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# EFFECTS OF NITROGEN FERTILIZER ON THE YIELD AND MALTING QUALITY OF BARLEY ON THE SOUTHERN DARLING DOWNS, QUEENSLAND

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SUMMARY

**The effect of nitrogen fertilizer on the yield and malting quality of barley was studied over four seasons on red loam soils.**

**Increases of applied nitrogen tended to increase yield and protein percentage of grain and decrease predicted extract and bushel weight.**

**However, at the lower rates of nitrogen application, grain yield could be considerably increased while grain quality was maintained at an acceptable level.**

**The economic implications of the results are discussed.**

## I. INTRODUCTION

The southern Darling Downs is one of the major barley-growing areas in Queensland, accounting for approximately 25% of the State's production.

The heavy black soils of the area are generally avoided for barley growing as their inherent total nitrogen content could be expected to produce high-protein grain not wanted by maltsters. Malting barley production therefore is confined on the southern Downs to a variety of soil types of relatively light texture and colour with low to medium-high total nitrogen content. These soils produce good quality malting grain but yields are not high—15–30 bus/ac on old cultivations.

S. R. Walsh (unpublished data) demonstrated in 1960 that significant yield increases of barley could be obtained on red loam soils by the application of urea or ammonium sulphate, but also found that grain protein content tended to increase.

The series of trials reported here was initiated in 1961 to examine the effects of urea application on yield, grain protein content and malting quality.

## II. MATERIALS AND METHODS

The 1961 and 1962 trials were located on a red-brown loam soil in the Junabee district, and those in 1963 and 1964 on a similar soil type in the Swan Creek district, some 3 miles distant.

Soil analyses and cropping histories for the 1961, 1963 and 1964 trial sites are presented in Table 1. A general soil analysis from the 1962 site showed that soil reaction was neutral, available nitrogen low, available phosphorus low and available potassium high. This site had been cropped to barley in 1960 and 1961 and to maize in the summer of 1959-60.

**TABLE 1**

SOME DETAILS OF EXPERIMENTAL SITES (0–10 in.)

| Site | pH | Total N (%) | Avail. $P_2O_5$ (p.p.m.) | Repl. K+ (m-equiv. %) | Cropping History |
|---|---|---|---|---|---|
| Expt. 1 (1961) | 6·1 | 0·09 | 30 | 0·46 | Maize, maize, barley |
| Expt. 3 (1963) | 5·6 | 0·16 | 64 | 0·75 | Barley, sudan grass, barley |
| Expt. 4 (1964) | 6·1 | 0·12 | 44 | 1·05 | Oats, millet, sudan grass |

Immediately prior to sowing, a basal dressing of superphosphate (½ cwt/ac) was applied broadcast to each site to ensure an adequate supply of available phosphorus.

Trial design in each season was a 5 x 5 long-faced randomized block. Treatments were nil, ½, 1, 1½ and 2 cwt urea per acre. With the exception of the 2 cwt rate, the urea (46% N) was applied from the fertilizer box of the combine, falling through the same hose as the seed. Due to seedling mortality at the highest rate of application in the initial trial, this treatment was in subsequent trials applied broadcast immediately prior to sowing, to avoid intimate contact between seed and urea in the soil.

In all trials except the first, seedling stand counts were taken over the fortnight following first seedling emergence to determine treatment effects on seedling mortality and time of emergence.

Plot size, excluding buffer areas, was 1/40 ac. Two-pound grain samples were analysed for protein content and predicted extract of the grain. Bushel weight was also determined.

Immediately prior to harvest, whole-plant samples (1961) and aboveground parts (1962, 1963) were obtained from areas within each plot for determination of nitrogen percentage and dry-matter yield. Nitrogen was determined by the

Kjeldahl procedure and grain protein calculated using the factor N x 6·25. All grain protein percentages were calculated on the common basis of 13·5% moisture.

Predicted extract (P.E.) of the grain was calculated from the following formula:—

$$P.E. = 138{\cdot}2 - 3 \times I.C.\% - 9{\cdot}5 \times N\%,$$

where percentages are expressed on a moisture-free basis. Insoluble carbohydrate (I.C.) percentage was determined by the method of Bishop and Marx (1934).

The variety Prior was used in all experiments because of its popularity with both local maltsters and producers.

Rainfall and some experimental details are given in Table 2. It will be seen that all four trials were conducted under below-average rainfall conditions during the crop growth period. During the precropping fallow period, however, above-average rainfall was received in 1962, 1963 and 1964, while in 1961 the rainfall received during this period was below normal.

**TABLE 2**

SOWING AND HARVESTING DATES AND RAINFALL DATA

| Season | 1961 | 1962 | 1963 | 1964 |
|---|---|---|---|---|
| Sowing date | June 9 | July 23 | June 3 | June 10 |
| Harvesting date | Nov. 16 | Nov. 26 | Nov. 18 | Nov. 17 |
| Rainfall (in.), Jan. 1 to sowing* | 10·06 | 18·99 | 17·16 | 16·94 |
| Rainfall (in.) during cropping period— | | | | |
| June (av. 1·70) | — | — | 0·49 | 1·10 |
| July (av. 1·80) | 3·45 | 0·30 | 0·21 | 1·19 |
| Aug. (av. 1·40) | 1·62 | 2·15 | 2·14 | 0·80 |
| Sept. (av. 1·75) | 0·60 | 2·02 | 0·26 | 1·32 |
| Oct. (av. 2·32) | 1·30 | 1·38 | 1·13 | 2·35 |
| Nov. (av. 2·66) | 1·45 | 0·25 | 0·98 | 1·17 |

* District average rainfall from Jan. to May inclusive is 12·36 in.

## III. RESULTS

### (a) General Observations

Reduced seedling stand counts were noted at the 2 cwt/ac rate of urea in 1961, when the fertilizer was applied with the seed in all treatments. In 1962 a stand count taken following final seedling emergence revealed that no treatment had significantly reduced final stand, although there was an indication that the 1½ cwt rate had delayed final emergence of a proportion of the population. Accordingly, a series of stand counts were taken during the emergence period in 1963 and 1964 to determine treatment effects on time of emergence in addition to seedling mortality. The results of these counts are presented in Table 3.

In 1963, the ½ cwt application caused a delay in final emergence, while final stand count was not significantly reduced. Both 1 cwt and 1½ cwt urea applied with the seed resulted in delayed emergence and significant reduction in final stand count. The 2 cwt rate applied broadcast before sowing had no adverse effects on emergence or stand count. In 1964, the 1½ cwt rate significantly reduced the final stand count in addition to delaying emergence.

**TABLE 3**

Seedling Stand Counts for Ten 5-ft Lengths of Row at a Number of Dates Following Emergence—1963, 1964

| Treatment | 1963 | | | | 1964 | | |
|---|---|---|---|---|---|---|---|
| | June 14 | June 17 | June 19* | June 28 | June 23 | June 29 | July 6 |
| Control .. .. | 295 | 325 | 309 | 312 | 263 | 272 | 274 |
| ½ cwt urea .. .. | 228 | 299 | 295 | 300 | 238 | 261 | 264 |
| 1 cwt urea .. .. | 166 | 245 | 243 | 255 | 237 | 262 | 266 |
| 1½ cwt urea .. .. | 131 | 203 | 203 | 218 | 193 | 233 | 241 |
| 2 cwt urea .. .. | 293 | 326 | 321 | 319 | 267 | 277 | 278 |
| L.S.D. 5% .. .. | 53 | 49 | 42 | 42 | 27 | 26 | 22 |
| 1% .. .. | 74 | 67 | 58 | 57 | 37 | 35 | 31 |
| S.E. .. .. | 17·8 | 16·2 | 14·1 | 13·9 | 9·6 | 9·0 | 7·0 |

* Heavy frost on June 18, 1963, caused slight reductions in stand count.

Darker green foliage colour due to urea treatment was noted in all trials following commencement of tillering. Increased number of tillers and of heads per plant was observed in each season with increasing rate of urea application. Head counts taken in the first three trials showed that this increase reached a maximum at the 1 cwt rate. Percentage increases in head numbers in these trials at that rate were 68 (1961), 119 (1962) and 80 (1963). In general, application of urea tended to produce a slight delay in crop maturity, the period increasing with increasing rate of application.

Plant height at maturity was increased due to urea application in one season only (1962). Plant height in control plots averaged 24 in., while that of all other treatments averaged 29 in.

### (b) Effect on Grain Yield and Malting Quality

Grain yield and malting quality data are presented in Table 4. Significant increases in grain yield due to urea application were recorded in each trial. However, the peak rate differed from season to season. No significant increases occurred above 1 cwt in 1961 and 1963, and above 1½ cwt in 1962. In 1964, 2 cwt significantly outyielded all other treatments.

Protein level of the grain was significantly ($P<0\cdot01$) increased at rates above ½ cwt in 1963 and 1964, and at rates above 1 cwt in the 1961 and 1962 seasons.

Significant reduction ($P<0\cdot01$) of predicted extract of the grain occurred at all levels of urea application in 1962 and 1963, and at levels above 1 cwt in 1961 and 1964. A significant ($P<0\cdot05$) reduction also occurred at the 1 cwt rate in 1961.

In 1961, significant reductions in bushel weight were recorded at all rates of urea application, with the reductions at ½ and 2 cwt being highly significant

**TABLE 4**

Effects on Yield, Protein, Predicted Extract and Bushel Weight of Grain

| Treatment (cwt urea per acre) | Yield | Protein Percentage (13·5% moisture) | Predicted Extract (lb moisture-free) | Bushel Weight (lb) |
|---|---|---|---|---|
| 1961 | | | | |
| Nil | 18·2 | 9·14 | 97·20 | 53·60 |
| ½ | 27·0 | 9·73 | 95·50 | 52·95 |
| 1 | 30·3 | 9·84 | 94·84 | 53·05 |
| 1½ | 31·9 | 10·92 | 93·32 | 53·05 |
| 2 | 29·8 | 11·62 | 91·06 | 52·65 |
| L.S.D. 5% | 2·2 | 0·81 | 1·75 | 0·42 |
| 1% | 3·0 | 1·11 | 2·41 | 0·57 |
| S.E. | 0·7 | 0·27 | 0·58 | 0·14 |
| 1962 | | | | |
| Nil | 15·7 | 8·22 | 102·88 | 57·20 |
| ½ | 29·9 | 7·68 | 100·24 | 54·65 |
| 1 | 37·5 | 8·49 | 100·90 | 55·15 |
| 1½ | 45·9 | 9·90 | 98·54 | 55·55 |
| 2 | 47·4 | 11·25 | 95·84 | 55·40 |
| L.S.D. 5% | 2·7 | 0·28 | 1·49 | 0·76 |
| 1% | 3·8 | 0·38 | 2·06 | 1·05 |
| S.E. | 0·9 | 0·09 | 0·50 | 0·26 |
| 1963 | | | | |
| Nil | 27·9 | 7·35 | 102·16 | 53·50 |
| ½ | 40·0 | 7·89 | 99·36 | 52·50 |
| 1 | 44·3 | 9·52 | 96·18 | 52·90 |
| 1½ | 43·1 | 10·22 | 95·02 | 52·30 |
| 2 | 46·8 | 9·19 | 97·66 | 52·40 |
| L.S.D. 5% | 6·4 | 0·65 | 1·07 | 0·63 |
| 1% | 8·9 | 0·86 | 1·47 | 0·87 |
| S.E. | 2·1 | 0·21 | 0·36 | 0·21 |
| 1964 | | | | |
| Nil | 15·6 | 7·60 | 98·42 | 52·10 |
| ½ | 24·1 | 7·72 | 98·30 | 52·00 |
| 1 | 33·9 | 8·40 | 98·36 | 53·05 |
| 1½ | 37·1 | 9·04 | 96·20 | 53·20 |
| 2 | 43·1 | 11·00 | 95·24 | 54·50 |
| L.S.D. 5% | 3·6 | 0·30 | 1·17 | 0·70 |
| 1% | 5·0 | 0·41 | 1·61 | 0·96 |
| S.E. | 1·2 | 0·10 | 0·39 | 0·23 |

($P<0\cdot01$). In 1962, highly significant ($P<0\cdot01$) reductions occurred at all levels of urea application. In 1963, highly significant ($P<0\cdot01$) reductions were recorded at the ½, 1½ and 2 cwt rates, while the reduction at the 1 cwt level was not significant. However, in 1964 no significant reductions in bushel weight were recorded, while significant increases were obtained at the 1½ and 2 cwt ($P<0\cdot01$) and 1 cwt ($P<0\cdot05$) rates of application.

### (c) Effect on Whole-plant Dry-matter Yield and Nitrogen Content

Data presented in Table 5 are for whole plants including roots in 1961 and for aboveground plant portions only in 1962 and 1963.

**TABLE 5**

Whole–plant Dry–matter Yields and Nitrogen Content

| Treatment (cwt urea per acre) | Dry-matter Yield (lb/ac) | Nitrogen Percentage (moisture-free) |
|---|---|---|
| 1961* | | |
| Nil | 2,458 | 0·84 |
| ½ | 4,190 | 0·92 |
| 1 | 3,981 | 1·06 |
| 1½ | 4,487 | 1·29 |
| 2 | 4,081 | 1·51 |
| L.S.D. 5% | 577 | 0·08 |
| 1% | 795 | 0·12 |
| S.E. | 193 | 0·03 |
| 1962† | | |
| Nil | 1,715 | 0·88 |
| ½ | 3,040 | 0·81 |
| 1 | 4,297 | 0·86 |
| 1½ | 4,439 | 1·09 |
| 2 | 4,963 | 1·11 |
| L.S.D. 5% | 629 | 0·05 |
| 1% | 857 | 0·06 |
| S.E. | 210 | 0·01 |
| 1963† | | |
| Nil | 3,342 | 0·77 |
| ½ | 4,793 | 0·84 |
| 1 | 5,555 | 1·02 |
| 1½ | 5,558 | 1·15 |
| 2 | 5,414 | 1·06 |
| L.S.D. 5% | 824 | 0·07 |
| 1% | 1,136 | 0·09 |
| S.E. | 275 | 0·02 |

* Data presented for 1961 season are for whole-plant parts including roots.
† Data presented for 1962 and 1963 are for aboveground portions.

In all three seasons for which data were obtained there was a significant ($P<0\cdot01$) response in whole-plant dry-matter yield to all rates of urea application. The greatest increase, in each trial, was to the first increment of ½ cwt of urea. Significant ($P<0\cdot01$) increases above ½ cwt were confined to the 1962 trial.

As would be expected, similar treatment and seasonal trends as were demonstrated for grain protein are shown in the figures for nitrogen percentage of the whole plant. With two exceptions, increasing the increments of applied nitrogen resulted in increased nitrogen content of the plant.

**TABLE 6**

Efficiency of Recovery of Applied Nitrogen

| Treatment (cwt urea per acre) | N applied (lb/ac) | Grain | | | Whole Plant | | |
|---|---|---|---|---|---|---|---|
| | | N Removed (lb/ac) | Applied N Recovered (lb/ac) | Applied N Recovered (%) | N Removed (lb/ac) | Applied N Recovered (lb/ac) | Applied N Recovered (%) |
| 1961 | | | | | | | |
| Nil .. | Nil | 14·3 | — | — | 20·5 | — | — |
| ½ .. .. | 25·8 | 22·3 | 8·0 | 31 | 38·4 | 17·9 | 69 |
| 1 .. .. | 51·5 | 25·3 | 11·0 | 21 | 42·3 | 21·8 | 42 |
| 1½ .. .. | 77·3 | 29·6 | 15·3 | 20 | 57·3 | 36·8 | 48 |
| 2 .. .. | 103·0 | 29·2 | 14·9 | 15 | 61·2 | 40·7 | 40 |
| 1962 | | | | | | | |
| Nil .. | Nil | 11·8 | — | — | 15·1 | — | — |
| ½ .. .. | 25·8 | 20·1 | 8·3 | 32 | 24·7 | 9·6 | 37 |
| 1 .. .. | 51·5 | 28·1 | 16·3 | 32 | 37·1 | 22·0 | 43 |
| 1½ .. .. | 77·3 | 40·4 | 28·6 | 37 | 48·4 | 33·3 | 43 |
| 2 .. .. | 103·0 | 47·3 | 35·5 | 35 | 55·1 | 40·0 | 39 |
| 1963 | | | | | | | |
| Nil .. | Nil | 17·6 | — | — | 25·8 | — | — |
| ½ .. .. | 25·8 | 26·5 | 8·9 | 34 | 40·4 | 14·6 | 57 |
| 1 .. .. | 51·5 | 35·8 | 18·2 | 35 | 56·4 | 30·6 | 59 |
| 1½ .. .. | 77·3 | 36·9 | 19·3 | 25 | 64·0 | 38·2 | 49 |
| 2 .. .. | 103·0 | 36·0 | 18·4 | 18 | 57·1 | 31·3 | 30 |
| 1964 | | | | | | | |
| Nil .. | Nil | 9·9 | — | — | Data not obtained | | |
| ½ .. .. | 25·8 | 15·5 | 5·6 | 22 | Data not obtained | | |
| 1 .. .. | 51·5 | 24·2 | 14·3 | 28 | Data not obtained | | |
| 1½ .. .. | 77·3 | 28·6 | 18·7 | 24 | Data not obtained | | |
| 2 .. .. | 103·0 | 41·3 | 31·4 | 30 | Data not obtained | | |

### (d) Efficiency of Recovery of Applied Nitrogen

Nitrogen recovery data for whole plant and grain are presented in Table 6. The pattern of efficiency of recovery of applied nitrogen in the grain followed the same treatment-seasonal trends as those in the whole plant.

### (e) Economics

Some data on the economics of the use of urea were obtained. Costs associated with increased production consisted of urea at \$98 per ton, bags at 40c each, bag sowing at 5c per bag and cartage at 20c per bag. In calculating additional gross income, an amount of \$1.06/bus was employed.

Allowing that acceptable grain quality was obtained at the ½ and 1 cwt levels of urea application, mean (over the four trials) increased net return per acre from the use of urea was \$6.74 at the ½ cwt level and \$9.61 at the 1 cwt level.

## IV. DISCUSSION

The main quantitative requirements for a good malting quality barley sample are a low protein grain ($<9\%$ at $13 \cdot 5\%$ moisture), a high bushel weight ($>54$ lb) and a high predicted extract ($>95$ lb).

This series of trials demonstrated that barley grain yield could be appreciably increased by the use of nitrogenous fertilizer without serious detrimental effects on grain malting quality. Even the longer fallow period following sudan grass which preceded the 1964 trial did not materially affect the responses in yield and quality to applied nitrogen.

The optimum rate of urea application in terms of economics of grain yield return varied, and was determined largely by seasonal moisture conditions. Overall, the greatest yield responses were obtained in the wettest seasons. Taking treatment means over the four trials, the first increment of nitrogen application (½ cwt urea/ac) resulted in an increase of 10·9 bus/ac over control. The further increment of nitrogen to 1 cwt urea/ac resulted in an additional mean yield increases of 6·3 bus/ac. The increases to 1½ and 2 cwt urea resulted in additional mean yield increases of 3·0 and 2·8 bus respectively. Thus, in a normal season, maximum net return could be expected at the 1 cwt level of urea application. In a season of low soil moisture reserves at planting, the ½ cwt application would possibly be the wiser recommendation. Similar yield responses to urea were obtained in wheat by Littler (1963) on a heavy clay soil of the Darling Downs.

Grain protein content tended to increase with increasing rate of urea application. An exception was at the ½ cwt rate of application in 1962, during which season growth conditions were close to optimum. Similarly, Russell (1964) demonstrated that the overall effect of nitrogen fertilizer on wheat was to increase grain nitrogen percentage, but there were situations, at low rates of nitrogen application, where no change and even decreases in grain nitrogen percentage occurred. From the practical viewpoint, it is doubtful whether the actual magnitude of protein increases, as found in the present study, was sufficient to consider applications of urea up to 1 cwt/ac as detrimental to malting quality.

Bushel weight, even in the unfertilized treatment, was below malting barley requirements in three of the four trial seasons. Significant reductions due to urea application occurred in three seasons, while in the fourth season bushel weight increased at the higher rates of fertilizer application. Overall, the decreases corresponding to urea application were quite small compared with the bushel weight differences which occurred in the unfertilized treatment due to changes in seasonal conditions and site. This supports the findings of Colwell (1963) for wheat in New South Wales.

Values for predicted extract of the grain decreased with nitrogen additions. However, satisfactory values were obtained from all treatments in the final three seasons. In the 1961 season, predicted extract became unacceptably low at rates of urea application above 1 cwt/ac.

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