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THE EFFECT OF TIME OF NITROGEN APPLICATION ON THE YIELD AND QUALITY OF CONTRASTING CULTIVARS OF AUTUMN SOWN WHEAT

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ABSTRACT

Nine cultivars of wheat, Abele, Karamu, Kotare, Oroua, Rongotea, Tui, Weka, 3024,01 and 3033,06, were sown in May, June and October on Wakanui soils at Lincoln. In addition, Otane was sown in October. Three nitrogen fertilizer regimes were applied, 50 kg/ha at late tillering, 50 kg at late tillering and 50 kg at booting, and 100 kg at late tillering.

Eight autumn sown and four spring sown cultivars were harvested. Autumn wheats averaged 7.7 t/ha at 1.7% grain nitrogen and spring wheat 5.2 t/ha at 2.1% grain nitrogen.

There was generally an inverse relationship between yield and grain nitrogen content. In the autumn sowings, applying extra nitrogen at tillering raised yield and grain nitrogen percentage. Applying the extra nitrogen at booting raised yield by a similar amount but had a greater effect on grain nitrogen. In the spring sowing, applying extra nitrogen had no effect on yield or grain nitrogen percentage.

Bake scores and grain protein concentrations were higher for spring wheat, but responded less to nitrogen treatments. There were significant cultivar differences in the relationship between bake score and flour protein, with newer lines achieving similar bake scores at flour proteins of 1-1.5% below older wheat cultivars. Bake scores and flour proteins of May sown Rongotea and Oroua did not respond to increased nitrogen at tillering, but showed a large response to nitrogen at booting. Other autumn sown cultivars did not show such a marked response in both bake score and flour protein to extra nitrogen.

Additional Key Words: Grain nitrogen, bake score, grain weight.

INTRODUCTION

Following deregulation of the New Zealand wheat industry, domestic wheat growers now have to compete with imported wheat in terms of price and quality. This is particularly true of milling wheat, most of which is used for breadmaking in New Zealand (Logan, 1985). Wheat production in major countries exporting this type of wheat, such as Australia, is characterized by extensive low cost production systems, and by low rainfall-high temperature conditions during the latter part of the growing season, giving low yields of high quality wheat.

New Zealand millers have sharply raised their acceptable quality requirements for New Zealand wheat to match those of imported Australian wheat. The only cultivars which consistently approach the new required quality standards are spring sown cultivars such as Otane, which can only be sown in the spring, and Oroua, which suffers from susceptibility to stripe rust.

One method of improving quality is late applications of nitrogen, which, although known for some time to increase grain nitrogen (Scott, 1981) has only recently been investigated in detail as a means of boosting grain nitrogen and, hopefully, baking score (Guy, 1986, McCloy, 1986; Drewitt, 1986). However, the effect of late nitrogen depends on cultivar (Drewitt, 1986; McCloy, 1986).

This trial investigated the effect of three nitrogen fertilizer regimes on a number of cultivars sown on three dates in a trial orginally set up to study cereal development. The hypotheses under investigation were that:

1. Autumn sown wheats give higher yields but grains of lower quality than spring sown wheats.

2. Extra nitrogen applied at tillering will increase grain yield, but nitrogen applied at booting will increase grain quality.

Quality for this trial was defined as grain weight, grain nitrogen and bake score. Cultivars of contrasting quality were included in the trial to see if these hypotheses were generally applicable to wheat.

MATERIALS AND METHODS

The experiment was carried out in 1986-87 on a Wakanui silt loam at the MAFTech Research Farm at Lincoln. Soil quick test data before ploughing for the top 150 mm of soil were pH 5.8, Ca 12, K 12, P 19, and Mg 23. The previous crop on the site was part peas and part lentils. The paddock was ploughed in April and maxitilled twice. Before each planting the plots were again maxitilled to produced a suitable seedbed.

A split-split plot design was used, with sowing dates as main plots, cultivars as sub plots and nitrogen treatments as sub-sub plots. There were two replicates and each sub-sub plot was 6 m by 1.5 m.

Sowing dates were 6 May, 5 June and 3 October. The last was intended to be 1 July, but wet weather delayed drilling for three months.

Cultivars sown were Abele, Karamu, Kotare, Oroua, Otane (October sowing only), Rongotea, Weka, Tui, 3024,01 and 3033,06. The last three cultivars were unreleased lines from DSIR Crop Research Division, Tui showing promise as a high yielding feed wheat, and the other two as high quality wheats. All seed was treated with Baytan IM. The plots were drilled with a precision drill at a seed rate designed to give 200 plants/m^2. Superphosphate at 10 kg/ha P was drilled with the seed.

Nitrogen treatments were:

(a) 50:0

50 kg/ha of nitrogen at late tillering (growth stage 26,30 in Rongotea).

(b) 50:50
50 kg/ha at both late tillering and booting (GS 37).
(c) 100:0
100 kg at late tillering.

The nitrogen was applied as ammonium sulphate, broadcast by hand. Application dates were 17 September and 31 October for the May sowing, 17 September and 17 November for the June sowing and 17 November and 5 December for the October sowing.

The plots were sprayed with Glean herbicide at tillering, and were sprayed with appropriate fungicides to keep the crop free of disease.

On 6 August and at the time of the first nitrogen application in each sowing, soil samples were taken at 15 cm intervals from 0-60 cm. Soil nitrate and ammonium nitrogen and mineralizable nitrogen were determined by methods described by Quin *et al.*, (1982).

At maturity, areas of approximately 2.5 m^2 were hand harvested from each plot. A subsample from the May and October sowings was taken for analysis of yield components. The main sample was machine threshed and grain yield, moisture, size and nitrogen content determined. Grain nitrogen determinations were by the Kjeldahl method. For the first and third sowing dates, bake tests and flour protein were determined on bulked samples of certain cultivars by the DSIR Wheat Research Institute. The bulk fermentation (BF)baking test was used for Weka, and the mechanical dough development (MDD) test was used for Kotare, Oroua, Rongotea, 3024,01 and 3303,06.

RESULTS

Weather

Table 1 summarizes the actual and long term average temperature, sunshine hours and rainfall at the Lincoln College meterorological station 1.5 km west of the experimental site.

The season was characterized by a milder April and May and a much warmer January than average. Sunshine hours were well above normal in May and January but below normal in October. Rainfall was below average for May and June but 82% above normal over the next five months. However, rainfall was only half the normal in January.

Soil moisture data taken from an adjacent winter wheat trial showed that gravimetric soil moistures in the top 150 mm did not drop below 10% until after mid-January.

Mineralizeable nitrogen levels (0-600mm) averaged 225 kg/ha on 6 August but rapidly declined through the spring to be 70 kg/ha at the end of tillering for the autumn sowings (18 September), and 60 kg/ha for the October sowing (17 November). Using the method of Quin *et al.*, (1982), the base yield without application of nitrogen fertilizer was calculated from the August data to be 4.7 t/ha.

General

The wet spring was highly conducive to diseases such as stripe rust and frequent fungicide applications were necessary, particularly to Oroua and Rongotea which are susceptible cultivars. The trial was infested with Phalaris minor, and there were localized outbreaks of wild oats and Californian thistles.

Maturity Data

Rongotea was typical of most cultivars and took 205 days from sowing to mid anthesis and 51 days from anthesis to maturity in the May sowing. For the June sowing the times were 183 and 46 days and for the October sowings 84 and 38 days. In winter sowings, Karamu, the earliest maturing cultivar, and Abele, the latest, were respectively 15-20 days faster and 7 days slower to anthesis, but were little different in time from anthesis to maturity. There was little difference in maturity times between spring sown cultivars.

Table 1 1986-87 and long term average monthly mean daily temperatures, total sunshine and total rainfall.

Month	Daily temperature (^0C) Actual	Daily temperature (^0C) Mean	Sunshine (hours) Actual	Sunshine (hours) Mean	Rainfall (mm) Actual	Rainfall (mm) Mean
May	8.8	8.5	150	124	35	65
June	6.4	5.7	115	113	30	63
July	5.5	5.3	121	118	119	68
August	5.5	6.6	131	141	125	54
September	8.5	8.8	163	162	46	47
October	11.9	11.3	129	209	100	46
November	12.9	13.1	213	211	95	52
December	15.8	15.2	224	217	27	58
January	18.0	16.4	280	219	7	55

Because of the delay in the third sowing, the true winter wheats did not become vernalized, and only 4 cultivars which did not need vernalization were harvested, i.e. Karamu, Oroua, Otane and Rongotea.

Grain yield, grain nitrogen data, grain weight, and yield component data are presented in Table 2. All yields and nitrogen percentage data are presented on a 14% moisture basis. There were no significant interactions between cultivar and nitrogen in Table 2.

There was little difference in yield and nitrogen data between the two autumn sowings, and so they have been combined for the general cultivar and nitrogen analysis.

Ear numbers and grain numbers per ear were not measured on the June sowing, and, so for the autumn wheats, these data do not necessarily match the other data in Table 2.

Autumn sowings of Karamu, which was the first cultivar to mature, were badly damaged by birds and so were omitted from the analysis.

Grain Yield

The two sowings of autumn wheat averaged 7.7 t/ha. Highest yields were obtained from the feed wheats Abele, Tui, and also the new line 3024,01 whereas lowest yields were from the high quality wheats Weka, Kotare and Oroua. The 50:50 and 100:0 nitrogen treatments gave similar yields, which were about 1 t/ha higher than the 50:0 treatment.

For the spring sowing, wheat yields averaged 5.2 t/ha. There was considerable variation in yield, particularly for the bird damaged Karamu, and so yield differences between cultivars and nitrogen treatments failed to achieve significance. Yields of Oroua and Rongotea sown in spring were only 67% of autumn yields (Table 2).

Grain weight

Grain weights averaged 45.8 mg in the autumn sowings and 44.2 mg in the spring sowing. Grain weights in the autumn sowing varied markedly between cultivars, with Abele, Rongotea and Weka having highest grain weights, and Oroua and Tui lowest grain weight. Highest grain weights were obtained from the 50:50 treatment, significantly higher than from the single nitrogen dressings. In the October sowing Otane and Rongotea had the highest grain weights. There was no significant effect of nitrogen.

Table 2 Grain yield (kg/ha), grain nitrogen content (%), grain nitrogen yield (kg/ha), ear population (ears/m²), grains/ear, and grain weight (mg) for (a) May and June sowings combined, (*May sowing only) and (b) October sowing.

	Grain Yield	Grain N%	Grain N Yield	Ear* No.	Grains* /ear	Grain Weight
(a) Autumn sowings (May and June)						
Cultivars						
Tui	8590	1.61	119	697	33.5	39.8
Abele	8240	1.56	111	477	36.9	48.6
3024,01	8220	1.59	113	638	30.5	47.3
3033,06	7730	1.63	109	658	30.4	41.5
Rongotea	7480	1.79	115	635	25.2	51.1
Weka	7150	1.75	107	518	30.0	50.4
Kotare	7070	1.88	114	786	20.7	45.6
Oroua	6900	1.81	107	718	25.3	41.6
LSD (5%)	792	0.12	18	88	6.7	1.3
Nitrogen						
50:0	7090	1.58	96	637	27.2	45.5
50:50	7890	1.82	122	642	30.2	47.1
100:0	8040	1.70	117	643	29.8	44.8
LSD (5%)	270	0.04	5	62	2.4	0.6
(b) Spring sowing (October)						
Cultivars						
Karamu	5750	1.78	88	431	31.7	42.1
Otane	5480	2.01	95	295	39.1	47.1
Rongotea	4990	2.16	93	442	23.8	46.5
Oroua	4680	2.27	91	324	35.1	40.8
LSD (5%)	1120	0.13	19	114	11.5	2.1
Nitrogen						
50:0	5220	2.02	90	376	31.9	44.3
50:50	5170	2.04	90	365	32.3	44.4
100:0	5280	2.10	95	377	33.0	43.8
LSD (5%)	350	0.11	9	35	2.9	1.2

Grain Nitrogen Percentage

Grain nitrogen concentration averaged 1.70% in the autumn sowings and 2.05% in the spring sowing. Oroua and Rongotea, common to both, had similar differences in grain nitrogen between autumn and spring sowings. In the autumn sowings high grain nitrogen concentrations occurred in Kotare, Oroua, Rongotea and Weka, and low concentrations in Abele, Tui, 3024,01 and 3033,06. There were large differences between nitrogen treatments with the 50:50 treatment significantly higher than the 100:0, which in turn was significantly higher than 50:0. In the spring sowing, Oroua and Rongotea had the highest grain nitrogen concentrations. There were no significant differences between nitrogen treatments.

Grain Nitrogen Yield

The yield of nitrogen in the grain averaged 112 kg/ha in the autumn sowings and 92 kg/ha in the spring sowing. In autumn sowings there was no significant difference between cultivars, but the 50:0 nitrogen treatment had significantly lower grain nitrogen yield. In the spring sowing there was no significant difference between cultivars or nitrogen treatment.

Grain Yield v Grain Protein Percentage

In Figure 1 the mean grain yield for each cultivar for each nitrogen treatment for the autumn and spring sowings are plotted against grain nitrogen.

In the autumn sowings, extra nitrogen at tillering (100:0) and at booting (50:50) increased both grain yield and grain nitrogen, but the increase in grain nitrogen percentage was greater when the extra nitrogen was applied at booting.

Initial regression analysis showed that the regression lines for each nitrogen treatment within each sowing were nearly parallel, with slopes within 20% of each other. So covariance analysis was used assuming that the lines were parallel and these are plotted in Figure 1.

In the spring sowing, extra nitrogen at tillering or booting had no discerned effect on grain yield or nitrogen percentage, and so a common regression line has been plotted for these data in Figure 1.

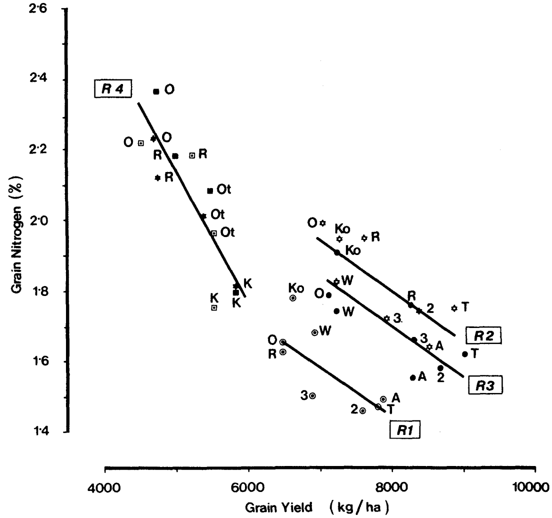

Figure 1. Relationship between grain nitrogen percentage and grain yield for the Autumn (combined May and June) sowing and the Spring (October) sowing.

Symbols: Autumn ○ 50:0, ☆ 50:50, ● 100:0,
Spring □ 50:0, ★ 50:0, ■ 100:0.

Abbreviations: A Abele, K Karamu, Ko Kotare, O Oroua, Ot Otane, R Rongotea, T Tui, W Weka, 2 3024,01, 3 3033,06.

Autumn 50:0 (R1) : $GN = 1.52 - 0.000143\ (GY - 7500)$
50:50 (R2) : $GN = 1.88 - 0.000143\ (GY - 7500)$
100:0 (R3) : $GN = 1.78 - 0.000143\ (GY - 7500)$
($r^2 = 0.60^{***}$; s.e. slope = 0.00002)

Spring: (R4) : $GN = 1.82 - 0.000363\ (GY - 5000)$
($r^2 = 0.71^{**}$; s.e. slope = 0.000068)

Regression equations (GN = grain nitrogen percentage, GY = grain yield (kg/ha) :

Grain Weight v Grain Yield and Grain Nitrogen Percentage

There was no relationship between grain weight and grain yield, except that spring sowings had a lower yield at a given weight, due to lower numbers of ears (Table 2). There was also no relationship between grain weight and grain nitrogen percentage, except that spring sowings generally had a higher nitrogen percentage for a given grain weight.

Ear Numbers and Grains per Ear

Ear numbers averaged $641/m^2$ in the May and $373/m^2$ in the October sowings. Grains/ear averaged 29.1 in the May sowing and 32.4 in the October sowing. There were significant differences between cultivars in both the May and October sowings, but not between nitrogen treatments.

Flour Protein v Grain Protein

There was a close relationship between flour protein (FP) and grain protein (GP) (grain nitrogen * 5.7) for Kotare, Oroua, Otane, Rongotea, Weka, 3024,01 and 3033,06 from the May and October sowings at the three nitrogen treatments:

$FP = 0.38\ (\pm0.34) + 0.90\ (\pm0.02)\ GP\ R^2=96.7^{**}$

There was no obvious effect of cultivar or nitrogen treatment on this relationship, which over the range of proteins in this study, means that flour protein was 94% of grain protein.

Flour Protein and Bake Scores

Flour protein and bake scores for Kotare, Oroua, Rongotea, Weka, 3024,01 and 3303,06 for the May and October sowings are detailed in Table 3. This table shows that:

(a) The spring sown wheat had a much higher bake score than the autumn sown wheat. For Oroua and Rongotea, which were common to both sowings, the difference averaged 9 MDD points.

(b) The 50:50 nitrogen treatment had a large and simultaneous effect on bake score and flour protein on autumn sown Oroua and Rongotea, raising BS by 7 and 3 MDD points respectively. However, the 100:0 treatment had less effect on flour protein and no effect on bake score.

(c) The extra nitrogen treatments had less effect on Kotare, 3024,01 and 3033,06, and the 100:0 treatment was up to 3 bake score points higher than the 50:50 treatment.

(d) The extra nitrogen treatments also had less effect on the spring sowings. Bake scores of Oroua were only raised 3 points and bake scores for Rongotea were reduced.

(e) There were large differences in the ratio of bake score to flour protein between cultivars and sowing dates. Rongotea, with a ratio of 1.77 and 2.16, had the lowest bake score for a given flour protein for both sowing dates, whilst 3024,01 and 3033,06 had the highest ratio of bake score to flour protein of all the autumn sown wheats, and Otane the highest for the spring sown wheats.

(f) There was little effect of nitrogen treatment on the Bulk Fermentation score or flour protein content of Weka.

DISCUSSION

In this experiment, autumn sown wheat produced higher yields but grains of lower quality than spring wheat. This supports previous findings that delaying sowing reduces wheat yield (Hanson *et al.*, 1982; Carter and Stoker, 1985).

The major reason for the higher yields in the May sowing was the greater number of ears. Abele was an exception, having low number of ears, but a high number of grains per ear and a high grain weight. In New Zealand, grain yield is strongly correlated with ear populations (Hampton *et al.*, 1981). Visually, the June sowing had a similar number of ears to the May sowing, and certainly much higher populations of ears than the October sowing. A similar relationship between time of sowing, ear numbers and yield has been found in winter and spring sown barley (Ellis and Russell, 1984). Total tiller numbers before stem elongation were similar in both autumn and spring sowings, and so the greater number of ears in the May sowing was probably due to the slower rate of reproductive development compared to growth, which results in more tillers being physiologically able to become

Table 3 Flour protein % (FP) and Mechanical Dough Development bake score (BS) and the ratio of mean bake score to flour protein for milling wheats for May and October sowings (* = Bulk Fermentation).

Sowing Date		May					October				
Nitrogen Treatment		50:0	50:50	100:0	Mean	Ratio	50:0	50:50	100:0	Mean	Ratio
Cultivar											
Otane	FP	-	-	-	-	-	10.0	10.3	10.6	10.3	2.52
	BS	-	-	-	-	-	25	28	26	26	-
Oroua	FP	8.1	10.1	9.2	9.1	1.97	11.9	11.8	12.3	12.0	2.33
	BS	16	23	16	18	-	26	29	28	28	-
Rongotea	FP	8.9	10.2	9.6	9.6	1.77	11.7	11.6	11.5	11.6	2.16
	BS	16	19	16	17	-	26	25	25	25	-
Kotare	FP	8.9	10.3	9.8	9.7	2.16	-	-	-	-	-
	BS	18	21	23	21	-	-	-	-	-	-
3024,01	FP	7.5	8.1	8.6	8.1	2.47	-	-	-	-	-
	BS	20	19	22	20	-	-	-	-	-	-
3033,06	FP	7.9	9.1	9.0	8.7	2.41	-	-	-	-	-
	BS	19	20	23	21	-	-	-	-	-	-
Weka	FP	8.7	9.2	8.7	8.9	-	-	-	-	-	-
	BS*	38	40	38	39	-	-	-	-	-	-

reproductive when the main stem becomes reproductive (Masle, 1985). However, seeding rates in this trial were below those currently recommended for spring sowing (MAF, 1986).

Grain yields from the 50:50 and 100:0 treatments in the autumn sowings were similar. This indicates that the 50 kg of nitrogen per hectare applied at late tillering did not restrict ear and grain development until after booting, although final grain numbers per ear in the 50:0 treatment in the May sowing were significantly lower.

Although soil nitrogen availability at the end of winter was relatively high, the high spring rainfall was conducive to a high yield potential, and also associated with a rapid reduction in availability of soil nitrogen. Possibly greater yields and nitrogen contents could have been obtained if more nitrogen had been applied. Indications from district trials were that, to optimize yields, normal rates of nitrogen should have been increased this season (E.G.Drewitt, pers comm).

Extra nitrogen at tillering reduced grain weight in the autumn sown crop. This has often been observed in wheat crops, and was presumably due to competition for assimilate among the increased number of grains per ear (Scott, 1981).

Despite a similar increase in grain numbers, extra nitrogen at booting probably increased grain size through its effect on supplying extra nitrogen to the plant during grain filling. This would have reduced translocation of nitrogen out of the leaves to the developing ear, hence enabling the leaves to maintain a high rate of photosynthesis and prolonging grain growth (Gregory *et al.*, 1981).

The reduced numbers of ears may have resulted in the spring sown crop being partly sink limited in that more assimilate was available to the reduced number of grains. Hence despite the increase in temperature during grain filling (Table 1), which would have reduced the duration of grain filling, and hence grain size (Vos, 1981), grain weights were only 2% lower in Oroua and 8% lower in Rongotea sown in spring compared to autumn. Sink limitation of carbohydrate supply rather than source limitation could also explain the lack of response of grain weight to nitrogen treatments in the October sowing (Evans *et al.*, 1975).

Grain protein percentage was considerably higher in the spring sown wheats. In Oroua and Rongotea, this increase was greater than the decrease in grain weight, so that the amount of nitrogen in each grain increased by 23% and 10% respectively. This must have been a result of a greater rate of translocation of nitrogen relative to carbohydrate, either due to the reduced number of grains that the nitrogen could move into, or to a reduced rate of carbohydrate assimilation under the higher temperatures experienced during grain filling in the spring sown crop, or to a combination of these (Evans *et al.*, 1975; Vos, 1981).

Bake scores were also higher in the spring sown wheats. Increased mean temperatures also increase bake score, but higher bake score – flour protein ratios indicate that temperatures increase bake score relatively more than grain protein content, suggesting an alteration in the structure of grain protein with increasing nitrogen, (Stevenson, 1987).

Grain protein is not a good measure of baking quality (Mitchell, 1985), and Table 3 shows considerable variation in the ratio between bake score and flour protein among cultivars. These can be interpreted in two ways. At a given flour protein of say 9%, the mean bake score of autumn sown wheat ranges from 16 for Rongotea to 22 for the two numbered lines. Conversely, to achieve a bake score of 20 required a flour protein of 11.3% for Rongotea, but only around 8.2% for the two numbered lines. Similarly, for spring wheats, a bake score of 26 requires a flour protein of 12% for Rongotea and 10.3% for Otane. The different relationships between bake score and flour protein for different cultivars is also evident in the data presented by Drewitt (1986), Stevenson (1987), and Grama *et al.* (1987). These results suggest that cultivars such as 3024,01 and 3033,06, which have a much higher bake score for a given grain protein, should be able to achieve higher bakes scores for a given yield, or vice versa, compared with cultivars such as Rongotea. In fact the grain nitrogen percentages of the two numbered lines were very similar to those of the feed wheats Abele and Tui, which are amongst the highest yielding wheats currently grown in New Zealand. This indicates that protein quality must be markedly different between the numbered lines and the feed wheats. It also indicates that superior bread making quality may not necessarily be associated with high levels of flour protein, as suggested by Grama *et al.*, (1987). There appears to be a definite need for closer examination of protein quality in agronomic research so that explanations can be found for the different effects of cultivar and nitrogen fertilizer on protein content and bake score.

Purchase of cultivars on the basis of grain nitrogen is convenient because rapid determinations of grain nitrogen by near-infra-red reflectance techniques can be made at the weighbridge. However, unless the purchase price is adjusted to take account of the difference in the relationship between bake score and grain protein between cultivars, growers of the newer cultivars will be disadvantaged.

The strong inverse relationship between grain yield and grain nitrogen, resulting in an almost constant yield of grain nitrogen, has been demonstrated before (e.g. Pushman and Bingham, 1976), and indicates that breeding to increase both grain protein and yield may be difficult. However, this and other studies (Pushman and Bingham, 1976; Guy, 1986; McCloy, 1986) show that farmers can increase both yield and nitrogen content by the judicious use of nitrogen fertilizer.

However, the effect of nitrogen applications on baking quality of the autumn sown milling wheats was dependent on cultivar. The large increases in bake score with late applications of nitrogen in Oroua and Rongotea contrast with the relative lack of response in Kotare, 3024,01 and 3033,06. This again may be related to different types or amounts of protein structures in these wheats. Pushman and Bingham (1976) found in many British cultivars, late nitrogen raised protein content but did not give the expected improvement in bake score. They suggest the use of protein fractionation studies to establish the reason for this. There may also be differences in the uptake, translocation and accumulation of nitrogen between different cultivars (Quin and Drewitt, 1979) which could be taken advantage of in crop management packages.

There was no response in grain nitrogen and grain quality to increased or split applications of nitrogen in the spring wheat. This contrasts with marked increases in quality with late nitrogen in spring sown wheat at Winchmore (Drewitt, 1986). However, this spring crop was sown later and had less nitrogen put on at booting than the Winchmore study. Figure 1 would suggest that some response to nitrogen would occur as yield potential, as reflected by time of sowing, increased. Yield and quality responses in spring wheats vary widely between years (Drewitt and Dyson, 1987) and reflect the great variation in spring growing seasons in Canterbury and resulting effects on factors such as development times, leaf area development and persistence.

These data are from a single trial, and so general applicability of the results to other sites and seasons is limited. However, the relationships between grain yield and grain nitrogen content and between bake score and flour protein found in this study have important implications for the interpretation of current and future research aimed at improving the quality of the New Zealand wheat crop without sacrificing yield.

CONCLUSIONS

1. Spring sown wheat had lower yields but a higher grain nitrogen content that autumn sown wheat. The higher grain nitrogen content was associated in milling wheats with a higher bake score.
2. There was an inverse relationship between yield and grain nitrogen irrespective of sowing date, so cultivars with inherently high concentrations of grain nitrogen are likely to have a lower potential yield.
3. Increases in nitrogen fertilizer increased both yield and grain nitrogen content in autumn sown wheat, but not in spring sown wheat.
4. The relationship between protein and bake score depended on cultivar, some newer cultivars having a much higher bake score at a given protein content than established cultivars.
5. The response to time of nitrogen application also depended on cultivar. Newer cultivars may not be so responsive to late nitrogen applications.
6. Further research on the effect of nitrogen and cultivar on grain yield and quality should include examination of the composition of the grain protein.

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