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FERTILISER USE BY WINTER WHEAT WHEN STRAW IS BURNT OR INCORPORATED: A STUDY WITH ISOTOPICALLY LABELLED FERTILISER

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FERTILISER USE BY WINTER WHEAT WHEN STRAW IS BURNT OR INCORPORATED: A STUDY WITH ISOTOPICALLY-LABELLED FERTILISER

by

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CONTENTS

ABSTRACT

The response of winter wheat to fertiliser nitrogen, when straw was burnt or incorporated during three successive seasons, was measured on a clay soil at ADAS Boxworth Experimental Husbandry Farm.

A total of 120, 200 or 280 kg/ha of fertiliser nitrogen was applied at 3 timings nil or 40 kg/ha N shortly after crop emergence, 40 or 80 kg/N in early spring and the remainder at the start of stem extension.

Recovery of fertiliser nitrogen by the crop, and the amount remaining in soil were determined by distinguishing between soil and fertiliser derived nitrogen by using 15-N enriched or depleted ammonium nitrate. The levels of nitrogen used in this experiment were part of a larger experiment designed to produce full response curves using 0, 80, 120, 160, 200, 240, 280 and 320 kg/ha N applied in the manner described.

Optimum yields and fertiliser nitrogen requirement were both similar when straw was burnt or shallowly incorporated with tines, provided chemical weed control was successful. In contrast, ploughing in straw resulted in the largest optimum yields with notable reduction in fertiliser nitrogen requirement.

When uncontrolled grass weeds (and volunteers) were competing, optimum yield was greatly reduced and fertiliser nitrogen requirement increased, especially after the first year of non-plough incorporation.

In no case was there a unique benefit from the 40 kg/ha N added in the autumn that could not be realised by an adequate spring top dressing. Addition of 80 kg/ha instead of 40 kg/ha N in early spring was not consistently beneficial, irrespective of whether straw was burnt or incorporated.

Recovery of autumn fertiliser nitrogen by the crop in the following spring was small, between 0.9 and 9.2% depending strongly on early dry matter growth achieved up to that stage. 28 to 65% of the autumn fertiliser nitrogen survived in the top 30 cm layer of soil after winter. Marginally more of the autumn applied nitrogen remained in the topsoil after winter 1986 where straw was incorporated rather than burnt.

Recovery of fertiliser nitrogen by the crop at harvest was less when 40 kg/ha of the total nitrogen had been added in the autumn but recovery was independent of straw disposal method. Total dry matter growth achieved by the crop was of major importance in accounting for fertiliser nitrogen recovery. Seedbed conditions and competition from volunteers and grass weeds, influenced fertiliser nitrogen recovery far more than whether straw was burnt or incorporated.

Results support the evidence from other ADAS-AFRC experiments in confirming both the smaller recovery of autumn fertiliser nitrogen and the lack of a unique yield response to it. The results also demonstrate the sufficiency of the indigenous normal soil nitrogen supply to sustain early crop growth, dispelling reservations about straw decomposition using up soil mineral nitrogen to the detriment of crop needs.

1. INTRODUCTION

A change from burning to incorporation of cereal straw results in retention of the straw nitrogen that would have been lost as gaseous products of combustion. The total straw from a wheat crop yielding 8 t/ha grain at 85% DM contains 35-40 kg/ha nitrogen.

The wide ratio of carbon to nitrogen in straw is the basis for the general belief that microbial degradation will immobilise 5-9 kg of mineral nitrogen per tonne of straw (AFRC, 1985), using for this purpose mineral nitrogen present in the soil at the time of incorporation. This immobilisation is considered to retard early crop growth for want of adequate mineral nitrogen supply.

However a review of results from a large number of recently conducted field experiments in England concluded that 40 kg/ha N applied in autumn was on average uneconomic for all methods of straw disposal, when compared with saving this nitrogen for the spring topdressing (HGCA, 1989).

The same review also examined whether straw incorporation resulted in a need for any changes in timing and quantity of spring nitrogen topdressing of winter wheat, and concluded none was necessary.

Immobilisation of N by decomposing straw residues has been linked with cereal yield depressions in the field (Short, 1973; Elliot et al., 1981). However, nitrogen immobilisation does not always result in yield penalties (Myers and Paul, 1971), particularly if soil mineral nitrogen level is normal (Lord, et al., 1986) or if spring fertiliser nitrogen application rates are optimal.

At current levels of fertiliser nitrogen use on winter wheat sufficient soil nitrogen is present after harvest in most seasons to supply the nitrogen requirements of the decomposing straw (Cannell, 1984, Christensen, 1985a, Powlson et al., 1985). In these circumstances, straw could have a benefit in protecting soil nitrate from over-winter leaching (Powlson et al., 1985). This may be particularly important at a time when nitrate levels in sources of drinking water draining from arable areas are a cause for concern.

Farmers incorporating straw for the first time in the mid-1980's were warned of the problems of nitrogen immobilisation and phytotoxicity that may be associated with straw decomposition under certain conditions, through the work and publications of the AFRC (AFRC, 1985), MAFF (MAFF, 1984b) and via articles in the farming press. This caused the misconception that a rapid rate of straw breakdown was necessary to minimise these deleterious effects and that seedbed fertiliser nitrogen was beneficial in this respect.

Where applying nitrogen occasionally accelerates straw decomposition, any effect is mainly confined to the early stages and the overall effect is small (Knapp et al., 1983). Smith and Douglas (1968) found N additions (to adjust straw N content from 0.29 to 1.5%) increased dry weight loss by only 5% over 2 months. Leuken et al. (1962) also found no evidence that decomposition of crop residues was tardy in the absence of nitrogen additions. Parker (1962) demonstrated in field studies that where fertiliser nitrogen was added during the early stages of straw decomposition, the amount of nitrogen immobilised by straw increased, ie 'luxury' uptake of fertiliser N by the decomposing microflora occurred.

Sequential incorporation of straw over several years slowly builds up organic nitrogen in the soil. In consequence, whereas net immobilisation may occur in early years eventually the balance may change to enhanced nitrate release through mineralisation of these reserves.

A long-term study was therefore initiated at Boxworth EHF in the autumn of 1985, designed to measure the grain yield response of winter wheat sown after 3 methods of straw disposal, to increasing levels of fertiliser N applied under 3 timing regimes. The work reported here covers the first three years of the study in which labelled nitrogen fertiliser was employed to measure the efficiency of different fertiliser nitrogen timings.

2. AIMS AND OBJECTIVES

2.1 The aim of this study was to compare the effects of straw disposal methods on fate of fertiliser nitrogen applied at one site in successive years. This eliminates 'between site and between season' variability, which usually confounds such comparisons.

The main objectives were:

a) To establish whether straw incorporation changed the total nitrogen requirement of wheat.

b) To examine if extra fertiliser nitrogen is needed earlier in the growing season when straw is incorporated.

c) To determine whether different methods of incorporating straw, result in different fertiliser nitrogen requirements.

d) To examine the effects of successive years of straw incorporation on fertiliser nitrogen requirements.

In autumn 1985 a long term experiment on straw incorporation was established with full nitrogen response curves that would test the need for autumn or early spring fertiliser nitrogen supplementation, less equivocally than contemporary experiments. Labelled fertiliser was used for all nitrogen applications. Samples from this experiment, comprising three seasons' cropping - 1985-86, 1986-87 and 1987-88 - were analysed using the HGCA funds. This report contains:

(i) comparison of the response of crops to fertiliser nitrogen under 3 straw disposal systems during the three seasons,

(ii) nitrogen offtakes by crops following three straw disposal treatments and recovery of fertiliser nitrogen applied shortly after crop emergence, in early spring and at stem extension.

3. MATERIALS AND METHODS

3.1 Site and layout

The experiment was established in a field growing direct-drilled winter wheat with straw burnt annually since 1969. The soil is a calcareous clay loam derived from chalky boulder clay.

For each year 0.63 ha 'blocks' comprising 9 plots, 700 m^2 each, were established for each method of incorporation and year of incorporation.

Three methods of straw disposal were tested:-

i) Straw burnt, followed by 2 passes with 'flexitines' at 10 cm depth.

ii) Straw chopped and spread, not burnt, then as (i).

iii) Straw chopped and spread, then ploughed to a depth of 20 cm.

Each 'block' consisted of 3 sections, with a new section used for nitrogen treatments each year to avoid residual nitrogen effects from the previous year's range of dressings. Within the treatment sections, 24 nitrogen plots were established. One of the rate x timing combinations, featured in table 1 being randomly assigned to each plot. The experiment was designed to run for several years, with 1 replicate of each disposal method and year of incorporation.

Areas of the trial not receiving nitrogen tests were 'blanket' dressed with 200 kg/ha N.

3.2 15-N labelled fertiliser treatment:

Labelled fertiliser was applied to microplots within the main plots of all 3 methods of straw disposal, at total applications of 120, 200 and 280 kg/ha N, and all 3 application timings (see Table 1).

To determine the crop uptake of individual autumn, early-spring or late-spring nitrogen dressings, each individual dressing was labelled in 1985-86 and

Table 1

Applied N rates and N application timings used in the Boxworth EHF 'N for straw incorporation' trial. (All figures in kg/ha N)

N application sequence									
1 (0-40)			2 (0-80)			3 (40-40)			
Autumn	Early spring	Main dressing	Autumn	Early spring	Main dressing	Autumn	Early spring	Main dressing	Total N applied
0	40	40	0	80	0	40	40	0	80
0	40	80	0	80	40	40	40	40	120
0	40	120	0	80	80	40	40	80	160
0	40	160	0	80	120	40	40	120	200
0	40	200	0	80	160	40	40	160	240
0	40	240	0	80	200	40	40	200	280
0	40	280	0	80	240	40	40	240	320

Plus three nil-nitrogen plots per cultivation block, as controls.

_____ = Treatments in which 15-N labelled fertiliser was utilised

This sequence was followed in each of the three straw disposal treatments.

1986-87, establishing separate duplicate microplots. In the cases where labelled fertiliser was applied in the autumn, extra pairs of microplots were established for destructive spring sampling.

Application at each of the three timings was to the same duplicate microplots in the main plots in the 1987-88 season, so that only uptake from the total of 120, 200 and 280 kg/ha N was estimated at harvest 1988.

Care was taken to avoid placing microplots over mole drains, which could transport labelled fertiliser to neighbouring plots.

In the autumn of 1985 and 1986 double labelled ammonium nitrate fertiliser was applied at an enrichment of 5 atom %, and for all spring dressings at 1 atom % in both years. 15-N depleted ammonium nitrate was used in 1987-88 for all three timings and rates. Unenriched laboratory grade ammonium nitrate was used to dilute the 15-N ammonium nitrate stocks in 1985/86 and 1986/87.

The 15-N fertilisers were applied on the same day that the main nitrogen-plots were hand-dressed with prilled ammonium nitrate fertiliser. Microplots were protected by covers to avoid contamination with unlabelled fertiliser.

Labelled fertiliser was applied in solution using equipment similar to that described by Johnston and Powlson (1985). This consisted of a trolley, running along a 1 m track carrying a 4 channel peristaltic pump delivering fertiliser solution to 8 drip nozzles, mounted on a 90 cm boom. The boom was repositioned by ±5 cm on three successive runs, to ensure an even spread of fertiliser over a width of 1 m. The pump was driven mechanically, using a rack and pinion system.

The applicator was calibrated before each spreading session to deliver an accurate volume of solution over a wide range of speeds.

3.3 Definition of terms used in 15-N studies

Natural abundance: The natural relative amounts of 14-N and 15-N isotopes found in nitrogen expressed as atom %. For nitrogen the natural abundance is 0.366% 15-N.

Atom % excess:	Refers to the difference between the relative amounts of 14-N and 15-N in a given sample and that of natural abundance.
Double labelled ammonium nitrate:	Ammonium nitrate in which the N atoms of both the ammonium and the nitrate components are labelled.

For further information see IAEA (1983).

3.4 Timetable of husbandry:

Dates of straw incorporation, drilling and nitrogen application in 1985/86 and 1986/87

	:	1985/86	1986/87	1987/88
Incorporation date, plough	:	17/9/85	20-29/8/86	17/9/87
tine	:	17/9/85	6/9/86	24/9/87
Winter wheat drilling date (cv Avalon)	:	14/10/85	13/10/86	6/11/87
N application dates				
Autumn	:	22/11/85	27/11/86	4/12/87
Early spring	:	11/3/86	13/3/87	11/3/88
Main dressing	:	2/5/86	29/4/87	26/4/88
Grain harvest	:	16/8/86	9/9/87	8/9/88

3.5 Crop and soil sampling of 15-N labelled microplots

3.5.1 Spring sampling:

In the spring of 1986 and 1987, crop and soil samples were taken from microplots receiving 15-N fertiliser in the autumn. The crop was sampled from within a central 0.16 m^2 area at 45° to the direction of the rows.

Individual plants were dug out and rinsed clean of soil. Plant and shoot numbers were assessed, and samples were dried at 70°C in a forced draught oven for 48 hours. The dry weight and plant population data were used to calculate:- dry weight/plant, dry weight/shoot and dry weight/ha. The whole sample was ground in a hammer mill to pass through a 1 mm mesh sieve prior to determination of %N.

Soil cores (75 mm) were taken to 90 cm in 3 layers, 0-30, 30-60 and 60-90 cm, from the microplot crop sampling areas. Three cores per microplot were bulked by depth, dried at 70°C for 48 hours and disc-milled to <100 mesh for %N. Isotope ratio analyses were made only on the 0-30 cm samples.

3.5.2 Harvest sampling:

3.5.2a Whole crop samples for dry weight and N uptake:

Above ground plant samples were taken from the middle 0.16 m^2 (1986, 1987) or 0.25 m^2 (1988) of microplots a few days prior to harvest. Dry weights of the samples were used to calculate total above ground dry matter. After counting the number of shoots, half of each sample was dried at 70°C for 48 hours and then threshed for yield component analysis. The remainder was dried and used for chemical analysis. % N in crop and soil samples was determined after Kjeldahl digestion with salicylic acid to include nitrate N.

The mass ratio of 14-N:15-N was measured in residues of ammonium sulphate saved from distillates of Kjeldahl digests.

3.5.2b Grain harvest: A 20 x 2.6 m cut from each plot was harvested and yield calculated as t/ha at 85% dry matter.

3.6 DATA PROCESSING

3.6.1 Optimum yields and optimum fertiliser nitrogen requirement

Yield responses to fertiliser nitrogen were fitted to a linear plus exponential (LPE) N-response model (George, 1982). Economic optimum (opt-N) was defined as the point on the curve when the response reached 3 kg grain/kg N applied.

3.6.2 Statistical analysis of microplot data

Analysis of variance was performed on data from the 15-N microplots, using duplicate microplots as replicates. The design enabled analysis by cultivation, N-rate and N-timing and, in the second and third years, by number of years of incorporation in addition. Nitrogen treatments were fully randomised within cultivation treatments in each block. Straw disposal method and year of cultivation were treated as split plots.

3.6.3 Calculation of the fraction of nitrogen derived from fertiliser (FDF) in a sample (IAEA, 1983)

$$\text{FDF} = \frac{\text{atom \% excess in soil or plant sample}}{\text{atom \% excess in applied fertiliser}}$$

FDF x 100 = % FDF.

3.6.4 Calculation of the quantities of soil and fertiliser derived nitrogen in the crop and soil

A determination of total nitrogen offtake by the crop, or total nitrogen contained in the soil, on an area basis is required. Total crop nitrogen offtake, was estimated by analysing samples from the microplots. Total nitrogen content of the 0-30 cm soil layer was calculated using %N and a bulk density of 1.333 g/cc (average from spring soil core data).

The following derivations were also made:

1) Fertiliser derived N in crop (FDN) = Total N content in crop x FDF
2) Soil derived N in crop (SDN) = Total N content of crop - FDN
3) % Recovery of applied fertiliser N in crop = (FDN/fert N applied) x 100.

4. RESULTS AND DISCUSSION

4.1 Soil nitrogen supply in autumn and spring

Mineral nitrogen measurements in autumn and spring for the 1985-86 and 1986-87 seasons are shown in table 1 and 2; more detailed information is given in Appendices A1-4.

Plots in the block set up in 1985 and continued in 1986 showed a net overwinter "loss" in 9 out of 12 treatments. Overwinter "losses" of autumn applied nitrogen averaged 30% in 1985-86 and 15% in 1986-87. Of the plots not receiving autumn fertiliser, tine incorporation resulted in "loss" of 10-20% of the initial mineral nitrogen in the two seasons. Ploughing in straw resulted in a "loss" of about 16% in year 1 but a "gain" of about 14% in year 2. Where straw was burnt and no autumn nitrogen was given, there was a small increase of about 9% in both years but, with the addition of 40 kg/ha N, a net "loss" of about 21% of the mineral + fertiliser N was seen. 'Losses' associated with straw incorporation were probably due to immobilisation.

Plots in the block started in autumn 1986 gained mineral nitrogen between autumn 1986 and spring 1987 irrespective of presence or absence of straw. This contrasted with the plots receiving 40 kg/ha N in autumn which showed a net 'loss' of soil + fertiliser N of 14% for all cultivation treatments.

The dry conditions in autumn 1985 compared with the moist conditions in autumn 1986 are perhaps responsible for the contrasting patterns. Irrespective of presence or absence of straw it was clear though that "loss" of mineral nitrogen was more pronounced where its concentration was larger, eg. due to addition of autumn fertiliser nitrogen.

Evidence in the literature for net soil nitrogen immobilisation or mineralisation in the presence of decomposing straw is given in appendix B1-3.

Table 1. Soil mineral nitrogen in autumn and spring (1985-86) kg/ha N

	Burn-tine		Tine incorporation		Plough incorporation	
Autumn N	0	40	0	40	0	40
0-90 cm 21/11/95	68	-	67	-	75	-
0-90 cm 6/3/96	68	86	58	65	56	70
Soil nitrogen supply (Min N + Crop uptake)	74	93	65	71	58	72
Increase due to autumn N		19		6		14

Table 2. Soil mineral nitrogen in autumn and spring (1986-87) kg/ha N

	Burn tine				Tine incorporation				Plough incorporation			
Year of treatment	Year 1		Year 2		Year 1		Year 2		Year 1		Year 2	
Autumn N	0	40	0	40	0	40	0	40	0	40	0	40
0-90 cm 11/11/86	73	-	69	-	61	-	52	-	85	-	98	-
0-90 cm 16/2/87	73	88	88	100	42	66	67	96	87	108	93	109
Soil nitrogen supply (min N + crop uptake)	79	94	95	107	49	71	73	104	96	120	103	121
Increase due to autumn N		15		12		22		29		24		18

4.2 Autumn and early spring crop measurements: 1986 and 1987

4.2.1 Crop establishment, growth and nitrogen uptake: spring 1986 (Appendix C1)

Dry conditions in autumn 1985 delayed crop establishment, acutely where straw was ploughed in, resulting in very low production of dry matter. The effects persisted through to spring, 5 months after primary cultivations and drilling. Plant numbers in the burnt plots were one and a half times the 300/m² expected from the seed rate used, while those in the tine incorporated treatment were 116% of expected population, because of volunteer growth. Emergence was very protracted where ploughing in straw created harsh, cloddy and dry seedbeds; plant population in early spring was slightly less than target and significantly lower than that of the non-plough treatments.

Inter-plant competition in tine cultivated treatments and slow emergence in the ploughed plots resulted in small dry matter accumulation in early spring.

Method of straw disposal had no significant effect on crop nitrogen concentration; differences in dry weight were, therefore, not due to difference in nitrogen availability or other straw-related constraints to growth. Crop nitrogen contents, reflected the adverse or favourable effects of cultivation methods on emergence and subsequent growth. Addition of fertiliser nitrogen in the autumn did not redress the adverse effects of cultivation method.

4.2.2 Crop establishment, growth and nitrogen uptake: autumn 1986 (Appendix C2)

Autumn 1986 was wet after drilling. This enabled a rapid emergence and better crop dry weight production, prompting a late autumn crop sampling in December 1986.

Differences in plant populations were not significant except for a trend of lower numbers where straw had been burnt. Establishment was better in plots in the second successive year of cultivation, particularly when straw was burnt or ploughed in.

Ploughing in straw produced the largest dry weight. No phytotoxic effects were seen in either of the incorporation treatments.

Plant nitrogen concentrations (4.07 to 4.82%) increased regularly with the amount of soil mineral nitrogen measured to 90 cm depth, by about 0.06% for each additional kg N. Concentrations were largest in the plough treatment, which combined with larger dry weights, resulting in the largest crop nitrogen uptake. Shallow incorporation of straw did not influence early crop uptake of nitrogen.

4.2.3 Crop growth and nitrogen uptake: spring 1987 (Appendix C3)

Plant stands had increased by an average of 47 plants/m^2 especially in plots not given autumn fertiliser nitrogen. Ploughing resulted in significantly larger stands. Plots in the second successive year of cultivation had an average of 40 plants/m² more than those in first year of treatment. Shoot population was also similarly influenced.

Crop dry weight differences between the two tine cultivation treatments were not significant in the majority of cases. Dry matter production and nitrogen uptake were consistently greater in crops following plough incorporation.

Favourable seedbed conditions were clearly effective in promoting growth and associated nitrogen uptake. Presence or absence of straw influenced the young crop through the quality of seedbed achieved by the method of incorporation. Soil nitrogen supply was sufficient to support early growth, even when retained straw led to some reductions in soluble nitrogen level.

4.2.4 Crop nitrogen derived from fertiliser and soil sources in early spring

Spring 1986. Fertiliser nitrogen accounted for one fifth of the crop nitrogen uptake where straw was burnt in contrast to only 13 and 14% in shallow and plough incorporation, respectively (table 3). This significant depression in fertiliser nitrogen use was not due to immobilisation by straw because, the top 30 cm soil layer retained similar amounts of the 40 kg/ha nitrogen applied (28-30%). The variation in the amounts of total, fertiliser and soil derived nitrogen in crop were largely accounted for by the dry matter production (Fig. 1a).

Spring 1987. 23% to 30% of the total nitrogen uptake was from fertiliser (FDF). Differences in FDF were not significant but the actual uptake of fertiliser nitrogen (FDN) and recovery of this nitrogen by crops after plough incorporation were significantly larger than those after tine cultivation. Incorporating the straw with tines did not significantly reduce crop uptake of nitrogen fertiliser or soil nitrogen when the straw was incorporated shallowly. As in spring 1986, dry matter accumulation accounted for much of the variation in total, fertiliser and soil derived nitrogen in crops (Fig 1b).

Fig. 1a

Boxworth EHF, spring 1986

Effect of crop dry weight production on crop offtakes of N derived from soil sources, in spring 1986.

Regresssion function:-

Soil derived N in crop = 0.019 x dwt./ha + 1.01 (**)

Effect of crop dry weight production on crop offtakes of N derived from autumn-applied fertiliser (40 kg/ha N), in spring 1986.

Regression function :-

Fertiliser N in crop = 0.005 x crop dwt./ha - 0.056 (**)

Effect of crop dry weight production on crop recovery of autumn-applied fertiliser N (40 kg/ha), in spring 1986.

Regression function :-

% Recovery of fertiliser N = 0.013 x crop dwt./ha - 0.173 (**)

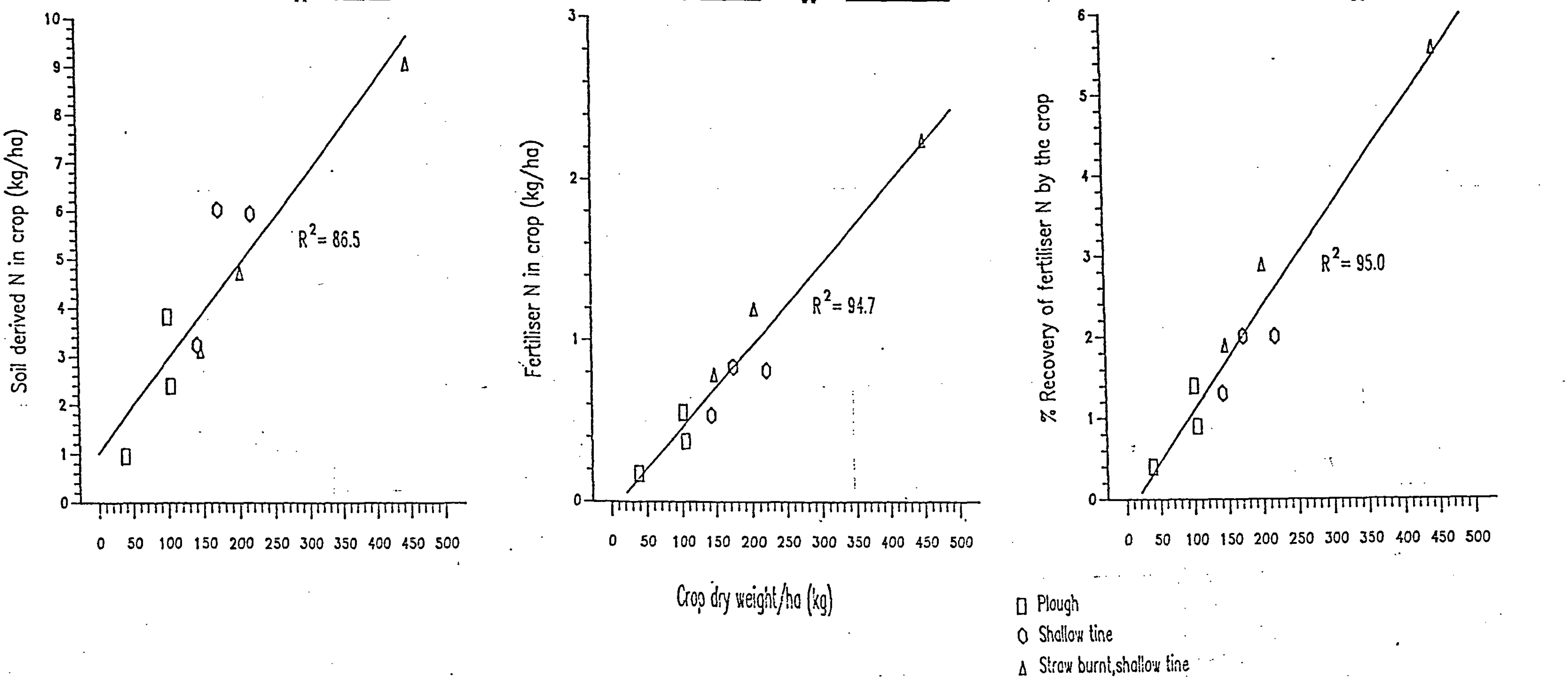


Fig. 1b

Boxworth EHF, spring 1987.

Effect of crop dry weight production on crop offtakes of N derived from soil sources, in spring 1987.

Regression function :-

Soil derived N in crop = 0.0326 x crop dwt./ha + 0.737
**

Effect of crop dry weight production on crop offtakes of N derived from autumn-applied fertiliser (40 kg/ha N) in spring 1987.

Regression function :-

Fertiliser N in crop = 0.014 x crop dwt./ha - 0.116

Effect of crop dry weight production on crop recovery of autumn-applied fertiliser N (40 kg/ha), in spring 1987.

Regression function :-

% Recovery of fertiliser N = 0.036 x crop dwt./ha - 0.31

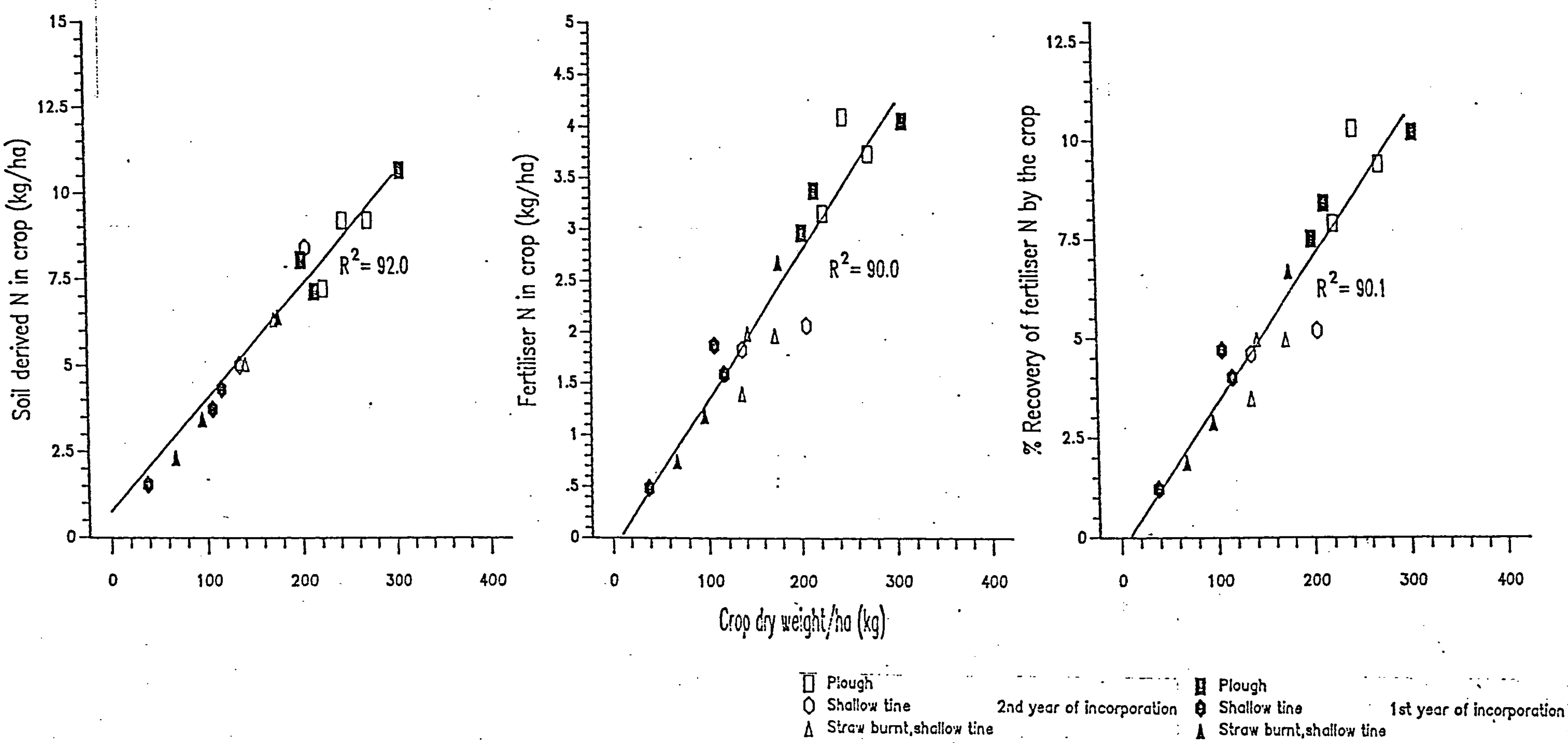


Table 3. Recovery of 40 kg/ha of autumn-applied fertiliser N from the crop and 0-30cm soil layer in the spring of 1986 (sampled 5/3/1986) and in the spring of 1987 (sampled 13/2/1987)

Straw disposal method	Year of incorporation	Fraction of N in crop derived from fertiliser (%)	N in crop derived from:- fertiliser (kg/ha)	N in crop derived from:- Soil (kg/ha)	% Recovery of applied N in:- Crop	Soil (0-30cm)	Crop+ soil
Spring 1986							
Straw-burnt, shallow tine	1	20.0	1.41	5.65	3.5	30.5	34.0
Shallow tine	1	12.7	0.72	5.06	1.8	29.7	31.5
Plough	1	13.7	0.36	2.38	0.9	28.4	29.3
SED (6 d.f.)		0.84**	0.377	1.764	0.94	9.69	9.16
CV%		7	55	50	55	40	36
Spring 1987							
Straw-burnt, shallow tine	1	26.5	1.54	4.07	3.8	40.1	43.9
	2	24.5	1.80	5.51	4.5	43.8	48.4
Shallow tine	1	28.1	1.31	3.19	3.3	65.2	68.5
	2	23.3	1.95	6.70	4.9	57.0	61.9
Plough	1	28.9	3.47	8.60	8.7	41.2	49.9
	2	30.1	3.67	8.53	9.2	56.3	65.5
SED (11 d.f.)							
Straw disposal method		1.97	0.368**	0.943**	0.92**	8.29	8.43
Incorporation year		1.61	0.300	0.770**	0.75	6.77	6.88
Straw disposal method x incorporation year		2.79	0.520	1.334	0.13	11.72	11.92
CV%		13	28	27	28	28	26

The top 30 cm of soil retained 40-65% of the autumn applied 40 kg/ha N. Differences were not significant but rather more of this nitrogen remained and was accounted for in the 0-30 cm soil layer, when straw was not burnt. This result suggests straw immobilised nitrogen overwinter.

Soil nitrogen uptake was larger after two years of incorporation in the tine cultivation treatments. Presence of straw did not influence this relationship. Ploughing in straw substantially and significantly increased soil nitrogen uptake, probably reflecting the favourable seedbed conditions compared with tine cultivation.

4.2.5 <u>Comparison of recoveries of autumn applied fertiliser N in spring 1986 and 1987</u> (table 3)

Crop and (0-30 cm) soil recoveries of the 40 kg/ha N applied in the autumn were much larger in 1987 (56%) than in 1986 (33%). The majority of this recovered fertiliser nitrogen was in the soil.

Two processes, viz. denitrification and leaching, could be responsible for this difference.

4.2.5a <u>Denitrification</u>: In both 1985 and 1986 soil was at field capacity soon after autumn application of fertiliser nitrogen. However in 1985 the topsoil was warmer during the period (fig. 2) which may have favoured denitrification activity in that season. A maximum of 6 kg/ha N (15% of 40 kg) could have been "lost" by denitrification, calculated using "loss" rates determined by Burford et al. (1959) on the same soil series.

4.2.5b <u>Leaching</u>. Despite the dry start in autumn 1985, between addition of fertiliser nitrogen and spring sampling, rainfall in excess of that required to bring the soil to field capacity, was by 35 mm greater than in the 1986-87 season (92 mm as against 57 mm). This extra drainage could account for some leaching "loss", but, importantly the presence of straw did not mitigate the "loss".

Some reductions in soil mineral nitrogen early in the season could be attributed to shallowly incorporated straw. However, there was sufficient soluble nitrogen in the soil to meet crop requirements until spring so that addition of fertiliser nitrogen in the autumn was not beneficial.

4.2.6 Spring 1988. No spring sampling was done in this season.

4.3 Harvest results

4.3.1 Grain yields

Grain yields and associated yield components for 1986 are given in table 4a; appendices D1-4 contain additional data. Seasonal effects of dry soil at the time of cultivation and increasing incidence of weed patches (fig 3) influenced crop performance far more than the presence or absence of straw or the addition of autumn nitrogen. The retention of straw, therefore, affected yields and response to added nitrogen only indirectly.

4.4 Uptake of soil and fertiliser nitrogen at harvest

4.4.1 1986.

Table 4 b and c show %N of top growth, total nitrogen and recovery of all the fertiliser nitrogen given. Averaged over the three nitrogen rates and timings, crops after incorporation by ploughing contained 1.36% N and those after tine incorporation 1.26% N. Larger plant and shoot densities in the latter due to volunteers was most probably the cause of this statistically significant depression. Crops where straw was burnt contained 1.31% N, not significantly different from either incorporation treatment. This was the only measurement in table 4b that shows significant effects of method of straw incorporation.

%N, amounts of total and fertiliser nitrogen and fraction of nitrogen in crop derived from fertiliser, all increased regularly and significantly with increasing total fertiliser nitrogen addition, with no consistent or

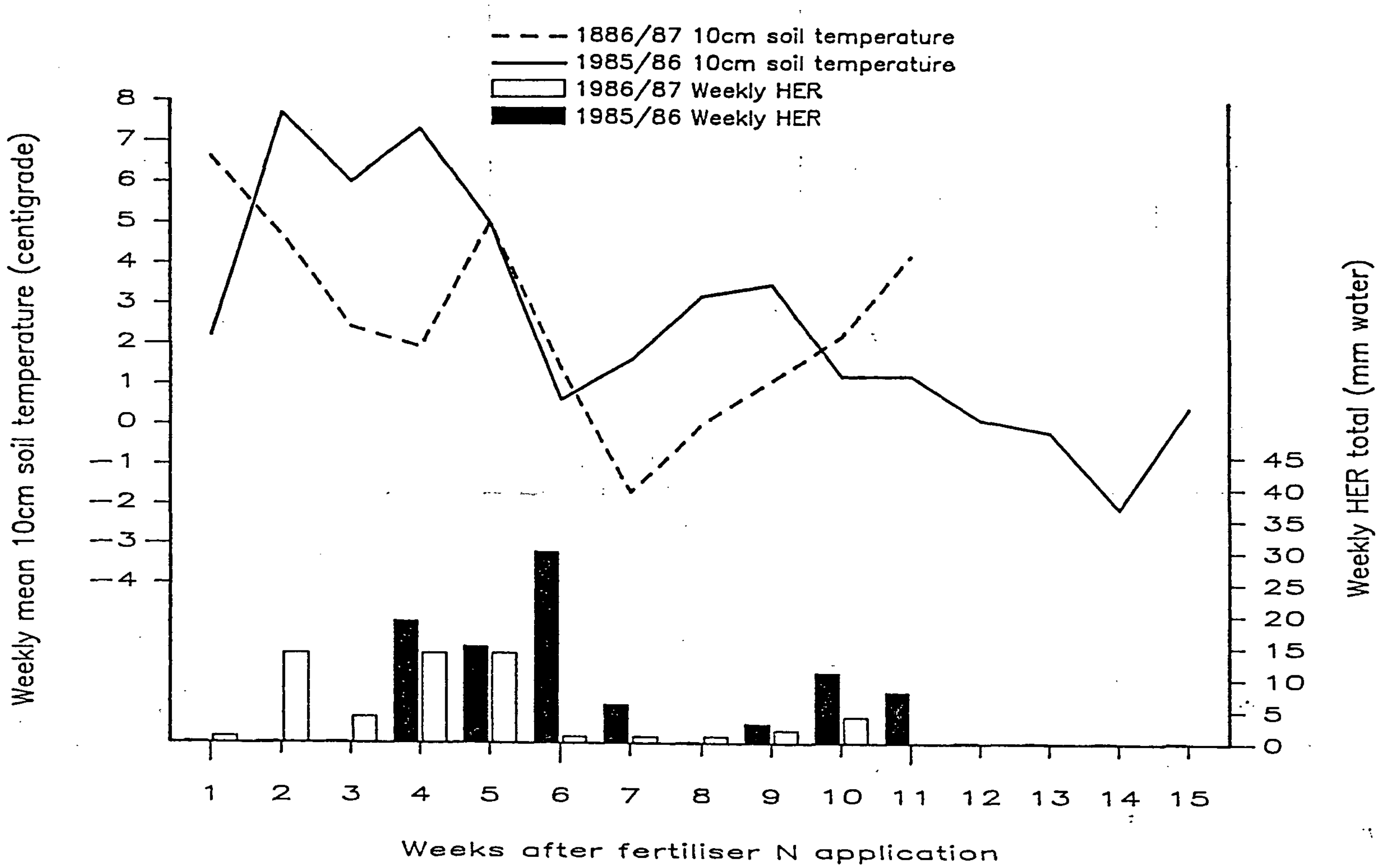


Figure 2 Over-winter soil temperatures at 10 cm depth (recorded at Boxworth EHF) and weekly totals of hydrologically effective rainfall (HER) (provided by MORECS), between autumn fertiliser N application and spring crop sampling, in 1985/86 and 1986/87.

Figure 3

Effect of B.sterilis infestation, in 1st year of tine cultivation treatments, on grain yield of winter wheat growing on N fertilised plots.

(B.sterilis score = visual quantitative estimate of degree of weed infestation per plot)

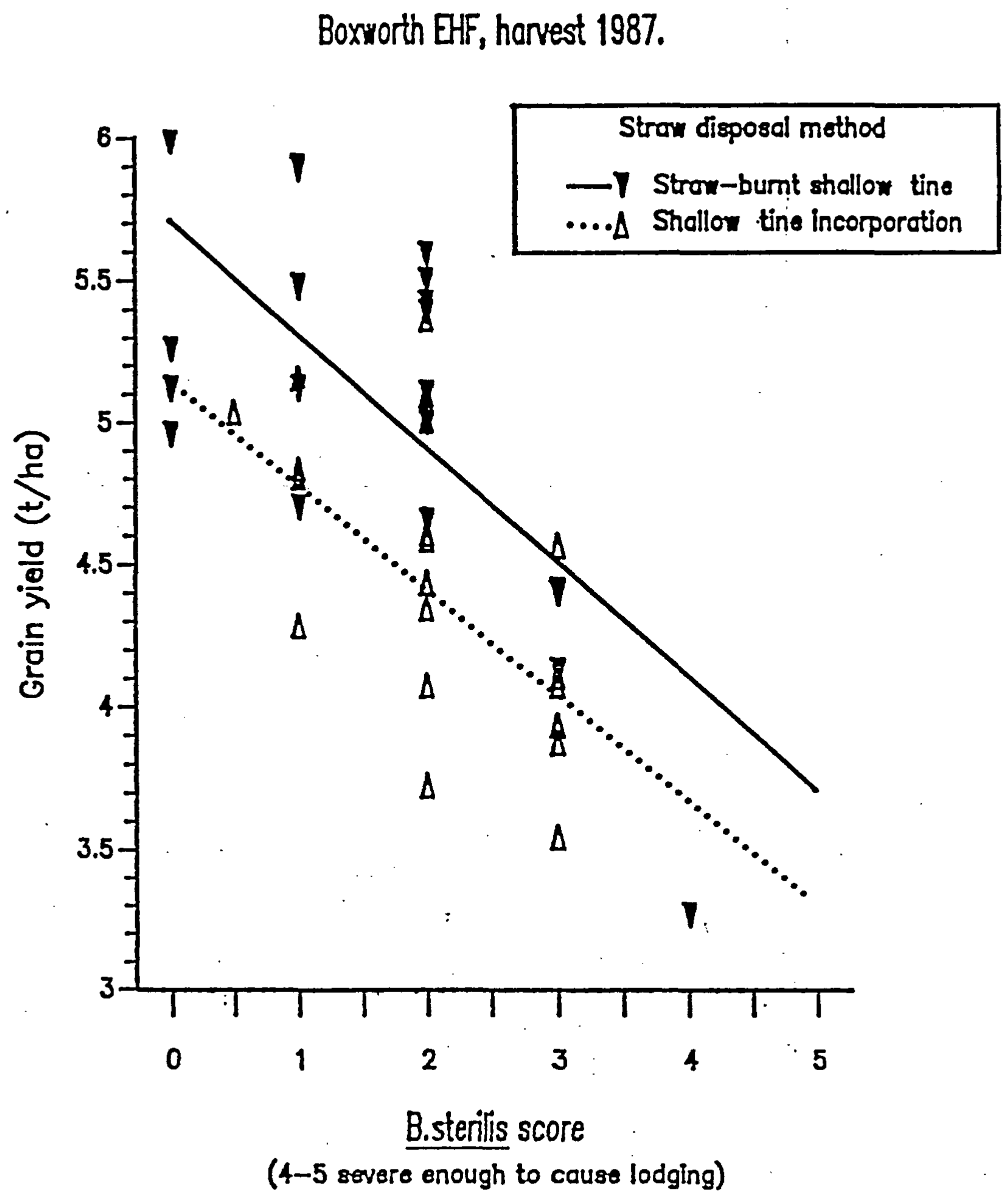
Regression functions:-

Straw-burnt tine

$Y = -0.398^{***} X + 5.70^{***}$ (R^2 = .46)

Tine incorporation

$Y = -0.390^{***} X + 5.26^{**}$ (R^2 = 36)



significant effect due to timing of the application regardless of the presence or absence of straw (Table 4b).

Recovery of the fertiliser nitrogen was significantly less when 40 kg/ha of the total was added in the seedbed, clearly showing decreased efficiency. Retention or burning of the straw did not influence this effect but the reduced efficiency was less pronounced in the ploughed treatments (Table 4b)

Table 5 compares the recovery of the 40 kg/ha N given in the autumn and 40 or 80 kg/ha N given early in the spring. Topping up to 120, 200 and 280 kg/ha total N by late spring application did not significantly influence the recovery of the earlier applications. However, overall shallow incorporation by tines recovered the smallest proportion, (30% compared with 36-37% of burnt and ploughed treatments).

The recovery of 40 kg/ha N applied in autumn was the lowest at 19.1% averaged over all nitrogen levels and methods of straw disposal. This compared with recoveries of 42.4% and 37.6% of the 40 kg/ha N applied in early spring and 35.2% of the 80 kg/ha application (table 5).

This unequivocal confirmation, through the use of labelled nitrogen of the much smaller efficiency of autumn applied fertiliser nitrogen, combined with the absence of any benefit in offsetting yield penalties due to seedbed conditions and weed/ volunteer competition, should disabuse those who continue to believe in and advocate this environmentally undesirable input.

Table 6 shows that recovery of the remainder of the total fertiliser nitrogen, given in late spring, was unaffected by the presence or absence of straw, the method of incorporation or the amounts of nitrogen added as topdressing. The level of recovery at about 50% compared favourably with about 40% for nitrogen applied earlier in spring.

Fig 4 shows that nearly 39% of the variation in the amount of the fertiliser nitrogen in the crop at harvest, was accounted for by the above ground dry matter at harvest. The scatter in this relationship was much greater for the plough incorporation.

Table 4a

Boxworth EHF, 15-N labelled trials. Harvest 1986 grain yields and associated yield components

Straw incorporation treatment	Total N applied (kg/ha)	Early N split-timing (Aut - E Spr) (kg/ha)	Combine grain yield (t/ha, 85% DM)	Hand harvest crop dry weight (t/ha)	Ear population /m²	Thousand grain weight (g, 85% DM)	Dry weight /shoot (g)	Grain weight per ear (g, 85% DM)	Grain number /ear	Grain number /m²	Harvest index
	0	-	4.23	8.75	359	53.1	2.55	1.53	29	9622	0.52
		0-40	7.53	15.55	503	45.8	3.07	1.84	40	20403	0.52
	120	0-80	7.60	12.56	430	45.2	3.01	1.69	37	15118	0.49
		40-40	7.69	14.28	435	43.0	2.99	1.74	35	17143	0.50
Straw-burnt, tine		0-40	8.11	15.31	497	42.6	3.11	1.73	42	20630	0.50
	200	0-80	8.32	16.00	535	45.9	3.03	1.83	40	20557	0.52
		40-40	8.17	13.59	444	44.2	3.07	1.85	42	18494	0.52
		0-40	8.15	16.46	513	43.7	3.22	1.94	44	22669	0.52
	280	0-80	8.12	17.24	602	44.0	2.83	1.61	37	21951	0.49
		40-40	7.97	16.51	538	44.4	3.07	1.86	42	22437	0.53
	0	-	3.27	6.91	594	50.4	1.21	0.67	13	7411	0.48
		0-40	6.79	14.31	663	45.4	2.21	1.19	26	15589	0.47
	120	0-80	6.27	13.50	694	43.9	1.98	1.03	23	15884	0.45
		40-40	5.96	11.32	621	45.1	1.84	1.86	19	11573	0.41
Tine incorporation		0-40	7.49	14.54	635	42.6	2.21	1.13	28	15273	0.44
	200	0-80	7.69	15.69	518	45.5	3.08	1.81	40	20017	0.51
		40-40	7.33	14.52	572	43.2	2.54	1.42	33	13709	0.49
		0-40	7.74	13.45	455	42.9	2.78	1.53	37	17754	0.50
	280	0-80	7.98	15.75	542	42.5	2.93	1.60	38	20182	0.48
		40-40	7.41	15.17	538	42.4	2.83	1.62	38	20491	0.50
	0	-	4.26	8.72	291	47.8	3.05	1.80	38	10779	0.51
		0-40	6.73	13.84	421	45.8	3.34	1.98	44	13403	0.52
	120	0-80	6.76	14.03	414	45.2	3.42	2.14	47	19014	0.54
		40-40	6.55	14.13	425	43.0	3.32	1.95	43	18747	0.51
		0-40	6.96	13.53	391	45.5	3.51	2.03	45	17341	0.51
Plough incorporation	200	0-80	7.16	15.45	463	44.2	3.58	2.15	49	22499	0.53
		40-40	7.10	15.18	425	44.6	3.60	2.13	48	20173	0.52
		0-40	7.20	14.93	442	41.9	3.39	2.02	49	21150	0.52
	280	0-80	7.38	12.59	333	41.8	3.29	2.05	49	18306	0.55
		40-40	7.20	15.61	459	42.8	3.35	1.91	45	20897	0.50
SED's (27 d.f.) (a)											
Straw disposal			0.07***	0.50	19.8***	0.36**	0.07***	0.06***	1.2***	658**	0.01***
N-rate			0.07***	0.50**	19.8	0.36***	0.07***	0.06***	1.2***	658***	0.01
N-timing			0.07*	0.50	19.8	0.36	0.07	0.06	1.2	658	0.01
Straw disposal x N-rate			0.12**	0.87	34.4**	0.62	0.13***	0.10***	2.0***	1140	0.02
Straw disposal x N-timing			0.12	0.87	34.4	0.62	0.13	0.10	2.0	1140	0.02
N-rate x N-timing			0.12	0.87	34.4	0.62	0.13	0.10	2.0	1140*	0.02
Straw disposal x N-rate x N-timing			-(b)	1.50	59.5	1.07*	0.22	0.17	3.5	1974	0.03
CV%			2	10	12	2	7	10	9	10	6

(a) Excluding comparisons with nil-N treatments - also only 8 d.f. for combine grain yield SED's

(b) Highest order SED's were not calculated due to lack of replication.

Table 4b Overall recoveries of applied fertiliser N, and utilisation of soil derived N, by the crop at harvest in 1986.

Straw disposal Method	Total N applied (kg/ha)	N split timing (Aut-E.Spr-Main D) (kg/ha)	Crop N Concentration (%)	Crop N Offtake (kg/ha)	Fertiliser derived N in crop (FDN) (kg/ha)	Soil derived N in crop (SDN) (kg/ha)	Fraction of N derived from fertiliser (FDF) (%)	% Recovery of applied nitrogen
		0-40-80	1.13	176.0	53.1	122.9	30.1	44.3
	120	0-80-40	1.07	134.1	57.0	77.0	42.4	47.5
		40-40-40	1.13	161.8	46.6	115.1	28.6	38.8
Straw Burnt,		0-40-160	1.46	217.4	99.3	118.1	45.7	49.6
Shallow Tine	200	0-80-120	1.30	207.1	105.6	101.4	51.8	52.8
		40-40-120	1.31	178.7	80.5	98.1	44.9	40.3
		0-40-240	1.42	234.6	126.1	108.6	54.3	45.0
	200	0-80-200	1.46	250.9	145.5	105.3	58.1	52.0
		40-40-200	1.47	241.7	120.0	121.7	49.7	42.8
		0-40-80	1.07	153.5	54.1	99.4	35.4	45.1
	120	0-80-40	1.05	142.0	52.1	89.9	36.9	43.4
		40-40-40	1.09	123.9	41.6	81.4	33.4	34.7
		0-40-160	1.27	186.2	108.0	78.3	58.3	54.0
Shallow Tine	200	0-80-120	1.30	206.3	98.3	108.9	47.9	49.2
		40-40-120	1.26	183.5	76.4	107.1	42.4	38.2
		0-40-240	1.48	198.3	113.1	85.3	56.9	40.4
	280	0-80-200	1.44	227.0	133.0	94.0	58.5	47.5
		40-40-240	1.37	208.2	117.1	91.0	56.7	41.8
		0-40-80	1.38	192.3	67.4	124.9	35.5	56.1
	120	0-80-40	1.28	178.7	59.7	119.0	33.0	49.8
		40-40-40	1.18	172.6	48.5	124.1	28.0	40.4
		0-40-160	1.44	194.4	84.7	109.7	43.4	42.3
Plough	200	0-80-120	1.26	208.7	88.7	119.9	42.7	44.4
		40-40-120	1.26	190.3	94.5	95.8	49.7	47.3
		0-40-240	1.50	223.2	128.0	95.2	58.3	45.7
	280	0-80-200	1.44	182.4	103.8	78.6	57.3	37.1
		40-40-200	1.49	232.5	125.7	106.8	54.5	44.9

SED's (27 d.f.)	Crop N Concentration (%)	Crop N Offtake (kg/ha)	FDN (kg/ha)	SDN (kg/ha)	FDF (%)	% Recovery of applied nitrogen
Straw disposal	0.03 ***	8.8	3.8	7.3	1.9	2.2
N-rate	0.03 ***	8.8 ***	3.8 ***	7.3	1.9 ***	2.2
N-timing	0.03	8.8	3.8 *	7.3	1.9	2.2 *
Straw disposal x N rate	0.05 *	15.2	6.6	12.6	3.3	3.9
Straw disposal x N-timing	0.05	15.2	6.6	12.6	3.3	3.9
N-rate x N-timing	0.05	15.2	6.6	12.6	3.3	3.9
Straw disposal x N-rate x N-timing	0.09	26.3	11.4	21.8	5.7	6.7
CV%	7	14	13	21	13	15

Table 4c: Mean crop nitrogen uptake and recovery of soil and fertiliser nitrogen at harvest 1986

Factor Determined	kg/ha Total Fert N	Burn-tine	Straw disposal method Incorporation Shallow-tine	Plough	Mean
All factors averaged over timings					*** sed ±0.03
% N	120	1.11	1.07	1.28	1.15
	200	1.36	1.28	1.32	1.32
	280	1.45	1.43	1.48	1.45
	Mean	1.31	1.26	1.36	1.31 NS
Total nitrogen uptake kg/ha N	120	157.3	139.8	181.2	159.4
	200	201.1	192.0	197.8	197.0
	280	240.4	211.2	212.2	222.1
	Mean	200.3	181.0	157.2	192.8 NS
Fertiliser derived nitrogen, kg/ha	120	52.2	49.3	58.5	53.3
	200	95.1	94.2	89.3	92.9
	280	130.5	121.1	119.2	123.6
	Mean	92.6	88.2	89.0	89.9 NS
Soil derived nitrogen, kg/ha	120	105.0	92.8	122.7	106.8
	200	105.9	98.1	108.5	104.2
	280	111.9	90.1	93.5	98.5
	Mean	107.6	93.7	108.2	103.2 NS
					*** sed ±1.9
Percentage nitrogen derived from fertiliser	120	33.7	35.2	32.2	33.7
	200	47.5	49.5	45.3	47.4
	280	54.0	57.4	56.7	56.0
	Mean	45.1	47.4	44.7	45.7 NS
					NS
Recovery of fertiliser nitorgen %	120	43.5	41.1	48.8	44.5
	200	47.6	47.1	44.7	46.5
	280	46.6	43.2	42.6	44.1
	Mean	45.9	43.8	45.4	45.0 NS
averaged over rates of nitrogen and disposal method	0-40	46.9			
	0-80	47.1			
	40-40	41.0			
	sed	±2.2*			

Table 5

% Recovery of autumn and early-spring applied N dressings by the crop at harvest in 1986.

Straw disposal x N split-timing x N-rate SED (36d.f.)=8.06 CV% = 23

Total N Applied	120 kg/ha N				200 kg/ha N				280 kg/ha N				
Straw Incorporation Treatment / N split-timing (Aut-E.Spr-Main D)	[40]-40-40	40-[40]-40	0-[80]-40	0-[40]-80	[40]-40-120	40-[40]-120	0-[80]-120	0-[40]-160	[40]-40-200	40-[40]-200	0-[80]-200	0-[40]-240	Cultivation overall means
Straw Burnt, Shallow Tine	25.5	42.3	46.2	37.9	21.9	43.6	43.0	36.7	16.9	39.7	41.6	36.6	36.0
Shallow Tine	15.0	37.3	40.2	45.2	17.5	31.7	31.1	27.6	16.5	40.5	32.0	26.0	30.0
Plough	12.7	56.2	43.1	47.8	16.6	43.5	51.0	44.8	29.3	46.9	24.7	35.5	37.7
Total N applied-overall means	37.4				34.1				32.2				SED (36d.f.)=2.33* *
	SED (36 d.f.) = 2.33												

N split-timing overall means	[40]-40-Main D	40-[40]-Main D	0-[80]-Main D	0-[40]-Main D
	19.1	42.4	39.2	37.6
	SED (36 d.f.) = 2.69 ***			

[ ] = N-15 Labelled dressing to which the % recoveries quoted, apply.

Table 6

% Recovery of late-spring applied N maindressings by the crop at harvest in 1986

% Recoveries of Fertiliser N

Straw disposal x N-rate x N split-timing SED (27 d.f.) = 8.62, CV% = 17

Total N applied	120 kg/ha N			200 kg/ha N			280 kg/ha N			
Straw Incorporation Treatment / N split-timing (Aut-E.Spr-Main D)	0-40-[80]	0-80-[40]	40-40-[40]	0-40-[160]	0-80-[120]	40-40-[120]	0-40-[240]	0-80-[200]	40-40-[200]	Cultivation overall means
Straw Burnt, Shallow Tine	47.5	50.2	48.6	52.8	59.4	45.2	46.5	56.2	48.7	50.6
Shallow Tine	45.0	49.8	51.6	60.6	61.2	47.2	42.9	53.7	47.2	51.0
Plough	60.3	63.0	52.4	41.7	39.9	58.7	47.4	42.0	47.6	50.4
										SED (27 d.f.)=2.87
Total N applied-overall means		52.1			51.9			48.0		
					SED (27 d.f.) = 2.87					
N split-timing, overall means	0-40-[Main D]	0-80-[Main D]	40-40-[Main D]							
	49.4	52.8	49.7							
	SED (27 d.f.) = 2.87									

[ ] = N-15 Labelled dressing to which the % recoveries quoted, apply.

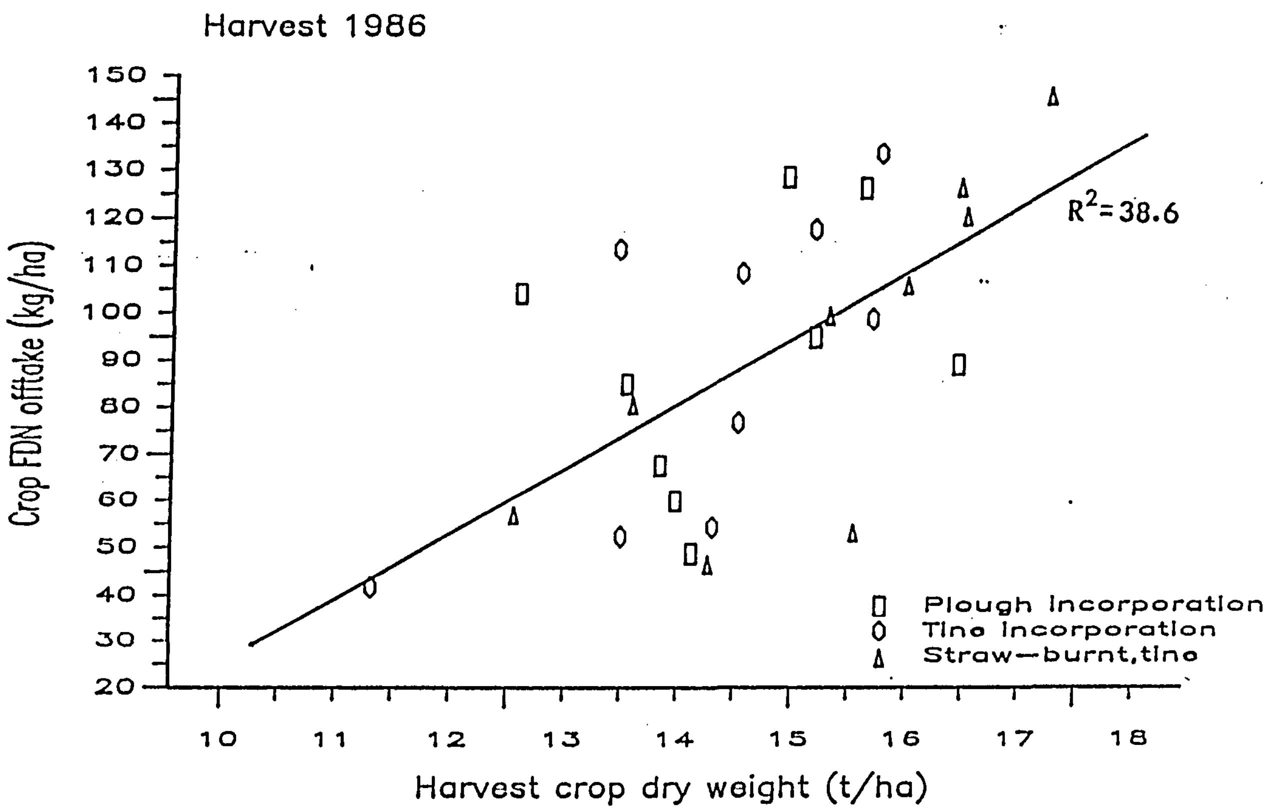


Figure 4. The relationship between crop dry weight at harvest and the quantity of fertiliser derived N (FDN) assimilated by the crop.

Regression function :-

Crop FDN offtake = 13.9 x crop dry weight - 113
                   ***   *

Correlation coefficients for individual straw disposal methods :-

Straw-burnt, tine $r = 0.79$
Tine incorporation $r = 0.69$
Plough incorporation $r = 0.31$

4.4.2 1987:

Table 7 a-h show crop dry weight, nitrogen uptake and recovery of soil and fertiliser nitrogen at harvest 1987, for both first and second year of disposal. Details of yield components are given in appendices E 1-3.

Crops after shallow incorporation of straw with tines, accumulated the least dry matter in both phases with the first year of cultivation being the most affected. This was probably because of volunteers and grass weeds. Of the crops in the first year of disposal, ploughing in straw produced the largest dry matter; of those in the second successive year of cultivation, the crops after burning straw outgrew those where straw was retained.

% N of the above ground crop showed the usual increase with increasing amounts of nitrogen added (Appendix E1). There was little consistent effect of straw disposal method and timing of nitrogen application so that total N (table 7b), FDN (table 7c) and SDN (table 7d) closely reflected the levels of dry matter with no significant treatment differences.

There was a notable depression in the average amount of soil derived nitrogen in tine incorporated treatments in both years of cultivation (table 7d). Averaged over nitrogen timings and cultivation methods with or without straw, crops given a total of 280 kg/ha N had 25% less SDN than those receiving 120 or 200 kg/ha. SDN was strongly related to dry weight over a 3 fold range (52.8 to 159.9 kg/ha) showing a steady increase of 8-10 kg SDN for each additional tonne of dry matter (fig 5).

The fraction of crop nitrogen derived from fertiliser (FDF) also showed the usual pattern, increasing regularly with increasing fertiliser nitrogen but with timing of the application having no effect (table 7e). One notable feature was that straw burning resulted in the smallest FDF and averaged overall this effect was significant. This means that the retention of straw depresses uptake of soil nitrogen by crops relative to that of fertiliser nitrogen, compared with crops after straw burning. This effect is consistent with some soil nitrogen being immobilised by straw and rendered less usable than added fertiliser; adding fertiliser nitrogen in the autumn does not materially alter this. By the second year of incorporation this effect was not evident, suggesting some re-mobilisation of nitrogen held by straw.

Table 7

Harvest 1987. Dry weight/ha (tonnes)

Year of Disposal	Disposal method	N rate (kg/ha N) 120, N split - timing 0-40	40-40	0-80	200 0-40	40-40	0-80	280 0-40	40-40	0-80	Mean	Overall Mean SED = 1.406 ns	Overall Mean SED = 1.148 ns
1	Straw burnt, tine	12.95	10.45	8.85	13.47	12.46	13.25	12.15	9.75	8.64	11.33	12.43	11.39
	Tine incorporation	8.84	6.35	9.22	8.26	9.40	12.14	9.49	9.30	10.49	9.28	10.30	
	Plough incorporation	12.42	13.49	12.78	12.93	15.78	14.80	14.63	13.39	11.83	13.56	12.90	
	mean	11.41	10.10	10.28	11.55	12.55	13.39	12.09	10.81	10.32			
	mean	10.60			12.50			11.07					
2	Straw burnt, tine	12.30	12.85	14.17	10.99	15.15	14.08	15.25	12.59	14.33	13.52		12.36
	Tine incorporation	11.16	11.87	10.63	11.32	13.08	12.12	10.98	7.87	12.84	11.32		
	Plough incorporation	12.00	11.99	11.48	11.69	13.87	11.20	12.83	12.67	12.50	12.24		
	mean	11.82	12.23	12.09	11.33	14.03	12.46	13.02	11.04	13.22			
	mean	12.05			12.61			12.43					
Overall mean SED = 0.834 ns		11.61	11.16	11.19	11.44	13.29	12.93	12.55	10.93	11.77			
Overall mean SED = 0.482 ns		11.32			12.55			11.75					

CV% = 12

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

Table 7b Harvest 1987. Crop N content (kg/ha N)

Year of Disposal	Disposal method	N rate (kg/ha N) 120, N split - timing 0-40	40-40	0-80	200 0-40	40-40	0-80	280 0-40	40-40	0-80	Mean	Overall Mean SED = 18.9 ns	Overall Mean SED = 15.4 ns
1	Straw burnt, tine	192	152	131	225	209	218	217	165	149	184	199	179
	Tine incorporation	116	78	129	143	149	197	171	160	177	147	159	
	Plough incorporation	167	171	144	194	246	240	263	223	204	197	197	
	mean	158	134	135	187	201	217	217	183	177			
	mean	142			202			192					
2	Straw burnt, tine	192	197	210	170	235	230	250	208	246	215		191
	Tine incorporation	160	147	132	182	199	183	187	141	221	172		
	Plough incorporation	165	158	153	188	214	183	218	199	208	187		
	mean	172	165	165	180	216	198	218	183	225			
	mean	167			198			208					
Overall mean SED = 13.7 ns		165	149	150	184	209	208	217	183	201			
Overall mean SED = 7.9 ns		155			200			200					

CV = 12

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

Table 7c   Harvest 1987. Fertiliser derived N in crop (kg/ha N)

Year of Disposal	Disposal method	N rate (kg/ha N) 120 N split - timing 0-40	40-40	0-80	200 0-40	40-40	0-80	280 0-40	40-40	0-80	Mean	Overall Mean SED = 9.25 ns	Overall Mean SED = 7.55 ns
1	Straw burnt, tine	52.1 *	38.7	40.6	100.2	84.7	74.5	115.0	59.1	82.1	83.1	83.1	79.2
	Tine incorporation	12.5	23.1	36.6	84.6	70.6	78.4	117.9	109.4	104.7	74.2	74.2	
	Plough incorporation	59.8	52.9	39.7	80.1	109.2	109.3	154.1	125.7	122.5	90.2	90.2	
	mean	41.5	38.2	39.0	88.3	88.2	87.4	129.0	98.0	103.1			
	mean	39.6			87.9			110.0					
2	Straw burnt, tine	56.9	50.3	49.8	86.4	93.1	100.5	160.0	115.7	136.1			85.8
	Tine incorporation	56.9	36.5	43.6	85.0	82.6	80.6	106.8	73.2	131.6			
	Plough incorporation	53.3	43.4	47.4	75.0	106.9	67.4	120.2	126.0	129.8			
	mean	55.7	43.4	46.9	82.2	94.2	82.8	129.0	105.0	132.5			
	mean	48.7			86.4			112.2					
Overall mean SED = 8.30 ns		48.6	40.8	43.0	85.2	91.2	85.1	129.0	101.5	117.8			
Overall mean SED = 4.79 ns		44.1			87.2			116.1					

CV = 24

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

* exceptionally small. Reasons are uncertain; late spring labelled N dressing may have been omitted.

Table 7d Harvest 1987. Soil derived N in crop (kg/ha N)

Year of Disposal	Disposal method	N rate (kg/ha N) 120 N split - timing 0-40	40-40	0-80	200 0-40	40-40	0-80	280 0-40	40-40	0-80	Mean	Overall Mean SED = 9.99 ns	Overall Mean SED = 8.15 ns
1	Straw burnt, tine	139.9	113.1	90.2	124.3	124.7	143.5	101.6	106.2	66.9	112.3	116.3	99.6
	Tine incorporation	103.8	54.8	92.3	58.2	78.0	119.0	52.8	50.2	71.8	75.6	85.2	
	Plough incorporation	106.8	117.7	103.8	114.4	137.1	130.5	108.6	97.6	81.1	110.8	106.3	
	mean	116.8	95.2	95.4	99.0	113.3	131.0	87.7	84.7	73.3			
	mean	102.5			114.4			81.9					
2	Straw burnt, tine	135.2	140.1	159.9	83.8	141.8	129.6	89.6	91.9	110.2	120.2		105.6
	Tine incorporation	102.6	110.3	88.0	96.7	116.3	101.8	80.3	68.0	89.8	94.9		
	Plough incorporation	111.7	114.9	105.8	113.1	107.0	115.1	97.6	73.4	77.8	101.8		
	mean	116.5	121.8	117.9	97.9	121.7	115.6	89.2	77.8	92.6			
	mean	118.7			111.7			86.5					
Overall mean SED = 10.32 ns		116.7	108.5	106.7	98.4	117.5	123.3	88.4	81.2	82.9			
Overall mean SED = 5.96 ns		110.6			113.0			84.2					

CV = 23

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

Table 7e Harvest 1987. Fraction of crop N content derived from Fertiliser (%)

Year of Disposal	Disposal method	N rate (kg/ha N) 120, N split - timing 0-40	40-40	0-80	200 0-40	40-40	0-80	280 0-40	40-40	0-80	Mean	Overall Mean SED = 0.89,Pz	Overall Mean SED = 0.73 ns
1	Straw burnt, tine	27.6	25.7	31.2	45.4	40.5	34.5	53.2	34.1	55.8	38.6	41.0	43.1
	Tine incorporation	10.9	31.6	28.7	59.4	47.1	40.7	69.1	68.3	59.9	46.2	45.0	
	Plough incorporation	36.0	30.9	27.7	41.9	44.4	45.8	58.4	55.9	60.0	44.5	44.4	
	mean	24.8	29.4	29.2	48.9	44.0	40.3	60.2	52.8	58.6			
	mean	27.8			44.4			57.2					
2	Straw burnt, tine	29.7	25.4	24.1	51.2	40.1	43.8	64.2	55.7	55.2	43.4		43.8
	Tine incorporation	36.2	25.5	33.2	46.4	41.6	44.3	56.6	52.0	59.7	43.9		
	Plough incorporation	32.4	27.6	30.8	40.1	50.0	36.7	55.1	63.3	62.4	44.2		
	mean	32.7	26.6	29.3	45.9	43.9	41.6	48.6	57.0	59.1			
	mean	29.5			43.8			58.2					
Overall mean SED = 3.43 ns		28.8	27.9	29.3	47.4	43.9	40.9	59.4	54.9	58.8			
Overall mean SED = 2.0 ns		28.7			44.1			57.7					

CV = 22

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

* exceptionally small. Reasons are uncertain; late spring labelled N dressing may have been omitted.

Table 7f Harvest 1987. % Recovery of autumn and early spring applied N dressings by the crop

Year of disposal	Disposal method	120 N split-timing 40-40-40	40-40-40	0-80-40	0-40-80	200 40-40-120	40-40-120	0-80-120	0-40-160	280 40-40-200	40-40-200	0-80-200	0-40-240	Mean	Overall mean SED= 3.02 NS	Overall mean SED= 2.47 NS
	Straw burnt tine	21.5	31.7	33.3	31.6	16.6	42.4	29.4	21.5	10.9	28.9	32.2	40.9	28.4	31.7	27.6
	Tine incorporation	14.3	18.6	18.6	19.6	17.0	21.0	30.2	17.8	11.9	31.0	15.9	21.9	19.8	22.3	
1	Plough incorporation	32.8	33.8	22.0	30.5	23.9	65.9	37.8	25.4	21.0	50.9	33.9	38.8	34.7	33.9	
	Mean	22.8	28.0	24.6	27.2	19.2	43.1	32.5	21.6	14.6	36.9	27.3	33.9	27.6		
	Mean	25.7				29.1				28.2						
	Straw burnt tine	24.7	44.0	30.6	42.9	17.6	55.4	36.1	36.5	17.6	43.2	36.6	33.6	34.9		30.9
	Tine incorporation	17.2	26.7	22.6	24.1	15.3	47.1	28.2	22.0	13.7	27.1	22.0	31.6	24.8		
2	Plough incorporation	21.4	34.3	30.2	33.2	20.8	63.1	31.1	35.7	20.2	32.9	34.2	40.1	33.1		
	Mean	21.1	35.0	27.8	33.4	17.9	55.2	31.8	31.4	17.1	34.4	30.9	35.1	30.9		
	Mean	28.3				34.1				29.4						
Overall mean SED = 3.09 NS		22.0	31.5	26.2	30.3	18.6	49.2	32.1	26.5	15.8	35.7	29.1	34.5			
Overall mean SED = 1.54 NS CV = 30.4%		27.5				31.6				28.8						

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's.

N split timing overall mean	40-40-Main D	40-40-Main D	0-80-Main D	0-40-Main D
Year of disposal 1	18.9	36.0	28.1	27.6
Year of disposal 2	18.7	41.5	30.2	30.4
Mean	18.8	38.8	29.2	29.0

Table 7g Harvest 1987. Recovery of late spring applied N dressings by the crop (%)

Year of Disposal	Disposal method	N rate (kg/ha N) 120			200			280			Mean	Overall Mean SED =	Overall Mean SED =
	N split-timing	0-40-[80]	40-40-[40]	0-80-[40]	0-40-[160]	40-40-[120]	0-80-[120]	0-40-[240]	40-40-[200]	0-80-[200]		7.42 ns	6.06 ns
1	Straw burnt, tine	49.3	43.6	35.0	57.3	50.9	42.5	41.1	21.6	28.2	41.0	47.9	48.5
	Tine incorporation	-	53.0	54.4	48.5	46.1	45.2	37.9	46.1	47.7	46.8	52.6	
	Plough incorporation	59.6	65.6	55.1	43.7	61.1	65.8	57.8	48.5	46.1	56.1	48.4	
	mean	54.5	45.3	48.1	49.8	52.7	51.2	45.6	38.7	40.7			
	mean	52.3			51.2			41.7					
2	Straw burnt, tine	49.7	62.9	63.3	44.9	53.2	59.7	61.1	44.0	53.5	54.8		50.7
	Tine incorporation	59.2	48.4	63.9	41.5	48.0	48.4	39.3	28.5	57.1	48.2		
	Plough incorporation	50.1	52.3	58.4	38.0	61.2	35.5	43.4	52.4	51.3	49.2		
	mean	54.5	52.9	61.8	41.4	54.1	47.8	47.9	41.1	53.9			
	mean	55.9			47.7			47.6					
Overall mean SED = 4.76 ns		53.0	53.6	55.0	45.6	53.4	49.5	46.7	39.8	47.3			
Overall mean SED = 2.75 ns		54.6			49.5			44.7					
CV = 22													

N.B: The late spring dose, boxed, were labelled.

- missing value; late spring labelled N dressing may have been omitted.

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

Table 7h   Harvest 1987. Recovery of applied N (%)

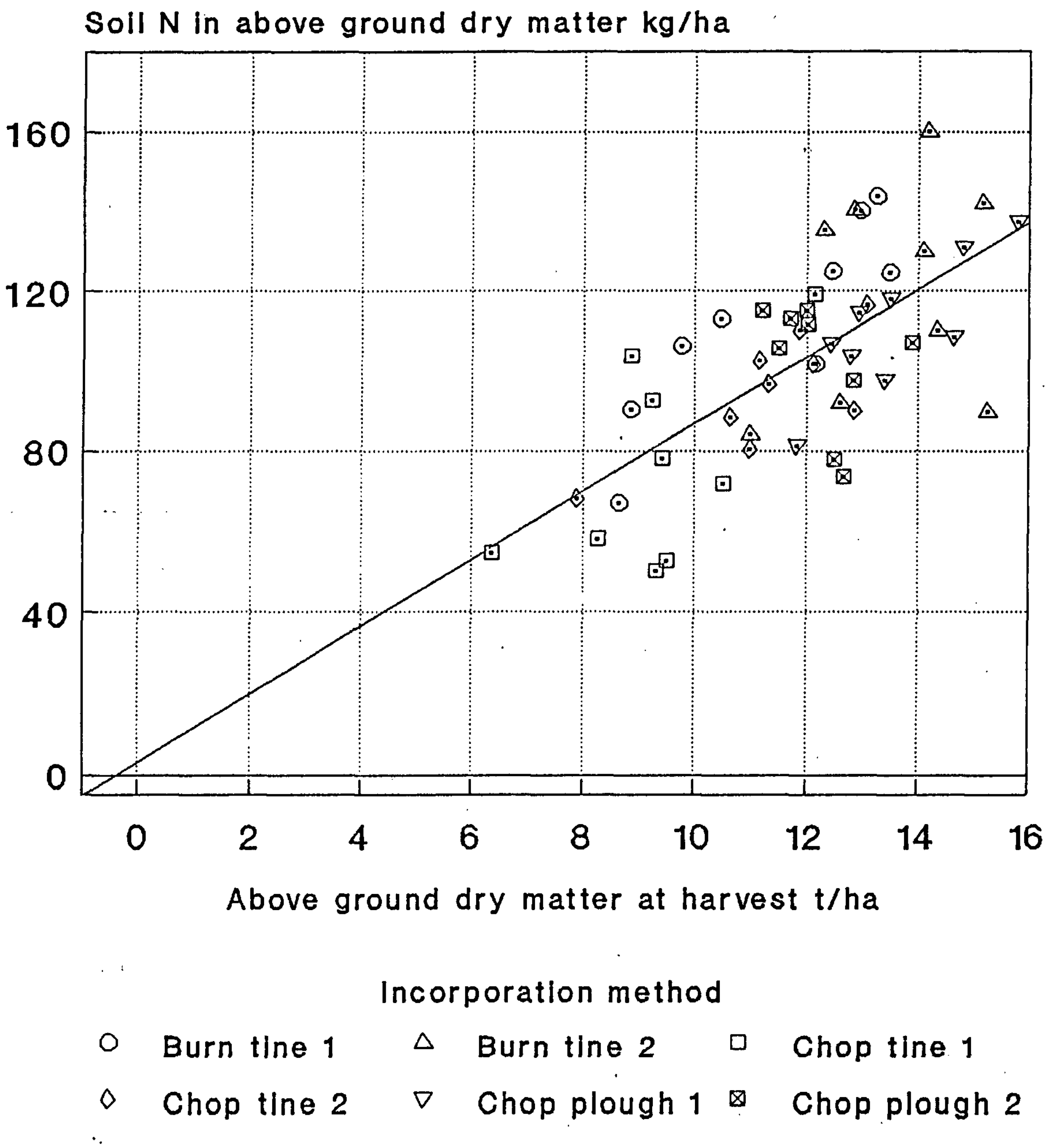
Year of Disposal	Disposal method	N rate (kg/ha N) 120, N split - timing 0-40	120 0-80	120 40-40	200 0-40	200 0-80	200 40-40	280 0-40	280 0-80	280 40-40	Mean	Overall Mean SED = 4.65 ns	Overall Mean SED = 3.80 ns
1	Straw burnt, tine	43.5	32.2	33.9	50.1	42.4	37.3	41.1	21.1	29.4	36.7	41.6	38.7
	Tine incorporation	10.4	19.3	30.5	42.3	35.3	39.2	42.1	39.1	37.5	32.8	35.8	
	Plough incorporation	49.9	44.1	33.1	40.1	54.6	54.6	55.0	44.9	43.8	46.6	44.4	
	mean	34.6	31.8	32.5	44.2	44.1	43.7	46.1	35.0	36.9			
	mean	33.0			44.0			39.3					
2	Straw burnt, tine	47.5	41.9	41.5	43.2	46.5	50.3	57.2	41.3	48.6	46.4		42.5
	Tine incorporation	47.5	30.4	36.4	42.5	41.3	40.3	38.2	26.2	47.0	38.8		
	Plough incorporation	44.5	36.3	39.6	37.6	53.5	33.8	43.0	45.0	46.4	42.1		
	mean	45.5	36.2	39.1	41.1	47.1	41.4	45.1	37.5	47.3			
	mean	40.6			43.2			43.6					
Overall mean SED = 4.15 ns		40.5	34.0	35.8	42.6	45.6	42.6	45.1	36.2	42.1			
Overall mean SED = 2.40 ns		36.8			43.6			41.5					

CV = 21

2 d.f. for year of disposal and disposal method SED's, 24 d.f. for all other SED's

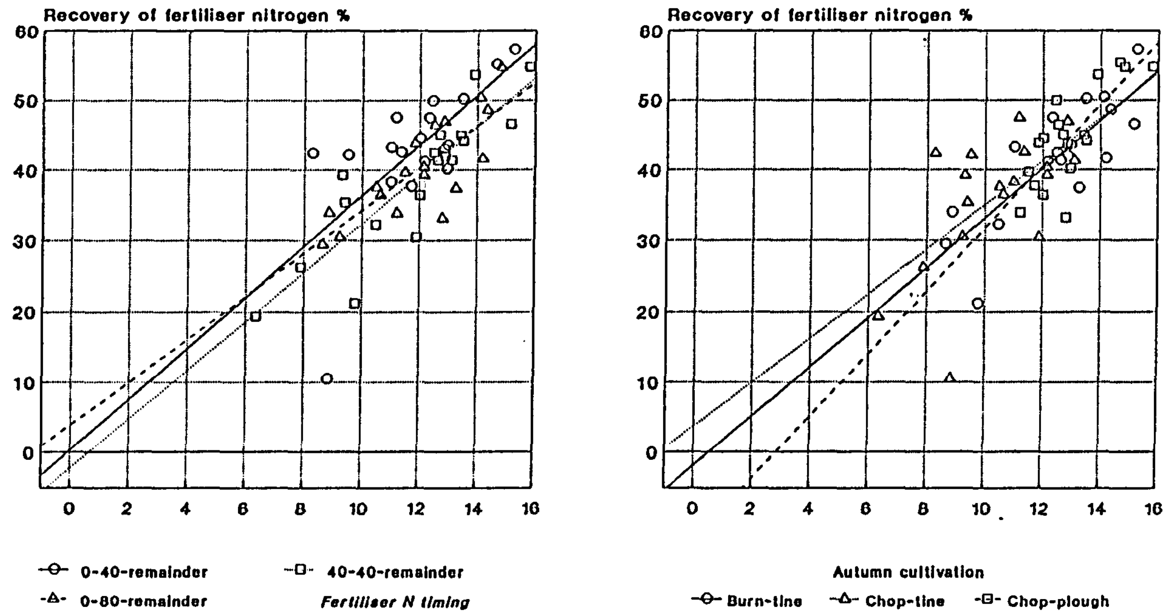
Fig 5

Boxworth straw incorporation study 1987
Soil nitrogen uptake as function of above ground dry matter



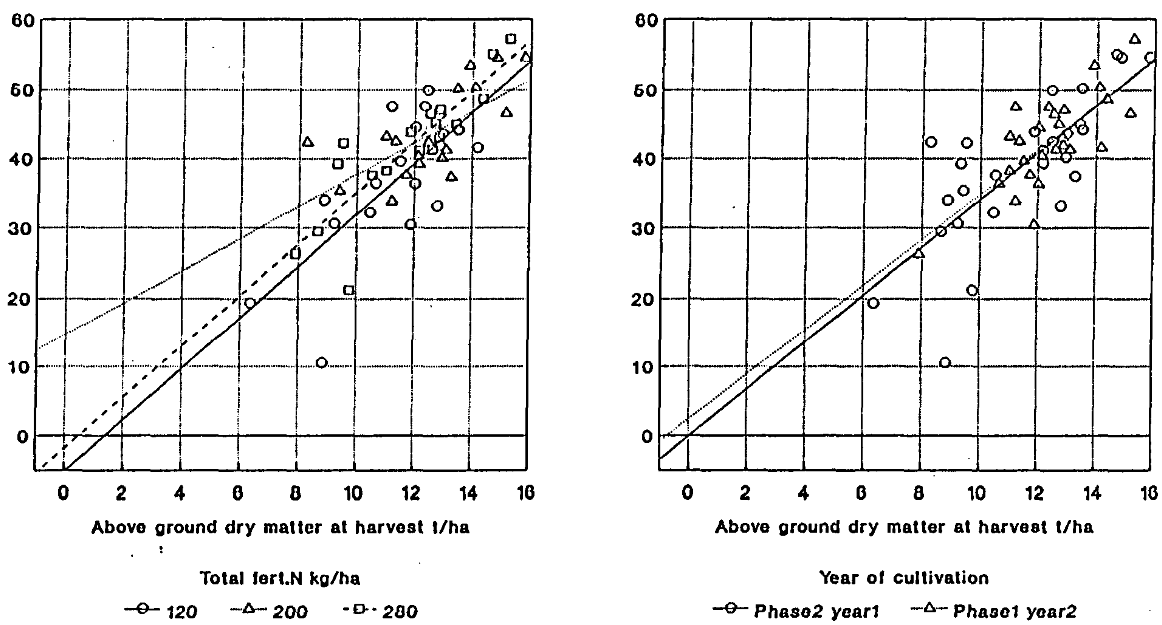
1= phase2 year1; 2= phase1 year2

Fig. 6



Boxworth straw incorporation study 1987

Recovery of fertiliser nitrogen related to above ground dry matter



Recovery- proportion of added fertiliser N in above ground dry matter at harvest

The relatively smaller efficiency of the autumn applied part of the fertiliser nitrogen is again confirmed (table 7f). The later the nitrogen addition, the greater the recovery regardless of nitrogen rates or straw disposal method. Autumn nitrogen is only a little more than half as efficient as the early spring dose and without any benefit to crop performance.

The recovery of the total fertiliser nitrogen (table 7h) was slightly less in 1987 (41%) than in 1986 (45%). Shallow incorporation of straw with tines showed the smallest recovery in both years but there were no significant treatment differences. Fig 6 shows the overriding effect of quantity of dry matter production on fertiliser nitrogen recovery and illustrates the very minor influence of the other treatments.

4.4.3 1988:

The crop in this third season of the experiment suffered much from severe blackgrass and brome grass infestation. The most serious competition was in shallow tine treatments in the 2nd and 3rd year of successive cultivation. Even the plough treatment in the 2nd year of incorporation was penalised, though not to the same extent as the non-plough cultivation treatments. For crop and soil nitrogen data see table 8a, b and Appendix F1-6).

Above ground dry matter in crops at harvest 1988 ranged more than 3 fold, from 5.19 t/ha to 16.70 t/ha (Table 8a). The large differences were not statistically significant because of large errors of estimation (CV 26%). This lack of precision was, to some extent, because of grass weeds. The penalty from this competition was a tonne or more reduction in above ground dry matter production for each tonne of weed dry matter found at harvest (Fig 7). Burning the straw was not always a remedy, nor the addition of increasing amounts of fertiliser nitrogen or its timing.

%N in the above ground dry matter (table 8c) followed the pattern of previous seasons, crops given 40 kg/ha N in the autumn had, almost invariably, a lower concentration irrespective of the amount of nitrogen applied or the method or year of disposal, but differences were not large enough to be statistically significant.

Table 8b Harvest 1988. Grass weed dry matter in 15N labelled micropolots (t/ha)

Year of disposal	Disposal method	N rate kg/ha 120, N split-timing 0-40	0-80	40-40	200 0-40	0-80	40-40	280 0-40	0-80	40-40	Mean	Overall mean	Overall mean
	Straw burnt tine	1.13	0.91	0.91	1.79	1.64	0.50	0.49	1.58	1.42	1.15	0.70	0.61
	Tine incorporation	0.30	0.12	0.13	0.16	0.17	0.25	1.08	0.35	0.52	0.39	0.52	
1	Plough incorporation	1.12	0.29	0.00	0.00	0.00	0.36	0.57	0.34	0.29	0.33	0.25	
	Mean	0.85	0.44	0.35	0.65	0.60	0.37	0.71	0.76	0.74		0.49	
	Mean	0.55			0.54			0.74					
	Straw burnt tine	1.53	1.87	0.20	0.00	0.78	0.13	0.05	1.04	2.74	0.93		0.81
	Tine incorporation	3.09	0.87	2.02	0.10	0.71	0.56	0.95	0.52	1.21	1.11		
2	Plough incorporation	0.10	0.08	1.44	0.00	1.23	0.04	0.09	0.31	0.10	0.38		
	Mean	1.57	0.94	1.22	0.03	0.91	0.24	0.36	0.62	1.35			
	Mean	1.24			0.39			0.78					
	Straw burnt tine	0.00	0.00	0.00	0.00	0.07	0.00	0.04	0.00	0.00	0.01		0.04
	Tine incorporation	0.00	0.05	0.11	0.10	0.15	0.05	0.09	0.00	0.00	0.06		
3	Plough incorporation	0.00	0.00	0.00	0.00	0.10	0.00	0.37	0.00	0.00	0.05		
	Mean	0.00	0.02	0.04	0.03	0.11	0.02	0.17	0.00	0.00			
	Mean	0.02			0.05			0.06					

Averaged over disposal methods and N rates

Year of disposal	N split-timing 0-40	0-80	40-40	Mean
1	0.74	0.60	0.49	0.61
2	0.65	0.82	0.94	0.81
3	0.07	0.04	0.02	0.04
Mean	0.49	0.49	0.48	0.49

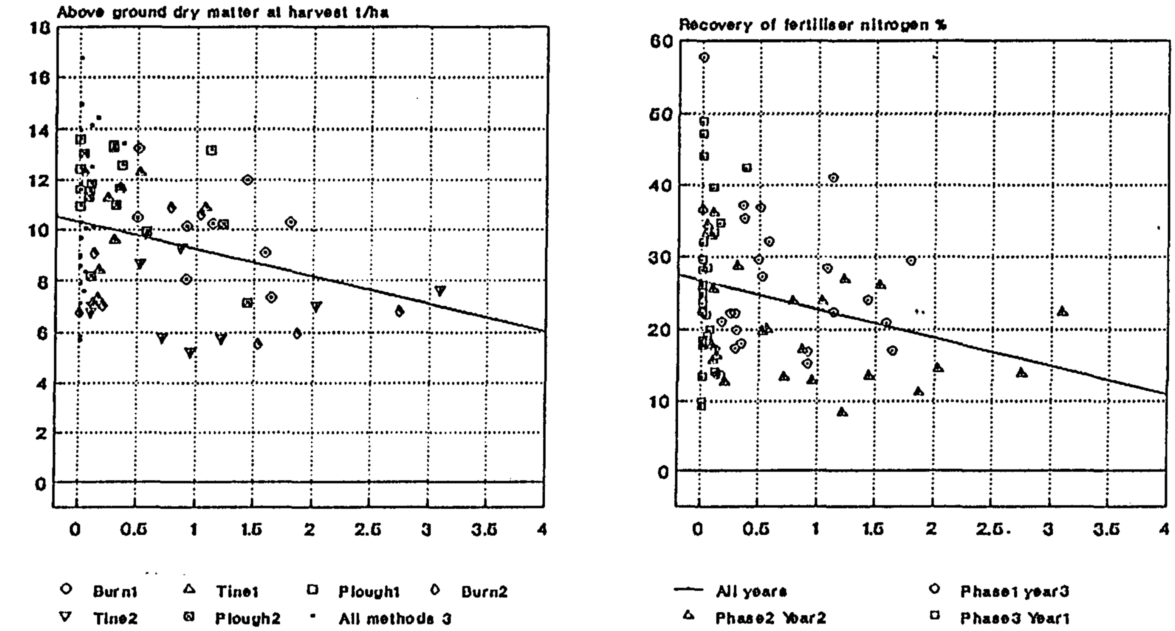
Table 8a Harvest 1988. Crop dry weight (t/ha)

Year of Disposal	Disposal method	N rate (kg/ha N) 120 N split - timing 0-40	0-80	40-40	200 0-40	0-80	40-40	280 0-40	0-80	40-40	Mean	Overall Mean SED = 1.064 ns	Overall Mean SED = 1.064 ns
1	Straw burnt, tine	10.21	10.09	7.99	10.23	7.28	13.12	10.43	9.03	11.95	10.04	8.50	10.61
	Tine incorporation	9.56	7.11	7.02	7.29	8.39	11.25	10.87	11.66	12.29	9.49	9.20	
	Plough incorporation	13.16	13.38	10.92	13.59	12.39	12.56	9.89	11.61	13.26	12.31	11.74	
	mean	10.98	10.19	8.65	10.36	9.35	12.31	10.40	10.77	12.50			
	mean	9.94			10.68			11.22					
2	Straw burnt, tine	5.50	5.93	7.01	6.73	10.86	9.04	12.26	10.56	6.79	8.30		8.76
	Tine incorporation	7.57	9.26	6.97	6.75	5.72	9.79	5.19	8.64	5.70	7.29		
	Plough incorporation	11.78	11.26	7.11	11.54	10.19	13.01	11.50	10.95	8.14	10.69		
	mean	8.28	8.82	7.03	8.34	8.92	10.61	9.65	10.05	7.13			
	mean	8.04			9.29			8.94					
3	Straw burnt, tine	6.57	7.08	5.79	6.57	7.06	8.95	7.52	7.82	7.05	7.16		10.06
	Tine incorporation	8.84	8.29	10.05	12.45	14.41	10.02	11.91	9.64	11.80	10.82		
	Plough incorporation	8.52	10.23	5.67	16.70	14.11	12.42	13.42	14.91	13.91	12.21		
	mean	7.98	8.53	7.17	11.91	11.86	10.46	10.95	10.79	10.92			
	mean	7.89			11.41			10.89					
Overall mean SED = 0.930 ns		9.08	9.18	7.61	10.20	10.04	11.13	10.33	10.53	10.18			
Overall mean SED = 0.537 ns		8.62			10.46			10.35					
CV% = 26													

4 d.f. for year of disposal and disposal method SED's, 48 d.f. for all other SED's

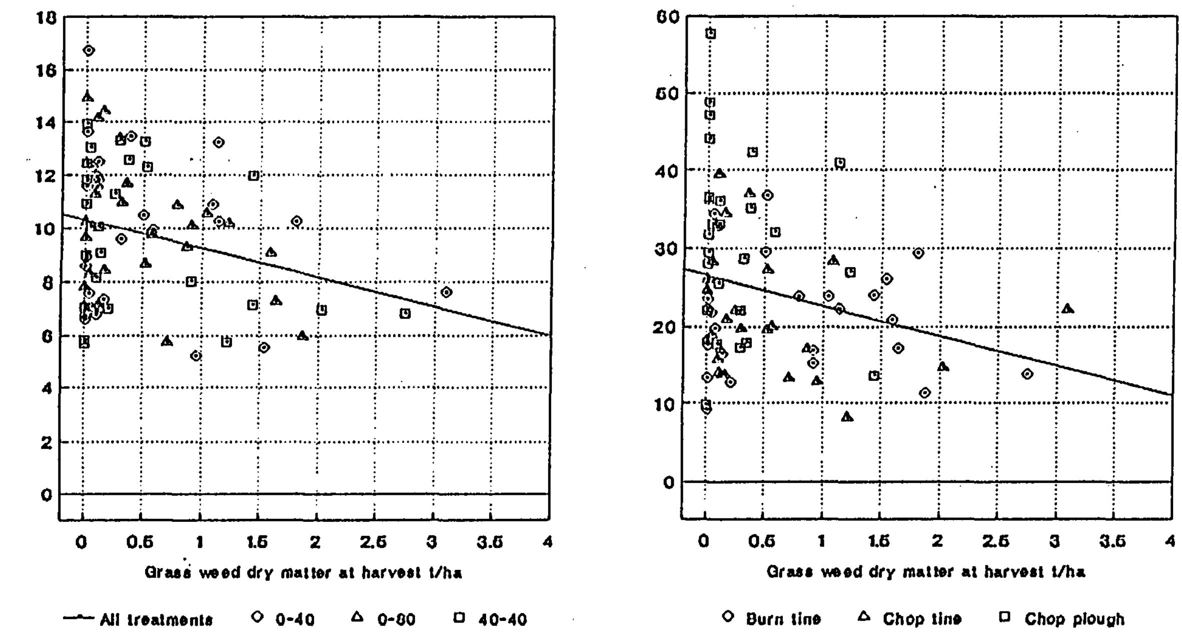
Fig. 7

1•phase3 year1; 2•phase2 year2; 3•phase1 year3;



Boxworth straw incorporation study 1988

Above ground dry matter and fertiliser N recovery related to grass weed dry matter at harvest

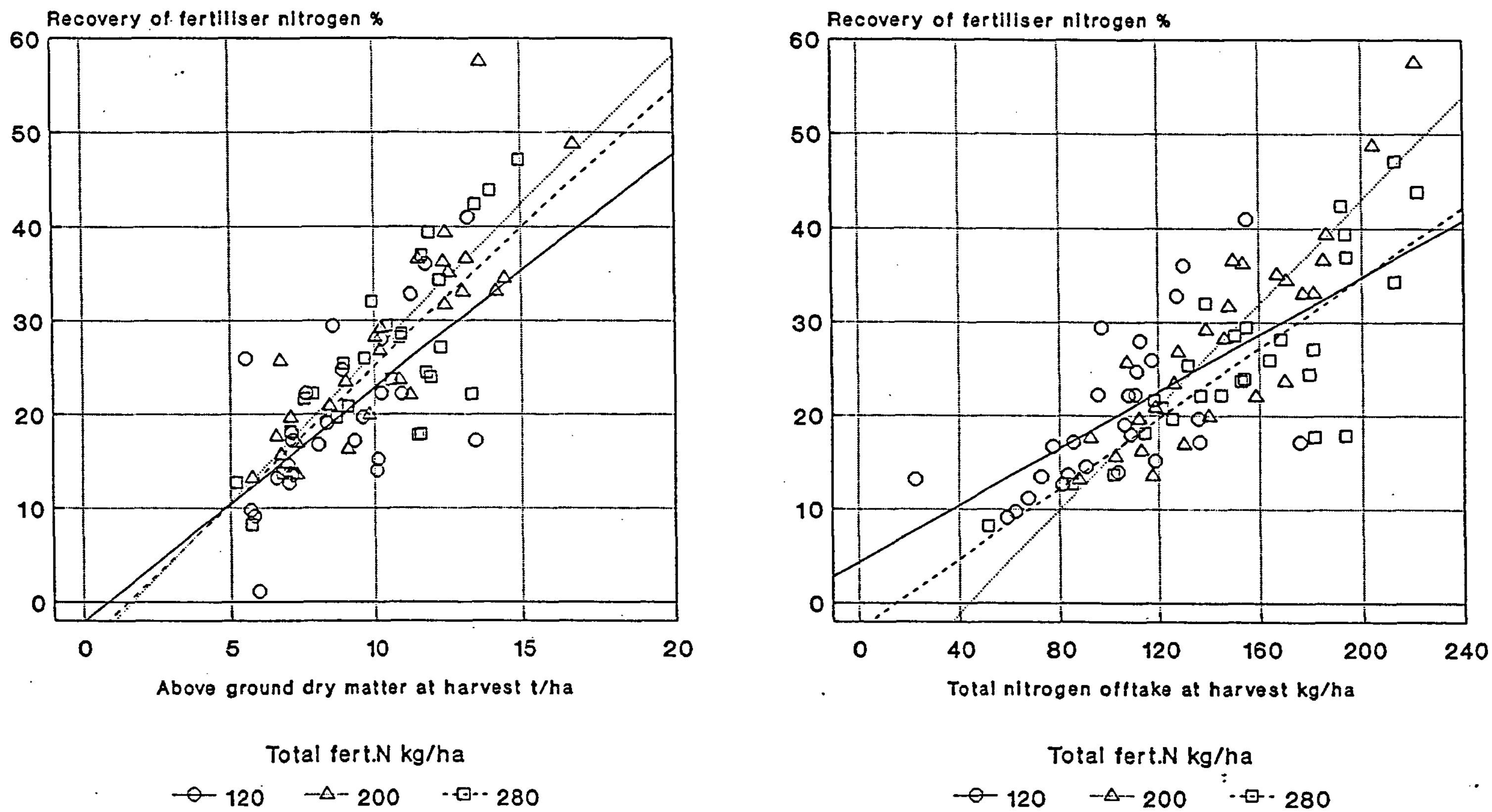


Measurements made on samples from duplicate 0.25 square meter 15N labelled plots

Fig. 8

Boxworth straw incorporation study 1988

Recovery of fertiliser N related to above ground dry matter and N uptake at harvest

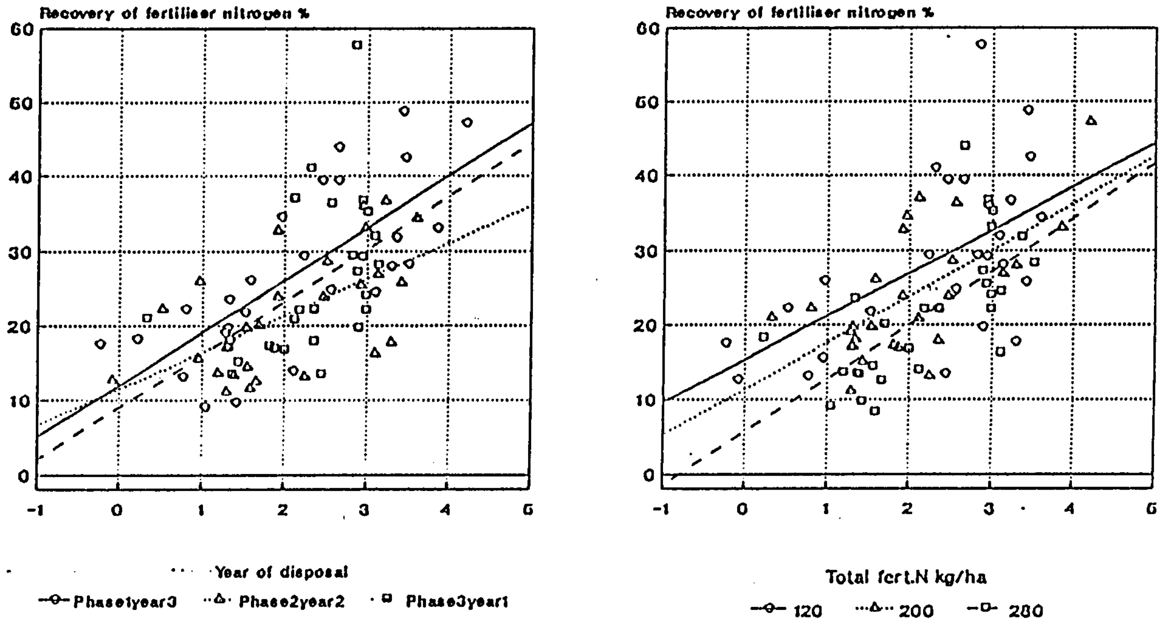


Continuous winter wheat

Straw burnt and tined or incorporated by tine cultivation or ploughing

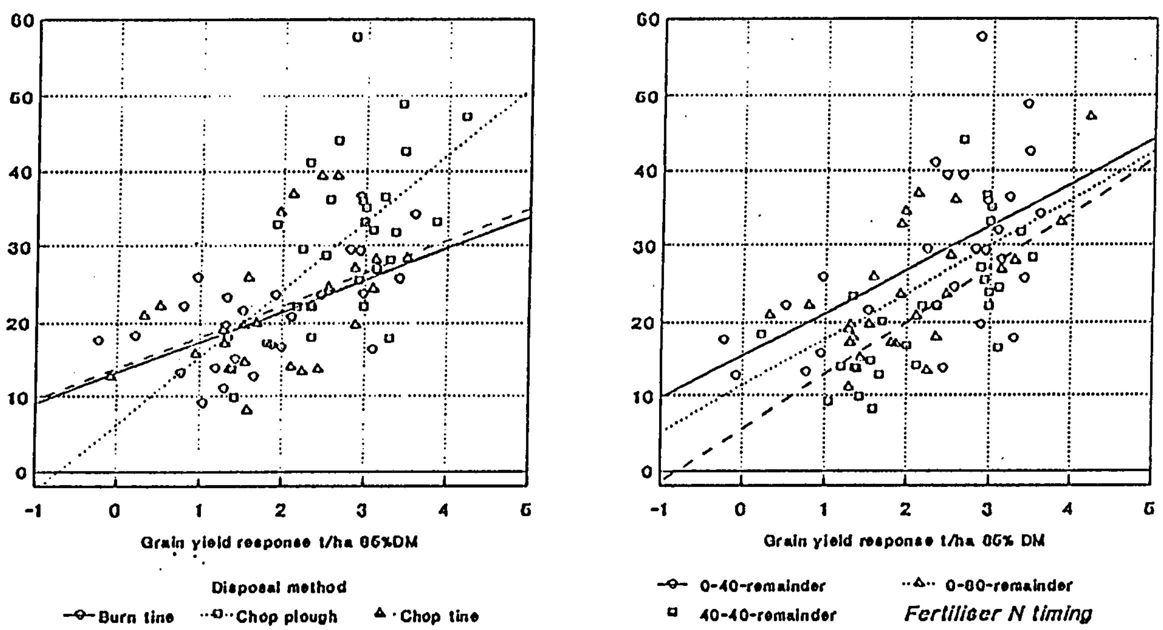
Recovery = proportion of added fertiliser N in above ground dry matter at harvest

Fig 9



Boxworth straw incorporation study 1988

Recovery of fertiliser N related to grain yield response



Total N in crop and its components derived from fertiliser and soil followed the dry matter pattern as in earlier years with no consistent treatment effects fig. 8, 9.

5.0 CONCLUSIONS

5.1 The use of labelled fertiliser nitrogen provided the means to estimate how much of the nitrogen applied at different times was used by crops, and whether these estimates were affected by straw disposal method.

5.2 The dry autumn of 1985 demonstrated the severe constraint to early growth and to consequent yield, caused by loss of soil moisture and cloddy seedbeds following plough incorporation. In all three seasons the penalty from volunteer plants and escalating populations of grass weeds were major limitations where burning or plough inversion were not employed. These factors limited crop growth and ability to respond to spring applied nitrogen.

5.3 The absence or presence of straw per se did not influence crop performance as much as the adverse factors referred to in (2). Synchronous emergence favoured by good tilth and sufficient moisture, coupled with success in limiting competition from volunteers and grass weeds were the factors that favoured response to spring topdressing.

5.4 In all three seasons there was little evidence that soil mineral nitrogen limited the early growth of crops irrespective of the presence of straw. These results confirm other UK findings that the soil nitrogen supply normally prevailing, in medium textured soils growing cereals intensively, is sufficient for normal straw decomposition and adequate to support both early crop growth and yield. This finding is still valid even when incorporated straw causes some reduction in mineral nitrogen.

5.5 Rate and extent of straw decomposition were not apparently affected either by inadequate soil mineral nitrogen or the method of incorporation. There was no evidence of toxic decomposition products inhibiting crop performance.

5.6 Autumn applied nitrogen did not benefit straw decomposition, early crop growth or yield irrespective of straw disposal method. In none of the seasons was there evidence of any unique benefit from autumn applied nitrogen that could not be achieved by adequate spring topdressing. Uptake by the young crop up to spring, of the 40 kg/ha N applied in autumn was small (0.9-3.5% in 1985-86 and 3.3-9.2% in 1986-87). The extent of uptake was almost entirely dependent upon the extent of dry matter accumulation achieved. The crop recovery at harvest of autumn fertiliser nitrogen was only about half that of early spring applied nitrogen (19.1% compared with 39.7%).

5.7 The need for a larger early spring nitrogen application (80 kg/ha instead of the usual 40 kg/ha was not consistent. In 1985-86 the effect was negligible but in 1986-87 there was evidence of benefit. Recovery of nitrogen applied in late spring at stem extension was substantially greater than the recovery of early spring applications (50.6% compared with 39.7%), and unaffected by method of straw disposal.

5.8 Immobilisation of the soil mineral nitrogen or of autumn fertiliser nitrogen was small and inconsistent. It tended to be greater where mineral nitrogen was present in larger quantities, that is after ploughing and addition of autumn nitrogen.

5.9 The unused part of the autumn applied nitrogen was poorly retained in the cultivated layer of soil and was not well protected by the presence of straw against leaching or presumed denitrification.

6.0 COMPARISON WITH OTHER UK FINDINGS

Results affirm the evidence from other ADAS-AFRC experiments to evaluate the importance of split applications, particularly the need for autumn nitrogen. Data from this study:

(i) confirms the expected smaller efficiency of autumn fertiliser nitrogen,

(ii) strengthens advice against autumn nitrogen use,

(iii) confirms the sufficiency of normal soil nitrogen supply to sustain early crop growth, dispelling reservations about straw decomposition using up soil mineral nitrogen to the detriment of crop needs,

(iv) confirms the adequacy of the normal spring topdressing policy for wheat growing in conditions of low fertility (ADAS N index 0). This includes an early spring split dose of a quarter to a third of the total optimum fertiliser nitrogen.

and

(v) emphasises the importance of achieving seedbed conditions favourable for crop establishment, early growth and successful weed control. Prudent choice and timing of autumn cultivation/straw incorporation method suited to the soil type and its moisture content during cultivation are the means to avoid problems.

7. ACKNOWLEDGEMENTS

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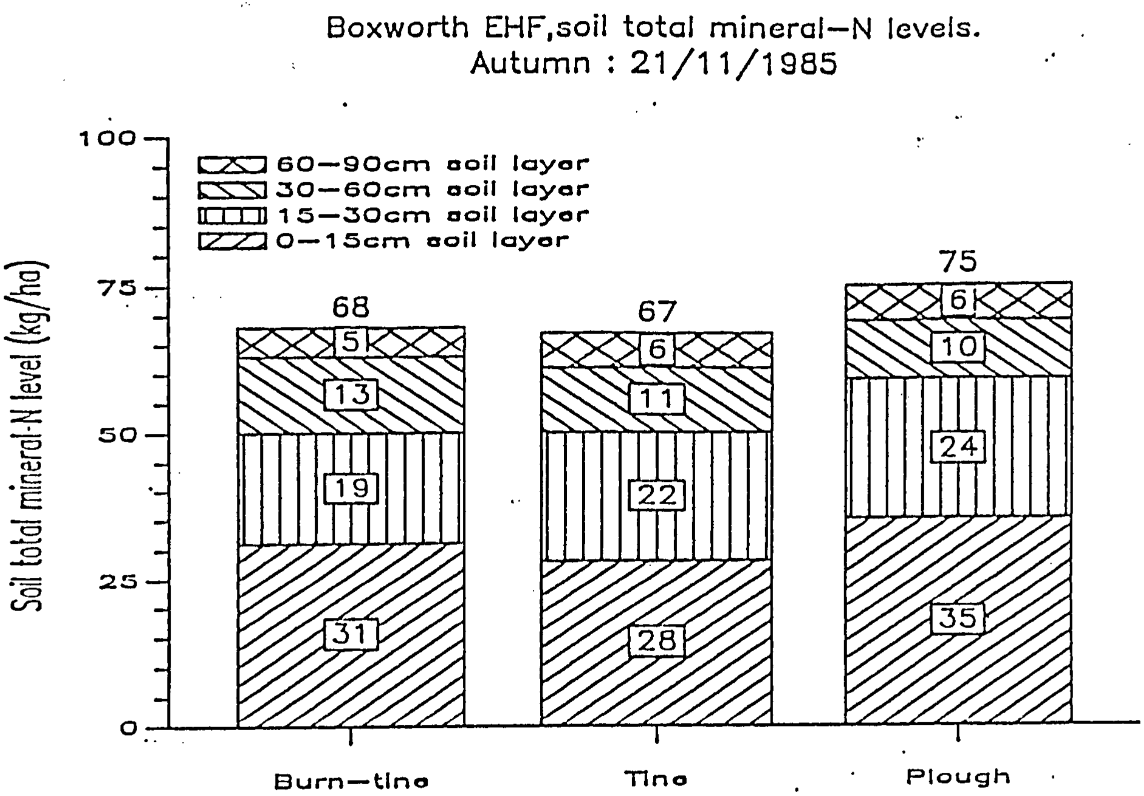
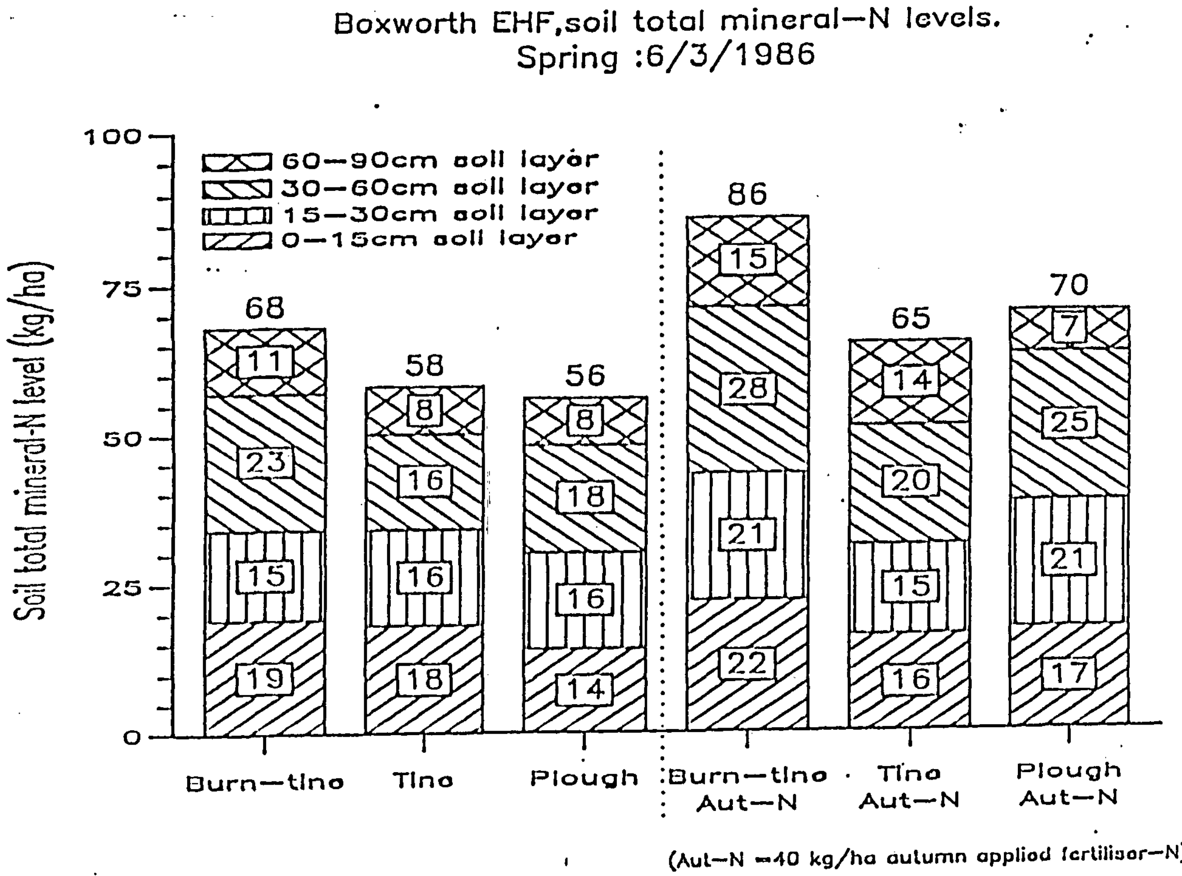
Appendix A1



Soil layer (cm)	Cultivation SED (18 d.f.)	CV%
0-15	2.05 **	12.3
15-30	1.57 *	13.6
30-60	1.36	22.2
60-90	1.33	43.2
0-90	4.20	11.2

Soil mineral-N levels at 2 months after straw incorporation, for the first year of incorporation at Boxworth EHF.

Appendix A2

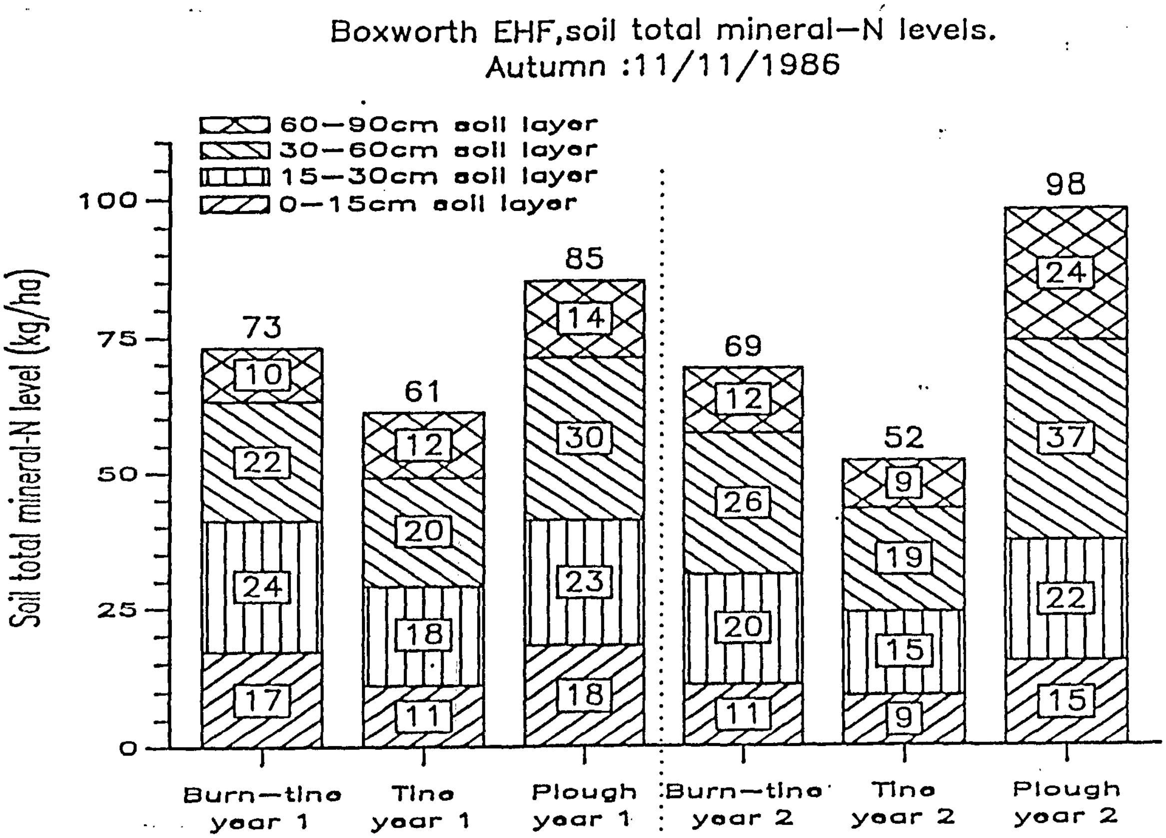


Soil layer (cm)	Cultivation SED	Aut-N SED	Cult x Aut-N SED	CV%
0-15	1.92	1.57	2.71	19
15-30	1.65	1.35 *	2.34	17
30-60	3.20	2.61	4.52	26
60-90	1.58 *	1.29	2.23	26
0-90	5.00 *	4.08 **	7.07	13

(12 d.f. for SED's)

Soil mineral-N levels at 5 months after straw incorporation, for the first year of incorporation at Boxworth EHF.

Appendix A3



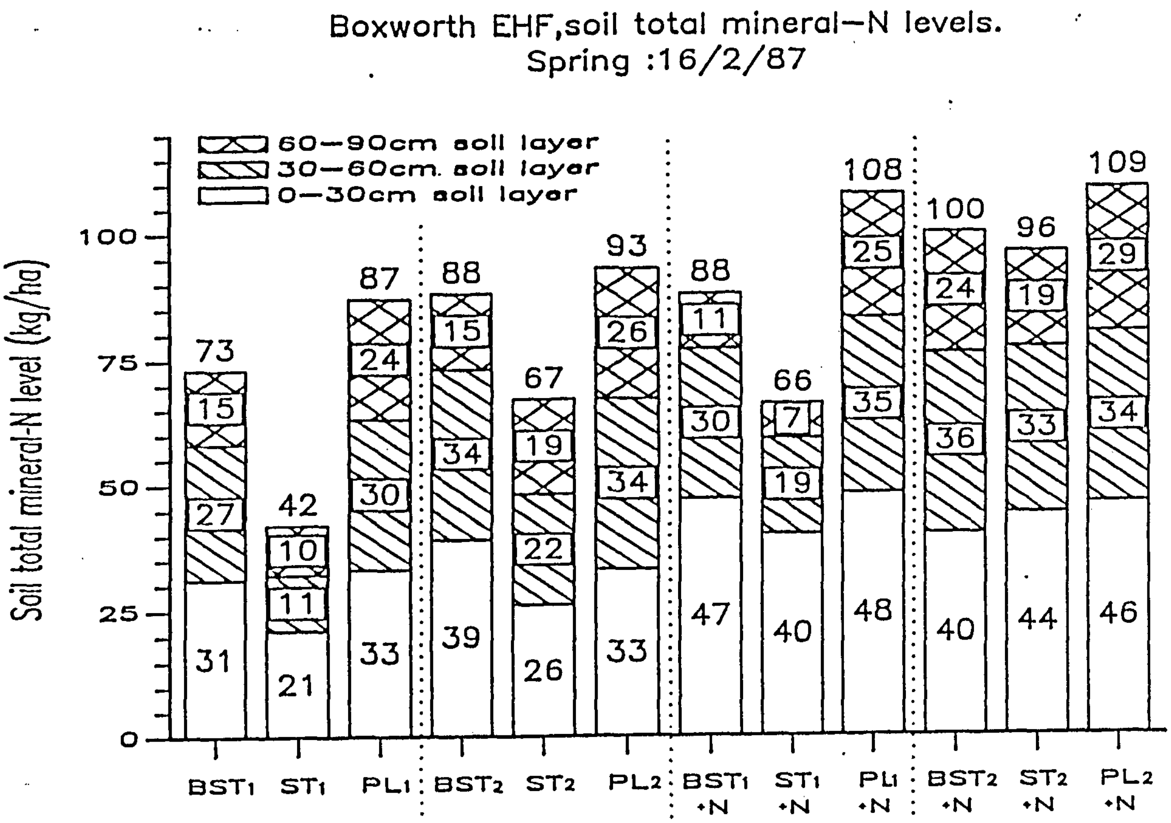
Year 1 = 1st year of incorporation.
Year 2 = 2nd year of incorporation.

Soil layer (cm)	Incroporation Year SED	Cultivation SED	Incorp-year x Cultivation SED	CV%
0-15	0.72 **	0.88 **	1.24	11
15-30	1.28	1.57 **	2.22	14
30-60	1.71	2.08 **	2.95	14
60-90	0.99 **	1.21 **	1.71 **	15
0-90	2.69	3.30 **	4.66 **	8

(12 d.f. for SED's)

Soil mineral-N levels at 2 months after straw incorporation, for the second year of incorporation at Boxworth EHF.

Appendix A4



BST = Straw burnt, tine
PL = Plough incorporation
1 = 1st year of incorporation
ST = Tine incorporation
+N = 40 kg/ha N applied in autumn
2 = 2nd year of incorporation

Soil layer (cm)	Incorporation year SED	Cultivation SED	Aut-N SED	Incorp-year x Cultivation SED
0-30	2.28	2.79 *	2.28 **	3.95
30-60	2.06 **	2.52 **	2.06	3.57
0-90	3.52 **	4.32 **	3.52 **	6.10 *

Soil layer (cm)	Incorp year x Aut-N SED	Cultivation x Aut-N SED	Incorp year x Cult x Aut-N SED	CV%
0-30	3.23	3.95	5.59	18
30-60	2.91	3.57	5.04	21
0-90	4.98	6.10	8.63	12

(24 d.f. for SED's)

Soil mineral-N levels at 5½ months after straw incorporation, for the second year of incorporation at Boxworth EHF.

Appendix B1 Changes in straw total N content during straw decomposition, within a single season, calculated (or estimated) from data presented in studies of straw decomposition in buried mesh-bags

Reference	Straw source	'Effective' straw load (t/ha)	Original straw composition: N Concentration (%)	Original straw composition: N Content (kg/ha)	Original straw composition: C:N Ratio	Straw N content at maximum net N immobilisation (kg/ha)	Amount of N immobilised at maximum net N immobilisation (kg/ha)	Straw N content at end of studied decomposition period (kg/ha)	Net gain or loss of N (kg/ha)
Parker (1962) (USA Iowa)	Maize stalks	7.5	0.74	56	57	62 (1 month)[a]	6	49-54 (5 months)[b]	-2 - -7
Brown and Dickey (1970) (USA - Montana)	Wheat	1.1		3		4-5	1-2		
		2.2		6		9	3		
		3.4	0.26	9	150 c	12	3	Not calculated due to residue and soluble N loss	
		4.5		13		15-16	2-3		
		6.7		17		22-23 (3 months)	5-6		
Smith and Douglas (1968) (USA - Idaho)	Wheat	5.6	0.27-0.29	15-16	142-145	17-21 (6 months)	2-5	9 (12 months)	-6 - -7
Douglas et al. (1980) (USA - Oregon)	Wheat	4.3	0.19	8	210	10	2	10	+2
			0.49	21	80	m	0	11	-10
			0.78	34	51	m (6 months)	0	24 (12 months)	-10
Christensen (1985a) (Denmark)	Spring barley	3.3	0.45	15	94	21-25	6-10	18-21	+3 - +6
	Wheat		0.70	23	61	26-32 (8 months)	3-9	21-23 (12 months)	-2 - 0
Christensen (1985b) (Denmark)	Spring barley	3.3	0.41	14	108	14	<1	13	-1
			0.48	16	96	22	6	10	-6
			0.57	19	81	m	0	14	-5
			0.92	31	50	m (8 months)	0	14 (12 months)	-17

Notes:
a) Time to maximum net N immobilisation
b) Period of decomposition for calculated figures
c) Assuming straw C content = 40% of straw dry weight
m) Net mineralisation of N from straw commenced after burial

Appendix B2

Amounts of straw-N mineralised and assimilated by crops during straw decomposition, recorded in, or calculated from, studies following the release of N from buried 15-N labelled straw.

A) Amounts of straw-N occurring as inorganic-N in soil during the 1st season of decomposition

Reference	Straw Source	'Effective' straw load	Original straw-N content		% of straw-N mineralised after 1 year	
			%	kg/ha	%	kg/ha
Broadbent and Nakashima (1974)(I)	Barley	1% (=20t/ha,0-15 cm)	2.33	466	30	140

B) Amounts of straw-N assimilated by the crop, and remaining in the soil, after 1 season of decomposition

Reference	Straw source	'Effective' straw load t/ha	Original straw N content		% of straw-N assimilated by crop	% straw-N remaining in soil	
			%	kg/ha		Organic	Mineral
Myers and Paul (1971)(F)	Oat	4.5	1.07	46	6	57	3
Fredrickson et.al. (1982)(F)	Wheat	5.0	1.20	60	10-12	60-77	
Powlson et al.(1986)(F)	Wheat	3.0	0.51	15	12	78	

Notes:

(I) Laboratory incubation involving leaching of inorganic N from soil.

(F) Microplot field trial.

Appendix B3

Size of the soluble-N component of cereal straws (chopped straw)

Reference	% N in straw	Soluble-N fraction (%)	Extraction method
Reinertsen et al. (1984) (Spring wheat)	1.13	58	Leached in 8 changes of cold water, with vigorous agitation.
	0.79	72	
	0.18	33	
Douglas et al. (1980) (Winter wheat)	0.78	40	One cold water wash, with gentle agitation.
	0.49	32	
	0.19	25	
Christensen (1985b) (Spring barley)	0.45	20	One cold water extraction, with vigorous agitation, then soaked for 18 hours + repeat.
	(with decomposition between extractions)	43	

Appendix C1

Components of crop production associated with the crop recoveries of autumn-applied fertiliser N (displayed in table 8.7) for spring 1986 (sampled 5/3/1986 - Zadoks GS 21)

Straw disposal method	Autumn N application (kg/ha)	Plants/m^2	Dry weight/ plant (mg)	Crop dry weight (kg/ha)	Plant N concentration (%)	Crop N offtake (kg/ha)
Straw-burnt, shallow tine	0	435	45.6	198	2.97	5.87
Shallow tine	0	677	33.6	230	3.04	7.00
Plough	0	246	23.6	58	3.60	2.06
Straw burnt, shallow tine	40	473	55.5	267	2.70	7.06
Shallow tine	40	625	28.5	178	3.23	5.78
Plough	40	283	27.8	81	3.31	2.74
SED's (12d.f.)						
Straw disposal method		64.5**	5.02**	43.1**	0.279	1.19**
Autumn N dressing		52.6	4.10	35.2	0.228	0.97
Straw disposal x Autumn N dressing		91.1	7.1	60.9	0.395	1.69
CV%		24	24	44	15	41

Appendix C2

Crop dry weights, N uptakes, plant populations and effective sowing depths at Boxworth EHF in autumn 1986 (sampled 16/12/1986 - Zadoks GS 12-13)

Straw disposal method	Year of incorporation	Plants/m^2	Dry weight /plant (mg)	Crop dry weight (kg/ha)	Shoots/m^2	Dry weight /shoot (mg)	Plant N concentration %	Crop N offtake kg/ha	'effective' sowing depth (cm)
Straw-burnt, shallow tine	1	129	47.7	61.7	150	41.0	4.54	2.81	5.17
Shallow tine	1	174	38.3	66.3	209	32.3	4.08	2.71	4.47
Plough	1	161	57.3	92.2	201	46.0	4.29	3.96	6.33
Straw-burnt, shallow tine	2	163	42.3	79.4	208	39.7	4.19	2.91	6.83
Shallow tine	2	203	40.7	82.0	177	39.0	4.07	3.34	6.03
Plough	2	203	45.0	91.1	230	40.0	4.82	4.38	6.23
SED's (17d.f.)									
Incorporation year		13.3*	1.12**	5.77	18.3	1.77	0.05	0.25	0.34**
Straw disposal method		16.2	1.43**	7.07*	22.5	2.17*	0.06**	0.31**	0.41
Straw disposal x incorporation year		23.0	2.02**	9.99	31.7	3.07*	0.08**	0.44	0.58
CV%		16	6	16	10	10	2	16	12

Appendix C3

Components of crop production associated with the crop recoveries of autumn-applied fertiliser - N (displayed in table 8.10) for sping 1987, (sampled 13/2/1987 - Zadoks GS 21)

Straw disposal method	Incorporation year	Autumn N dressing (kg/ha)	Plant numbers $/m^2$	Shoot number /plant	Shoot number $/m^2$	Dry weight /plant (mg)	Dry weight /shoot (mg)	Crop dry weight/ha (kg)	Crop N concentration (%)	Crop N offtake (kg/ha)
Straw-burnt, Shallow tine	1	0	169	2.08	374	69.8	35.2	112.8	5.11	5.75
Shallow tine	1	0	221	2.31	529	59.3	26.0	133.2	5.13	6.91
Plough	1	0	193	2.05	397	88.6	43.5	170.9	4.96	8.53
Straw burnt, shallow tine	1	40	155	2.04	332	72.2	36.7	113.4	4.85	5.61
Shallow tine	1	40	176	2.09	359	47.6	23.0	86.5	5.22	4.50
Plough	1	40	285	2.40	684	84.0	35.0	240.4	5.08	12.10
Straw-burnt, shallow tine	2	0	220	1.71	376	66.8	39.3	146.5	4.62	6.80
Shallow tine	2	0	244	1.73	439	50.6	29.7	125.1	4.85	6.10
Plough	2	0	237	2.99	699	83.7	28.3	198.4	5.00	9.80
Straw-burnt, shallow tine	2	40	207	2.65	540	72.6	27.8	149.9	4.87	7.30
Shallow tine	2	40	255	2.24	583	61.0	27.6	157.1	5.08	7.99
Plough	2	40	280	3.13	877	88.0	28.1	246.5	4.95	12.20
SED's (24 d.f.)										
Incorporation year			18.4*	0.12	52.1*	2.64	1.84	14.0	0.09	0.72
Straw disposal method			22.6*	0.15**	63.8**	3.23**	2.25**	17.2**	0.11	0.88**
Autumn N dressing			18.4	0.12*	52.1	2.64	1.84*	14.0	0.09	0.72
Straw disposal x incorporation year			31.9	0.21**	90.3	4.57	3.19*	24.3	0.15	1.24
Straw disposal x Autumn N dressing			31.9	0.21	90.3	4.57	3.19	24.3	0.15	1.24
Incorporation year x Autumn N dressing			26.1	0.17	73.7	3.73	2.60	19.8	0.13	1.01
Incorporation year x Straw disposal x Autumn N			45.1	0.30	127.7	6.46	4.51	34.3	0.22	1.75
CV%			25	16	30	11	17	27	5	28

Appendix D1

Boxworth EHF, harvest 1986. Grain yield at nil-N and opt-N and its response to applied N.

Straw disposal method	N-timing Aut-Spr (kg/ha N)	Nil-N yield (t/ha)	Yield at opt-N (t/ha)	Yield response to fertiliser (t/ha)	Opt-N rate (kg/ha N) (SE)
Straw-burnt, tine	0-40		8.26	4.06	213 (11.2)
	0-80	4.20	8.29	4.09	229 (17.5)
	40-40		8.09	3.89	204 (17.5)
	Mean	4.20	▫8.21	4.01	▫218 (7.2)
Tine incorporation	0-40		7.86	4.59	283 (32.9)
	0-80	3.27	8.09e	4.82	240 e
	40-40		7.63	4.36	245 (19.7)
	Mean	3.27	▫7.81	4.54	▫249 (8.1)
Plough incorporation	0-40		7.13	2.90	198 (14.5)
	0-80	4.23	7.26	3.03	210 (4.9)
	40-40		7.26	3.03	214 (14.8)
	Mean	4.23	▫7.22	2.99	▫208 (7.3)

e = 'Eye fitted' optimum

▫ = produced by fitting a single LPE function to data from all 3 N-timing regimes

Appendix D2 Boxworth EHF, harvest 1987. Grain yield at nil and opt-N, and its response to applied N.

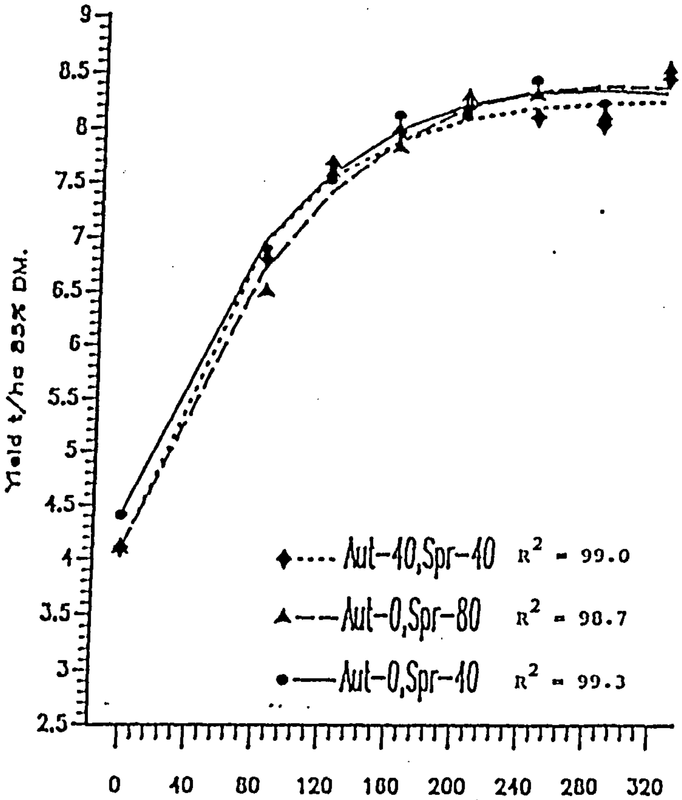
Straw disposal method	N-timing Aut-Spr (kg/ha N)	Nil-N yield (t/ha)	Yield at opt-N (t/ha)	Yield response to fertiliser N (t/ha)	Opt-N (kg/ha)	(SE)
1st year of incorporation						
Straw burnt, tine	0-40		5.47	2.07	164	(25.4)
	0-80	3.40	5.05	1.65	118	(13.0)
	40-40		5.45	2.05	187	(41.8)
	∇ mean	3.40	5.26	1.86	147	(8.9)
Tine incorporation	0-40		5.01e	2.41	200e	
	0-80	2.60	4.80	2.20	154	(14.5)
	40-40		4.59e	1.99	160e	
	∇ mean	2.60	4.50	1.90	175	(45.0)
Plough incorporation	0-40		6.21	2.21	145	(13.6)
	0-80	4.00	6.45	2.45	165	(12.6)
	40-40		6.29	2.29	173	(12.1)
	∇ mean	4.00	6.31	2.31	161	(7.0)
2nd year of incorporation						
Straw burnt, tine	0-40		5.85	2.09	155	(11.9)
	0-80	3.77	5.95	2.18	169	(16.0)
	40-40		6.02	2.25	162	(7.2)
	∇ mean	3.77	5.95	2.18	162	(9.7)
Tine incorporation	0-40		5.97	2.57	161	(15.5)
	0-80	3.40	6.25	2.85	176	(14.8)
	40-40		6.24	2.84	193	(24.8)
	∇ mean	3.40	6.15	2.75	177	(12.9)
Plough incorporation	0-40		6.27	1.67	142	(17.5)
	0-80	4.60	6.59	1.99	151	(10.7)
	40-40		6.56	1.96	144	(9.6)
	∇ mean	4.60	6.47	1.87	146	(11.0)

Notes:-

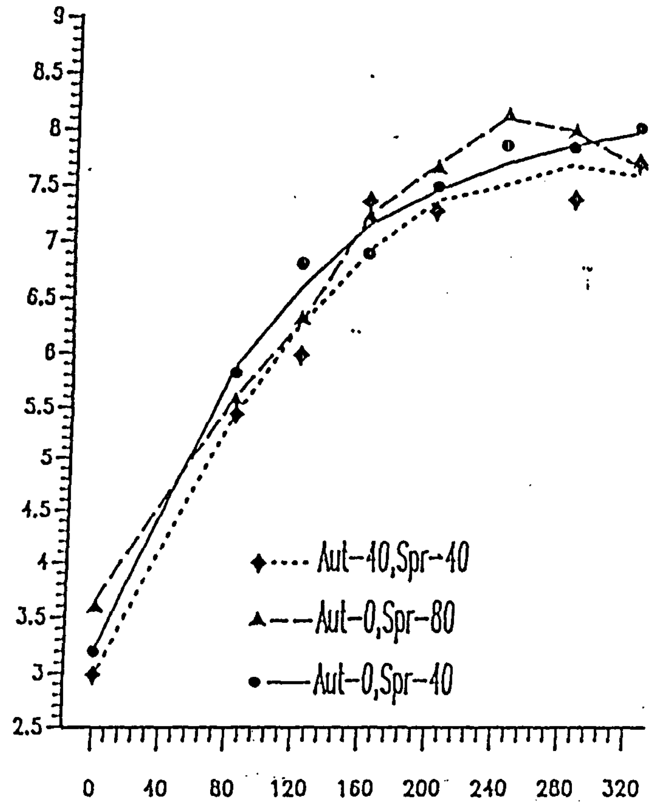
∇ = Produced by fitting a single LPE function to data from all N split timings

e = 'Eye-fitted' estimate of opt-N yield (LPE estimate of opt N > highest N rate tested).

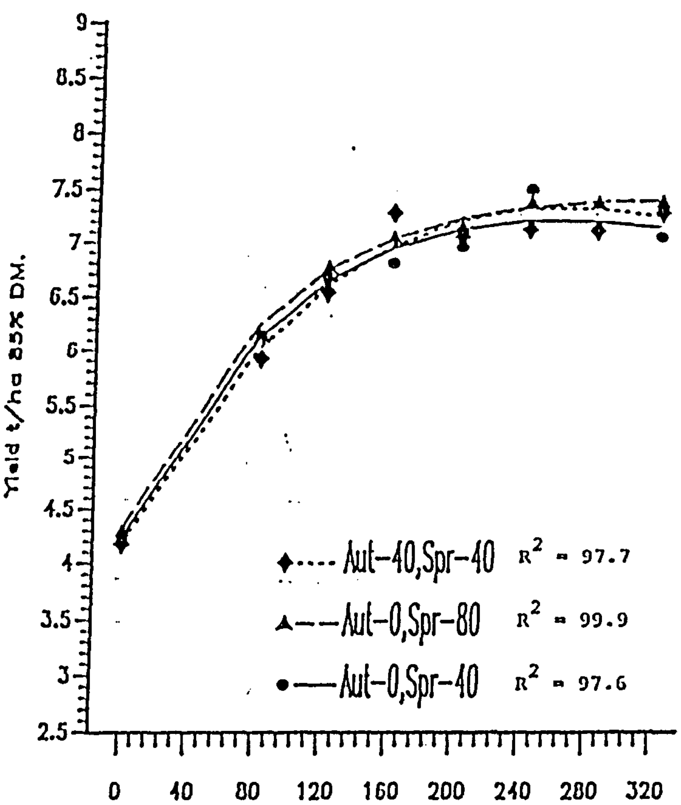
Straw Burnt,Shallow Tine



Shallow Tine Incorporation

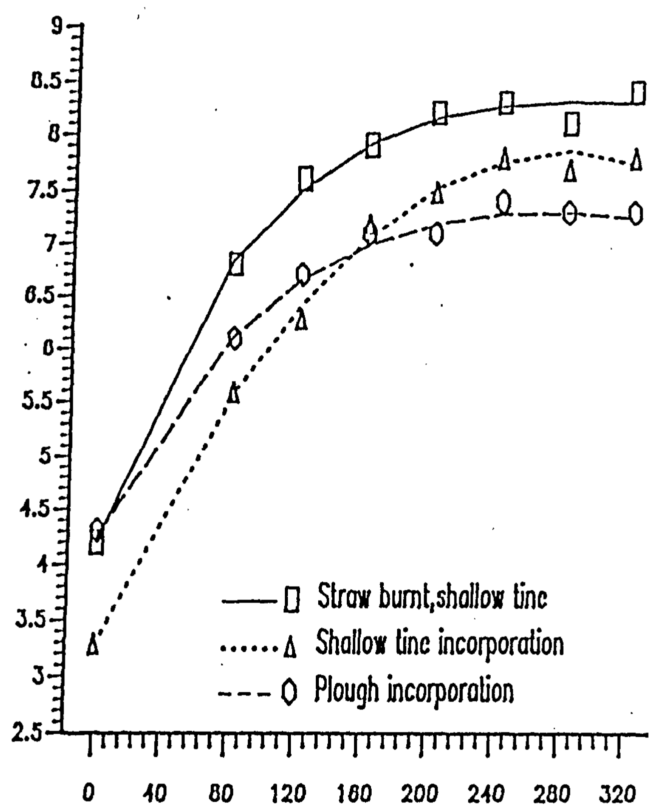


Plough Incorporation



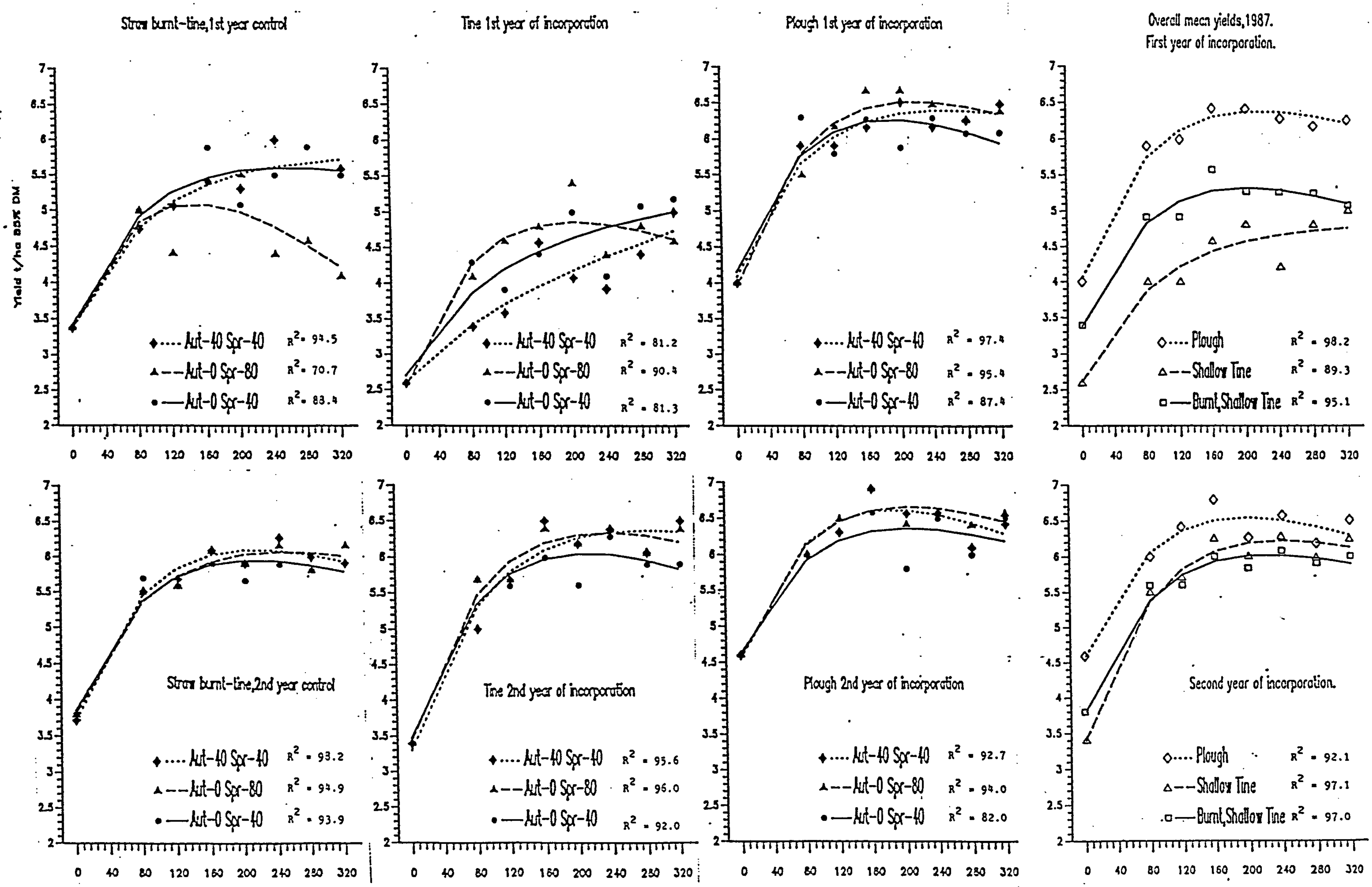
Total N applied (kg/ha)

Overall mean yields, Harvest 1986.



Total N applied (kg/ha)

Appendix D4


Straw burnt-tine,1st year control
Yield t/ha 85% DM
Aut-40 Spr-40 R² = 93.5
Aut-0 Spr-80 R² = 70.7
Aut-0 Spr-40 R² = 83.4
Tine 1st year of incorporation
Aut-40 Spr-40 R² = 81.2
Aut-0 Spr-80 R² = 90.4
Aut-0 Spr-40 R² = 81.3
Plough 1st year of incorporation
Aut-40 Spr-40 R² = 97.4
Aut-0 Spr-80 R² = 95.4
Aut-0 Spr-40 R² = 87.4
Overall mean yields,1987.
First year of incorporation.
Plough R² = 98.2
Shallow Tine R² = 89.3
Burnt,Shallow Tine R² = 95.1
Straw burnt-tine,2nd year control
Aut-40 Spr-40 R² = 93.2
Aut-0 Spr-80 R² = 94.9
Aut-0 Spr-40 R² = 93.9
Tine 2nd year of incorporation
Aut-40 Spr-40 R² = 95.6
Aut-0 Spr-80 R² = 96.0
Aut-0 Spr-40 R² = 92.0
Plough 2nd year of incorporation
Aut-40 Spr-40 R² = 92.7
Aut-0 Spr-80 R² = 94.0
Aut-0 Spr-40 R² = 82.0
Second year of incorporation.
Plough R² = 92.1
Shallow Tine R² = 97.1
Burnt,Shallow Tine R² = 97.0
0 40 80 120 160 200 240 280 320
2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7

Appendix E1

Harvest 1987 crop N concentrations and N offtakes.

(SED's for comparisons between years of disposal are presented overleaf)

Straw disposal treatment	Total N applied (kg/ha)	N split-timing (Aut.-E.Spr.-Main D.) (kg/ha)	1st Year of straw disposal: Crop N Concentration (%)	1st Year of straw disposal: Crop N offtake (kg/ha)	2nd Year of straw disposal: Crop N concentration (%)	2nd Year of straw disposal: Crop N offtake (kg/ha)
	0	-	1.10	129.5	1.07	102.4
	120	0-40	1.43	192.0	1.58	192.1
		0-80	1.50	130.8	1.46	209.6
		40-40	1.43	151.8	1.43	196.5
Straw-burnt, tine	200	0-40	1.67	224.6	1.55	170.1
		0-80	1.65	217.9	1.63	230.1
		40-40	1.69	209.3	1.55	234.8
	280	0-40	1.73	216.6	1.62	249.6
		0-80	1.72	149.1	1.72	246.4
		40-40	1.70	165.3	1.68	197.9
	0	-	1.03	63.6	1.00	83.0
	120	0-40	1.30	116.3	1.43	159.6
		0-80	1.38	128.9	1.24	131.6
		40-40	1.32	77.9	1.22	146.7
Tine incorporation	200	0-40	1.74	142.8	1.61	181.7
		0-80	1.61	197.4	1.51	182.5
		40-40	1.59	148.6	1.52	198.8
	280	0-40	1.78	170.2	1.71	187.2
		0-80	1.70	176.6	1.72	221.4
		40-40	1.71	159.5	1.79	141.2
	0	-	1.06	88.0	1.05	87.7
	120	0-40	1.34	156.7	1.38	165.0
		0-80	1.14	143.5	1.33	153.3
		40-40	1.25	170.6	1.33	158.4
Plough incorporation	200	0-40	1.49	194.4	1.60	188.2
		0-80	1.62	239.7	1.64	182.6
		40-40	1.55	245.2	1.54	214.0
	280	0-40	1.79	252.6	1.70	217.8
		0-80	1.73	203.6	1.65	207.6
		40-40	1.65	223.1	1.57	199.4
SED's (8 d.f.)+						
Straw disposal method			0.04*	5.64***	0.02	7.69**
N-rate			0.04***	5.64***	0.02***	7.69**
N-timing			0.04	5.64	0.02*	7.69
Straw disposal x N-rate			0.05	9.77*	0.04	13.31
Straw disposal x N-timing			0.05	9.77**	0.04	13.31
N-rate x N-timing			0.05	9.77**	0.04	13.31*
CV%			5	7	3	9

+ excludes comparisons with nil-N treatments

Appendix E2

Boxworth EHF, 15 - N labelled trials. Harvest 1987 grain yields and associated yield components, for 1st year of straw disposal treatments.

Straw disposal treatment	Total N applied (kg/ha)	N split-timing (Aut-E Spr-Main D) (kg/ha)	Combine grain yield (t/ha, 85% DM)	Crop dry weight (t/ha)	Ear population /m²	Thousand grain weight (g, 85% DM)	Dry weight shoot (g)	Grain weight per ear (g, 85% DM)	Grain number /ear	Grain number /m²	Harvest index
	0	-	3.39	11.57	298	45.8	3.36	1.74	38	11281	0.45
		0-40	5.11	12.95	402	42.7	2.23	1.07	25	10131	0.41
	120	0-80	4.40	8.85	302	43.1	2.88	1.47	34	10250	0.44
		40-40	5.09	10.45	317	41.5	3.33	1.70	41	12983	0.45
		0-40	5.11	13.46	363	41.4	3.36	1.68	41	14742	0.44
Straw-burnt, tine	200	0-80	5.47	13.25	411	40.7	2.74	1.36	33	13756	0.43
		40-40	5.25	12.40	342	41.3	3.87	2.20	53	18218	0.48
		0-40	5.88	12.15	353	41.4	2.72	1.36	33	11574	0.43
	280	0-80	4.64	8.63	269	35.8	2.70	1.13	32	8469	0.36
		40-40	3.26	9.75	335	40.4	3.10	1.64	41	13617	0.46
	0	-	2.59	6.27	246	48.3	2.53	1.28	27	6544	0.44
		0-40	3.94	8.84	296	40.0	2.54	1.12	28	8019	0.38
	120	0-80	4.61	9.23	291	36.3	2.80	1.24	34	9887	0.38
		40-40	3.55	6.35	213	41.4	2.89	1.44	35	7401	0.43
Tine incorporation		0-40	5.01	8.25	309	40.5	2.11	0.92	23	7031	0.38
	200	0-80	5.37	12.14	397	38.4	3.05	1.53	40	15804	0.44
		40-40	4.08	9.40	328	37.6	2.10	0.72	19	6239	0.30
		0-40	5.10	9.58	331	38.1	2.71	1.33	35	11575	0.43
	280	0-80	4.84	10.49	363	40.0	2.90	1.56	39	14167	0.47
		40-40	4.44	9.30	330	36.7	2.29	1.06	29	9557	0.40
	0	-	4.03	8.32	243	42.5	2.93	1.50	35	8504	0.44
		0-40	5.63	12.43	350	45.0	3.15	1.63	36	12566	0.45
	120	0-80	6.17	12.78	361	43.6	3.58	1.96	45	16256	0.48
		40-40	5.90	13.49	388	43.0	3.43	1.83	43	16526	0.46
Plough incorporation		0-40	5.92	12.93	378	45.2	3.27	1.74	39	14552	0.46
	200	0-80	6.67	14.79	419	44.0	3.28	1.73	39	16400	0.46
		40-40	6.45	15.78	439	45.1	3.23	1.70	38	16585	0.45
		0-40	6.10	14.63	414	42.8	3.49	1.76	41	17058	0.44
	280	0-80	6.26	11.83	342	42.8	3.44	1.80	42	14422	0.46
		40-40	6.33	13.39	398	42.7	2.90	1.58	37	14729	0.47
SED's (8 d.f.) (see footnote)											
Straw disposal			0.24***	0.35***	11.8***	1.0**	0.13**	0.10**	2.31*	735***	0.02*
N-rate			0.24	0.35**	11.8**	1.0	0.13	0.10	2.31	735	0.02
N-timing			0.24	0.35	11.8	1.0	0.13	0.10	2.31	735	0.02
Straw disposal x N-rate			0.42	0.60	20.5	1.7	0.22	0.18	3.99	1273	0.03
Straw disposal x N-timing			0.42	0.60**	20.5*	1.7	0.22*	0.18	3.99*	1273**	0.03
N-rate x N-timing			0.42	0.60*	20.5	1.7	0.22	0.18	3.99	1273	0.03
CV%			10	7	7	5	9	15	14	12	9

SED's exclude comparisons with nil-N treatments.
Highest order SED's were not calculated, due to lack of replication.

Appendix E3

Boxworth EHF, 15-N labelled trials. Harvest 1987 grain yields and associated yield components, for 2nd year of straw disposal treatments.

Straw disposal treatment	Total N applied (kg/ha)	N split-timing (Aut-E Spr-Main D) (kg/ha)	Combine grain yield (t/ha, 85% DM)	Crop dry weight (t/ha)	Ear population /m²	Thousand grain weight (g, 85% DM)	Dry weight /shoot (g)	Grain weight /ear (g, 85% DM)	Grain number /ear	Grain number /m²	Harvest index
	0	-	3.76	9.74	291	45.2	3.24	1.70	38	10985	0.46
	120	0-40	5.57	12.30	345	44.6	3.03	1.72	39	13278	0.49
		0-80	5.57	14.17	406	41.5	3.11	1.64	39	16017	0.46
		40-40	5.57	13.82	393	44.7	3.44	1.84	41	16127	0.46
Straw-burnt, tine	200	0-40	5.71	10.99	338	43.7	3.10	1.65	38	12722	0.46
		0-80	5.85	14.07	447	43.0	3.17	1.60	37	16668	0.44
		40-40	5.90	15.16	427	43.9	3.16	1.71	39	16602	0.47
	230	0-40	5.80	15.25	443	41.4	3.04	1.65	40	18020	0.48
		0-80	5.73	14.32	405	45.3	3.05	1.62	36	14512	0.46
		40-40	6.04	11.81	363	41.3	3.56	1.81	44	16103	0.44
	0	-	3.37	8.30	279	46.8	2.51	1.23	27	7641	0.44
	120	0-40	5.57	11.15	331	41.7	3.06	1.56	37	14205	0.44
		0-80	5.65	10.63	353	44.3	2.64	1.27	29	10303	0.42
		40-40	5.72	11.86	354	45.2	3.17	1.67	37	13106	0.46
Tine incorporation	200	0-40	5.60	11.33	423	41.4	2.48	1.27	31	12970	0.44
		0-80	6.19	12.12	373	41.3	2.79	1.43	36	13367	0.46
		40-40	6.24	13.09	407	41.5	3.75	2.06	50	20167	0.48
	230	0-40	5.90	13.97	345	41.6	2.54	1.39	33	11542	0.43
		0-80	6.07	12.84	433	40.9	3.07	1.77	43	13723	0.50
		40-40	6.08	7.87	402	39.7	2.67	1.53	39	15539	0.50
	0	-	4.53	6.41	331	45.0	2.84	1.49	33	10999	0.46
	120	0-40	6.34	12.00	402	42.4	2.53	1.31	31	12370	0.45
		0-80	6.51	11.47	364	40.3	2.41	1.17	29	10540	0.42
		40-40	6.33	11.99	375	42.1	3.15	1.62	38	14395	0.45
Plough incorporation	200	0-40	5.83	11.68	363	41.2	3.18	1.63	40	14378	0.45
		0-80	6.41	11.20	314	38.8	3.42	1.71	44	13862	0.44
		40-40	6.60	13.80	455	39.7	2.87	1.38	35	16079	0.42
	230	0-40	6.02	12.83	389	41.4	2.93	1.45	35.1	13671	0.42
		0-80	6.41	12.50	430	40.7	2.74	1.40	34.5	14808	0.44
		40-40	6.12	12.67	417	42.0	2.53	1.05	25.0	10416	0.36
SED's (8 d.f.) (see footnote)											
Straw disposal			0.06***	0.51**	22.5	0.69*	0.13	0.10	2.7	1262	0.01***
N-rate			0.06	0.51	22.5	0.69	0.13	0.10	2.7	1262	0.01
N-timing			0.06**	0.51	22.5	0.69	0.13	0.10	2.7	1262	0.01
Straw disposal x N-rate			0.10*	0.88	39.0	1.20	0.31	0.17	4.6	2186	0.01**
Straw disposal x N-timing			0.10	0.88	39.0	1.20	0.31	0.17	4.6	2186	0.01*
N-rate x N-timing			0.10	0.83*	39.0	1.20	0.31	0.17	4.6	2186	0.01*
CV%			2	9	12	4	13	14	15	19	3

SED's exclude comparisons with nil-N treatments
Highest order SED's were not calculated, due to lack of replication.

Appendix F1 Harvest 1988. % N in above ground plots

Year of disposal:	Disposal method	N rate kg/ha 120 N split-timing 0-40	0-80	40-40	200 0-40	0-80	40-40	280 0-40	0-80	40-40	Mean	Overall mean	Overall mean
	Straw burnt tine	1.08	1.17	0.97	1.36	1.79	1.41	1.48	1.35	1.29	1.32	1.43	1.35
	Tine incorporation	1.42	1.20	1.19	1.61	1.41	1.41	1.55	1.66	1.47	1.44	1.42	
1	Plough incorporation	1.08	1.17	0.97	1.63	1.24	1.33	1.40	1.66	1.03	1.28	1.32	
	Mean	1.19	1.18	1.04	1.53	1.45	1.38	1.48	1.56	1.26		1.39	
	Mean	1.14			1.45			1.43					
	Straw burnt tine	2.13	1.14	1.16	1.59	1.56	1.25	1.74	1.45	1.49	1.50		1.47
	Tine incorporation	1.25	1.47	1.30	1.30	1.26	1.36	1.64	1.45	1.48	1.55		
2	Plough incorporation	1.10	1.13	1.02	1.51	1.53	1.43	1.57	1.37	1.48	1.35		
	Mean	1.49	1.25	1.16	1.47	1.44	1.35	1.65	1.42	1.29			
	Mean	1.30			1.42			1.44					
	Straw burnt tine	1.10	1.53	1.03	1.40	1.58	1.41	1.57	1.85	1.62	1.45		1.39
	Tine incorporation	1.25	1.27	1.03	1.49	1.18	1.46	1.62	1.70	1.52	1.39		
3	Plough incorporation	1.13	1.10	1.11	1.23	1.28	1.19	1.57	1.85	1.62	1.34		
	Mean	1.16	1.30	1.06	1.37	1.35	1.35	1.59	1.80	1.59			
	Mean	1.17			1.36			1.66					

Averaged over disposal methods and N rates

Year of disposal disposal	N split-timing 0-40	0-80	40-40	Mean
1	1.40	1.40	1.33	1.38
2	1.50	1.37	1.38	1.38
3	1.37	1.48	1.33	1.39
Mean	1.42	1.42	1.35	1.39

Appendix F2 Harvest 1988. Crop N content (kg/ha N)

		N rate (kg/ha N)											
		120			200			280			Mean	Overall	Overall
Year of	Disposal	N split - timing										Mean SED =	Mean SED =
Disposal	method	0-40	0-80	40-40	0-40	0-80	40-40	0-40	0-80	40-40		14.15 ns	14.15 ns
1	Straw burnt, tine	110.2	118.2	77.3	139.1	130.2	184.7	154.8	121.4	153.8	132.2	120.7	143.6
	Tine incorporation	135.9	85.2	83.1	117.2	118.6	158.4	168.1	193.7	180.7	137.9	152.8	
	Plough incorporation	154.7	175.1	107.4	221.1	153.5	166.8	139.0	192.9	136.7	160.8	130.1	
	mean	133.6	125.1	89.3	159.1	134.1	169.9	154.0	169.3	157.1			
	mean	116.3			156.4			160.1					
2	Straw burnt, tine	117.1	67.8	81.1	107.2	169.5	112.9	213.1	152.7	101.3	124.7		122.8
	Tine incorporation	95.1	136.3	90.3	102.1	87.6	140.0	85.1	125.3	84.4	105.1		
	Plough incorporation	130.0	127.2	72.7	149.8	128.0	176.8	180.9	150.3	132.0	138.6		
	mean	114.1	110.4	81.4	119.7	128.4	143.2	159.7	142.8	105.9			
	mean	102.0			130.4			136.1					
3	Straw burnt, tine	72.4	108.2	59.5	92.1	111.8	126.0	117.9	144.8	114.8	105.2		138.4
	Tine incorporation	110.9	105.7	103.0	185.8	170.5	146.3	193.3	163.9	179.1	150.9		
	Plough incorporation	96.6	112.4	62.8	204.6	180.8	147.8	191.7	213.4	222.1	159.1		
	mean	93.3	108.8	75.1	160.90	154.3	140.0	167.6	174.0	171.8			
	mean	92.4			151.7			171.2					
Overall mean SED = 14.58 ns		113.7	115.1	81.9	146.6	138.9	151.0	160.4	162.0	144.9			
Overall mean SED = 8.42 ns		103.6			145.5			155.8					
CV = 27													

4 d.f. for year of disposal and disposal method SED's, 48 d.f. for all other SED's

Appendix F3 Harvest 1988. Fertiliser derived N in crop (kg/ha N)

		N rate (kg/ha N)											
		120			200			280			Mean	Overall	Overall
Year of	Disposal	N split - timing										Mean SED =	Mean SED =
Disposal	method	0-40	0-80	40-40	0-40	0-80	40-40	0-40	0-80	40-40		7.56 ns	7.56 ns
1	Straw burnt, tine	26.6	18.1	20.0	58.4	33.9	73.3	82.4	58.3	66.9	48.7	43.4	52.8
	Tine incorporation	23.6	20.5	16.3	27.2	41.9	44.1	78.9	103.3	75.9	48.0	45.6	
	Plough incorporation	49.1	20.6	26.6	115.2	72.5	70.3	89.5	50.0	61.9	61.7	63.6	
	mean	33.1	19.7	21.0	66.9	49.4	62.6	83.6	70.5	68.2			
	mean	24.6			59.7			74.1					
2	Straw burnt, tine	31.0	13.3	15.1	51.5	47.4	32.5	96.1	66.4	38.5	43.5		43.2
	Tine incorporation	26.7	20.5	17.3	31.2	26.4	40.0	35.7	54.8	32.5	31.7		
	Plough incorporation	43.2	39.3	16.2	71.7	53.7	66.1	48.2	79.9	70.9	54.4		
	mean	33.6	24.4	16.2	51.5	42.5	46.2	60.0	67.1	47.3			
	mean	24.7			46.7			57.1					
3	Straw burnt, tine	15.8	21.6	10.9	35.3	39.4	46.9	60.7	62.1	50.8	38.2		57.0
	Tine incorporation	29.7	22.8	16.8	78.8	69.0	56.6	110.2	72.6	68.6	58.3		
	Plough incorporation	35.2	33.6	11.7	97.7	66.3	63.4	109.2	131.8	122.8	74.6		
	mean	26.9	26.0	13.1	70.6	58.2	55.6	93.4	88.8	80.7			
	mean	22.0			61.5			87.6					
Overall mean SED = 7.86 ns		31.2	23.4	16.8	63.0	50.1	54.8	79.0	75.5	65.4			
Overall mean SED = 4.54 ns		23.8			56.0			73.3					
CV% = 31													

4 d.f. for year of disposal and disposal method SED's, 48 d.f. for all other SED's

Appendix F4 Harvest 1988. Soil derived N in crop (kg/ha N)

Year of Disposal	Disposal method	N rate (kg/ha N) 120, N split - timing 0-40	120 0-80	120 40-40	200 0-40	200 0-80	200 40-40	280 0-40	280 0-80	280 40-40	Mean	Overall Mean SED = 9.79 ns	Overall Mean SED = 9.79 ns
1	Straw burnt, tine	83.6	60.6	70.2	79.0	96.2	100.1	72.5	62.5	73.6	77.6	76.1	80.2
	Tine incorporation	112.3	87.8	66.8	89.9	76.7	114.2	89.2	146.9	107.0	99.0	89.7	
	Plough incorporation	99.9	154.5	80.8	135.1	81.0	102.0	67.0	150.8	68.0	104.3	87.5	
	mean	98.6	101.0	72.6	101.3	84.6	105.4	76.2	120.1	82.9			
	mean	90.7			97.1			93.1					
2	Straw burnt, tine	86.1	54.5	66.0	76.9	122.1	80.4	117.0	86.3	62.8	83.6		80.4
	Tine incorporation	68.4	115.8	73.0	70.9	61.2	100.0	49.4	70.4	55.9	73.9		
	Plough incorporation	86.8	87.9	56.5	120.6	74.3	110.6	86.2	70.3	61.1	83.8		
	mean	80.4	86.1	65.2	89.5	85.9	97.0	84.2	75.7	55.9			
	mean	77.2			90.8			70.3					
3	Straw burnt, tine	56.7	86.6	48.6	56.8	72.4	79.1	57.2	82.7	63.6	67.1		93.6
	Tine incorporation	81.2	82.9	86.3	107.0	101.5	89.8	83.1	91.3	110.5	92.6		
	Plough incorporation	61.3	78.8	35.2	108.7	96.1	84.3	72.7	91.2	99.3	80.9		
	mean	66.4	82.8	56.7	90.8	90.0	84.4	71.0	88.4	91.1			
	mean	68.6			88.4			83.5					
Overall mean SED = 9.69 ns		81.8	89.9	64.8	93.9	86.8	95.6	77.1	94.7	78.0			
Overall mean SED = 5.59 ns		78.9			92.1			88.3					
CV% = 32													

4 d.f. for year of disposal and disposal method SED's, 48 d.f. for all other SED's

Appendix F5 Harvest 1988. Fraction of N content derived from fertiliser (%)

Year of Disposal	Disposal method	N rate (kg/ha N) 120 N split - timing 0-40	0-80	40-40	200 0-40	0-80	40-40	280 0-40	0-80	40-40	Mean	Overall Mean SED = 2.63 ns	Overall Mean SED = 2.63 ns
1	Straw burnt, tine	17.4	18.9	20.4	25.0	33.2	28.0	47.0	41.3	41.5	36.9	34.4	34.7
	Tine incorporation	24.2	23.0	22.2	42.5	28.8	42.2	53.1	48.3	47.6	30.3	32.5	
	Plough incorporation	33.0	11.8	24.7	46.0	47.2	40.8	52.6	24.9	47.6	37.0	39.8	
	mean	24.8	17.9	22.4	37.8	36.4	37.0	52.4	38.2	45.6			
	mean	21.7			37.1			45.4					
2	Straw burnt, tine	28.3	16.1	19.3	29.7	30.0	28.7	42.3	43.3	44.0	31.9		33.8
	Tine incorporation	26.5	21.0	18.1	40.1	28.0	28.8	42.9	43.5	38.5	31.3		
	Plough incorporation	33.0	31.1	22.2	33.5	41.9	37.2	38.8	53.2	53.8	38.3		
	mean	29.3	22.7	19.9	34.2	33.3	31.5	41.3	45.7	45.4			
	mean	24.0			33.1			44.5					
3	Straw burnt, tine	26.3	21.3	16.1	42.4	40.5	38.7	57.0	44.3	37.7	34.4		38.2
	Tine incorporation	20.9	20.5	18.5	39.0	35.1	37.3	51.6	43.0	43.8	36.0		
	Plough incorporation	34.5	30.7	24.9	47.3	40.8	42.3	62.2	59.1	55.3	34.4		
	mean	27.2	24.2	19.8	42.9	38.8	39.4	56.9	48.7	45.6			
	mean	23.7			40.4			50.4					
Overall mean SED = 2.46 ns		27.1	21.6	20.7	38.4	36.2	36.0	50.2	44.5	45.5			
Overall mean SED = 1.42 ns		23.1			36.8			46.8					
CV% = 13													

4 d.f. for year of disposal and disposal method SED's, 48 d.f. for all other SED's

Appendix F6 Harvest 1988. Recovery of applied N by crop (%)

Year of Disposal	Disposal method	N rate (kg/ha N) 120, N split - timing 0-40	120 0-80	120 40-40	200 0-40	200 0-80	200 40-40	280 0-40	280 0-80	280 40-40	Mean	Overall Mean SED = 3.25 ns	Overall Mean SED = 3.25 ns
1	Straw burnt, tine	22.2	15.1	16.7	29.2	17.0	36.6	29.4	20.8	23.9	23.4	20.8	25.6
	Tine incorporation	19.7	17.1	13.6	13.6	20.9	22.1	28.2	36.9	27.1	22.1	21.9	
	Plough incorporation	40.9	17.2	22.1	57.6	36.2	35.1	32.0	17.9	22.1	31.2	31.3	
	mean	27.6	16.5	17.5	33.5	24.7	31.3	29.9	25.2	24.4			
	mean	20.5			29.8			26.5					
2	Straw burnt, tine	25.9	11.1	12.6	25.7	23.7	16.3	34.3	23.7	13.7	20.8		21.6
	Tine incorporation	22.2	17.1	14.5	15.6	13.2	20.0	12.7	19.6	11.6	16.3		
	Plough incorporation	36.0	32.8	13.5	36.5	26.8	33.1	17.7	28.6	25.4	27.8		
	mean	28.0	20.3	13.5	25.9	21.2	23.1	21.6	24.0	16.9			
	mean	20.6			23.4			20.4					
3	Straw burnt, tine	13.2	18.0	9.1	17.6	19.7	23.4	21.7	22.2	18.2	18.1		26.9
	Tine incorporation	24.7	19.0	14.0	39.4	34.5	28.3	39.4	26.0	24.5	27.7		
	Plough incorporation	29.4	28.0	9.7	48.8	33.1	31.7	42.3	47.1	43.9	34.9		
	mean	22.4	21.6	10.9	35.3	29.1	27.8	34.4	31.8	28.8			
	mean	18.3			30.7			31.7					
Overall mean SED = 3.35 ns		26.0	19.5	14.0	31.6	25.0	27.4	28.6	27.0	24.1			
Overall mean SED = 1.94 ns		19.8			27.9			26.6					
CV% = 31													

4 d.f. for year of disposal and disposal method SED's, 48 d.f. for all other SED's

Appendix G Effect of Successive Years of Straw Disposal on Winter Wheat Yield; Optimum* fertiliser N requirement; 1986-88

Straw disposal method	No of years of disposal	Yield t/ha @ 85% DM: Nil N	With optimum* fertiliser, N: all in spring	40 kg/ha autumn	Optimum N kg/ha: all in spring	SE	40 kg/ha autumn	SE
1985/86-dry autumn								
Straw burnt								
tine	1	4.20	8.26	8.09	213	(11.2)	204	(17.5)
Straw incorporated								
tine	1	3.27	7.86	7.63	283	(32.9)	245	(19.7)
plough	1	4.23	7.13	7.26	198	(14.5)	214	(14.8)
1986/87								
Straw burnt								
tine+	1	3.40	5.47	5.46	164	(25.4)	187	(41.8)
	2	3.77	5.86	6.02	155	(11.9)	162	(7.2)
Straw incorporated								
tine+	1	2.60	5.01e	4.59	200e		160e	
	2	3.40	5.97	6.24	161	(15.5)	193	(24.8)
plough	1	4.00	6.21	6.29	145	(13.6)	173	(12.1)
	2	4.60	6.27	6.56	142	(17.5)	144	(9.6)
1987/88								
Straw burnt								
tine+	1	2.08	3.55	2.81	240e		92	(72.5)
	2	2.49	4.98	5.05e	227	(106.7)	200e	
	3	2.62	4.96	5.60	178	(63.8)	240e	
Straw incorporated								
tine+	1	2.89	5.18	5.80e	137	(64.9)	240e	
	2	2.53	4.08	4.15e	240e		200e	
	3	2.75	5.25e	5.50e	220e		280e	
plough	1	2.42	5.97	5.80e	252	(51.2)	200e	
	2	2.32	5.07	-	175	(30.4)	240e	
	3	2.96	5.78	-	223	(11.4)	246	(12.8)

e 'eye fitted' optimum, LPE model failed to fit the data.

* assuming grain to N price ratio of 3:1

\+ severe brome grass infestation reduced yields in the second and third seasons - see section on weeds.

Overall averages

Straw disposal method	Nil N	Yield @ 85% DM t/ha, With optimum* fertiliser N: None in autumn	40 kg/ha N in autumn	Mean	Optimum* fertiliser N kg/ha^{-1}: None in autumn	40 kg/ha N in autumn	Mean
Burnt	3.09	5.51	5.51	5.51	196	181	189
Tine+	2.91	5.56	5.65	5.61	207	220	213
Plough	3.42	6.07	6.21	6.14	189	203	196
SED	0.627	0.408	0.423	0.412	14.87	14.85	11.16
P =	0.516	0.688	0.607	0.642	0.791	0.344	0.442