Undersowing *Poa pratensis* L., *Festuca rubra* L., *Festuca pratensis* Huds., *Dactylis glomerata* L. and *Lolium perenne* L. for Seed Production in Five Cover Crops.

I. The Yield of the Cover Crops and the Seed Yield of the Undersown Grasses

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ABSTRACT

The effect of undersowing grasses on both cover crop and grass seed yield was investigated over three seasons at the same site. The grass species were smooth stalked meadow grass (*Poa pratensis* L.), red fescue (*Festuca rubra* L.), meadow fescue (*Festuca pratensis* Huds.), cocksfoot (*Dactylis glomerata* L.) and perennial ryegrass (*Lolium perenne* L.), while the cover crops were winter rape (*Brassica napus* L.), winter wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.), field bean (*Vicia faba* L.) and field pea (*Pisum sativum* L.). The cover crops were established at three plant densities. On average the yields of the cover crops were reduced by 5-11% when undersown in grasses compared to no undersowing, with the exception of field bean for which yield was not reduced. The yield reduction in the spring sown cover crops could be overcome by increasing cover crop density, whereas no effect of cover crop density was recorded in the autumn sown crops. Cover crop had no effect on perennial ryegrass and meadow fescue seed yields. The seed yield of smooth stalked meadow grass, red fescue and cocksfoot was increased by undersowing in winter rape compared to spring barley, because of the production of an increased number of fertile tillers.

***Additional index words*: winter rape, winter wheat, spring barley, field bean, field pea, fertile tillers, crop yield, seed yield.**

INTRODUCTION

Grass seed production in Denmark occupies 56,556 ha (The Danish Seed Council, 1996) which is two per cent of arable land. Spring-established perennial grasses do not become reproductive during the first growing season in Denmark, and typically they require two full growing seasons to produce economically harvestable seed yields. For satisfactory seed yields, grass seed crops must be established before 15 July in the Danish environment (Nordestgaard, 1994). However, the fields are normally not cleared from the previous crop until mid August. To provide a longer establishment period, grasses for seed production are therefore established with a cover crop. Traditionally spring barley has been preferred (Olsen, 1995), but since the introduction of winter cereals and winter rape into Danish farming systems, these have also been tested as cover crops (Nordestgaard, 1979, 1988, 1990).

Establishment of tall fescue (*Festuca arundinacea* Schreb.) and cocksfoot (*Dactylis glomerata* L.) in spring sown crops of barley, wheat and oats was examined by Chastain and Grabe (1989a,b). In two consecutive years, establishment of the grasses in a pure stand out yielded establishment in any of the cover crops. On average, establishment in a cover crop reduced the first year seed yields by 61% in tall fescue and by 45% in cocksfoot. In both grass species, the seed yield reduction was closely correlated to reduced tiller production in autumn and therefore a reduced number of fertile tillers. Chastain and Grabe (1988) also examined seed production of red fescue (*Festuca rubra* L.) following establishment by undersowing in two cultivars of autumn sown winter barley and winter wheat. In year one, red fescue establishment in either cover crop did not reduce seed yield compared to sowing in a pure stand. In year two establishment in winter wheat reduced the red fescue seed yield by approximately 170 kg ha^{-1}compared to the pure stand sowing. Red fescue seed yields were 70 kg ha^{-1} higher in both years when established in winter barley, possibly because the winter barley was harvested 14 days earlier than winter wheat. Similarly Nordestgaard (1988) found that establishing smooth stalked meadow grass (*Poa pratensis* L.) in winter barley produced higher seed yields than in winter wheat, but in red fescue he found no significant difference between these two cover crops. Liefstingh and Vreeke (1971) had previously found that undersowing smooth stalked meadow grass and red fescue in winter wheat gave satisfactory yields. However, as improved management has increased winter wheat yields, the seed yields of the undersown grasses have been reduced (Meijer, 1987). Alteration of the cover crop management

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systems was needed to increase seed yields of the undersown grasses (Meijer, 1987).

The purpose of the trial reported in this and subsequent papers was to find the optimum crop management system for the cover crop and the undersown grasses with respect to: the yield of the cover crop, the seed yield of the undersown grasses, the cover crop plant density and the amount of autumn nitrogen applied to the undersown grasses. In this paper, cover crop yields and seed yield of the undersown grasses are presented and discussed. The subject of subsequent papers will be the effect of cover crop plant density and the amount of nitrogen applied in autumn to the undersown grasses on grass seed yield. Preliminary results have been presented in Danish by Nordestgaard and Boelt (1992).

MATERIALS AND METHODS

Five grass species for seed production were undersown in five different cover crops. The grass species were smooth stalked meadow grass (*Poa pratensis* L.) cv. Erte , red fescue (*Festuca rubra* L.) cv. Rubina, meadow fescue (*Festuca pratensis* Huds.) cv. Senu, cocksfoot (*Dactylis glomerata* L.) cv. Amba and perennial ryegrass (*Lolium perenne* L.) cv. Borvi. All the cultivars were forage types. The cover crops were winter rape (*Brassica napus* L.) cv. Ceres, winter wheat (*Triticum aestivum* L.) cv. Kraka, spring barley (*Hordeum vulgare* L.) cv. Grit, field bean (*Vicia faba* L.) cv. Cargo and field pea (*Pisum sativum* L.) cv. Solara. The field trials were conducted from 1988-1992 at the Danish Institute of Agricultural Sciences, Dept. of Cereals, Seeds and Industrial Crops on a sandy loam soil, with grass seed crops being established in 1988, 1989 and 1990. The previous crop in all three years was spring barley.

The grasses and the cover crops were sown separately, the grass seeds immediately after the cover crop except for perennial ryegrass which was spring sown in the established stand of winter rape and winter wheat (Table 1). The grasses were sown at 3 or 6 kg ha^{-1} (see Table 3) in rows 12 cm apart parallel to the cover crop, and at a depth of 1 cm. The cover crops were all sown to establish three different plant densities (denoted as x, y and z, Table 2). Plots at the middle plant density (y) were also established without undersown grasses (denoted as yc, Table 2). All nitrogen for the cover crops (Table 1). was spring applied.

In the autumn sown cover crops the number of plants m^{-2} were recorded approximately one month after sowing in autumn and again in spring. In the spring sown cover crops the number of plants m^{-2} were recorded approximately one month after sowing. Prior to harvest of the cover crops, lodging was assessed using a scale where 0 equals no lodging and 10 equals complete lodging. The cover crops were direct harvested, except for winter rape which was swathed and combined 7-14 days later (Table 1). The straw from the cover crops was removed immediately after harvest and the stubble was cut to approximately 10 cm height.

In September, grass re-growth was cut to approximately

Table 1. Mean cover crop sowing date, mean grass sowing date, amount of nitrogen applied and mean cover crop harvest date.

Cover crop	Cover crop sowing date[1]	Grass sowing date [1,3]	Nitrogen[4] (kg ha^{-1})	Harvest date[1]
Winter rape	20 August	20 August	175	20 July [2]
Winter wheat	17 September	17 September	150	9 August
Spring barley	4 April	4 April	90	8 August
Field bean	4 April	4 April	0	6 September
Field pea	4 April	4 April	0	10 August

1 Mean of three years.
2 Swathed on 11 July.
3 Except Lolium perenne which was also sown 4 April in winter rape and winter wheat.
4 Applied to the cover crops in spring

Table 2. Desired and actual plant density in winter rape, winter wheat, spring barley, field bean and field pea.1

	Plants m^{-2}									
	Winter rape		Winter wheat		Spring barley		Field bean		Field pea	
	Desired	Actual [2]	Desired	Actual	Desired	Actual	Desired	Actual	Desired	Actual
yc[3]	120	126	400	391	350	292	40	48	60	57
x	80	91	300	305	250	205	25	30	40	38
y	120	128	400	388	350	290	40	47	60	58
z	160	167	500	493	450	351	55	62	80	76

1 mean of three years.
2 plants m^{-2} present after the winter.
3 plots without undersown grasses.

10 cm stubble height (if re-growth had exceeded 15-20 cm) and either 0, 30 or 60 kg N ha^{-1} was applied (Table 3). All plots in each grass species received one spring nitrogen application (Table 3). It was applied to smooth stalked meadow grass, red fescue and cocksfoot as soon as a vehicle could move across the field without damaging the crop. On average for the three experimental years this was on 7 March. In meadow grass and perennial ryegrass the spring nitrogen was applied on 27 March.

The grasses for seed production were swathed before shedding and combined after 7-14 days of windrowing. Perennial ryegrass was combined directly in 1990 and 1991. The seed moisture content at swathing and combining was not measured. Immediately after harvest the seed was dried to 13% moisture with cold air for one day. If moisture content was high, heated air was used after day one. Only a single harvest was taken for each grass seed crop. Records of plant density were made in the autumn and in spring in the grass seed crops. Lodging was assessed at flowering and prior to harvest. Plant height was measured after flowering. Prior to harvest, plant samples were cut within frames of 0.5m x 0.5m, and the number of fertile tillers counted.

The trial was established as a split, split plot trial, with the cover crop as the main plot and the grass species as subplots. Within each grass species the various cover crop plant densities and nitrogen levels were completely randomised. Net plot size was 2.5m x 8m. All results are means of three years and the data were analysed as a three-factorial block design with year as a random factor. Tests for the main effects of cover crop, seed yield, plant density, lodging and their two and three way interactions were performed by F-tests. The denominator in the F-test was the interaction between the effect in question and year. Least significant differences (LSD) at the 5% probability level were used to separate means of main effects. The analyses were performed using the Statistical Analysis System (SAS, 1989a, 1989b). The results for seed yield presented in this paper are means of the three cover crop plant densities and the three autumn applied nitrogen levels. The cover crop and seed yields are adjusted to 100% purity.

RESULTS

The yield of the cover crop

The interaction between plant density and the yield of the cover crop was significant, as for the five cover crops yield was usually lower at the lowest plant density (x) compared to the intermediate and highest plant densities (y and z). No effect of undersowing, grass species or cover crop plant density was found on lodging of the cover crop. The number of cover crop plants ha^{-1} in autumn and/or in spring was not influenced by the undersown grass species.

Winter rape

The yield of winter rape was higher when established without undersown grasses (Table 4). Yield depression from undersowing averaged over the five grass species was 0.29

Table 3. Cultivar, sowing rate and the amount of autumn and spring applied nitrogen for the five grass species.

Species	Cultivar	Sowing rate (kg ha^{-1})	N (kg ha^{-1})			
			Autumn [1]			Spring
Poa pratensis	Erte	6	0	30	60	60
Festuca rubra	Rubina	6	0	30	60	50
Festuca pratensis	Senu	6	0	30	60	70
Dactylis glomerata	Amba	3	0	30	60	100
Lolium perenne	Borvi	6	0	30	60	100

1 Applied as calcium ammonium nitrate in late September.

Table 4. Yield of the five cover crops with (y) and without (yc) undersown grasses.

	Cover crop yield [2] (t ha^{-1})				
	Winter rape	Winter wheat	Spring barley	Field bean	Field pea
y[1]	3.15	6.90	4.93	3.97	3.44
yc	3.44	7.48	5.19	4.12	3.85
LSD P<0.05	0.14	0.19	0.21	NS	0.20

1 Average for the five undersown grasses at the intermediate plant density (y).

2 Yields are expressed at 9% seed moisture for winter rape, 14% seed moisture for field bean and field pea and 15% for winter wheat and spring barley. Applies also for Table 5 and 6.

t ha^{-1}, equivalent to 8.4% at the intermediate plant density (120 plants ha^{-1}). The yield of winter rape when undersown in red fescue, smooth stalked meadow grass, perennial ryegrass or meadow fescue did not differ (Table 5), but cocksfoot reduced winter rape yield. The yield of winter rape did not differ with plant density (Table 6).

Winter wheat

Undersowing reduced the yield of winter wheat by an average of 0.58 t ha^{-1}, equivalent to 7.8% at the intermediate plant density of 400 plants m^{-2} (Table 4). Winter wheat yield was not influenced by the undersown grass species (Table 5) or by plant density (Table 6).

Spring barley

Undersowing grasses for seed production reduced the grain yield of spring barley by 0.26 t ha^{-1}, equivalent to 5.0% at the intermediate plant density of 350 plants m^{-2} (Table 4). Within the five grass species, undersowing perennial ryegrass reduced the yield compared to undersowing smooth stalked meadow grass or red fescue (Table 5). The yield was 5.11 t ha^{-1} when established with undersown red fescue compared to 4.55 t ha^{-1} when established with undersown perennial ryegrass. The yield of spring barley increased by 0.20 t ha^{-1} (Table 6) when the plant density was increased from x (250 plants m^{-2}) to y (350 plants m^{-2}).

Field bean

Undersowing grasses did not affect the yield of field bean (Table 4). However, within the five grass species the yield of field bean with undersown perennial ryegrass was 3.98 t ha^{-1} compared to 3.74 t ha^{-1} when smooth stalked meadow grass was undersown, a significant yield reduction (Table 5). The yield was increased by 0.63 t ha^{-1} (Table 6) at the intermediate plant density y (40 plants m^{-2}) compared to the lowest plant density x (25 plants m^{-2}).

Field pea

The yield of field pea was reduced by 0.41 t ha^{-1}, equivalent to 10.6% (Table 4) when undersown with grasses at the intermediate plant density (60 plants m^{-2}). Within the grass species undersown meadow fescue and perennial ryegrass reduced the yield compared to undersown cocksfoot (Table 5). Increasing the plant density from x (40 plants m^{-2}) to y (60 plants m^{-2}) significantly increased yield by 0.62 t ha^{-1} (Table 6).

The yield of the undersown grasses

The seed yield of the undersown grasses was not significantly influenced by the interaction of cover crop and undersown grass species at P<0.05. However the main effect of cover crop on seed yield was significant.

Table 5. The effect of five undersown grasses on the yield of winter rape, winter wheat, spring barley, field bean and field pea.

			Yield (t ha^{-1})		
Grass species	**Winter rape**	**Winter wheat**	**Spring barley**	**Field bean**	**Field pea**
Poa pratensis	3.19	6.94	5.10	3.74	3.40
Festuca rubra	3.21	6.85	5.11	3.87	3.23
Festuca pratensis	3.10	7.06	4.85	3.85	3.16
Dactylis glomerata	2.95	6.98	4.86	3.86	3.54
Lolium perenne	3.15	6.66	4.55	3.98	3.20
LSD P<0.05	0.16	NS	0.50	0.23	0.29

Table 6. Effect of three plant densities[1] on the yield of winter rape, winter wheat, spring barley, field bean and field pea.

			Yield (t ha^{-1})		
Plant density	**Winter rape**	**Winter wheat**	**Spring barley**	**Field bean**	**Field pea**
x	3.04	6.88	4.73	3.34	2.82
y	3.15	6.90	4.93	3.97	3.44
z	3.16	6.92	5.03	4.27	3.66
LSD P<0.05	NS	NS	0.14	0.55	0.48

1 (x = low, y = intermediate, z = high; see Table 1.)

The seed yield of smooth stalked meadow grass varied considerably among the cover crops, but only the difference between winter rape and spring barley was significant (Table 7). Seed yield was highest when smooth stalked meadow grass was undersown in winter rape (average 774 kg ha^{-1}) and lowest when undersown in spring barley (average 399 kg ha^{-1}). Undersowing red fescue in winter rape produced a significantly higher seed yield than in any of the other cover crops. While undersowing in field bean produced the lowest seed yield, this did not differ from that of all the other cover crops except winter rape. The seed yield of meadow fescue did not vary among the five different cover crops. Undersowing cocksfoot in winter rape resulted in a higher seed yield than undersowing in winter wheat or spring barley. The seed yield of perennial ryegrass was also not affected by the cover crops. However, the plant density in autumn was higher after undersowing in field pea or spring barley compared to winter rape or winter wheat. The cover crop did not have any effect on lodging of the undersown grasses prior to harvest (data not presented).

Fertile tillers

The number of fertile tillers was significantly influenced by the interaction between cover crop and undersown grass species.

In smooth stalked meadow grass the number of fertile tillers was higher (by 721 m^{-2}) when undersown in winter rape compared to undersowing in spring barley or field bean (Table 8). The number of fertile tillers in red fescue was higher when undersown in winter rape compared to the other cover crops, with the lowest number recorded when undersown in spring barley (a reduction of 788 fertile tillers m^{-2}). In meadow fescue the number of fertile tillers m^{-2} was lower when undersown in winter wheat compared to winter rape. Undersowing cocksfoot in winter wheat reduced the number of fertile tillers by 153 m^{-2} compared to undersowing in winter rape. In perennial ryegrass the number of fertile tillers was lower when undersown in winter rape or winter wheat compared to undersowing in field bean, field pea or spring barley.

Table 7. The influence of the cover crop on the seed yield[1] of *Poa pratensis, Festuca rubra, Festuca pratensis, Dactylis glomerata* and *Lolium perenne*.

Cover crop			Seed yield (kg ha^{-1})		
	Poa pratensis	*Festuca rubra*	*Festuca pratensis*	*Dactylis glomerata*	*Lolium perenne*
Winter rape	774	1448	1089	1005	1488
Winter wheat	486	1203	1053	900	1498
Spring barley	399	1180	1005	880	1478
Field bean	479	1124	1080	914	1298
Field pea	651	1181	1080	909	1377
LSD P<0.05	308	176	NS	104	NS

1 13% seed moisture content and 100% purity.

Table 8. The influence of the cover crop on the number of fertile tillers of *Poa pratensis, Festuca rubra, Festuca pratensis, Dactylis glomerata* and *Lolium perenne*.

Cover crop			Fertile tillers (no m^{-2})		
	Poa pratensis	*Festuca rubra*	*Festuca pratensis*	*Dactylis glomerata*	*Lolium perenne*
Winter rape	1769	4039	1596	1010	2389
Winter wheat	1381	3252	1407	857	2424
Spring barley	1126	3251	1444	906	2846
Field bean	1048	3298	1496	910	2957
Field pea	1561	3521	1572	935	2849
LSD P<0.05	564	433	178	140	355

DISCUSSION

Undersowing grasses for seed production reduced the yield of winter rape, winter wheat, spring barley and field pea by 5-11% compared to no undersowing. Field bean was not influenced by undersowing. The yield reductions in the cover crops did not appear to be related to a lower number of plants. de Ruiter and Hare (1993) also reported a yield reduction in spring barley when tall fescue was undersown at a barley plant density of 400 plants m^{-2}. Within the five cover crops, differences in yields were observed according to the undersown grass species. Perennial ryegrass reduced cover crop yield in spring barley and in field pea, but not winter rape and winter wheat, probably because the ryegrass was spring sown. Undersowing meadow fescue reduced field pea yields and in general, cover crop yields were reduced following the undersowing of meadow fescue compared to undersowing of the slow establishing grasses, smooth stalked meadow grass and red fescue. In the autumn sown cover crops no effects of cover crop plant density were recorded, but in the spring sown crops, higher yields were recorded at the two higher cover crop plant densities.

Cover crops had no effect on the seed yield of perennial ryegrass and meadow fescue. For smooth stalked meadow grass, red fescue and cocksfoot, winter rape was the superior cover crop. These results probably reflect the fact that winter rape is established one month earlier in the autumn than winter wheat, and is harvested one month earlier than any of the other cover crops. When undersown in winter rape, the grasses have a longer establishment period before the canopy closure prevents further development of the undersown grasses. This lead to a higher tiller number, a result also reported by Meijer (1987). The longer period in the autumn to develop tillers allowed more to become reproductive and contribute to the seed yield in the following year. Nordestgaard (1984) had previously noted that the seed yield of cocksfoot, red fescue and meadow fescue established in two different spring barley cultivars varied considerably according to harvest date of the barley cultivar, with the yield increase being correlated with a higher number of fertile tillers. Chastain and Grabe (1989a) also reported that a higher number of tillers in the autumn lead to a higher number of fertile tillers in cocksfoot.

In smooth stalked meadow grass, red fescue and cocksfoot, seed yield was significantly higher when established in winter rape compared to spring barley. However, the seed yield when undersown in winter wheat, field bean and field pea did not differ from undersowing in spring barley. Undersowing in winter rape is therefore superior to the traditional method of establishment in spring barley. The average seed yield of cocksfoot and red fescue obtained in this trial was approximately 100 kg ha^{-1} higher than the yields obtained in a trial using pure stand establishment (Nordestgaard, 1994). The latter research series was performed during the same experimental period and using the same grass cultivars. The yield of meadow fescue was approximately 200 kg ha^{-1} higher when established in a pure stand before 15 August compared to establishment in any of the cover crops in this trial, but in smooth stalked meadow grass higher yields (approximately 100 kg ha^{-1}) were obtained when undersowing in winter rape compared to pure stand establishment before 1 August. The higher seed yields from establishment in a cover crop were seen in the grass species which have requirements for a long induction period for reproductive growth.

The seed yield of smooth stalked meadow grass was variable, being 48% lower when undersown in spring barley than when undersown in winter rape. The traditional establishment method in Denmark is undersowing in spring barley with white clover. In this cropping system, spring barley is harvested in the establishment year, in the following year white clover seed is harvested, and in the third growing season the smooth stalked meadow grass is harvested. In the traditional cropping system the smooth stalked meadow grass therefore has an establishment period of two years compared to one year in this trial. The results of this trial confirm that spring barley is not an acceptable cover crop for smooth stalked meadow grass when only a first year seed harvest is considered, which is in agreement with Nordestgaard (1979). If seed yields had been taken for two consecutive years, the more open stands of the undersown grasses may well have produced a higher second year seed yield (Nordestgaard, 1979; Fairey and Lefkovitch, 1996).

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