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LONG-TERM EXPERIMENT WITH PLOUGHED IN CEREAL STRAW

by

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Ploughed in straw in autumn was compared with removal of the straw in two long-term field experiments with barley and oats on clay loam soils. The straw treatments was combined with four levels of nitrogen as calcium nitrate. Effects of straw on grain yields were small. Leaving out straw incorporation and fertilizer N after 24 years in one of the experiments resulted in significant positive after-effects of straw in following years. These residual effects were apparently counteracted by N-assimilation when straw incorporation was continued.

4. Emneord, norske

4. Emneord, engelske

N-fertilizer x straw
Barley, oats
N-balances
K-effects

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LONG-TERM EXPERIMENTS WITH PLOUGHED IN CEREAL STRAW.

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Incorporation of the straw in the soil is recommended in grain districts where the straw cannot be utilized as fodder. If autumn ploughing is not carried out, the straw left on the surface may reduce soil erosion during winter. It is believed, and in some experiments also found, that straw application did improve soil structure and counteracts a downward trend in soil organic matter content with arable cropping.

From the high C:N ratio of the straw, 50-100:1, a negative effect upon the nitrogen available for the following crop is to be expected. It was documented in a series of norwegian grain experiment (Uhlen 1973) that the reduced N-uptake of next year cereal crop was small, only 0.6 kg N per ton autumn ploughed in cereal straw. Furthermore, this negative effect disappeared after 2-3 years with annual straw application.

Ploughing in the straw may result in formation of plant toxins if oxygen is lacking, but also in reduced soil water supply in patches.

The straw contains plant nutrients, and, especially potassium may contribute significantly in the nutrition of the plants.

The main purpose of the long-term experiments was to investigate to what degree soil available nitrogen was influenced by annual application of cereal straw.

Materials and methods.

A. Long-term experiment, Ås 1962-1989.
The effect of ploughed in compared to removal of the straw in autumn was investigated at four levels of spring applied calcium nitrate. The rates of N (given in Table 1 and 2) were increased in the experimental period. Barley and oats were grown alternatively every other year.

B. Long-term experiment, Øsaker 1964-1991.
Same comparisons as in A. Barley and oats were grown alternatively, however, both species were represented every year.

In both experiments the straw was brought back on the same plot where it was produced. During the first five years, however, all plots with straw were given the same amount of straw (3.5 tons per hectare).

Phosphorus and potassium were in both experiments given annually as a basal dressing of superphosphate (25-30 kg P per hectare) and potassium chloride (65-75 kg K per hectare).

Nitrogen and potassium analyses of grain and straw were performed in the whole period for experiment A, and in most years also for experiment B. Total-N and total-C were determined in 1984 in soil samples from 64 subplots from both experiments. The results are reported earlier (Uhlen 1991). For experiment A a more complete soil analytical program was undertaken in 1984 and some analyses were also carried out in 1968 and 1977.

The soil on both sites was clay loam, 25-30% clay, and high in organic matter. Soil A had more sand and less silt than B. pH, P-AL, K-AL and loss on ignition were 5.8, 7, 12 and 8.7% on site A and 6.2, 5, 14 and 7% on B. In samples taken in 1984 tot-N and tot-C were 0.26 and 3.0 for A and 0.24 and 2.2% for B. The C/N ratio was, as we can see, much higher for A than for B.

The yield results

Grain yields from experiment A are given in Table 1. In the first 6 years period, and especially for barley in the first year, significant negative yield responses to straw application were found. Later on the effects were small, and mostly positive. In the first residual year, 1987, large and significant effects of earlier application of straw and of applied N fertilizers were found. Also in the next two years, 1988 and 1989, positive aftereffect of straw on yield and N-uptake was apparent. The small and insignificant effects of straw as an average for 24 years 1962-1986, indicate that additional N-assimilation, due to new straw additions has counteracted the positive long-term effect of increased N-mineralization from straw residues. The results from experiment B in Table 2 give the same picture as experiment A, that is, a tendency to negative responses in the first years, and likewise, small positive responses later on. No after-effect years were undertaken for experiment B. For both sites we notice a strong downward trend in grain yield in the three periods for treatments without N. The soils ability to meet the crop requirement of nitrogen has been rapidly deteriorated. (Fig. 1).

Nitrogen in grain and straw.

The nitrogen percentages of dry matter grain and straw are shown in Fig. 2 as averages for the whole period. Chemical analyses were not carried out for the first six and the last three years of the experiment B. The average figures give very much the same picture for the two sites. This was the case also in the individual years (not shown) although with some exception for grain in very dry years.

We notice the high nitrogen concentration in straw in N_0-treatment. With straw ploughed in the N content have a tendency to be higher than without straw in the N_0 treatment and lower at the higher rates of N application.

The high relative N-content in the N_0 treatment may be a concequence of less dense plant cover which gave more leaves

Table 1. Grain yields (85% dry matter) in straw experiment A, in tons per hectare and year 1962-89.

	Straw removed				Straw ploughed in			
1962-67:								
kg N/hectare	0	23	46	70	0	23	46	70
Barley 3 years	2.94	3.72	4.29	4.22	2.90	3.62	4.07	4.21
Oats 3 "	2.79	3.54	3.88	4.10	2.85	3.56	3.95	4.25
1968-77								
Kg N/hectare	0	31	62	93	0	31	62	93
Barley 5 years	2.02	3.20	3.87	4.09	2.15	3.27	3.81	4.17
Oats 5 "	2.19	3.44	4.19	4.46	2.31	3.53	4.15	4.60
1978-86								
kg N/hectare	0	47	93	140	0	47	93	140
Barley 4 years	1.33	3.39	4.64	4.88	1.49	3.41	4.66	4.90
Oats 3 years, Wheat 1 year	1.97	4.40	5.57	6.14	1.97	4.40	5.58	5.96
Mean 24 years	2.15	3.59	4.40	4.66	2.23	3.62	4.37	4.70
Effects of straw					+0.08	+0.03	-0.03	+0.04
Residual effects (No N-fertilizer and straw not ploughed in)								
1987 Oats	2.99	3.60	3.88	4.17	3.22	3.60	4.07	4.58
1988/89 "	1.64	1.69	1.76	1.74	1.77	1.90	1.90	1.98
Mean 3 years								
Effects of straw					+0.16	+0.14	+0.16	+0.30

Table 2. Grain yields (85% dry matter) in straw experiment B in tons per hectare and year 1964-91.

	Straw removed				Straw ploughed in			
1964-68:								
Kg N/hectare	0	23	46	70	0	23	46	70
Barley 5 yrs	2.34	3.25	4.06	4.87	2.22	3.06	4.08	4.65
Oats 5 "	2.87	3.82	4.78	5.17	2.76	3.62	4.78	5.14
1970-77:								
Kg N/hectare	0	39	78	116	0	39	78	116
Barley 8 yrs	2.14	3.34	4.12	4.40	2.13	3.30	4.18	4.34
Oats 8 yrs	2.71	3.91	4.49	4.38	2.75	3.84	4.45	4.48
1978-91:								
Kg N/hectare	0	47	94	140	0	47	94	140
Barley 14 yrs	1.16	2.80	3.83	3.98	1.20	2.77	3.78	4.07
Oats 14 yrs	1.76	3.36	4.23	4.41	1.78	3.43	4.30	4.45
Mean 27 yrs								
Barley + oats	1.96	3.33	4.19	4.40	1.96	3.29	4.20	4.44

in relation to stems at harvest.
The nitrogen yield are reported in Table 3 for both experiment. In experiment A the nitrogen in the fertilizers balances the yield output only at the highest rate of application. In experiment B the balance account is not complete, since figures are not available for the first 6 years with low application rates and high yields. In the period 1964-69, crop removal has probably exceeded application also for treatment N_3. The highest rate of N represents surplus application in experiment B in the later periods, mainly as a concequence of the relatively low yields in this experiment.

The high N-uptake and yield in treatment N_0 with straw in experiment A may be caused by soil heterogenity existing from the start in 1962. Soil analyses in 1984 showed a high tot-N content in the N_0-treatment with straw compared with the other treatments. The same difference existed, however, also at the first sampling in 1968, and may result from uneven application of farm manure in years prior to 1962.

Potassium

Analyses of K in grain and straw from experiment A were carried out in the period 1965 to 1987. The results in kg K per hectare and year and also the percentages of K in barley and oat straw are presented in Table 4. The increased uptake of K after straw addition is small compared to the K actually added in straw. The uptake is no more than 10% of added K in straw. The straw K has also increased K in soil as shown in Table 5. Some K-analyses were done for grain and straw also from experiment B. The results were in accordance with those from experiment A, and are not reported here.

The potassium added in fertilizers, 65-75 kg K per hectare and year, represents a surplus for cereals on these soils, indicated also by the increasing K-percentages in straw for increasing N-rates and yields. It is unlikely therefore, that K in straw has positively affected the grain yields in these experiments.

Soil analyses.

Chemical analyses of top soil samples from experiment A revealed signifi cant effect of straw on K-AL (exchangeable K) and also some effect on Mg-AL. No effect of straw on Ca-AL and pH was found. Increasing N application decreased K, P and Mg following the increased yield, wheras increases in pH and Ca result from the application of calcium nitrate.

Table 3. Nitrogen yields in grain + straw. Kg per hectare and year.

Treatments	Straw removed				Straw ploughed in			
	N_0	N_1	N_2	N_3	N_0	N_1	N_2	N_3
Exp. A 1962-86:								
N in fertilizer	0	34	68	102	0	34	68	102
N added in straw					8	12	16	21
N in crops	41	65	87	104	43	65	83	103
N in crops 1987-89[1]:	36	40	43	46	39	42	46	51
Exp. B 1970-88:								
N in fertilzer	0	43	86	129	0	43	86	129
N added in straw					6	10	14	18
N in crops	36	60	84	102	37	61	84	102

[1] N and straw not added in 1987-89

Table 4. Kg potassium in grain + straw per hectare and year and percent K in straw dry matter. Experiment A 1964-86.

Treatments	Without straw				With straw			
	N_0	N_1	N_2	N_3	N_0	N_1	N_2	N_3
Kg K. 23 yrs	31.9	53.3	66.5	74.4	33.4	54.8	68.8	80.5
K % in straw:								
Barley 11 yrs	1.14	1.16	1.21	1.32	1.17	1.17	1.24	1.36
Oats 10 "	1.66	1.79	1.87	1.94	1.74	1.91	1.98	2.03

Table 5. Soil analyses. 0-20 cm Experiment A 1984.

Treatments	Straw removed				Straw ploughed in				Significant level	
	N_0	N_1	N_2	N_3	N_0	N_1	N_2	N_3	Straw	N
K-AL[1]	16.6	12.3	11.6	10.3	18.8	17.3	15.8	15.9	xxx	xxx
P-AL	10.9	10.2	10.1	10.0	11.5	10.4	10.0	10.1		xxx
Mg-AL	5.2	5.0	4.8	4.1	5.6	5.2	5.0	4.2	x	xxx
Ca-AL	104	118	139	144	103	118	137	145		xxx
pH	5.33	5.45	5.55	5.55	5.30	5.38	5.55	5.63		xxx

[1] AL-method acc. to Egner et al in mg/100 g dry soil

Discussion

Twenty five years of straw incorporation in the soil gave significant positive yield effect only in the three following years when no straw was ploughed in. Increased N-uptake these years were 2-5 kg N hectare and year (Table 3). The assimilated nitrogen per year with continously straw incorporation seems to be roughly equal to the mineralized nitrogen from the straw residues. Straw ploughed in in autumn has been found to reduce nitrate leaching with 5-15 kg N per hectare and year (Lyngstad 1978, Christensen & Schjönning 1987). The reduced leaching could, however, be caused also by increased denitrification (Scherer & Mengel 1981).

The total-N in soil samples (0-20 cm) from the two experiments in 1984 (Uhlen 1991) was roughly 100-120 kg N per hectare higher after 20 years of straw addition than without straw. The difference was significant only for experiment B.

The mineralization rate per year assuming roughly 70% uptake efficency in the after-effect years is not at variance with the results found for residual nitrogen from farm manure and N fertilizer in long-term norwegian experiments (Uhlen 1991) (Half life 15 years and 5% yearly break down). Jansson (1963) using ^{15}N in pot experiment found that the mineralization rates for N in straw were the same as for residue N from fertilizer in soil.

Other effects of straw, besides the effect upon the assimilation-mineralization of nitrogen in soil, have apparently been small in these long-term experiments. In a long-term rotation experiment in the same area as experiment A, no effect of straw on soil aggregation and aggreate stability was found (Skøien 1993), wheras small positive effects on such properties are reported elsewhere (Christensen & Schönning, 1987). The potassium and other elements applied with the straw has likely not contributed to increased yield in these experiments. The gain in yield, not significant, when we exclude the first six years period in the two long-term experiment are calculated to 40 kg grain pr hectare and year. In addition the potassium fertilizer rates could have been reduced with 20-40 kg K per hectare and year by incorporation of the straw in the soil. The ash after burning may contain most of the minerals in the straw, although some potassium may be lost if flame temperature exceeds 5-600°C. Burning may be prohibited due to air pollution. Incorporation of the straw, therefore is a must if other ways straw utilisation are not available.

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Scherer, H W & K. Mengel 1981. Einfluss von Stroh und Nitrapyrin auf den Verfügbaren Stickstoff im Boden, den Ertrag und den Stickstoffentzug von Lolium multiflorum. Z. Pflanzenernaehr. Bodenk 144: 254-262.

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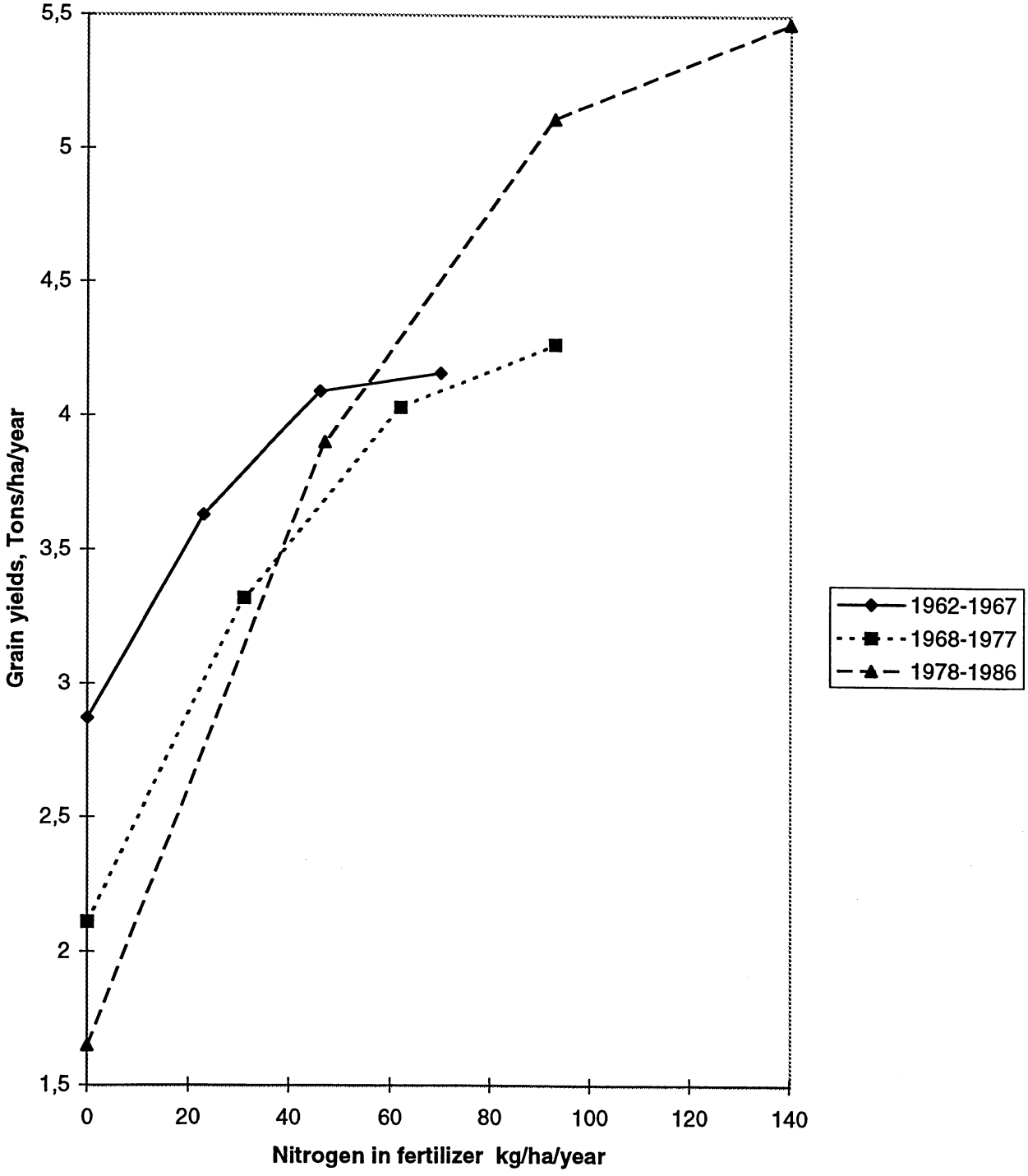

Fig.1. Grain yields in relation to N-fertilizers. Experiment A 1962-1986. Barley + oats.

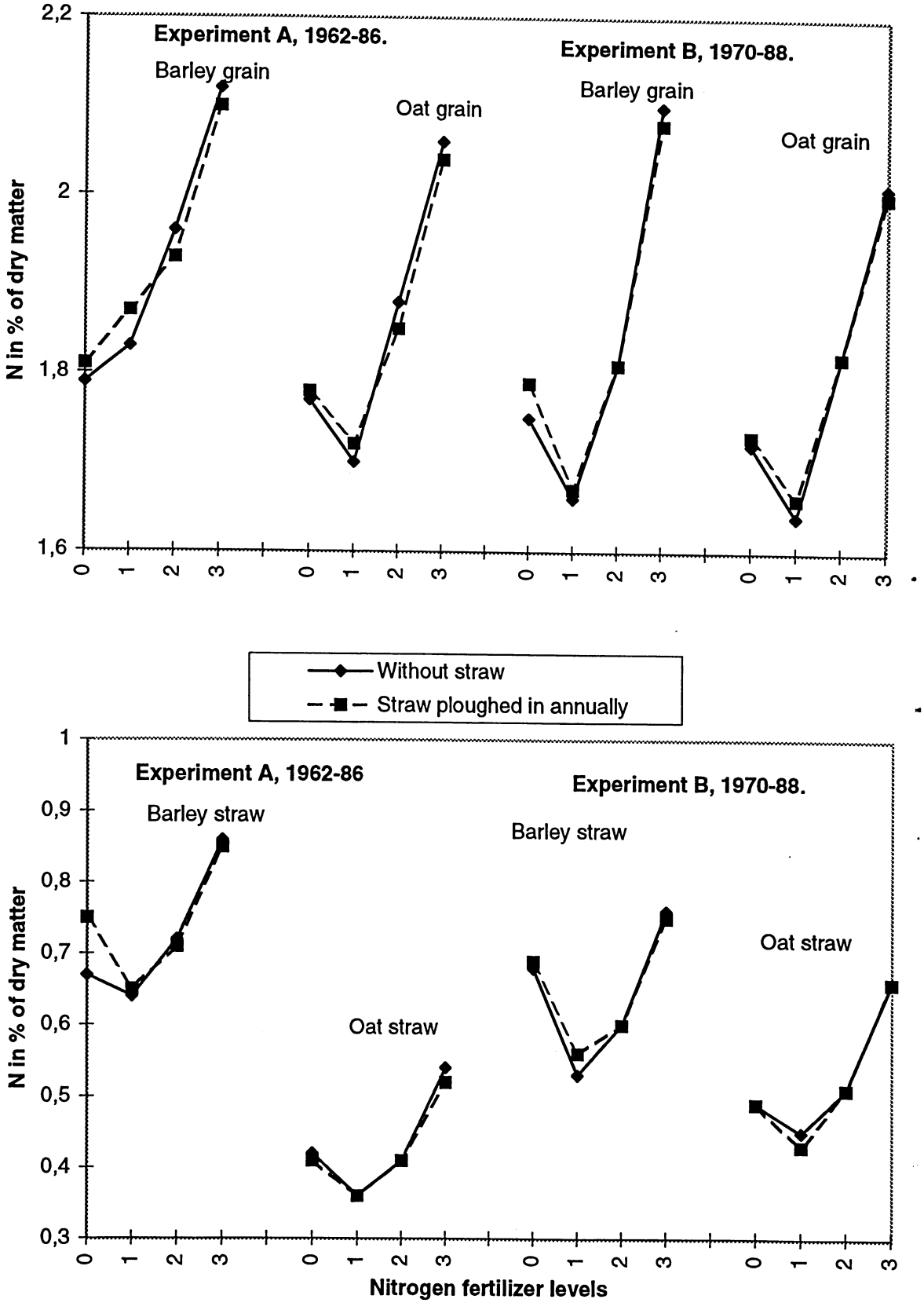

Fig. 2. Nitrogen, % in dry matter, grain and straw.

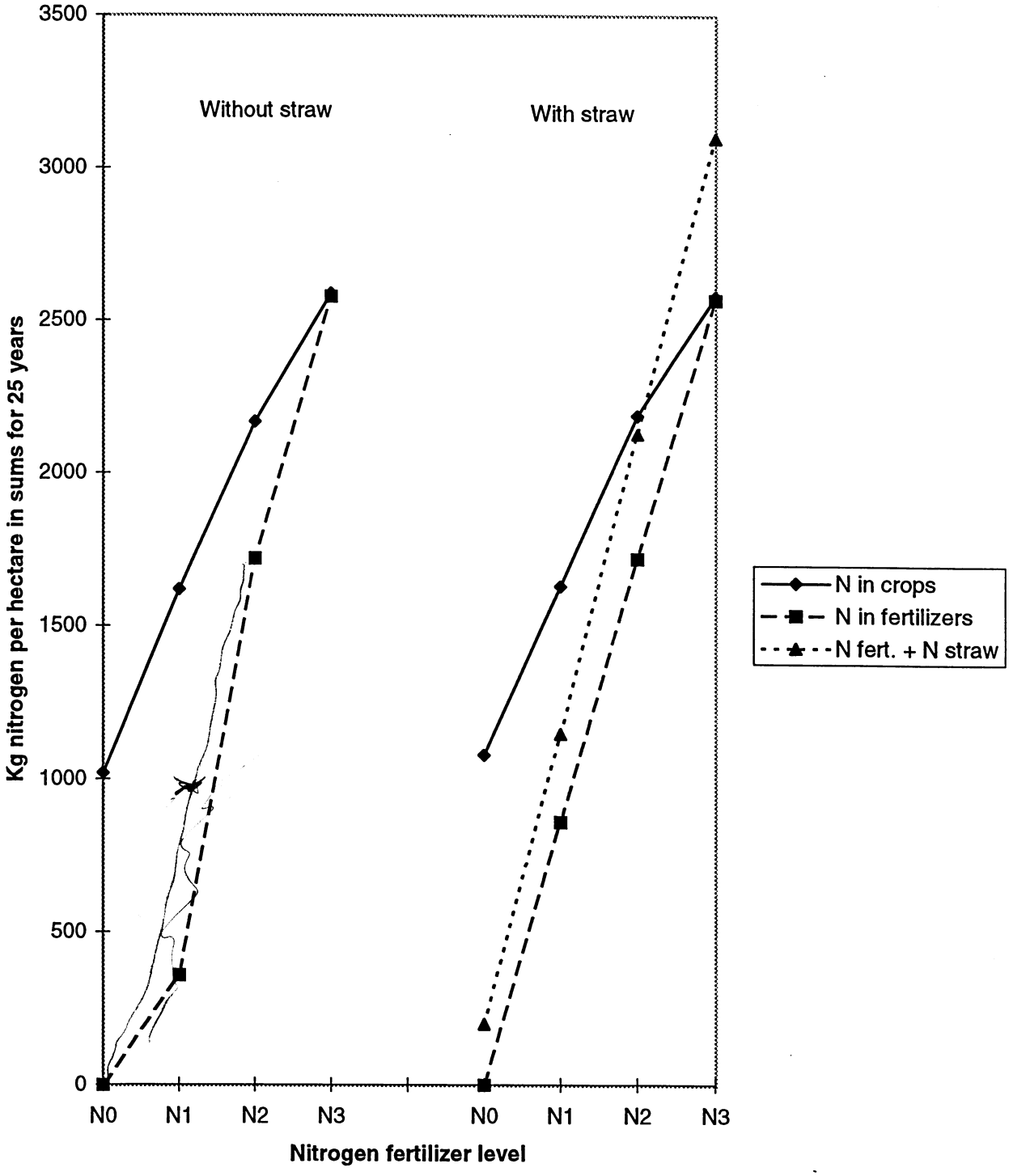

Fig. 3. Nitrogen in crops (grain + straw) in relation to added N in fertilizer and straw. Experiment A.