

## Results from two sets of experiments with spring barley, the first comparing injected with broadcast nitrogen granules, the second comparing injected and combine-drilled NPK solutions with broadcast NPK granules

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### SUMMARY

Six experiments from 1969–71 compared yields of, percentages of N in, and removals of N by barley given 63 or 126 kg N/ha either as urea or as 'Nitro-Chalk' which were either broadcast or injected into the seed bed. Both fertilizers were equally effective and each gave a slightly larger yield when injected.

Eleven more experiments compared yields of, percentages of N in, and removals of N by barley given either NPK solution fertilizers or NPK granules supplying 63 or 126 kg N/ha. One liquid (14–6–8) supplied the whole of the N and was either sprayed, combine-drilled or injected mid-way between the seed rows (15 cm apart). The other liquid (4–10–10) supplied one-fifth of the N and was either combine-drilled or injected; 'Nitro-Chalk' supplied the remainder of the N. The granular fertilizer (20–10–10) was broadcast.

The 14–6–8 solution always gave a smaller yield than comparable granules. Yields with injected dressings were no larger than with sprays, but each was safe. Combine-drilled dressings were harmful and often killed the barley and decreased yields especially when 126 kg N/ha was given.

The 4–10–10 solution was harmless when combine-drilled and gave a larger yield than the granules when 63 kg N/ha was given and the same yield when 126 kg N/ha was given. It gave a smaller yield than the granules when it was injected.

Grain percentage N tended to be larger with the injected liquids and smaller with the sprays than with the broadcast granules though the amount of N recovered by the barley from the injected liquids was no larger than from the granules.

### INTRODUCTION

Kahari & Elonen (1969) made experiments with barley on two clay soils in South Finland, an area subject to spring and early summer droughts. Both roots and shoots grew more quickly, and hence were larger, where the NPK fertilizer that they used was placed 8 cm deep, mid-way between the rows, than when it was broadcast. They obtained a strong positive correlation between the weight of roots and the yield of grain and concluded that 'it is important to place the fertilizer at a convenient depth, 5–10 cm, when cereals are in question. The horizontal distance between seedrows and fertilized rows appears to be of less importance'.

Dam Kofoed & Larsen (1971) compared alternative methods of applying urea for spring cereals. They confirmed that urea and seed should be sown separately, not together, to prevent damage to the

germinating seeds and also that broadcast urea should be worked into the soil to minimize the risk of loss of ammonia to the atmosphere as it hydrolysed. However, their mean yields (from 11 experiments) did not differ significantly with method of application.

Widdowson, Penny & Flint (1972) showed that an aqueous solution of urea injected into the seed bed was slightly more effective for spring barley, when judged by yield or by N recovery, than ammonium nitrate/limestone granules (21% N) broadcast over the seed bed. However, an NPK liquid fertilizer rich in urea was less effective when sprayed and more damaging when combine-drilled than a comparable granular NPK fertilizer (which contained most of its nitrogen as ammonium nitrate).

Liquid fertilizers not only save labour but also facilitate placement, because they can be pumped

under pressure into bands which the young roots can easily reach and hence readily take up the nutrients in them. Consequently, the experiments that we had begun in 1969 to value injected N for spring barley were extended to assess whether (1) liquid NPK fertilizers rich in urea could be injected safely between rows of barley, and (2) whether this technique would give increased yields under our conditions, as had been shown in Finland. This paper gives results from both sets of experiments.

## METHOD

### *Experiments with nitrogen fertilizers*

Two were made in 1969, in 1970 and in 1971 to compare injected and broadcast dressings of urea (46% N) and 'Nitro-Chalk' (ammonium nitrate/limestone) (21% N). Each fertilizer was applied to give 63 or 126 kg N/ha. These eight fertilizer treatments plus two plots not receiving nitrogen were arranged in four randomized blocks. Each year one experiment was at Rothamsted (clay loam over Clay-with-Flints) and one at Woburn (sandy loam over Lower Greensand).

In 1969 both fertilizers were injected into the plough furrows in bands 14 cm apart and 7–10 cm deep with a Tume fertilizer drill fitted with a

crumbler. In 1970 and 1971 a Fiona cultivator drill was used to inject the fertilizer in bands 15 cm apart and 8–10 cm deep into the seed bed. Equivalent broadcast dressings were applied by hand. Additionally, in 1971 only, an aqueous solution of urea (19% N) was either injected in bands 30 cm apart and 8–10 cm deep, or sprayed over the seed bed. Individual plots were 2.1 m wide and 30 m long. Basal P and K (250 kg/ha of 0–20–20) was combine-drilled in 1969 and broadcast in 1970 and 1971.

We grew Zephyr barley in 1969 and Julia in 1970 and 1971. In 1969 there was little lodging at Rothamsted, but barley given 126 kg N/ha lodged at Woburn. In 1970 there was no lodging at either farm, nor in 1971 at Rothamsted, but in 1971 at Woburn the barley lodged in June and yielded less with 126 kg N/ha than with none (this field had been ploughed out of grass in 1962). At harvest the plots were combine-harvested and the grain weighed and sampled for dry-matter and nitrogen content.

### *Experiments with liquid NPK fertilizers*

There were three in 1971 and four in 1972 and 1973, all on private farms. Each year two liquid fertilizers were used. The first supplied the whole

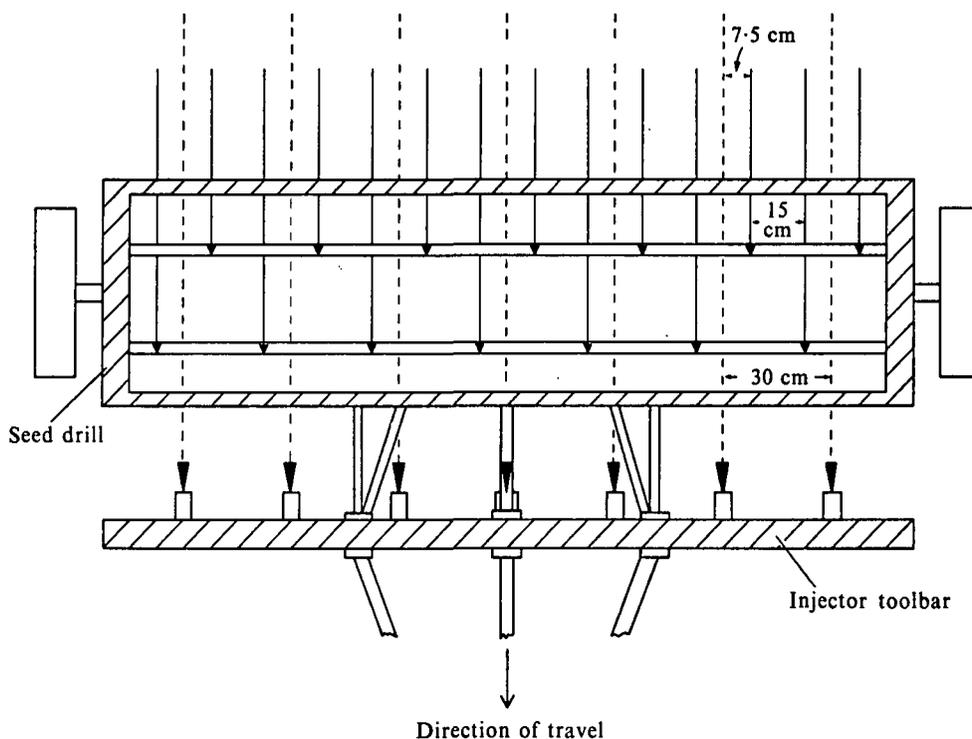


Fig. 1. The relationship between the bands of fertilizer and the rows of seed, in the trials rig made for the barley experiments with liquid fertilizers in 1972 and 1973. ---->, bands of injected fertilizer and fertilizer knives; —>, rows of seed and seed tines.

of the N given to the barley; it contained 14% N, 6% P<sub>2</sub>O<sub>5</sub> and 8% K<sub>2</sub>O (subsequently referred to as 14-6-8). The second supplied only one-fifth of the N given; it contained 4% N, 10% P<sub>2</sub>O<sub>5</sub> and 10% K<sub>2</sub>O (4-10-10). The balance (four-fifths) of this N was broadcast as 'Nitro-Chalk' (21% N) at sowing. Yields with each liquid fertilizer were compared with those from a granular NPK fertilizer containing 20% N, 10% P<sub>2</sub>O<sub>5</sub> and 10% K<sub>2</sub>O (20-10-10) broadcast over the seed bed. This contrast is complicated by the fact that the 14-6-8 liquid fertilizer was rich in urea (roughly 80% of its N content) and that both it and the 4-10-10 were based on di-ammonium phosphate. The 20-10-10 granules contained N mostly in the form of ammonium nitrate and were based on mono-ammonium phosphate. The techniques and methods of application were not consistent throughout.

In 1971 each of the liquid fertilizers was either injected in bands 30 cm apart and 8-10 cm deep as a separate operation before the seed was sown, or combine-drilled with the seed in rows 17.5 cm apart. The granular 20-10-10 was either broadcast or combine-drilled, using the same drill. The 'Nitro-Chalk' was broadcast immediately after sowing. All the fertilizers were applied to give either 63 or 126 kg N/ha. These 12 treatments plus two unmanured plots were arranged in four

randomized blocks in each experiment. Individual plots were 2.1 m wide and 20.1 m long. Julia barley was sown at Gaddesden (Flinty-head and rain wash) on 11 March and at Eversholt (sandy drift over clay) on 29 March, and Deba Abed at Wheathampstead (clay loam over Clay-with-Flints) on 30 March. Combine-drilling the liquid 14-6-8 checked early growth at Eversholt and Wheathampstead but not at Gaddesden, where rain followed sowing. All barley given N lodged at Eversholt and Wheathampstead, but only that given 126 kg N/ha at Gaddesden. The centre eight rows were combine-harvested and the grain weighed and sampled for dry matter and nitrogen determinations.

In 1972 the liquid fertilizer injector was adapted so that the liquid fertilizers could be injected simultaneously with sowing, in bands positioned mid-way between the rows of seed (Fig. 1). A six-point linkage allowed us to fasten a Fiona cultivator drill sowing seed in rows 15 cm apart directly behind the injector. A small stainless-steel tube was welded to the back of each seed tine so that the liquid fertilizers could be pumped directly into the seed row (contact placement) and thus combine-drilled. Also a spray boom was fastened to the front of the drill so that the 14-6-8 fertilizer could be sprayed in the path of the seed tines. The

Table 1. *Visual estimates of early growth (unmanured barley = 100) from two amounts of one granular and two liquid fertilizers applied in several ways*

	1971	1972	1973
Number of experiments ...	3	4	4
Date scored ...	29 April	20/26 April	8/15 May
Fertilizer applied to give 63 kg N/ha			
Granular 20-10-10			
Broadcast	128	128	150
Combine-drilled	133	—	—
Liquid 14-6-8			
Sprayed	—	117	147
Combine-drilled	113	80	130
Injected	115	124	153
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'			
Combine-drilled	138	152	180
Injected	120	118	160
Fertilizer applied to give 126 kg N/ha			
Granular 20-10-10			
Broadcast	131	121	170
Combine-drilled	110	—	—
Liquid 14-6-8			
Sprayed	—	130	162
Combine-drilled	64	30	83
Injected	113	123	149
Liquid 4-10-10			
Combine-drilled	146	164	196
Injected	120	129	170

test of combine-drilled granular 20-10-10 was no longer feasible and so the broadcast test became the standard. The 12 fertilized plots plus two not given fertilizer were again arranged in four randomized blocks. Vada barley was sown at Gaddesden on 17 March, Zephyr at Barton Hill (thin Flinty-head over Chalk) on 20 March, Julia at Eversholt on 21 March and Deba Abed at Wheathampstead on 22 March. Combine-drilling the 14-6-8 liquid fertilizer again checked early growth especially when 126 kg N/ha was given (Table 1). At Eversholt (which has sandy soil) this amount of this fertilizer killed most of the barley plants and these plots had to be resown. The damage was less severe elsewhere. By contrast combine-drilled 4-10-10 improved early growth. At harvest, lodging occurred on all the manured plots at Gaddesden and Eversholt and with 126 kg N/ha at Barton Hill. There was none at Wheathampstead.

In 1973 the experiments were repeated unchanged. Zephyr barley was sown at Barton Hill on 9 March, Julia at Eversholt on 14 March, Deba Abed at Wheathampstead on 15 March and at

Hexton (chalky downwash over Gault clay) on 19 March. The combine-drilled 14-6-8 again checked early growth, severely at Eversholt, whilst combine-drilled 4-10-10 improved it.

Thunderstorms during July caused extensive lodging at Wheathampstead and Hexton and severe lodging at Eversholt, where a grazed ley had been ploughed for oats in 1972.

## RESULTS

### *Experiments with nitrogen fertilizers*

Appendix Table 1 shows yields in individual experiments. Yield differed little with method of application, though the injected N tended to give the larger yield (Table 2). The benefit from injecting the N, though small, was consistent, for it gave the larger yield in 19 of 24 comparisons and was as large with 'Nitro-Chalk' as with urea. Percentage N in the barley grain was not changed by injecting either fertilizer (Appendix Table 2), though it was greatly increased by giving the barley 126 rather than 63 kg N/ha (Table 2). The largest variations

Table 2. Mean yields of, percentages of N in, and amounts of N removed by, barley grown in six experiments comparing injected and broadcast dressings of urea and 'Nitro-Chalk', 1969-71

	Nitrogen fertilizer		Number of occasions (maximum 6) when injected N was the better
	Broadcast	Injected	
Yield of grain (t/ha at 85% D.M.)			
Without nitrogen	3.61		
With 63 kg N/ha as			
'Nitro-Chalk'	5.10	5.18	5
Urea	5.13	5.29	5
With 126 kg N/ha as			
'Nitro-Chalk'	5.18	5.34	6
Urea	5.23	5.23	3
Percentage N in grain			
Without nitrogen	1.48		
With 63 kg N/ha as			
'Nitro-Chalk'	1.54	1.55	3
Urea	1.57	1.56	2
With 126 kg N/ha as			
'Nitro-Chalk'	1.90	1.86	2
Urea	1.83	1.88	3
N (kg/ha) removed by grain			
Without nitrogen	46.7		
With 63 kg N/ha as			
'Nitro-Chalk'	67.1	68.7	4
Urea	68.9	69.9	4
With 126 kg N/ha as			
'Nitro-Chalk'	82.5	83.6	4
Urea	80.8	82.8	3

in % N were caused by season and by site. Grain containing more than 2% N was produced by barley given 126 kg N/ha at three of the six sites.

*Experiments with liquid NPK fertilizers*

Appendix Table 3 shows yields in each experiment. Yields were greatly increased by both amounts of fertilizer at each centre except Eversholt where the barley was grown in fields which had been grazed by dairy cattle 2 or 3 years previously. The other sites were on farms which grew only arable crops, mainly cereals, hence the large responses to fertilizer there. Combine-drilled 4-10-10 gave a significantly larger yield than broadcast 20-10-10 on the chalky soils at Barton Hill (in 1972 and 1973), but not elsewhere.

Table 3 shows that the 14-6-8 liquid fertilizer rich in urea usually gave a smaller yield than granules supplying comparable amounts of N, P and K whether it was sprayed, or injected or combine-drilled. The risks from combine-drilling fertilizers rich in urea were amply confirmed, for the 14-6-8 fertilizer, combine-drilled at 126 kg N/ha,

gave significantly smaller yields than broadcast granules, in 5 of the 11 experiments. By contrast the 4-10-10 liquid, which contained little urea and supplied only one-fifth as much N, improved establishment when combine-drilled and was the only treatment involving liquid fertilizers which produced a significantly larger yield than broadcast granules did (in two of the 11 experiments). Although 14-6-8 was perfectly safe when it was injected mid-way between the rows of barley, subsequent growth was no better than when it was sprayed over the seed bed and yields from the two methods of application were similar. The proposition that the phosphate in the injected 14-6-8 fertilizer was too far away from the seed row to benefit the young seedlings was confirmed by the fact that growth on plots given injected 4-10-10 was inferior to that on plots given combine-drilled 4-10-10.

Table 4 shows that the sole benefit of injecting the 14-6-8 fertilizer was to limit the loss in yield that it caused when the double amount of it was combine-drilled. By contrast the 4-10-10 liquid

Table 3. Mean yields (t/ha at 85% D.M.) of barley grain each year, in experiments comparing alternative methods of applying liquid fertilizers in 1971-73

	1971	1972	1973	Number of occasions when liquid fertilizer gave yields larger (+) or smaller (-) than broadcast granular fertilizer	
Number of experiments ...	(3)	(4)	(4)		
Without fertilizer ...	3.26	3.12	3.25		
Fertilizer applied to give 63 kg N/ha					
Granular 20-10-10					
Broadcast	4.31	4.78	4.33	+	*
Combine-drilled	4.33	—	—		
Liquid 14-6-8					
Sprayed	—	4.43	4.20	1 (0)	7 (2)
Combine-drilled	4.30	4.64	4.28	4 (0)	7 (0)
Injected	4.29	4.62	4.26	3 (0)	8 (0)
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'					
Combine-drilled	4.36	4.83	4.44	8 (1)	3 (0)
Injected	4.38	4.59	4.24	6 (0)	5 (2)
Fertilizer applied to give 126 kg N/ha					
Granular 20-10-10					
Broadcast	4.47	5.03	4.49		
Combine-drilled	4.42	—	—		
Liquid 14-6-8					
Sprayed	—	4.98	4.39	4 (0)	4 (0)
Combine-drilled	4.16	4.47	4.06	0 (0)	11 (5)
Injected	4.47	4.88	4.33	4 (0)	7 (1)
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'					
Combine-drilled	4.44	5.13	4.41	4 (2)	6 (0)
Injected	4.44	4.94	4.34	3 (0)	8 (1)

\* Significance  $P = 0.05$ .

Table 4. Mean yields (t/ha at 85% D.M.) of barley grain without and with fertilizer, the mean increase in yield from each fertilizer treatment and the increases from the liquid fertilizers expressed as a percentage of that from broadcast granular fertilizer (= 100) in 11 experiments, 1971-73

	Total yield	Increases from fertilizers	Percentage equivalence of increases
Without fertilizer ...	3.21	—	—
Fertilizer applied to give 63 kg N/ha			
Granular 20-10-10	4.49	1.28	100
Liquid 14-6-8			
Combine-drilled	4.41	1.20	93.8
Injected	4.39	1.18	92.2
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'			
Combine-drilled	4.56	1.35	105.5
Injected	4.40	1.19	93.0
Fertilizer applied to give 126 kg N/ha			
Granular 20-10-10	4.68	1.47	100
Liquid 14-6-8			
Combine-drilled	4.24	1.03	70.1
Injected	4.57	1.36	92.5
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'			
Combine-drilled	4.68	1.47	100
Injected	4.59	1.38	93.9

Table 5. Mean percentages of N in barley grain, each year, in 11 experiments comparing alternative methods of applying liquid fertilizers, 1971-73

	1971	1972	1973	Mean
Number of experiments ...	(3)	(4)	(4)	
Without fertilizer ...	1.42	1.44	1.51	1.46
Fertilizer applied to give 63 kg N/ha				
Granular 20-10-10				
Broadcast	1.50	1.51	1.72	1.58
Combine-drilled	1.51	—	—	—
Liquid 14-6-8				
Sprayed	—	1.56	1.66	—
Combine-drilled	1.47	1.52	1.71	1.57
Injected	1.53	1.58	1.68	1.60
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'				
Combine-drilled	1.46	1.53	1.69	1.57
Injected	1.52	1.52	1.71	1.59
Fertilizer applied to give 126 kg N/ha				
Granular 20-10-10				
Broadcast	1.64	1.86	1.98	1.84
Combine-drilled	1.70	—	—	—
Liquid 14-6-8				
Sprayed	—	1.76	1.91	—
Combine-drilled	1.70	1.92	2.01	1.89
Injected	1.72	1.90	2.01	1.89
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'				
Combine-drilled	1.69	1.80	2.00	1.84
Injected	1.71	1.90	2.06	1.91

Table 6. Mean amounts (kg/ha) of N removed by barley grain, each year, in 11 experiments comparing alternative methods of applying liquid fertilizers, 1971-73

	1971	1972	1973	Mean
Number of experiments ...	(3)	(4)	(4)	
Without fertilizer ...	40.1	39.1	42.5	40.6
Fertilizer applied to give 63 kg N/ha				
Granular 20-10-10				
Broadcast	55.5	61.4	64.3	60.8
Combine-drilled	55.8	—	—	—
Liquid 14-6-8				
Sprayed	—	59.3	59.9	—
Combine-drilled	53.7	60.2	62.7	59.4
Injected	55.8	62.6	61.0	60.2
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'				
Combine-drilled	54.5	63.6	64.0	61.2
Injected	56.8	59.6	62.0	59.7
Fertilizer applied to give 126 kg N/ha				
Granular 20-10-10				
Broadcast	62.2	79.5	75.6	73.4
Combine-drilled	63.6	—	—	—
Liquid 14-6-8				
Sprayed	—	74.7	71.2	—
Combine-drilled	59.6	72.0	69.4	67.7
Injected	65.3	78.6	74.0	73.3
Liquid 4-10-10				
Combine-drilled	63.6	78.7	75.0	73.2
Injected	64.4	80.0	76.0	74.3

was always better combine-drilled than injected, though this technique produced a larger yield than the broadcast granules only when the single amount (63 kg N/ha) was given.

Appendix Table 4 shows percentages of N in the grain at each centre. Each year grain from the Eversholt site contained the most N and this was increased further both by the single and by the double amounts of N, whether or not they also increased yield. Grain percentage N was increased a little by 63 and greatly by 126 kg N/ha at all the other sites. Four of the sites produced grain containing more than 2% N when 126 kg N/ha was given.

Table 5 shows that there was no consistent difference in grain nitrogen content between barley manured with liquid or with granular fertilizer. Surprisingly, barley grain from plants which had been checked by combine-drilled 14-6-8 contained no more N than grain from plants where the 14-6-8 had been injected and hence was harmless. Presumably therefore uptake of N from each was delayed and so the nitrogen behaved as if it had been applied at a later date. Whether this was because the banded N was less accessible physically to the roots, or whether the urea in it nitrified more

slowly because of its concentration in the band we cannot tell.

Table 6 shows that the barley removed as much N from 63 kg N/ha given in liquid as in granular form and that removal differed little with method of application. However, when 126 kg N/ha was given, nitrogen uptake was altered by method of application, for the losses in yield of grain from combine-drilling the 14-6-8 and the smaller percentages of N in the grain from spraying it, were reflected in smaller total uptakes. Values from the other treatments were similar to those from granules.

#### DISCUSSION AND CONCLUSIONS

The technique of injecting nitrogen fertilizer with a cultivator drill whilst the seed bed was being prepared produced no outstanding advantage, though yields from N applied in this way tended to be a little larger than where N had been broadcast. Surprisingly, the gains from injecting urea were similar to and no greater than those from injecting 'Nitro-Chalk', though surface dressings of urea are sometimes subject to losses of ammonia by evaporation. Evidently sizeable increases in yield

cannot be expected from adopting this technique under our conditions, though no loss will be suffered if there are organizational advantages from adopting this practice on the farm.

The experiments with liquid fertilizers confirmed that those rich in urea should not be combine-drilled, but showed that these could safely be injected mid-way between rows of barley that were 15 cm apart. A liquid fertilizer supplying the same amounts of P and K, but only one-fifth of the N (and hence little urea), did no harm when it was combine-drilled, but greatly enhanced early growth on some calcareous soils which had been used to grow long runs of cereals. This benefit did not occur when the same fertilizer was injected between the rows of barley. Our conclusion is, therefore, that those farmers who grow barley on soils that contain little available phosphorus and who intend to use liquid fertilizers in future, should adapt their seed drills so that an NPK fertilizer supplying the whole of the P and K and a little of the N can be pumped down the rear of the seed

coulter and so in contact with the seed. The remainder of the N should be applied at the most appropriate time, depending on the date of sowing, the kind of soil and the risk of leaching. There seems little purpose in adding additional coulters or tines to drills, so that liquids rich in urea can be injected between the seeds rows (and hence supply all the N) without risk, because in our experiments sprayed dressings were equally as effective. The fact that early sown spring barley generally out-yields the late, especially on the lighter soils, provides an additional argument for split applications of nitrogen. For the only soils that consistently allow early sowing are the free draining ones where seed-bed N is at greatest risk from leaching.

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Appendix Table 1. *Yields of grain (t/ha at 85% D.M.) from barley experiments comparing 'Nitro-Chalk' with urea, when each was either injected into, or broadcast over the final seed bed, 1969-71*

Location ...	Rothamsted						Woburn					
	1969		1970		1971		1969		1970		1971	
	Broad-cast	In-jected										
Year ...												
Method ...												
Without nitrogen	4.57		2.33		3.99		1.26		3.70		5.80	
s.e.	±0.128		±0.078		±0.069		±0.151		±0.238		±0.118	
With 63 kg N/ha as 'Nitro-Chalk'	5.85	6.07	4.28	4.33	5.60	5.75	3.79	3.90	5.25	4.98	5.82	6.07
Urea	6.11	6.14	4.23	4.25	5.83	5.73	3.78	4.24	4.71	5.07	6.10	6.32
Aqua urea	—	—	—	—	5.73	5.76	—	—	—	—	5.88	5.88
With 126 kg N/ha as 'Nitro-Chalk'	5.77	5.97	4.53	4.63	6.10	6.27	4.35	4.64	4.83	4.92	5.47	5.60
Urea	5.80	5.90	4.48	4.49	6.26	6.25	4.44	4.67	4.78	4.67	5.62	5.40
Aqua urea	—	—	—	—	6.23	6.26	—	—	—	—	5.61	5.48
s.e. of a difference	±0.181		±0.110		±0.138		±0.214		±0.336		±0.235	

Appendix Table 2. *The percentages of N in barley grain from experiments comparing 'Nitro-Chalk' with urea, when each was either injected into, or broadcast over the final seed bed, 1969-71*

Location ...	Rothamsted						Woburn					
	1969		1970		1971		1969		1970		1971	
	Broad-cast	In-jected										
Year ...												
Method ...												
Without nitrogen	1.36		1.58		1.32		1.28		1.65		1.70	
s.e.	±0.035		±0.040		±0.031		±0.049		±0.040		±0.038	
With 63 kg N/ha as 'Nitro-Chalk'	1.31	1.38	1.70	1.68	1.38	1.40	1.15	1.12	1.77	1.92	1.90	1.81
Urea	1.38	1.32	1.68	1.71	1.44	1.39	1.15	1.28	1.97	1.86	1.81	1.78
Aqua urea	—	—	—	—	1.31	1.36	—	—	—	—	1.91	1.76
With 126 kg N/ha as 'Nitro-Chalk'	1.64	1.67	2.10	2.10	1.63	1.48	1.82	1.66	2.15	2.12	2.04	2.13
Urea	1.66	1.72	2.03	2.00	1.60	1.54	1.58	1.71	2.18	2.15	1.94	2.15
Aqua urea	—	—	—	—	1.56	1.61	—	—	—	—	2.07	2.04
s.e. of a difference	±0.049		±0.057		±0.062		±0.069		±0.057		±0.076	

Appendix Table 3. Yields (t/ha at 85% D.M.) of barley grain, in 11 experiments comparing alternative methods of applying liquid fertilizers, 1971-3

Location	1971			1972			1973				
	Eversholt	Gaddesden	Wheat-hampstead	Barton Hill	Eversholt	Gaddesden	Wheat-hampstead	Barton Hill	Eversholt	Hexton	Wheat-hampstead
Without fertilizer	4.02	2.36	3.40	2.08	4.73	3.25	2.44	2.19	4.60	3.54	2.66
S.E.	± 0.059	± 0.078	± 0.076	± 0.063	± 0.093	± 0.105	± 0.132	± 0.056	± 0.108	± 0.062	± 0.077
Fertilizers applied to give 63 kg N/ha											
Granular 20-10-10	4.47	3.94	4.52	4.49	5.57	5.17	3.88	3.96	4.72	4.52	4.13
Broadcast	4.36	4.23	4.39	—	—	—	—	—	—	—	—
Combine-drilled	—	—	—	4.46	5.31	4.76	3.20	3.86	4.80	4.50	3.62
Liquid 14-6-8	4.31	4.20	4.39	4.59	5.27	4.90	3.79	4.00	4.63	4.55	3.92
Sprayed	4.37	4.01	4.48	4.56	5.34	4.97	3.59	4.06	4.56	4.41	3.99
Combine-drilled	—	—	—	—	—	—	—	—	—	—	—
Injected*	4.45	4.06	4.62	4.57	5.55	5.23	3.97	4.33	4.73	4.76	3.95
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'	4.50	3.99	4.59	4.66	5.33	4.67	3.69	4.17	4.56	4.54	3.71
Combine-drilled	—	—	—	—	—	—	—	—	—	—	—
Injected*	4.23	4.72	4.47	5.33	5.26	5.56	3.96	4.47	4.50	4.76	4.23
Liquid 14-6-8	4.20	4.72	4.33	—	—	—	—	—	—	—	—
Sprayed	—	—	—	5.34	5.28	5.58	3.73	4.63	4.20	4.52	4.21
Combine-drilled	3.61	4.60	4.28	5.18	3.80	5.12	3.78	4.25	3.80	4.57	3.60
Injected*	4.24	4.63	4.54	5.37	5.24	5.12	3.80	4.51	4.23	4.63	3.94
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'	4.30	4.56	4.47	5.70	5.21	5.35	4.25	4.74	4.30	4.62	3.97
Combine-drilled	4.15	4.63	4.54	5.45	5.09	5.54	3.68	4.56	3.95	4.67	4.19
Injected*	± 0.117	± 0.156	± 0.151	± 0.127	± 0.187	± 0.209	± 0.263	± 0.113	± 0.215	± 0.123	± 0.153
S.E. of a difference											

\* Fertilizers were injected in bands 30 cm apart before the seed was sown in 1971, but mid-way between seed rows simultaneously with sowing in 1972 and 1973 (Fig. 1).

Appendix Table 4. *The percentages of N in barley grain, in 11 experiments comparing alternative methods of applying liquid fertilizers, 1971-73*

Location	1971			1972			1973				
	Eversholt	Gaddesden	Wheat-hampstead	Barton Hill	Eversholt	Gaddesden	Wheat-hampstead	Barton Hill	Eversholt	Hexton	Wheat-hampstead
Without fertilizer	1.60	1.27	1.38	1.21	1.49	1.58	1.47	1.50	1.71	1.40	1.44
s.e.	±0.035	±0.028	±0.044	±0.022	±0.051	±0.041	±0.044	±0.019	±0.031	±0.041	±0.041
Fertilizers applied to give 63 kg N/ha											
Granular 20-10-10											
Broadcast	1.78	1.29	1.43	1.27	1.53	1.65	1.58	1.58	1.95	1.72	1.63
Combine-drilled	1.78	1.30	1.46	—	—	—	—	—	—	—	—
Liquid 14-6-8											
Sprayed	—	—	—	1.31	1.77	1.63	1.53	1.61	1.96	1.57	1.50
Combine-drilled	1.73	1.32	1.35	1.31	1.67	1.62	1.47	1.62	1.98	1.65	1.60
Injected	1.74	1.38	1.46	1.31	1.75	1.71	1.57	1.65	1.91	1.62	1.52
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'											
Combine-drilled	1.75	1.30	1.34	1.29	1.78	1.58	1.48	1.64	1.97	1.56	1.58
Injected	1.79	1.29	1.48	1.32	1.63	1.63	1.50	1.61	2.00	1.60	1.63
Fertilizers applied to give 126 kg N/ha											
Granular 20-10-10											
Broadcast	1.84	1.46	1.63	1.59	2.14	1.86	1.85	1.92	2.19	1.91	1.91
Combine-drilled	1.89	1.42	1.79	—	—	—	—	—	—	—	—
Liquid 14-6-8											
Sprayed	—	—	—	1.51	1.97	1.84	1.73	1.79	2.14	1.89	1.81
Combine-drilled	1.84	1.46	1.79	1.66	2.21	1.92	1.87	1.97	2.17	2.01	1.90
Injected	1.89	1.49	1.78	1.60	2.06	2.08	1.86	1.94	2.14	2.06	1.89
Liquid 4-10-10 plus broadcast 'Nitro-Chalk'											
Combine-drilled	1.84	1.49	1.73	1.61	2.06	1.81	1.73	1.96	2.15	1.97	1.91
Injected	1.82	1.53	1.77	1.68	2.12	2.02	1.77	1.98	2.22	2.07	1.99
s.e. of a difference	±0.071	±0.057	±0.089	±0.044	±0.102	±0.082	±0.088	±0.038	±0.062	±0.082	±0.082