THE EFFECTS OF FOUR NITROGEN FERTILIZERS AND THE TIMING OF THEIR APPLICATION ON GRAIN YIELD IN WINTER-SOWN WHEAT

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ABSTRACT

Four nitrogen fertilizers, viz. pelleted urea, crystalline ammonium sulphate, coarsely granulated lime/ammonium nitrate and fine crystalline potassium nitrate were applied at four times to winter-sown 'Rongotea' wheat established at 13 sites in northern Canterbury. The times of nitrogen application were:- soon after crop emergence (Growth Stage 1), at early tillering (Growth Stage 2), at late tillering (Growth Stage 5) and at late stem elongation (Growth Stage 9).

Fertilizer nitrogen caused significant positive responses in grain yields at ten sites. At these sites, grain yield responses to individual nitrogen fertilizers applied at the same stage of growth did not differ significantly but, irrespective of its fertilizer source, nitrogen applied after the cessation of tillering at late stem elongation (Growth Stage 9) was significantly less effective than earlier applications of fertilizer nitrogen. At three sites, application of fertilizer nitrogen had non-significant effects on grain yields.

It was concluded that the efficacies of the nitrogen fertilizers tested on winter-sown wheat were similar, did not vary differentially with the timing of their application and that each was more effective when applied to the crop prior to the cessation of tillering.

Additional Key Words: urea, ammonium sulphate, lime/ammonium nitrate, potassium nitrate, growth stages

INTRODUCTION

Comparisons of the efficacies of fertilizers used as sources of nitrogen for wheat have generally been based on the crop's grain yield responses to applications of test materials made at a single time or stage of growth (Webber, 1962; Alessi and Power, 1972; Stephen, *et al.*, 1983). While this assessment procedure has yielded apparently satisfactory results, doubts regarding conclusions derived in this way were prompted by reports indicating that, in some instances, wheat grain yield responses to fertilizer nitrogen may differ significantly with the timing of the nitrogen application (Single, 1964; Rawson, 1970; Langer and Liew, 1973). Material presented in these reports suggest that the apparent efficacies of individual nitrogen fertilizers may vary differentially with time of application. It was decided, therefore, to set up a research programme to compare several nitrogen fertilizers applied to winter-sown wheat at each of several growth stages.

This paper details this research programme which was carried on concurrently with the previously reported nitrogen fertilizer comparison in which several rates of five test materials were all applied at mid tillering (Growth Stages 3-4) (Stephen *et al.*, 1983).

MATERIALS AND METHODS

Field experiments were established on northern Canterbury commercial farms in three cropping years, 1980/81, 1981/82 and 1982/83 to test the effects of urea, ammonium sulphate, lime/ammonium nitrate and potassium nitrate, each applied at four stages of crop growth, on grain yield in winter-sown wheat. The experiments were located at the same sites as the experiments reported on by Stephen *et al.* (1983). Site and other environmental details were as given in that paper. Brief details are listed in Table 1.

TABLE 1: Details of experimental sites.

Cropping year	Site	Locality	Soil	September/ January rainfall mm
1980/81	1	Methven	Mayfield	489
	2	Barrhill	Barhill	238
	3	Darfield	Eyre	276
	4	Sheffield	Lyndhurst	317
1981/82	5	Hororata	Ashley	257
	6	Darfield	Chertsey	219
	7	Leeston	Waterton	233
	8	Annat	Lyndhurst	227
1982/83	9	Ashburton	Kaiapoi	249
	10	Leeston	Waterton	285
	11	Waddington	Lynhurst	363
	12	Rokeby	Hatfield	313
	13	Methven	Mayfield	501

In the late autumn/early winter months (May/June), 125 kg/ha fungicide-treated seed of the wheat cultivar Rongotea (McEwan and Vizer, 1979) and 250 kg/ha reverted superphosphate were combine drilled into conventionally cultivated seed-beds in nine-row plots each 1.6 m wide x 25 m long. The median seeding date was May 31.

As the experimental wheat crops attained nominated phases of development or growth stages as described by the Feekes' scale (Large, 1954) *viz.* crop emergence (Growth Stage 1), early tillering (Growth Stage 2), late tillering (Growth Stage 5), and late stem elongation (Growth Stage 9) appropriate plots were treated with pelleted urea (46% N), crystalline ammonium sulphate (21% N), a coarsely granulated lime/ammonium nitrate mix (26% N) and finely crystalline potassium nitrate (13% N) each at rates which supplied 75 kg N/ha. The median dates for the applications of the nitrogen fertilizers were:

Growth Stage 1 : July 7
Growth Stage 2 : August 14
Growth Stage 5 : October 1
Growth Stage 9 : November 16

In all cases, the nitrogen fertilizers were topdressed onto the soil surface.

The trial design was a split plot, with three replicates laid out in blocks. The main plot treatments (4) were the nitrogen fertilizers and the sub plot treatments (4) were the times of nitrogen application. A single nil nitrogen 'control' plot was included in each replicate.

Prior to each application of the nitrogen fertilizers soil samples were taken from untreated areas within each site for laboratory determinations of concentrations of nitrate-nitrogen and ammonium-nitrogen both before and after a 7-day incubation of field-moist soil at 37 °C (Quin, *et al.*, 1982).

For each experimental site, monthly rainfall data for the winter-sown wheat growing season June to February inclusive were obtained from nearby New Zealand Meteorological Service rainfall observation stations.

The experimental crops were harvested at maturity for grain yield data in the manner reported previously (Stephen *et al.*, 1983).

Grain yield data for individual sites were subjected to analyses of variance. For an overall analysis, sites were assigned on the basis of overall mean grain yield response to applied nitrogen into four grain yield response classes. An analysis of variance was performed within each response class using the 16 nitrogen fertilizer treatment means for each site in a split plot design with sites treated as blocks. Regressions of overall mean grain responses to fertilizer nitrogen were carried out on site parameters such as soil concentrations of plant available nitrogen and rainfall.

RESULTS

The experimental wheat crops established well and subsequently made good growth. Apart from slight "Take-all" damage, caused by *Gaumannomyces graminis* var *tritici* Walker at sites 1, 2, 4 and 9, the experimental crops were not visibly affected by other diseases and/or pests. The 1981/82 cropping year was notable for the severe drought conditions experienced in mid and late summer.

Grain yield data for individual experimental sites are given in Table 2. Although wheat grain yields and grain yield responses to applied nitrogen varied among cropping years and sites, fertilizer nitrogen induced significant

TABLE 2: Grain yields t/ha at individual experimental sites.

Cropping Year	1980/81				1981/82					1982/83			
Site	1	2	3	4	5	6	7	8	9	10	11	12	13
Grain yield response class	1	4	3	2	4	2	3	4	2	3	2	3	1
'Control' mean	5.50	5.49	5.06	4.03	4.82	2.95	6.12	4.88	3.49	4.45	4.64	5.67	5.16
'Nitrogen' mean	7.32	5.52	5.62	5.15	4.81	3.93	6.43	4.44	4.83	4.92	6.00	6.35	7.01
L.S.D. (P = 0.05)	0.62	0.22	0.15	0.30	0.20	0.17	0.25	0.73	0.33	0.10	0.19	0.15	0.43
Significance	**	n.s.	**	**	n.s.	**	*	n.s.	**	**	**	**	**
Nitrogen Fertilizers													
Urea	7.38	5.58	5.49	5.37	4.86	3.76	6.45	4.53	4.89	4.88	5.89	6.29	6.82
Ammonium sulphate	7.45	5.71	5.66	5.22	4.71	3.79	6.52	4.35	4.98	4.86	6.01	6.41	7.48
Ammonium nitrate	7.39	5.51	5.60	5.32	4.77	3.98	6.20	4.45	4.86	4.94	6.00	6.38	6.93
Potassium nitrate	7.06	5.27	5.74	4.68	4.92	4.17	6.57	4.42	4.58	4.99	6.07	6.32	6.81
L.S.D. (P = 0.05)	0.83	0.44	0.42	0.73	0.42	0.15	0.61	0.35	0.69	0.20	0.14	0.32	0.99
Nitrogen Application Times													
Emergence	7.41	5.42	5.72	5.23	4.80	4.19	6.39	4.06	5.24	5.02	6.17	6.40	7.36
Early Tillering	7.36	5.54	5.63	5.44	4.84	4.14	6.34	4.42	5.11	5.02	6.21	6.41	7.35
Late Tillering	7.87	5.54	5.59	5.37	4.74	3.89	6.45	3.96	5.10	4.98	6.15	6.51	7.51
Late Stem Elongation	6.64	5.58	5.55	4.56	4.86	3.48	6.56	5.30	3.85	4.66	5.46	6.07	5.82
L.S.D. (P = 0.05)	0.43	0.14	0.10	0.21	0.14	0.12	0.17	0.50	0.23	0.07	0.13	0.10	0.30
Subplot Coefficient of Variation (%)	6.9	3.2	2.2	4.8	3.4	3.5	3.2	13.5	5.6	1.7	2.6	1.9	5.0

positive responses in grain yields at ten sites and at the other three caused small non-significant effects. Positive significant mean grain yield responses to applied nitrogen 75 kg N/ha, ranged from 0.31 t/ha to 1.85 t/ha and averaged 0.96 t/ha or 12.8 kg/kg N. Differences among the nitrogen fertilizers were not significant except at sites 6 and 11 where wheat treated with potassium nitrate gave the highest grain yields while wheat treated with urea gave the lowest response.

At the majority of responsive sites, applications of nitrogen fertilizers at late stem elongation gave grain yields inferior to those from applications made at earlier stages of growth. At all responsive sites, the nitrogen fertilizer × time of nitrogen application interation was not significant.

For an overall analysis, grain yield data for individual sites were assigned to grain yield responses classes (Table 2). Class 1 included sites where the overall mean grain yield response to fertilizer nitrogen exceeded 1.5 t/ha, Class 2 sites where the overall mean grain yield response fell in the range 0.75 t/ha to 1.5 t/ha, Class 3 sites where the overall mean grain yield response was significant but not more than 0.75 t/ha and Class 4 sites where the overall mean grain yield response was not significant. Analysis of variance of grain yield data combined in Class 1 showed no significant differences between grain yields induced by individual nitrogen fertilizers applied at the same time and that nitrogen applied at late stem elongation was significantly less effective than nitrogen applied at each of the three earlier stages of growth (Table 3). Analyses of variance in Classes 2 and 3 yielded similar patterns in grain yield responses (Table 3). Analyses of variance in Class 4 showed no significant differences between nitrogen fertilizers. In this class, unlike other classes, a significantly higher yield was associated with fertilizer nitrogen applied at stem elongation than with earlier applications (Table 3). For each grain yield responses class, the nitrogen fertilizer × time of nitrogen application interaction was not significant.

TABLE 3: Grain yields (t/ha) for grain yield response classes.

Grain yield response class	1	2	3	4
'Control' mean.	5.33	3.78	5.33	5.06
'Nitrogen' mean	7.16	4.97	5.83	4.92
Nitrogen fertilizers				
Urea	7.10	4.98	5.78	4.99
Ammonium sulphate	7.47	5.00	5.86	4.92
Ammonium nitrate	7.16	5.04	5.78	4.91
Potassium nitrate	6.93	4.88	5.91	4.87
L.S.D. (P = 0.05)	0.59	0.36	0.16	0.28
Nitrogen application times				
Emergence	7.38	5.20	5.88	4.76
Early Tillering	7.36	5.22	5.85	4.93
Late Tillering	7.69	5.13	5.88	4.75
Late Stem Elongation	6.23	4.34	5.71	5.25
L.S.D. (P = 0.05)	0.39	0.15	0.14	0.33

Grain yield responses to fertilizer nitrogen were regressed on soil concentrations of 'plant-available' nitrogen parameters but correlations were poor and not significant.

Regressions of grain yield responses to applied nitrogen on monthly rainfall and rainfall over longer periods, up to eight months, were calculated. Overall mean grain yield response to applied nitrogen and mean grain yield responses to nitrogen fertilizer applied at each growth stage correlated best with total rainfall over the five month period September to January (Table 4).

TABLE 4: Regressions of grain yield responses to fertilzer nitrogen on total rainfall over the five month period September to January.

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Overall mean grain yield response	0.85**
Mean grain yield response to fertilizer nitrogen applied at:	
(i) emergence	0.71**
(ii) early tillering	0.73**
(iii) late tillering	0.80**
(iv) late stem elongation	0.72**

DISCUSSION

The principle objectives of this research were to establish whether the efficacies of fertilizers used as sources of nitrogen for winter-sown wheat differ significantly and/or vary differentially with the timing of their application.

Apart from two sites where potassium nitrate which is not used locally in commercial wheat cultivation, outyielded urea, mean grain yields induced by individual nitrogen fertilizers did not differ significantly. Also, mean grain yields associated with each nitrogen fertilizer within each grain yield response class did not differ significantly. It was concluded, therefore, that urea, ammonium sulphate and lime/ammonium nitrate are equally effective sources of nitrogen for wheat drilled in the late-autumn/early-winter period in northern Canterbury.

In one previous study which compared nitrogen fertilizers used in wheat cultivation, the nitrogen fertilizer x time of nitrogen application interaction was significant and suggested that the efficacy of urea was affected differentially by the timing of its application (Feyter and Cossens, 1977). In that study, the timing of nitrogen fertilizer application was confounded with the method of nitrogen fertilizer application. An early application of urea, drilled in contact with the wheat seed, caused germination injury whereas a later application topdressed onto the established crop had no adverse effect and caused a higher grain yield. In this research programme urea, ammonium sulphate, lime/ammonium nitrate and potassium nitrate which were topdressed onto established crops did not cause crop damage and when applied at the same time, generally had similar effects on grain yields. It was concluded that, provided their method of application does not result in crop damage, the relative efficacies of the nitrogen fertilizers tested are not differentially affected by the timing of their application.

On the other hand, irrespective of fertilizer source, the efficacy of nitrogen applied at different times or stages of growth, varied. Data from Class 1-3 sites where overall mean grain yield responses to fertilizer nitrogen were positive and significant, the earlier applications made either soon after crop emergence, at early tillering or at late tillering were equally effective in improving grain yield and were more effective than the last application made at late stem elongation. In contrast to this more common experience, Class 4 which included data from sites at which individual overall mean grain yield responses to fertilizer nitrogen were not significant, the earlier applications of fertilizer nitrogen induced grain yields inferior to that obtained from the last application. This effect was statistically significant but it is seen as an aberration resulting from the disproportionate contribution of site 8 data to Class 4 grain yields. At site 8, the experimental wheat crop was drilled later in the winter than was the case at all other sites and was severely droughted throughout development following ear emergence. It is considered that these factors contributed to the lower grain yields at site 8 associated with the earlier applications of fertilizer nitrogen. Notwithstanding the trend seen in Class 4, it was concluded applications of fertilizer nitrogen to wheat made prior to the apparent cessation of tillering are more effective in improving grain yield than later applications.

In this investigation, nitrogen fertilizers applied to winter-sown wheat at intervals throughout the ten-week period mid July to the end of September, had similar effects on grain yields and it is concluded therefore that some current recommendations concerning the timing and number of nitrogen fertilizer applications to the wheat crop may be extravagantly detailed.

In the dry-land wheat crops used to test the efficacies of nitrogen fertilizers, grain yield responses to applied nitrogen were significantly associated with total rainfall for the September – January period and thus emphasised a continuing need for adequate soil moisture throughout much of the period of maximum growth and development in wheat.

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