sup>b</sup>	4650 <sup>b</sup>
Late autumn	4640 <sup>b</sup>	4290 <sup>b</sup>	4840 <sup>ab</sup>	4650 <sup>b</sup>	4600 <sup>b</sup>
Spring	4950 <sup>b</sup>	4420 <sup>b</sup>	5090 <sup>b</sup>	4400 <sup>b</sup>	4710 <sup>b</sup>
Reduced tillage	3730 <sup>a</sup>	2710 <sup>a</sup>	4410 <sup>a</sup>	3650 <sup>a</sup>	3630 <sup>a</sup>
<i>Average (SEM 165)</i>	<i>4600<sup>s</sup></i>	<i>3840<sup>f</sup></i>	<i>4790<sup>s</sup></i>	<i>4360<sup>fs</sup></i>	

Within columns, means followed by the same letter are not statistically different at level "P<0.05; the italic rows (Average) are excluded from this comparison. Within italic rows," means followed by the same letter are not statistically different at level P<0.05 (P2, T). Standard error of means (SEM) is presented for each comparison.

Ploughing in spring was not an advantageous on clay soil at Jokioinen (J1, J2), the grain yield of 1st year test crop being 250–550 kg ha<sup>-1</sup> lower than with autumn ploughing or reduced tillage in spring, irrespective of the precrop (Fig. 2). Even in P2 (sandy soil), incorporation of the green manure crops by ploughing in spring resulted in a smaller grain yield than did autumn ploughing (Table 4). In the other trials, the grain yield of 1st year test crop after spring ploughing was about the same as that after autumn ploughings.

Although spring tillage with a cultivator was applicable on clay soil at Jokioinen, at other sites the grain yield of 1st year test crop was often smallest after reduced tillage in spring, especially after red clover. The grain yield of 1st year test

crop was smallest after reduced tillage in spring in two trials irrespective of the precrop (P1, T), in two trials with red clover (P2, Y1) and in one trial (P2) with westerwold ryegrass as the precrop (Fig. 2, Table 4). In these cases, the difference between reduced spring tillage and autumn ploughing treatments was marked, on average 750 kg ha<sup>-1</sup>.

#### *Effect of N fertilization*

N fertilization clearly increased the grain yield of 1st year test crop (Table 5). However, in P2, N fertilization did not increase the grain yield after hairy vetch (interaction between precrop and N fertilization, P < 0.001), and the yield increase was smaller after early autumn plough-



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Table 5. Effect of precrop, incorporation and N fertilization on the 1st year test crop (spring barley) grain yield (kg ha<sup>-1</sup>). Standard errors of means (SEM) are presented in parentheses after abbreviation of each trial. J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, Y2 = Ylistaro 1993–1995, T = Toholampi 1991–1993.

	Hairy vetch			Red clover			Westerwold ryegrass			Spring barley		
	0N	40N	80N	0N	40N	80N	40N	80N	120N	40N	80N	120N
<i>J1 (SEM 88)</i>												
Early autumn	590	530	650	550	610	600	650	620	740	570	790	700
Late autumn	550	590	740	700	740	640	580	640	720	560	620	540
Spring	110	70	90	150	70	120	50	70	40	100	160	160
Reduced tillage	660	790	720	620	650	620	360	620	710	620	650	760
<i>J2 (SEM 638)</i>												
Early autumn	4900	5380	6140	4270	4390	4650	4430	5340	4910	3720	4530	4090
Late autumn	4620	5260	5650	4190	4140	5240	4240	5050	5340	3950	4310	4530
Spring	4260	5260	5690	3970	4310	3880	3880	4630	4580	3820	4360	4030
Reduced tillage	4630	5200	6020	3840	4890	4360	4590	4840	5020	3710	4180	4460
<i>P1 (SEM 512)</i>												
Early autumn	3560	3390	5290	2650	2880	3000	3110	3460	3700	2840	3270	3090
Late autumn	3400	4090	4380	2210	3930	3230	2710	3400	3040	2620	3340	4060
Spring	3170	3870	4050	2390	3220	3760	2810	3680	3380	2340	3240	3160
Reduced tillage	2250	3460	3410	2290	2430	3900	1980	2420	2580	2320	2790	2620
<i>P2 (SEM 187)</i>												
Early autumn	3210	3030	3040	1970	2230	2420	2230	2700	2730	2620	3110	3100
Late autumn	3290	3340	3200	1720	2210	2580	2110	2560	2710	2070	2920	2840
Spring	2760	3100	3060	1340	1960	2010	1790	2380	2440	2350	3140	2900
Reduced tillage	2930	2900	3470	1200	1470	1970	1240	2220	2410	2310	3040	3490
<i>Y1 (SEM 503)</i>												
Early autumn	4580	4700	5480	4600	4740	5220	5260	5350	6040	4780	5050	5550
Late autumn	4360	4860	5310	4670	5030	5610	4520	5600	4880	4190	4490	5320
Spring	4450	5580	5790	3900	5470	5510	5240	5680	6030	4770	5000	5150
Reduced tillage	4240	5540	5500	3730	4160	5140	5490	6020	6010	4480	5050	5870
<i>Y2 (SEM 260)</i>												
Early autumn	4970	5110	4800	4470	4800	4770	4830	4780	4860	4550	5290	4990
Late autumn	4750	4850	4860	4080	4820	4670	4760	4830	4810	4860	5040	5130
Spring	4680	5220	4840	4450	4600	5080	4330	4730	5020	4890	5090	4940
Reduced tillage	4790	5060	4750	3990	4520	4700	4320	4740	4900	4550	5010	5240
<i>T (SEM 281)</i>												
Early autumn	3670	5240	6340	2300	4190	5300	4060	4840	5580	3550	5010	5730
Late autumn	2980	4770	6160	3260	4090	5510	3570	5010	5930	3230	4820	5890
Spring	4170	4770	5900	3110	4410	5730	3870	5330	6060	3290	4850	5040
Reduced tillage	2200	3970	5020	1690	2400	4050	3050	4570	5610	2390	3710	4830

ing than after other incorporation treatments (interaction between incorporation and N fertilization,  $P = 0.012$ ). In one trial (T), the yield-increase due to N fertilization after vetch and barley was smaller when spring ploughing than oth-

er incorporation treatments (interaction between precrop, incorporation and N fertilization,  $P = 0.033$ ). The same phenomenon was found after westerwold ryegrass when early autumn ploughing was used. Even so, the yield-increase

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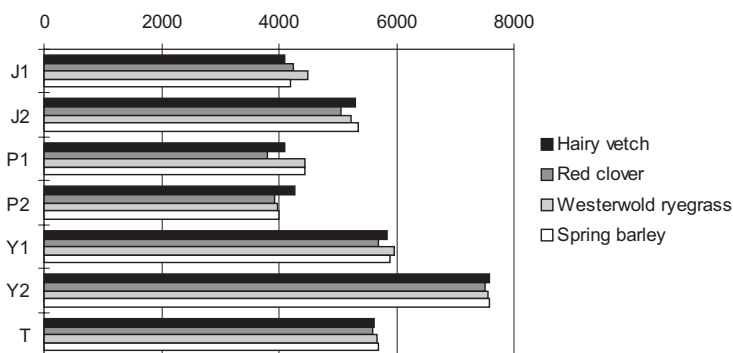


Fig. 3. The main effect of the pre-crop on grain yield of 2nd year test crop (oats). The bars are based on means of treatments (standard error of means, SEM: J1 = 366, J2 = 579, P1 = 168, P2 = 102, Y1 = 198, Y2 = 126, T = 149 kg ha<sup>-1</sup>). J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, Y2 = Ylistaro 1993–1995, T = Toholampi 1991–1993.

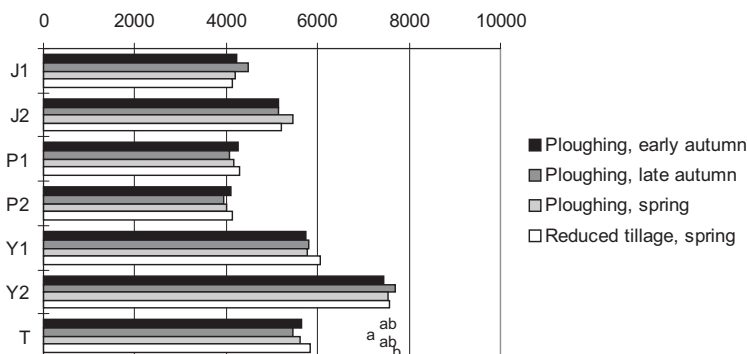


Fig. 4. The main effect of incorporation treatment after the pre-crop on grain yield of 2nd year test crop (oats). The bars are based on means of treatments (standard error of means, SEM: J1 = 271, J2 = 399, P1 = 130, P2 = 87, Y1 = 189, Y2 = 117, T = 149 kg ha<sup>-1</sup>). Within trials, yields followed by the same letter are not statistically different at level  $P < 0.05$ . J1 = Jokioinen 1991–1993, J2 = Jokioinen 1993–1995, P1 = Pälkäne 1991–1993, P2 = Pälkäne 1993–1995, Y1 = Ylistaro 1991–1993, Y2 = Ylistaro 1993–1995, T = Toholampi 1991–1993.

ing effect of N fertilization was clear in the above cases, too.

## Grain yield of 2nd year test crop

### Effect of precrop

The precrop did not have a statistically significant effect on the grain yield of 2nd year test crop (oats), although in all trials except J1 the yield was somewhat smaller (in J2, P1 and Y1 on average 200 kg ha<sup>-1</sup>) after red clover than after other precrops (Fig. 3).

### Effect of incorporation treatment

The incorporation treatment had a statistically significant effect on the grain yield of 2nd year test crop in two trials, Y1 and T (Table 3). In these trials, the plots with reduced spring tillage in the preceding season increased the average grain yield of 2nd year test crop by 200–400 kg ha<sup>-1</sup> as compared with other incorporation treatments (Fig. 4).

### Effect of N fertilization

At Jokioinen (J1, J2), the lowest rate of N fertilization of 1st year test crop resulted in a small-

er grain yield of 2nd year test crop than did the two higher N fertilization levels. In J1, the differences between the lowest level and the two higher fertilization levels were about 200 kg ha<sup>-1</sup>, irrespective of the other treatments. In J2, the differences varied considerably, depending on precrop (interaction between precrop and N fertilization,  $P = 0.006$ ): the maximum difference was nearly 1000 kg ha<sup>-1</sup> with barley as a precrop, whereas there were no differences when red clover was the precrop. In other trials, N fertilization of 1st year test crop did not affect the grain yield of 2nd year test crop. In two other individual cases, there was an interaction between N fertilization and other treatments (T: between incorporation and fertilization,  $P = 0.014$ ; P1: between precrop, incorporation and fertilization,  $P = 0.021$ . Table 3). For these interactions we could not find any solid explanations.

## Discussion

The ability of incorporated N-rich plant biomass to increase the succeeding cereal grain yield was expected, partly because N mineralized from the residues correlates positively with the crop N content (Vinther 1994, Clement et al. 1995), and partly because earlier results had suggested such an increase (Kauppila 1983, Känkänen 1993). The presumption of a 40 kg ha<sup>-1</sup> residual N effect after legumes was correct, although the effect of hairy vetch as a precrop exceeded this figure in some trials. Also the effect of red clover fell below the presumption, if the growth of clover was poor.

The study of soil mineral N (Känkänen et al. 1998), showed that early autumn ploughing increased soil mineral N at the beginning of the following growing season as compared with other incorporation times. Late autumn ploughing increased soil mineral N as compared with spring incorporation only when the soil mineral N content was exceptionally high. Soil conditions suitable for N mineralization after late autumn in-

corporation was concluded to last generally too short time under Finnish conditions to result in substantial net N mineralization before spring. Thus the release of N from incorporated plant biomass during the following summer can be essential for the yield of the following crop, accordingly to Francis et al. (1994), who found that grain yield of spring wheat correlated positively with net N mineralization during the growing season after crops with a different N content.

Francis et al. (1994) also found that grain yield of spring wheat correlated positively with soil mineral N content before the growing season. In the present study however, the yield could not be deduced from the soil N contents, as in general spring barley yields were similar after early and late autumn ploughing. Similar soil N but lower yields after spring incorporation in some cases when compared with late autumn ploughing confirms this conclusion. Tillage treatment obviously affected the other growing conditions so, that the effect of soil mineral N was masked.

Because decreasing the risk of N leaching (Haynes 1994, Känkänen et al. 1998), delayed ploughing in autumn is preferable to early autumn ploughing for incorporating a green manure crop. Delayed autumn ploughing is particularly suitable for red clover sown in the spring of the green manure year, giving the clover a longer time to accumulate N; Wivstad (1997) found that the N yield of red clover doubled between the ages of 14 and 20 weeks. In our study cereal yields were better after late ploughed red clover, even in Y1, in which late autumn ploughing otherwise decreased the grain yield of the following 1st year test crop (spring barley).

Changes in mineralization rate of plant biomass are also marked due to changes in chemical composition of the biomass during plant growth (Franzluebbers et al. 1994, Wivstad 1997). In our study, however, this effect was expected to be small as compared with the decrease in mineralization due to lower soil temperatures in late autumn (Anderson 1960).

Soil type and previous crop have to be taken

into account when considering time of tillage. Generally spring ploughing is not recommended for heavy clay soils (Mikkola 1989). On the other hand, reduced tillage with a cultivator in spring resulted in our study in comparable grain yield with autumn ploughing on heavy clay soil. However, mistiming either the basic tillage or seed bed preparation can lead to a major yield loss. On other soil types tested in our study, spring ploughing decreased the grain yield as compared with autumn ploughing in only one trial, whereas reduced tillage in spring reduced the yield in many cases.

When comparing reduced tillage and ploughing of green manure, Poutala and Hannukkala (1995) found that reduced tillage had an adverse effect on the following grain yield, but Maillard and Vez (1991) found a beneficial effect. In the former study autumn ploughing was compared with reduced tillage of hairy vetch and persian clover in both autumn and in spring in Finland, whereas the latter group compared shallow and deep autumn incorporation of mustard in Switzerland. According to the present study, the reduced tillage of red clover, a perennial strongly competing with cereal crops by regrowth, is particularly unsuitable. Even in the absence of competition, an adverse effect was obvious, reduced tillage in spring being an almost equally poor method for incorporating of both westerwold ryegrass and red clover.

Although N fertilization of the following crop can compensate the differences caused by pre-crops (Lindén and Wallgren 1993) or tillage methods (Francis and Knight 1993), the effect of incorporation time was similar at all N fertilization rates in this study. Thus, timing of incorporation of crop biomass do not depend on the fertilization intensity used in the farming

system, but the decisive factor is the amount and content of N in the biomass.

Because of the variable effects in individual trials during the second after-effect year, neither the timing nor the method of incorporation could be concluded to clearly affect the grain yield of 2nd year test crop, oats. The results suggest, that conventional early autumn ploughing is no more appropriate than any of the other tillage treatments used in this study.

Because of numerous experimental sites and two experimental years, this study covered well the Finnish growing conditions. However, there was variation in results between individual trials caused by anomalous weather conditions. In our opinion this did not cause serious problems in interpretation of the results, even in J1 where the drought severely decreased the yield of spring barley. The main conclusions of this study can be generalized in conditions where soil is frozen during long winter period.

## Conclusions

Our results suggest that autumn ploughing is a more reliable procedure than ploughing or reduced tillage in spring, in efforts to obtain good spring cereal yields under Finnish conditions. Because of no adverse effect on the grain yield of the succeeding spring barley, autumn ploughing should be delayed when incorporating N rich green manure crops. Also spring ploughing could be used on all but clay soils, although an adverse effect on the grain yield of spring barley was seen even on sandy soil in some cases. Reduced tillage is not recommended for incorporating grasses or perennial legumes in spring.

## References

- Anderson, O.E. 1960. The effect of low temperatures on nitrification of ammonia in Cecil sandy loam. *Soil Science Society of America Proceedings* 24: 286–289.
- Badaruddin, M. & Meyer, D.W. 1990. Green-manure legume effects on soil nitrogen, grain yield, and nitrogen nutrition of wheat. *Crop Science* 30: 819–825.
- Clement, A., Ladha, J.K. & Chalifour, F.P. 1995. Crop

- residue effects on nitrogen mineralization, microbial biomass, and rice yield in submerged soils. *Soil Science Society of America Journal* 59: 1595–1603.
- Finnish Meteorological Institute 1991. Climatological statistics in Finland 1961–1990. Supplement to the *Meteorological Yearbook of Finland* 90, 1: 125 p.
- Francis, G.S., Haynes, R.J. & Williams, P.H. 1994. Nitrogen mineralization, nitrate leaching and crop growth after ploughing-in leguminous and non-leguminous grain crop residues. *Journal of Agricultural Science* 123: 81–87.
- & Knight, T.L. 1993. Long-term effects of conventional and no-tillage on selected soil properties and crop yields in Canterbury, New Zealand. *Soil & Tillage Research* 26: 193–210.
- Franzluebbers, K., Weaver, R.W. & Juo, A.S.R. 1994. Mineralization of labeled N from cowpea (*Vigna unguiculata* L. Walp.) plant parts at two growth stages in sandy soil. *Plant and Soil* 160: 259–266.
- Haynes, R.J. 1994. Impact of management practices on nutrient cycling. In: Pankhurst, Doube, Gupta & Grace (eds.). *Soil biota: management of sustainable farming systems*. p. 172–181.
- Känkänen, H. 1993. Nitrogen in soil and yields of cereals after green fallows. *Soil Tillage and Environment*. Proceedings of NJF seminar no. 228, Jokioinen, Finland, 8–10 June 1993. p. 260–264.
- , Kangas, A., Mela, T., Nikunen, U., Tuuri, H. & Vuorinen, M. 1998. Timing incorporation of different green manure crops to minimize the risk of nitrogen leaching. *Agricultural and Food Science in Finland* 7: 553–567.
- Kauppi, R. 1983. Palkokasvien käyttö viherlannoituksessa. Summary: Use of legumes in green manuring. In: Biologisen typensidonnain ja ravinnetypen hyväksikäytön projekti. *Suomen itsenäisyyden juhluvuoden 1967 rahasto. Julkaisu* 6. p. 51–92.
- Kirchmann, H. & Marstorp, H. 1991. Calculation of N mineralization from six green manure legumes under field conditions from autumn to spring. *Acta Agriculturae Scandinavica* 41: 253–258.
- Lemon, R.G., Hons, F.M. & Saladino, V.A. 1990. Tillage and clover cover crop effects on grain sorghum yield and nitrogen uptake. *Journal of Soil and Water Conservation* 45: 125–127.
- Lindén, B. & Wallgren, B. 1993. Nitrogen mineralization after leys ploughed in early or late autumn. *Swedish Journal of Agricultural Research* 23: 77–89.
- Maillard, A. & Vez, A. 1991. Influence du travail du sol sur la valorisation des engrais de ferme et des engrais verts en grandes cultures. Summary: Influence of tillage on nitrogen efficiency of farmyard and green manure under cropland. *Revue Suisse d'Agriculture* 23, 1: 11–14.
- Mikkola, H. 1989. Syyskyntöä korvaavien muokkausmenetelmien vaikutus kevätevehnän satoon 1975–1988. Summary: Effects of autumn ploughing and different reduced tillage methods on yield and quality of spring wheat 1975–1988. *Vakolan tutkimusselostus* 54. p. 3–32.
- Müller, M.M. & Sundman, V. 1988. The fate of nitrogen (<sup>15</sup>N) released from different plant materials during decomposition under field conditions. *Plant and Soil* 105: 133–139.
- Poutala, R.T. & Hannukkala, A. 1995. The effect of the method of incorporation of *Trifolium resupinatum* L. and *Vicia villosa* Roth. residues in the soil and the performance of a succeeding cereal crop. *Acta Agriculturae Scandinavica, Sect. B, Soil and Plant Science* 45: 251–257.
- Sanderson, J.B. & MacLeod J.A. 1994. Soil nitrate profile and response of potatoes to fertilizer N in relation to time of incorporation of lupin (*Lupinus albus*). *Canadian Journal of Soil Science* 74, 2: 241–246.
- SAS Institute Inc. 1990. *SAS Procedures Guide*. Version 6, Third Edition, Cary, NC. 705 p.
- 1991. *SAS System for Statistical Graphics*. First Edition, Cary, NC. 697 p.
- 1992. *SAS Technical Report P-229. SAS/STAT Software: Changes and Enhancements*. Release 6.07, Cary, NC. 620 p.
- Thorup-Kristensen, K. 1996. Effect of catch crop incorporation time on N availability for a succeeding crop. In: Schröder, J.J. (ed.). *Long Term Reduction of Nitrate Leaching by Cover Crops*. First Progress Report of EU Concerted Action (AIR3) 2108. p. 49–54.
- Van Schöll, L., Van Dam, A.M. & Leffelaar, P.A. 1997. Mineralisation of nitrogen from an incorporated catch crop at low temperatures: experiment and simulation. *Plant and Soil* 188: 211–219.
- Vinther, F.P. 1994. N-mineralization and denitrification after incorporation of catch crops and plant residues. *The use of catch or cover crops to reduce leaching and erosion*. Proceedings of NJF seminar no. 245, Knivsta, Sweden, 3–4 October 1994. p. 105–114.
- Wallgren, B. & Lindén, B. 1991. Residual nitrogen effects of green manure crops and fallow. *Swedish Journal of Agricultural Research* 21: 67–77.
- Wivstad, M. 1997. Plant morphology and content of nitrogen, cell wall and lignin at different phenological stages of red clover and yellow sweetclover. *Swedish Journal of Agricultural Research* 27: 3–14.

## SELOSTUS

### Syyskyntö on luotettava tapa muokata kasvimassa maahan

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*Maatalouden tutkimuskeskus*

Huoli viherlannoitustypen kohtalosta maahan muokkaamisen jälkeen synnytti tarpeen selvittää sopivinta muokkaamisen ajankohtaa. Vaikka maan typpimääritykset antavatkin käsityksen muokkausajankohdan suorasta vaikutuksesta huuhtoutumisriskiin, vasta seuraavat kasvukaudet täydentävät tiedon ajoituksen onnistumisesta. Pieni seuraavan kasvin sato lisää vällillisesti ravinteiden huuhtoutumisriskiä, koska ravinteiden ottaminen maasta on vähäisempää suuren sadon tuottavaan kasviin verrattuna. Kahdesta typen huuhtoutumisriskiä vähentävästä muokkausajankohdasta tulee viljelyn kannattavuuden vuoksi valita se, joka antaa paremman satovaikutuksen.

Tutkimus perustuu viherkesantovaihtoehtoihin tavanomaisessa viljanviljelyssä. Aiempien tutkimustulosten osoittama viherlannoitteen muokkausajankohdan vaikuttavan typen huuhtoutumiseen ja hyväksikäyttöön yleensä, haettiin tässä tutkimuksessa parhaita ajankohtia typpipitoisuuksiltaan erilaisten kasvustojen muokkaamiseen.

Seitsemässä kokeessa Maatalouden tutkimuskeskuksen neljällä tutkimusasemalla yksivuotisena viherkesantona kasvaneet ruisvirna, puna-apila ja westerwoldin raiheinä sekä tuleentuneena korjatun ohran sänki ja puintijäte kynnettiin maahan joko aikaisin tai myöhään syksyllä (vaihdellen syyskuun alusta marraskuun alkuun) tai keväällä ennen kylvömuokkausta. Kyntöjen vaihtoehtona kasvustot muokattiin maa-

han myös kyntämättä keväällä ennen varsinaista kylvömuokkausta.

Syyskynnöt johtivat hyvään seuraavaan ohrasatoon luotettavammin kuin kevätkyntö tai kevennetty muokaus keväällä. Kevätkyntöä voidaan kuitenkin käyttää typen huuhtoutumisen välttämiseksi lukuun ottamatta savimaita, joilla se selkeästi pienensi ohran jyväsatoa. Erityisesti raiheinän ja puna-apilan kevennetty muokkaaminen maahan keväällä pienensi usein samana keväänä kylvetyn ohran jyväsatoa. Muokkauksen vaikutus kauran jyväsatoon toisena kasvukautena muokauksen jälkeen vaihteli, eikä mitään muokkausmenetelmää voida sen perusteella pitää muita parempana.

Aikaisemmin julkaistussa, maan mineraalityypen määriä selvittäneessä tutkimuksen osassa päädyttiin suositteluun kynnön viivyttämistä typen huuhtoutumisen vähentämiseksi. Jyväsatojen perusteella syyskynnön viivyttäminen ei vaaranna viljelyn kannattavuutta. Lokakuun olosuhteita tulee kuitenkin seurata, jotta vältetään maan rakenteen vaurioittaminen kyntämällä liian märissä oloissa. Kokeissa kasvustolliset ruudut olivat syksyllä kynnettäessä selkeästi kuivempia kuin sängellä olevat. Kun muokkausajankohdan vaikutus maan mineraalityypen määrään oli lisäksi pieni viljan jälkeen ja kasvoi viherkesannon typpipitoisuuden kasvaessa, kannattaa maatalan syyskynnöt aloittaa sängiltä ja päättää typpipitoisimpiin viherkesantoihin.