VG534

Nitrogen nutrition in onions

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Nitrogen topdressing in creamgold onions

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Summary. Three trials were conducted on Krasnozem soils in 1995/96 investigating the effect of nitrogen topdressing on the yield and quality of onions (cv. Creamgold). The following was discovered:
1. At least two or three applications of 41.25 kg/ha elemental nitrogen before bulbing is necessary to maximise yield.
2. Sap testing may assist in detecting deficiencies along with visual symptoms.
3. Soil testing for nitrogen gives no correlation to response to nitrogen.
4. There was no difference between ammonium nitrate, urea and calcium nitrate with regard to yield, bulb hardness and size.
5. There was weak evidence to suggest that less nitrogen produces smaller and harder bulbs.
6. Calcium nitrate and urea may help to reduce skin splitting in onions.
7. Low levels of nitrogen application may lead to misshapen bulbs.
8. Bacterial rot may be exacerbated by high levels of ammonium nitrate.

Introduction

Nitrogen topdressing of onions is a common practice on the krasnozem soils of the north west coast of Tasmania because of the likelyhood of nitrogen deficiency (Moody, 1994). Application of high rates of nitrogen at planting may lead to excessive leaching losses, groundwater contamination and phytotoxicity to developing onion seedlings. This had led to applications of nitrogen as the plant needs it, timed with rain or irrigation so that the nitrogen is solubilised and moves to the root zone. The current practice is to apply 45 kg/ha of nitrogen either spread on or band placed near the seed at sowing and then apply three doses of 42 kg/ha nitrogen (as either nitram or urea) between approximately 5 leaf and bulbing. Other workers have suggested that higher rates of nitrogen are necessary for optimal yields (Brewster, 1994) and in Tasmania, Laughlin found that application of 50 kg/ha of topdressed nitrogen gave a 25.9% increase in total yield and 27.3% increase in bulb yield of the 35 - 70 mm diameter size range (Laughlin, 1987). This yield increase occurred without any detrimental effect on bulb quality parameters (bulb hardness, dry matter, mineral content of bulbs and development of rots in storage). Laughlin (1988) in a further years work documented yield increases of 8 - 26 t/ha upon the application of between 40 - 160 kg/ha Nitram. No effects on bulb hardness or keeping quality were observed. In his final report (Laughlin, 1989), Laughlin found yield increases of 9 - 46% from top dressing 100 kg/ha ammonium nitrate at the 5 leaf stage. Nitrogen application may decrease skin retention on onions, but yield increases may overcome this negative effect (Allwright *et al.*, 1994).

This project further investigated the application of a range of rates of topdressed nitrogen (as Nitram) and measured the effect on onion yield, size, hardness and disease levels.

Ammonium nitrate (NH_4NO_3) and urea (CN_2H_4) are traditionally used as nitrogen sources for topdressing due to their ready availablilty and cost. Ammonium ions formed from the dissociation of these two fertilisers may cause problems with potassium, calcium and magnesium uptake by onion plants. For this reason, many growers of high value crops use calcium nitrate ($Ca(NO_3)_2$) as a nitrogen source for topdressing. The relative merits of using either ammonium nitrate, urea or calcium nitrate as nitrogen sources for topdressing were investigated in this project.

Plant sap testing is a service offered by Serve Ag on the North West Coast of Tasmania. Sap testing may be a beneficial way of scheduling nitrogen applications for onions so that topdressings are applied when needed, thus minimising the possibility of groundwater contamination. Sap testing work in Tasmania has proposed a critical level of 2500 ppm nitrate nitrogen in the sap at the 5 leaf stage (Laughlin, 1989). Sap testing was completed in conjunction with two of the rate response to Nitram experiments mentioned in this report.

Soil tests for nitrogen are not a common tool for the determination of nitrogen requirements in Tasmanian onion crops. Soil tests of total nitrogen, ammonia nitrogen and nitrate nitrogen were completed for all the topdressing trials in order to determine any relationship between response to nitrogen and initial soil levels of nitrogen.

Materials and Methods

Sites

Three sites were selected for the conduct of all the trials. The first site was at David Hill's on the Kindred Road, the second at Harold Motts on Mannings Jetty Road (North Motton) and the third at Brian Hopkins at Hopkins Road, Forth. All three were located on flat areas of krasnozem soil. The previous crops for the sites were barley, broccoli and poppies respectively. There was a large amount of undecomposed barley straw at the David Hill site and undecomposed broccoli residue at the Harold Mott site but at the Brian Hopkins site the level of undecomposed vegetable matter was minimal.

Soil analysis for nitrogen levels

Soil was analysed for total nitrogen, ammonia nitrogen and nitrate nitrogen using the procedures from Hesse (1971):

(a) Total nitrogen: from 10:3:2 Kjeldahl modified to include NO_2/NO_3,
(b) Ammonia nitrogen: from 10:3:3 KCl extract followed by distillation,
(c) Nitrate nitrogen: from 10:3:6 KCl extract, Devarda's alloy distillation after removal of ammonia.

Nitrogen topdressing trials - rates of nitrogen use

Each of the three sites had one of these trials.

The treatments were:

1. Untreated control
2. Ammonium nitrate: 125 kg/ha at 100 days after sowing
3. Ammonium nitrate: 125 kg/ha at 100 and 107 days after sowing
4. Ammonium nitrate: 125 kg/ha at 100, 107 and 114 days after sowing
5. Ammonium nitrate: 125 kg/ha at 100, 107, 114 and 121 days after sowing
6. Ammonium nitrate: 125 kg/ha at 100, 107, 114, 121 and 128 days after sowing.

There were four replicates in the trial arranged in a randomised complete block design. Plot size was 1.6 metres by 5 metres. There were nine onion rows in each plot. Only the inner four rows were assessed. The treatments were timed such that the first treatments were applied at the four true leaf stage and the last treatment was applied well before bulbing.

Nitrogen sources trials

Each of the three sites had one of these trials

The treatments were:

1. Untreated control
2. Ammonium nitrate: 125 kg/ha at 100 and 115 days after sowing (41.8 kg of elemental nitrogen at each application)
3. Urea: 91 kg/ha at 100 and 115 days after sowing (41.8 kg of elemental nitrogen at each application)
4. Calcium nitrate: 270 kg/ha at 100 and 115 days after sowing (41.8 kg of elemental nitrogen at each application)

There were six replicates in this trial arranged in a randomised complete block design. Plot size was 5 metres by 1.6 metres. There were nine onion rows in each plot. Only the inner four rows were assessed. The treatments were timed so they began at the four leaf stage. Bulbing had not occurred by the time of the second application.

Both trials - Fertiliser application, yield evaluation and quality analysis

The fertiliser was weighed out and applied by hand as evenly as possible over the plots.

The onions were lifted when approximately 70 % of the pseudostems had softened and the tops fallen over. This corresponds to the commercial lifting time. Two metres by four rows were lifted for analysis of yield and quality. Yield was measured at lifting time (i.e. fresh weight of onions and tops). Approximately half the onions lifted (approximately 20 per plot) were then taken to a field at Leith where they were allowed to cure on cultivated Krasnozem soil for 28 days. They were then graded into size ranges and also assessed for hardness (using a penetrometer), number of split skins and the presence or absence of disease.

Both trials - sap testing

Sap testing was conducted at regular intervals throughout the trials. The procedure consisted of: Sampling early morning, about 8:30am, and consisted of two whole plants per replicate being randomly sampled and combined for each treatment. A small basal section from each plant was sectioned and combined for sap extraction. A hydraulic press was utilised to extract the sap for analysis.

The sap nitrate (NO_3) was then determined in parts per million (ppm), with a standard analytical procedure utilising an Orion Ion Selective Electrode.

Results

1. Yield results - nitrogen topdressing - nitrogen requirements

Figures 1 - 3 show graphically the results for the nitrogen requirements trials and Tables 1 to 6 show these results in tabular form.

Figure 1 - The relationship between nitrogen application and onion yield - D. Hill trial

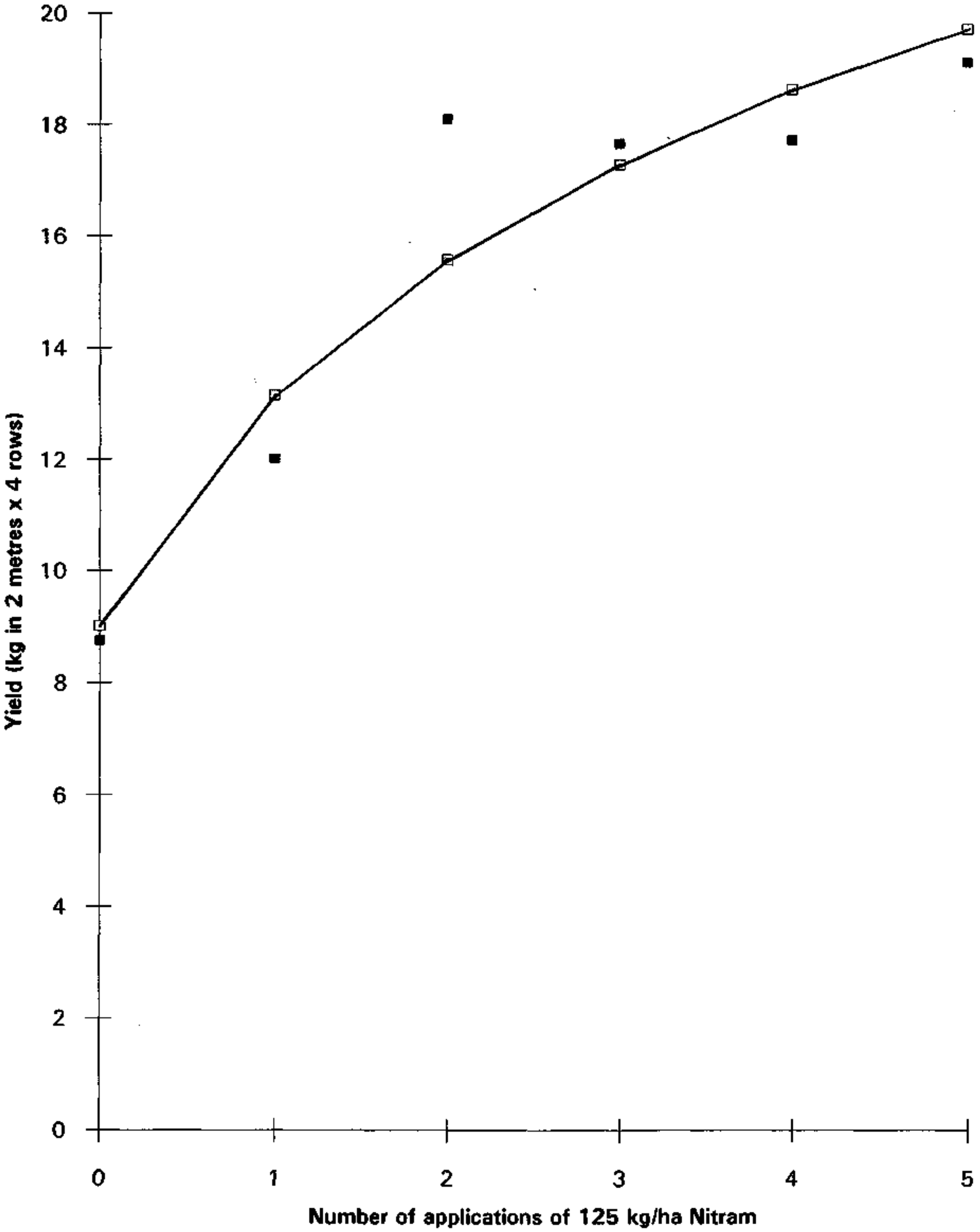


Figure 2 - The relationship between nitrogen application and onion yield - H. Mott trial

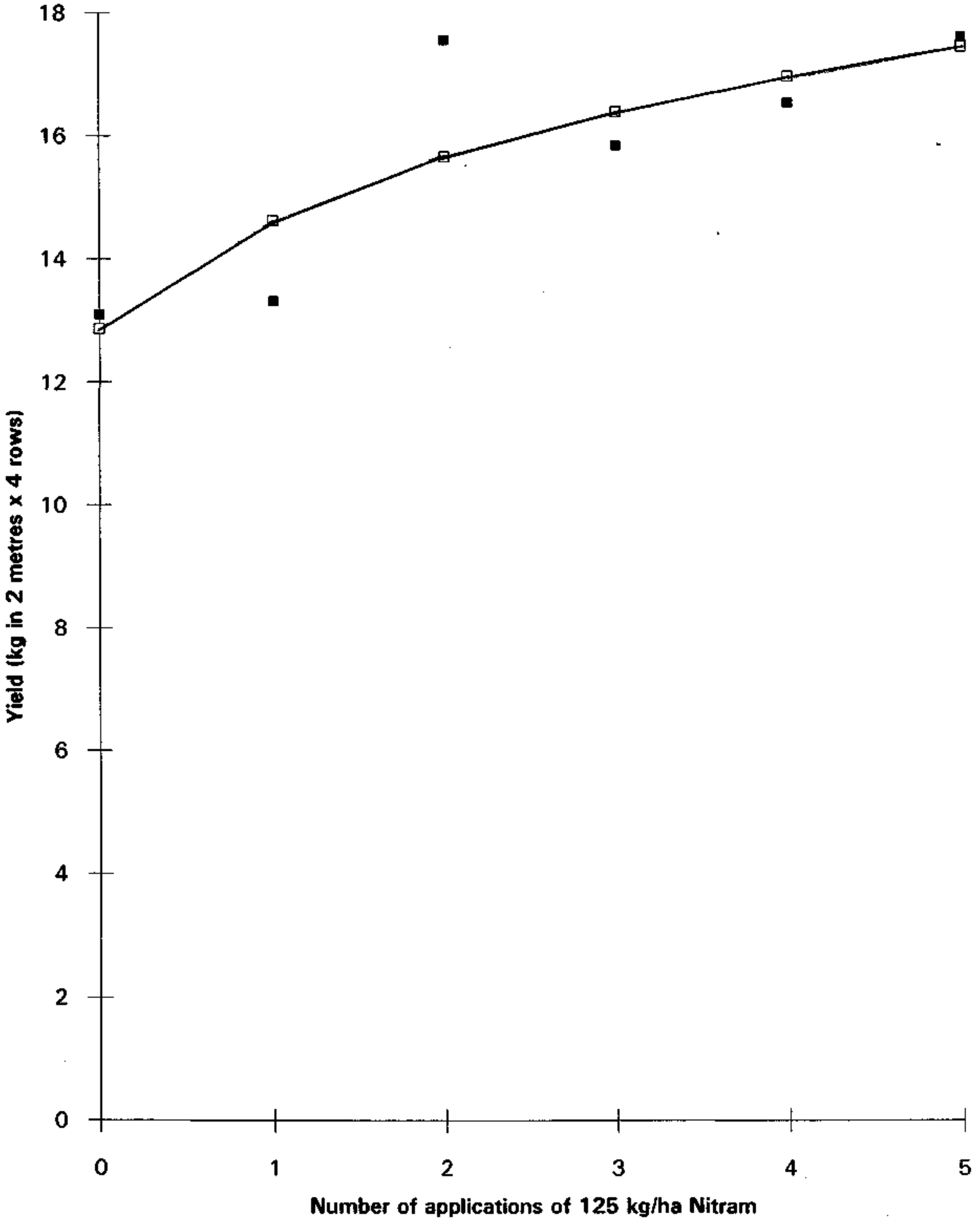


Figure 3 - The relationship between nitrogen application and onion yield - B. Hopkins trial

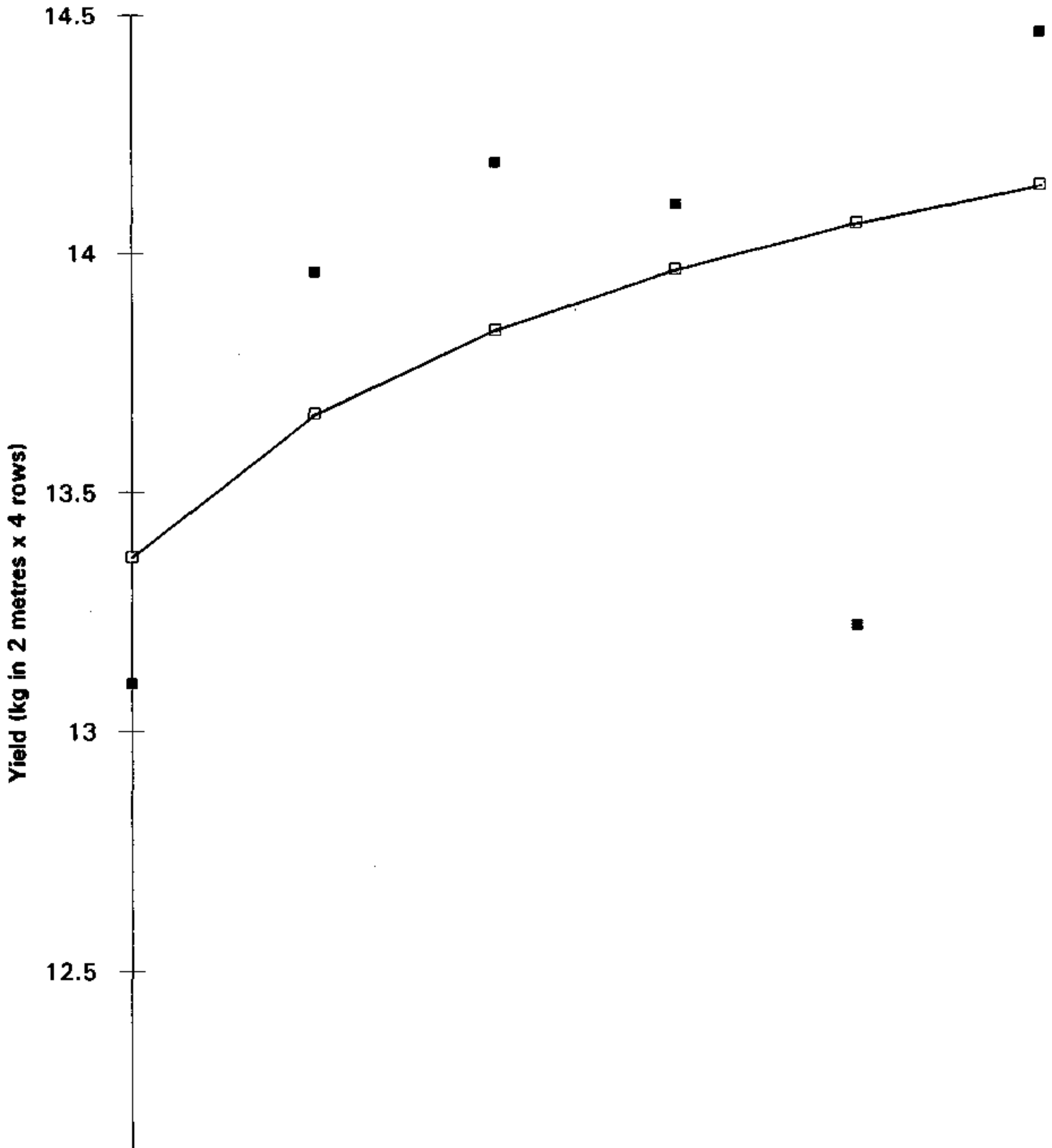


Table 1 - Nitrogen requirements - David Hill trial - yield assessed on 23rd January 1996 (yield results expressed in kg per 4 rows x 2 metre assessment area)*

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	8.54	9.52	8.30	8.64	8.75
Nitram x 1	12.64	10.90	13.00	11.50	12.01
Nitram x 2	16.20	19.22	17.90	19.02	18.09
Nitram x 3	14.50	19.60	19.06	17.94	17.65
Nitram x 4	13.34	18.18	22.30	17.00	17.71
Nitram x 5	19.08	17.52	17.74	22.04	19.10

* Note: 1. Least significant difference (LSD) for the means = 3.016532 ($p<0.05$)

2. Regression of nitrogen vs yield: Yield = 9.0217 + 13.712 (Log (Nitrogen) + 1)) r = 0.94653

Table 2 - Analysis of variance of yield results - David Hill trial

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	69.44670	17.32896	0.000009
Blocks	3	6.35250	1.58513	0.234577
Error	15	4.007551		

Table 3 - Nitrogen requirements - Harold Mott trial - yield assessed on 15th February 1996 (yield results expressed in kg per 4 rows x 2 metre assessment area)*

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	13.9	13.36	14.40	10.68	13.09
Nitram x 1	11.8	12.43	14.22	14.84	13.32
Nitram x 2	22.6	14.30	15.32	18.02	17.56
Nitram x 3	18.04	12.98	13.38	18.94	15.84
Nitram x 4	16.64	15.50	14.08	19.89	16.53
Nitram x 5	19.40	19.90	17.90	13.10	17.58

*Note: Regression of nitrogen against yield: Yield = 12.857 + 5.8723 (Log(Nitrogen) + 1) r = 0.84149

Table 4 - Analysis of variance of yield results - Harold Mott trial

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	16.12355	2.182567	0.110907
Blocks	3	6.94556	0.940187	0.445840
Error	15	7.387424		

Table 5 - Nitrogen requirements - Brian Hopkins trial - yield assessed on 15th February 1996 (yield results expressed in kg per 4 rows x 2 metre assessment area)*

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	10.28	16.60	12.36	13.16	13.10
Nitram x 1	11.82	12.10	14.02	17.90	13.96
Nitram x 2	15.04	12.96	11.86	16.88	14.19
Nitram x 3	12.10	15.50	15.22	13.56	14.10
Nitram x 4	10.52	13.90	14.88	13.58	13.22
Nitram x 5	16.38	15.38	12.86	13.20	14.46

*Note: Regression of nitrogen against yield: Yield = 13.363 + 0.99858(Log (Nitrogen) + 1) r = 0.52106

Table 6 - Analysis of variance of yield results - Brian Hopkins trial

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	1.206857	0.254818	0.930764
Blocks	3	5.000595	1.055834	0.396982
Error	15	4.736155		

2. Yield results - nitrogen topdressing - nitrogen sources.

Figures 4 - 6 show graphically the results of the nitrogen sources trials and Tables 7 - 12 show these results in tabular form.

Figure 4 - The effect of different nitrogen sources on yield - D. Hill trial

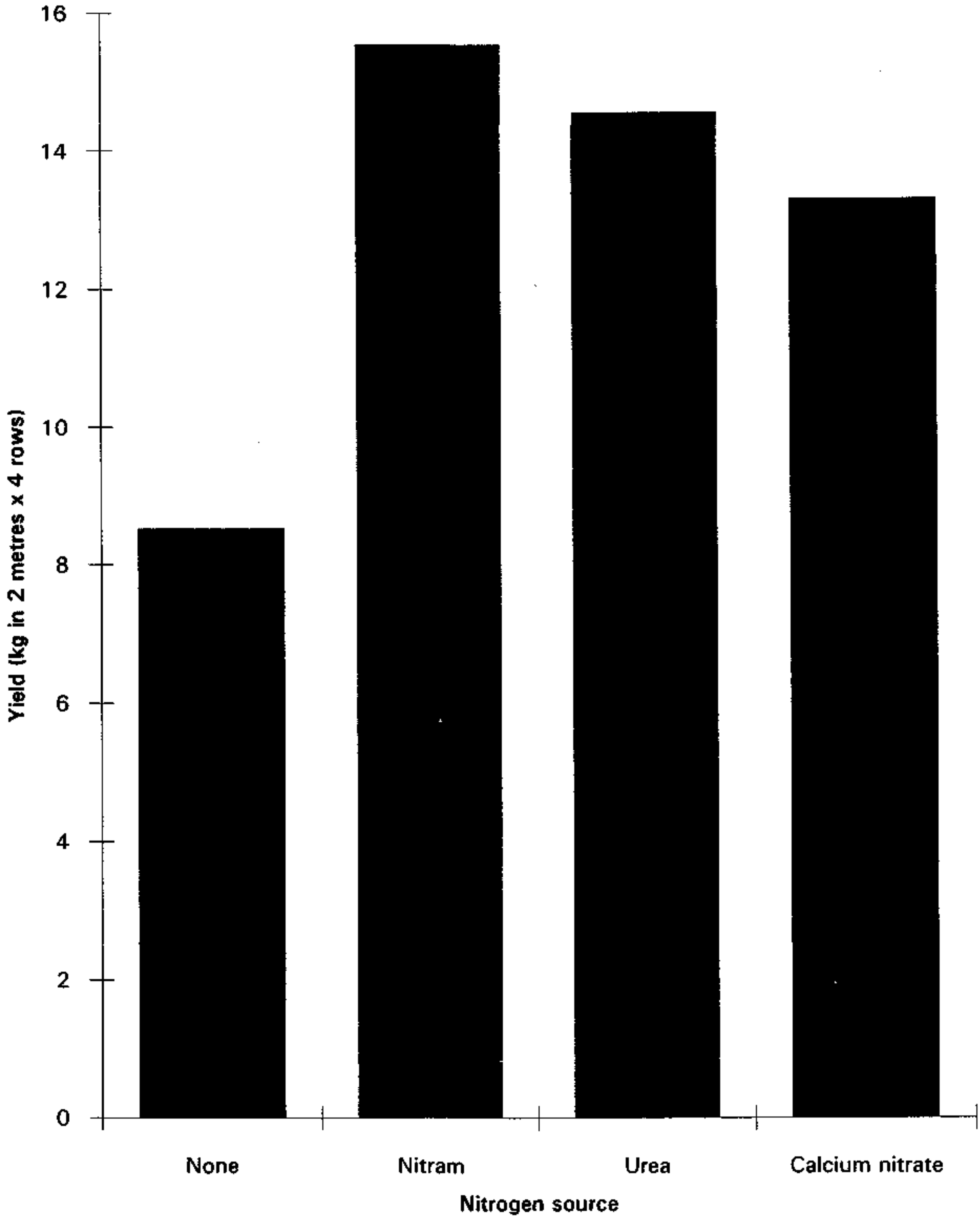


Figure 5 - The effect of different nitrogen sources on yield - H. Mott trial

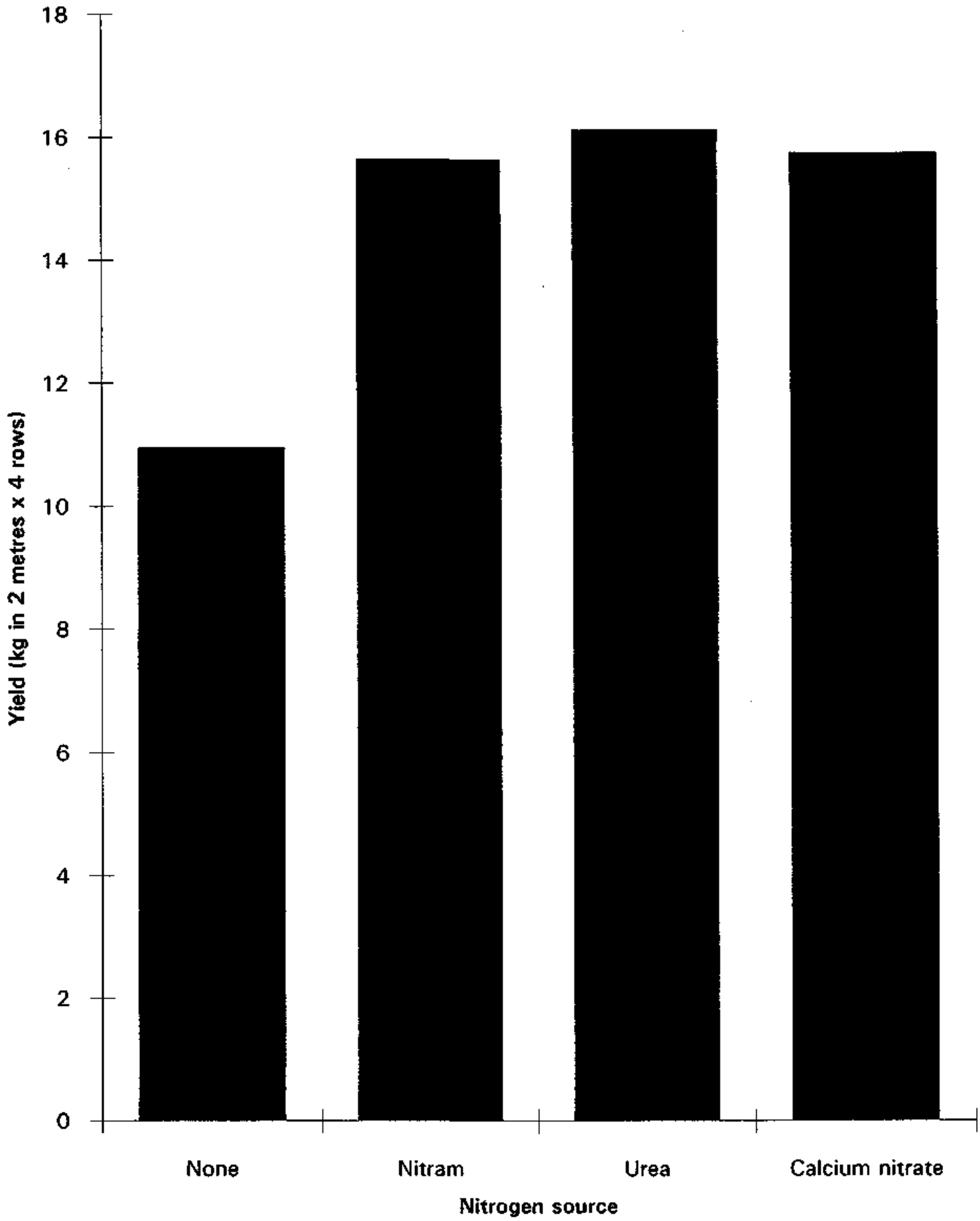


Figure 6 - The effect of different nitrogen sources on yield - B. Hopkins trial

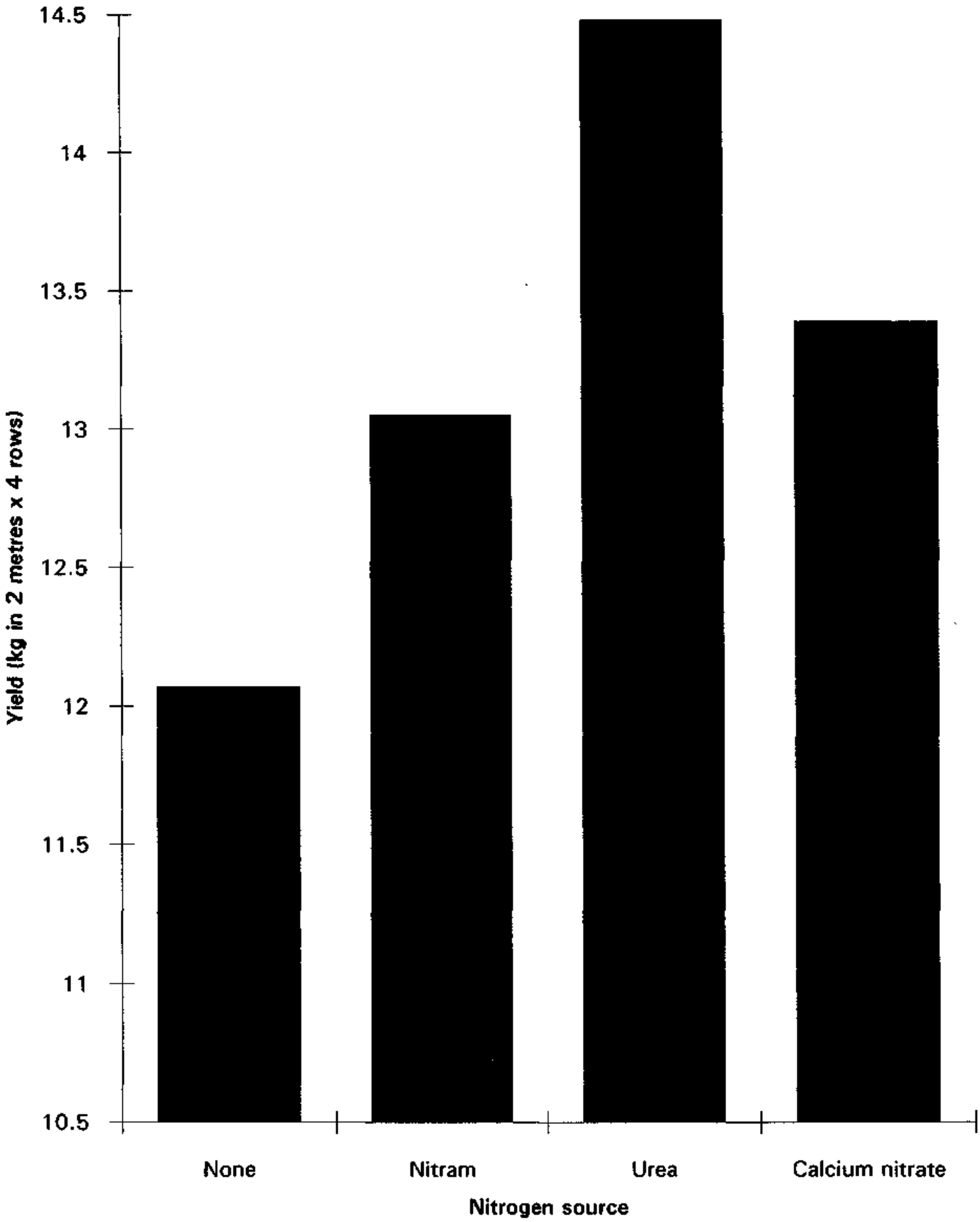


Table 7 - Nitrogen sources - David Hill trial - yield assessed on 23rd January 1996 (yield results expressed in kg per 4 rows x 2 metres assessment area)*

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Untreated	8.34	7.68	7.86	7.54	7.56	12.18	8.52
Nitram	12.62	17.92	15.38	14.42	15.88	16.96	15.53
Urea	15.52	13.68	14.80	15.50	11.72	16.04	14.54
Calcium nitrate	15.06	14.56	11.12	12.50	13.14	13.32	13.28

*Note: LSD for the means = 1.98705 ($p<0.05$)

Table 8 - Analysis of variance for David Hill - nitrogen sources trial

Effect	Degrees of freedom	Mean Square	F	P
Treatments	3	57.74073	22.13650	0.000009
Blocks	5	3.58414	1.37408	0.288714
Error	15	2.608394		

Table 9 - Nitrogen sources - Harold Mott trial - yield assessed on 15th February 1996 (yield results expressed in kg per 4 rows x 2 metres assessment area)*

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Untreated	11.18	9.86	10.26	10.04	9.68	14.68	10.95
Nitram	18.76	12.78	17.18	15.06	16.04	13.96	15.63
Urea	13.56	17.86	17.46	12.51	16.90	18.42	16.12
Calcium nitrate	15.48	18.76	16.22	14.74	12.50	16.76	15.74

*Note: LSD for the means = 3.3180446 ($p<0.05$)

Table 10- Analysis of variance of yield results - Harold Mott nitrogen sources trial

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	36.02122	7.429008	0.002814
Blocks	3	4.26256	0.879109	0.518407
Error	15	4.848725		

Table 11 - Nitrogen sources - Brian Hopkins trial - yield assessed on 15th February 1996 (yield results expressed in kg per 4 rows x 2 metres assessment area)

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Untreated	15.72	10.24	12.38	8.38	12.54	13.16	12.07
Nitram	14.52	11.16	12.48	12.72	12.46	14.98	13.05
Urea	13.46	12.46	16.76	13.78	16.20	14.22	14.48
Calcium nitrate	14.32	13.68	12.03	13.08	14.20	13.04	13.39

Table 12 - Analysis of variance of yield results - Brian Hopkins nitrogen sources trial

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	5.928082	2.439417	0.104668
Blocks	3	4.617797	1.900233	0.154043
Error	15	2.430122		

3. Bulb Hardness

Tables 13 - 18 tabulate the results for the bulb hardness assessments for the nitrogen requirements trials along with the associated analysis of variance tables.

Table 13 - Bulb hardness - David Hill nitrogen requirements trial - 1st March 1996 - mm penetration

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	3.16	3.1	3.08	2.92	3.07
Nitram x 1	3	3.24	3.08	2.88	3.05
Nitram x 2	2.85	3.18	3	3.18	3.05
Nitram x 3	2.66	3.08	3.38	3.08	3.05
Nitram x 4	3.46	2.25	2.87	2.93	2.88
Nitram x 5	2.8	3.12	2.85	3.14	2.98

Table 14 - Analysis of variance - David Hill nitrogen requirements trial - bulb hardness

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	0.021294	0.253950	0.931226
Blocks	3	0.003849	0.045898	0.986429
Error	15	0.083852		

Table 15 -Bulb hardness - Harold Mott nitrogen requirements trial - 19th March 1996 - mm penetration

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	3.26	2.84	3.12	3	3.06
Nitram x 1	2.94	2.96	2.78	3.22	2.98
Nitram x 2	2.94	3.24	3.32	3.32	3.21
Nitram x 3	3.12	2.98	3.3	3.42	3.21
Nitram x 4	3.3	3.2	3.36	3.44	3.33
Nitram x 5	2.82	3.18	3.38	3.34	3.18

Table 16 - Analysis of variance - Harold Mott nitrogen requirements trial - bulb hardness

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	0.061510	2.265191	0.100897
Blocks	3	0.074861	2.756864	0.078804
Error	15	0.027154		

Table 17 - Bulb hardness - Brian Hopkins nitrogen requirements trial - 26th March 1996 - mm penetration

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	3.14	3.18	3.58	3.36	3.32
Nitram x 1	3.48	3.2	3.48	3.3	3.37
Nitram x 2	3.64	3.14	3.16	3.22	3.29
Nitram x 3	3.64	3.14	3.54	2.9	3.31
Nitram x 4	3.16	3.24	3.64	3	3.26
Nitram x 5	3.5	3.3	2.88	3.42	3.28

Table 18 - Analysis of variance - Brian Hopkins nitrogen requirements trial - bulb hardness

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	0.005	0.090384	0.992553
Blocks	3	0.084867	1.413502	0.277772
Error	15	0.060040		

4. Bulb hardness

Tables 19 - 24 tabulate the results for the bulb hardness assessments of the nitrogen sources trials along with the associated analysis of variance tables.

Table 19 - Bulb hardness - David Hill nitrogen sources trial - 1st March 1996 - mm penetration

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Untreated	3.28	3.3	3.26	3.2	3.44	3.16	3.27
Nitram	3.04	3.18	3.2	3.36	3.06	3.32	3.19
Urea	3.28	2.94	3.26	2.98	3.48	3.18	3.19
Calcium nitrate	3.26	3.04	3.28	3.08	3.52	3.38	3.26

Table 20 - Analysis of variance - David Hill nitrogen sources trial - bulb hardness

Effect	Degrees of Freedom	Mean square	F	P
Treatments	3	0.011978	0.538462	0.663134
Blocks	5	0.033107	1.488312	0.251660
Error	15	0.022244		

Table 21 - Bulb hardness - Harold Mott nitrogen sources trial - 19th March 1996 - mm penetration

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Untreated	3.34	3.16	2.84	3.28	3.24	3.2	3.18
Nitram	3.1	3.4	3.24	3.6	3.16	3.26	3.29
Urea	3.4	3.56	3.16	3.56	3.52	2.86	3.34
Calcium nitrate	3.06	3.6	3.4	3.12	2.82	3.24	3.21

Table 22 - Analysis of variance - Harold Mott nitrogen sources trial - bulb hardness

Effect	Degrees of Freedom	Mean square	F	P
Treatments	3	0.035489	0.682712	0.576265
Blocks	5	0.061520	1.183482	0.362871
Error	15	0.051982		

Table 23 - Bulb hardness - Brian Hopkins nitrogen sources trial - 26th March 1996 - mm penetration

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Untreated	2.96	3.1	2.88	2.82	2.98	3.34	3.01
Nitram	3.2	2.94	3.02	3.04	3.4	3.24	3.14
Urea	3.68	3.52	3.14	3.2	3.2	3.16	3.32*
Calcium nitrate	3.64	3.38	3.42	3.4	3.2	3.26	3.38*

*Note: These values are significantly different ($p<0.05$) from the untreated control.

Table 24 - Analysis of variance - Brian Hopkins nitrogen sources trial - bulb hardness*

Effect	Degrees of Freedom	Mean square	F	P
Treatments	3	0.169911	5.022333	0.013163
Blocks	5	0.036827	1.088544	0.406242
Error	15	0.033831		

*Note: Least significant difference ($p < 0.05$) = 0.23

5. Percentage of small onions

Onion size data is presented as percentage of onions graded under 50mm, a size that is currently unacceptable in terms of financial return. Tables 25 - 36 describe the percentage of bulbs <50mm from each trial, with accompanying analysis of variance.

Table 25 - Percentage of bulbs less than 50 mm in diameter - David Hill nitrogen requirements trial - 1st March 1996

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	15.62	27.27	27.91	35.71	26.6275
Nitram x 1	60	28.57	62.50	35.29	46.59
Nitram x 2	30.77	70	17.14	39.02	39.2325
Nitram x 3	75	30.77	15.56	27.45	37.195
Nitram x 4	18.37	26.53	34.55	28.95	27.10
Nitram x 5	27.66	23.40	78.57	48.98	44.6525

Table 26 - Analysis of variance - David Hill Nitrogen requirements trial - bulbs less than 50mm diameter

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	288.8714	0.657472	0.660860
Blocks	3	28.4994	0.064865	0.977653
Error	15	439.3665		

Table 27 - Percentage of bulbs less than 50 mm in diameter - Harold Mott nitrogen requirements trial - 1st March 1996

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	19.23	40.00	10.53	30.00	24.94
Nitram x 1	30	28.57	28.57	25.00	28.035
Nitram x 2	15.79	10.00	27.78	5.00	14.6425
Nitram x 3	30.00	14.29	15.00	95.24	38.6325
Nitram x 4	10.00	19.05	22.22	10.53	15.45
Nitram x 5	12.50	15.00	20.00	31.82	19.83

Table 28 - Analysis of variance - Harold Mott Nitrogen requirements trial - bulbs less than 50mm diameter

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	326.6498	1.009809	0.445707
Blocks	3	235.3752	0.727642	0.551239
Error	15	323.4767		

Table 29 - Percentage of bulbs less than 50 mm in diameter - Brian Hopkins nitrogen requirements trial - 1st March 1996

Treatment	Replicate 1	Replicate 2	Replicate 3	Replicate 4	Mean
Untreated	15.79	31.58	31.82	71.43	37.655
Nitram x 1	35	50	42.86	33.33	40.2975
Nitram x 2	40	55	40	26.32	40.33
Nitram x 3	40	30	15	45	32.5
Nitram x 4	45	40	47.62	28.57	40.2975
Nitram x 5	35	9.52	30	15	22.38

Table 30 - Analysis of variance - Brian Hopkins Nitrogen requirements trial - bulbs less than 50mm diameter

Effect	Degrees of Freedom	Mean square	F	P
Treatments	5	204.0833	0.890087	0.511957
Blocks	3	5.02	0.021894	0.995413
Error	15	229.2847		

Table 31 - Percentage of bulbs less than 50 mm in diameter - David Hill nitrogen sources trial - 1st March 1996

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Nitram	45	17.65	10	95.24	31.82	21.74	36.90833
Urea	25	63.64	26.32	15	33.33	65	38.04833
Calcium nitrate	25	25	10	21.05	68.18	10.53	26.62667
Untreated	59.09	42.86	25	28.57	20	20	32.58667

Table 32 - Analysis of variance - David Hill Nitrogen sources trial - bulbs less than 50mm diameter

Effect	Degrees of Freedom	Mean square	F	P
Treatments	3	160.7475	0.265326	0.849318
Blocks	5	294.2010	0.485602	0.781804
Error	15	605.8479		

Table 33 - Percentage of bulbs less than 50 mm in diameter - Harold Mott nitrogen sources trial - 1st March 1996

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Nitram	20	10	31.58	28.57	35	30	25.85833
Urea	35	28.57	42.11	40	26.32	28.57	33.42833
Calcium nitrate	23.81	15	30	20	35	26.32	25.02167
Untreated	42.86	66.66	50	45	15	20	39.92

Table 34 - Analysis of variance - Harold Mott Nitrogen sources trial - bulbs less than 50mm diameter

Effect	Degrees of Freedom	Mean square	F	P
Treatments	3	295.2598	1.854739	0.180651
Blocks	5	75.9192	0.476911	0.787937
Error	15	159.1894		

Table 35 - Percentage of bulbs less than 50 mm in diameter - Brian Hopkins nitrogen sources trial - 1st March 1996

Treatment	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 5	Rep. 6	Mean
Nitram	25	44.44	50	27.27	25	26.92	33.105
Urea	23.08	38.46	40	38.10	60	25	37.44
Calcium nitrate	31.58	31.58	30	57.14	20	15	30.88333
Untreated	40	35	30	70	45	46.66	44.44333

Table 36 - Analysis of variance - Brian Hopkins Nitrogen sources trial - bulbs less than 50mm diameter

Effect	Degrees of Freedom	Mean square	F	P
Treatments	3	214.0980	1.261711	0.323024
Blocks	5	197.6022	1.164499	0.371184
Error	15	169.6886		

6. Soil analysis

Table 37 shows the mean readings for soil levels of nitrogen from nine untreated plots at each of the three trial sites.

Table 37 - Soil tests for nitrogen

These results are the means of nine readings from each site.

Grower	Total nitrogen	Ammonia nitrogen (ppm)	Nitrate nitrogen (ppm)
D. Hill	0.3	8.3	15.5
B. Hopkins	0.2	3.5	7.0
H. Mott	0.3	2.5	23.0

7. Quality assessments

Tables 38 - 43 summarise quality assessments of onions completed for each trial. Only those parameters relevant to each sample were included in the results.

Table 38 - Quality assessment - D. Hill - Nitrogen requirements - 8th May 1996

Treatment	Bacterial rot(%)	Misshapen(%)	Doubles(%)	Splits(%)	OK(%)
Untreated	0	14.93	5.97	2.24	76.87
Nitram x 1	0	11.90	1.59	4.76	81.75
Nitram x 2	0	11.90	0	5.55	82.54
Nitram x 3	1.64	16.34	1.64	4.92	77.05
Nitram x 4	0	16.34	2.0	5.23	76.47
Nitram x 5	0	14.79	0	3.52	81.69

Table 39 - Quality assessment - H. Mott - Nitrogen requirements - 8th May 1996

Treatment	Bacterial rot(%)	Misshapen(%)	Botrytis(%)	Splits(%)	OK(%)
Untreated	0	40.00	0	2.22	57.77
Nitram x 1	2.44	21.95	0	0	75.61
Nitram x 2	2.63	23.68	0	0	73.68
Nitram x 3	0	32.50	0	0	67.50
Nitram x 4	0	21.05	2.63	2.63	73.68
Nitram x 5	0	35.00	0	10.00	55.00

Table 40 - Quality assessment - B. Hopkins - Nitrogen requirements - 8th May 1996

Treatment	Bacterial rot(%)	Pitted neck(%)	Misshapen(%)	Splits(%)	OK(%)
Untreated	0	0	36.59	2.44	60.98
Nitram x 1	0	0	43.59	0	56.41
Nitram x 2	5.55	0	25.00	0	69.44
Nitram x 3	2.44	0	31.71	0	65.85
Nitram x 4	2.50	5	20.00	0	72.50
Nitram x 5	0	0	23.08	12.82	64.10

Table 41 - Quality assessment - D. Hill - Nitrogen sources - 8th May 1996

Treatment	Bacterial rot(%)	Misshapen(%)	Doubles(%)	Splits(%)	OK(%)
Nitram	4.84	29.03	1.61	6.45	58.06
Urea	0	18.03	4.92	4.92	72.13
Calcium nitrate	0	17.54	1.75	1.75	78.95
Untreated	0	18.75	0	14.06	67.19

Table 42 - Quality assessment - H. Mott - Nitrogen sources - 8th May 1996

Treatment	Bacterial rot(%)	Misshapen(%)	Split(%)	OK(%)
Nitram	1.69	27.12	3.39	67.80
Urea	0	23.73	0	76.27
Calcium nitrate	1.66	20.00	1.66	76.66
Untreated	1.69	32.20	3.39	62.71

Table 43 - Quality assessment - B. Hopkins - Nitrogen sources - 8th May 1996

Treatment	Bacterial rot (%)	Misshapen (%)	Split (%)	OK (%)
Nitram	1.72	36.21	5.17	56.90
Urea	3.51	38.60	1.75	56.14
Calcium nitrate	3.64	38.18	1.82	56.36
Untreated	0	43.10	3.45	53.45

8. Sap analysis

Figures 7 and 8 graphically depict sap nitrate levels during the growth of D. Hill's and H. Mott's nitrogen requirements trials respectively. The treatments are numbered 1 to 6 and are as follows:

1. Untreated control
2. 1 application of 125 kg/ha Nitram at 100 days after sowing
3. 2 applications of 125 kg/ha Nitram at 100 and 107 days after sowing
4. 3 applications of 125 kg/ha Nitram at 100, 107 and 114 days after sowing
5. 4 applications of 125 kg/ha Nitram at 100, 107, 114 and 121 days after sowing
6. 5 applications of 125 kg/ha Nitram at 100, 107, 114, 121 and 128 days after sowing

Figure 7

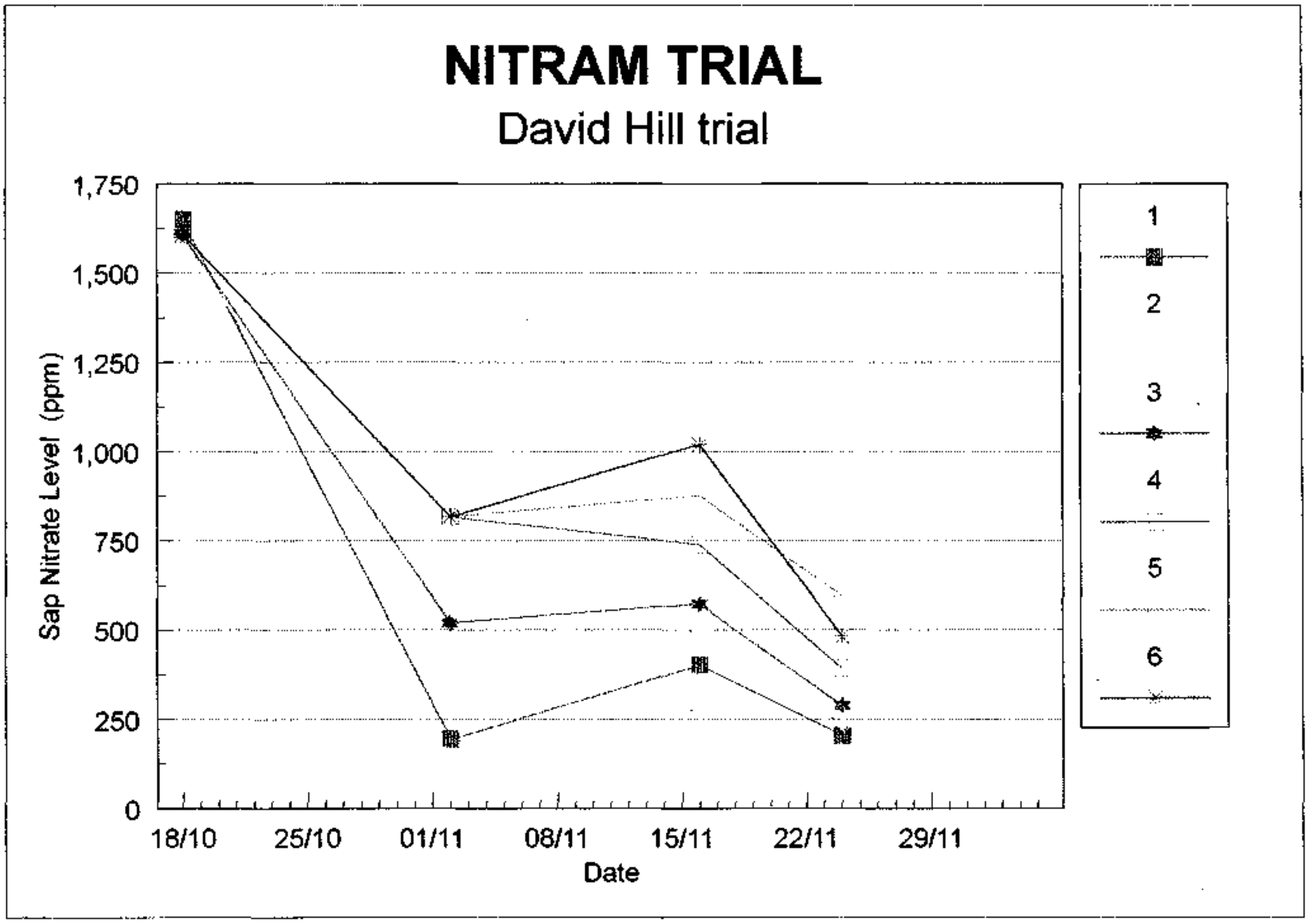
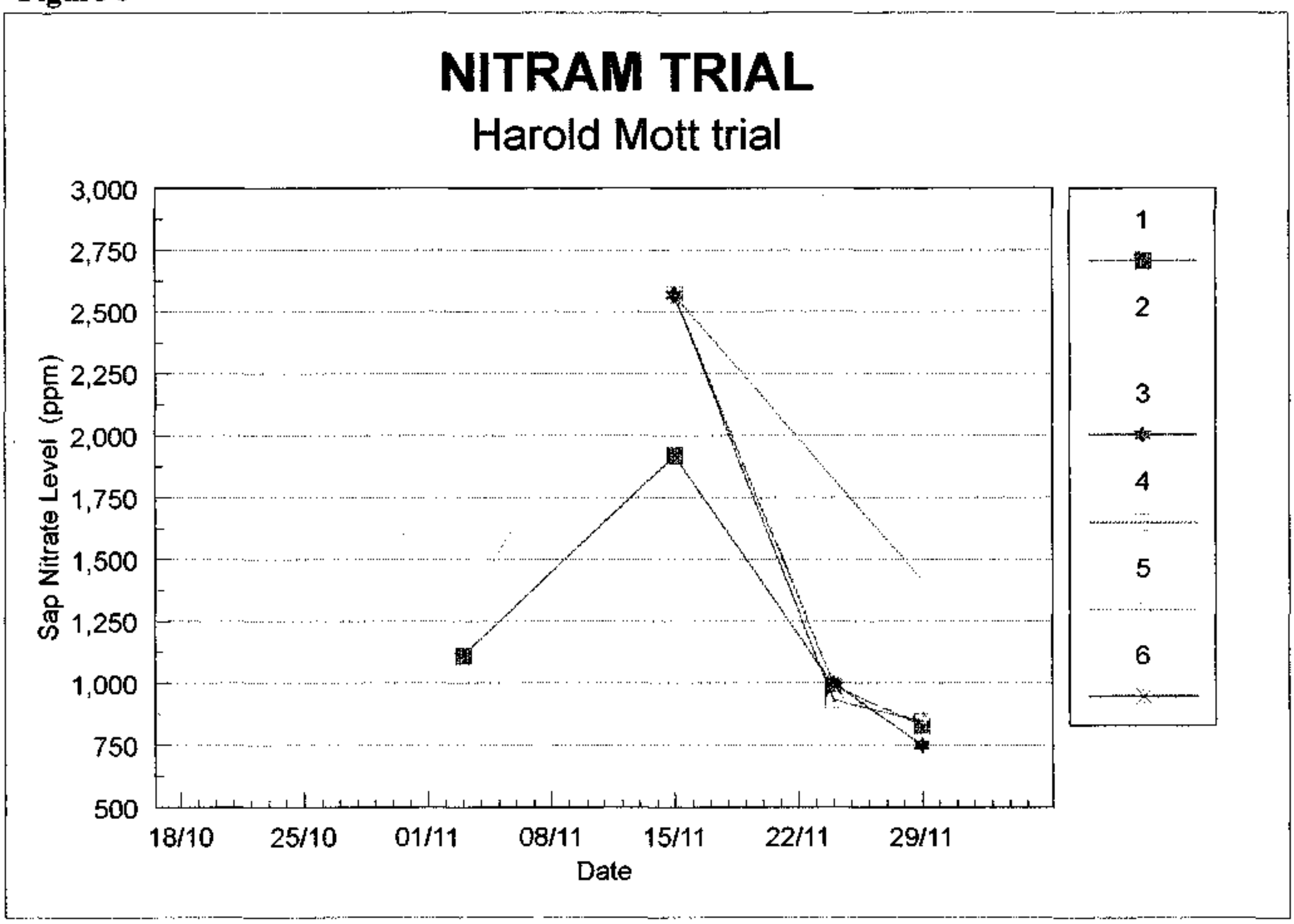


Figure 8



Discussion

Yield - Nitrogen requirements and sap testing/ soil testing

The yield results for the nitrogen requirements trials may be found in Tables 1 - 6 and Figures 1 to 3. There appeared to be a logarithmic relationship between the level of nitrogen applied and yield such that the relationship was in the form Yield = c + mLog (Nitrogen + 1) where c is the intercept with the y axes and m is a factor influencing slope. The regression coefficient when the relationship was expressed in this form was 0.94653 for the David Hill trial, 0.84149 for the Harold Mott trial and 0.52106 for the Brian Hopkins trial. Obviously the relationship was quite strong for the David Hill and Harold Mott trials while not so strong for the Brian Hopkins trial. This was also observed in the traditional analysis of variance where p for treatment differences was 0.000009 for the David Hill trial, 0.110907 for the Harold Mott trial and 0.930764 for the Brian Hopkins trial.

Both the David Hill and Harold Mott trial sites had high levels of undecomposed vegetative material in the soil at the time the trials were conducted while this was not the case in the Brian Hopkins trial. It may have been that these high levels of matter were locking up the nitrogen present in the soil in the former two trials, causing them to have a higher response to topdressed nitrogen compared to the latter trial. Other reasons for possible differences between the trial sites may have been different soil mineral levels of nitrogen. This is probably not the case, however, because the soil tests for nitrogen (Table 37) show no real differences between the different sites in terms of total nitrogen, ammonia nitrogen or nitrate nitrogen that is reflected in the results. Different microclimates may have influenced nitrogen uptake or accidental fertiliser topdressing from some farmers and not others which could confound the results.

In practical terms, it did not appear to be necessary to apply more than two applications of nitrogen to achieve close to maximum yield. In the sap analysis of the David Hill trial, there were distinctly higher levels of nitrate in the sap with higher applications of nitrogen, but this may have been luxurious to the growth requirements of the onion plants. (Figure 7). The sap analysis does, however, show clearly that at **approximately the start of bulbing (15th November in this case) sap levels of nitrate should be above 500 ppm for maximum yield.** For the Harold Mott trial (Figure 8) the relationship was less clear with the level of nitrate in all treatments above the untreated control being similar until after the 24th November when nitrate levels in the 4 and 5 applications of nitram treatments were higher than all the other treatments. This was not reflected in the yield results.

Yield - Nitrogen sources

The results for the nitrogen sources trials may be found in Tables 7 - 12 and also in Figures 4 - 6. In the David Hill and Harold Mott trials, the untreated control was always significantly lower yielding than the nitrogen treatments. There were no significant differences between the yields from the nitrogen treatments. The yield of the untreated control in the Brian Hopkins treatment was lower than those plots treated with nitrogen but this was not significant. From these trials it appears that there is no yield advantage in using any of the nitrogen sources over another nitrogen source, except on the basis of price and availability. Again, there was more response for the David Hill and Harold Mott trials than the Brian Hopkins trial. Possible reasons for this have been discussed in the above section.

The nitrogen sources trial further backs up the evidence that nitrogen application is necessary to improve yields.

Bulb hardness

The results for the bulb hardness assessments may be found in Tables 13 - 24. There were no significant differences or patterns in bulb hardness for any of the trials except for the Brian Hopkins nitrogen sources trial where the urea and calcium nitrate treatments were significantly softer than the untreated control. It may be that in this trial the onions were smaller and harder where no nitrogen was applied to when it was not applied. Indeed, the level of bulbs less than 50 mm in diameter was much higher in the untreated control in this trial (Table 35) but not significantly ($p<0.05$). The nitram treatment was also softer than the untreated control but not significantly ($p<0.05$).

Percentage of bulbs less than 50mm in diameter

At this point in time it is difficult to sell onions less than 50 mm in diameter. For this reason an analysis was completed of the size ranges of onions that were present in each plot, and the onions less than 50 mm diameter used as a summary statistic to evaluate the effect that nitrogen has on onion size (Tables 25 - 36).

For all of the nitrogen requirement trials there was no pattern between treatments for small onions and there were no significant ($p<0.05$) differences between treatments. This was also the case for the David Hill nitrogen sources trial.

For the Harold Mott and Brian Hopkins nitrogen sources trials the untreated control had a higher level of small onions compared to those plots treated with nitrogen, although this was not significant ($p<0.05$). The evidence that onions deficient in nitrogen were smaller was visually observed in the field suggesting that this was a real difference. **A tentative conclusion is made that nitrogen deficiency reduces bulb size.**

Quality assessments

Tables 38 - 43 describe a quality assessments done some time after harvest. The results were pooled for each treatment.

Table 38 describes the quality assessment at the D. Hill nitrogen requirements trial. There were no real patterns for any of the quality assessments as they related to treatments except that there were a high level of doubles in the untreated control.

Table 39 describes the quality assessments at the H. Mott nitrogen requirements trial. There were no real patterns for any of the quality assessments as they related to treatments except for the highest nitrogen treatment had a high level of split skins..

Table 40 describes the quality assessments from the B. Hopkins nitrogen requirements trial. There were high levels of misshapen bulbs for the zero and one nitram treatments. Most of these misshapen bulbs were shaped like 'torpedoes' i.e. had thick necks. The highest nitrogen treatment also had many split skins, which reflects the result for the H. Mott nitrogen requirements trial.

Table 41 describes the results for the D. Hill nitrogen sources trial. The treatment with the lowest level of OK bulbs (bulbs without noticeable defects) was the nitram treatment. Bacterial rot and a high level of misshapen bulbs were the main reason for this. Number of doubles was least in the untreated control (a result in contrast to the D. Hill nitrogen requirements trial) and number of onions with split skins was highest in the untreated control. It is interesting to note that the lowest level of split skins was with the calcium nitrate treatment. It may be that the extra calcium level is helping to strengthen the cell walls of the outer skins in these onions.

Table 42 describes the results for the H. Mott nitrogen sources trial. The untreated control in this case had a high level of misshapen bulbs (mainly torpedo shaped). Number of splits was lowest in the urea and calcium nitrate treatments. These two treatments also had the highest number of bulbs without defects.

Table 43 describes the results from the B. Hopkins nitrogen sources trial. The untreated control in this case had the lowest level of bacterial rot and the highest level of misshapen bulbs (similar to the H. Mott nitrogen sources trial). Splits were again lowest in the calcium nitrate and urea treatments.

Conclusions

These trials have shown the following:

1. That nitrogen is necessary on krasnozem soils for maximisation of yield.
2. Sap levels of nitrate may indicate deficiencies along with visual symptoms.
3. Soil levels of nitrogen do not indicate the need for nitrogen by the onion growing in that soil.
4. There is no real difference between different nitrogenous fertilisers with regards to yield, bulb hardness and size therefore decisions on which to use should be based on price and availability.
5. There was weak evidence to suggest that less nitrogen produces harder and smaller bulbs.
6. Calcium nitrate and urea may help in reduction in the level of split skins in onions. This may be due to calcium strengthening of call walls with the calcium nitrate treatment but it is unknown why with the urea treatment.
7. Low level of nitrogen application may lead to misshapen bulbs.
8. Bacterial rot may be increased by the application of Nitram.

Recommendations

1. Up to three applications of 125 kg/ha Nitram should be used during the growth of an onion crop before bulbing, the time of application based on growth stage, sap tests and symptoms of visual deficiency.

2. Further work should be completed with nitrogen sources and how they affect bacterial rot, split skins and misshapen bulbs.

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Photographs

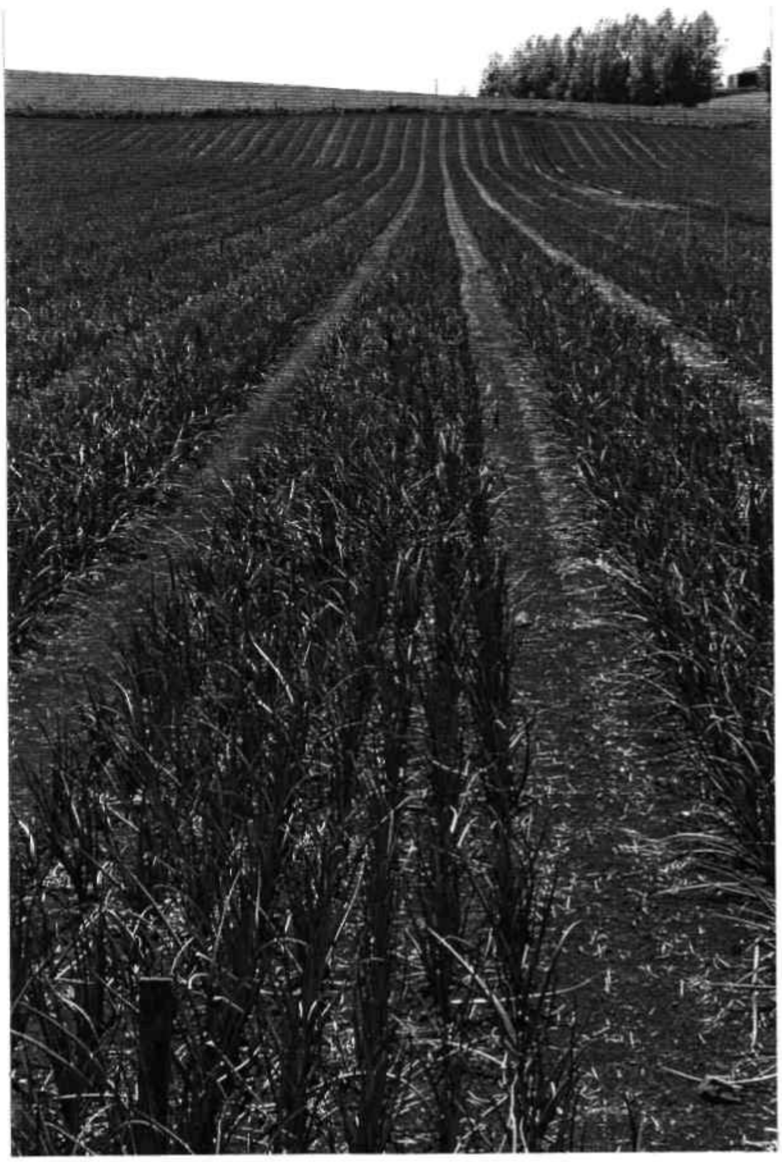

Plate 1 - D. Hill trial 16th November 1995
Foreground - Plot 4 (Untreated); Background - Plot 10 (2 x 125 kg/ha Nitram). Notice the chlorosis in the untreated plot due to nitrogen deficiency.

Plate 2 - D. Hill trial 16th November 1995
Foreground - Plot 1 (5 x 125 kg/ha Nitram); Background - Plot 7 (Untreated). Notice the chlorosis in the untreated plot due to nitrogen deficiency.

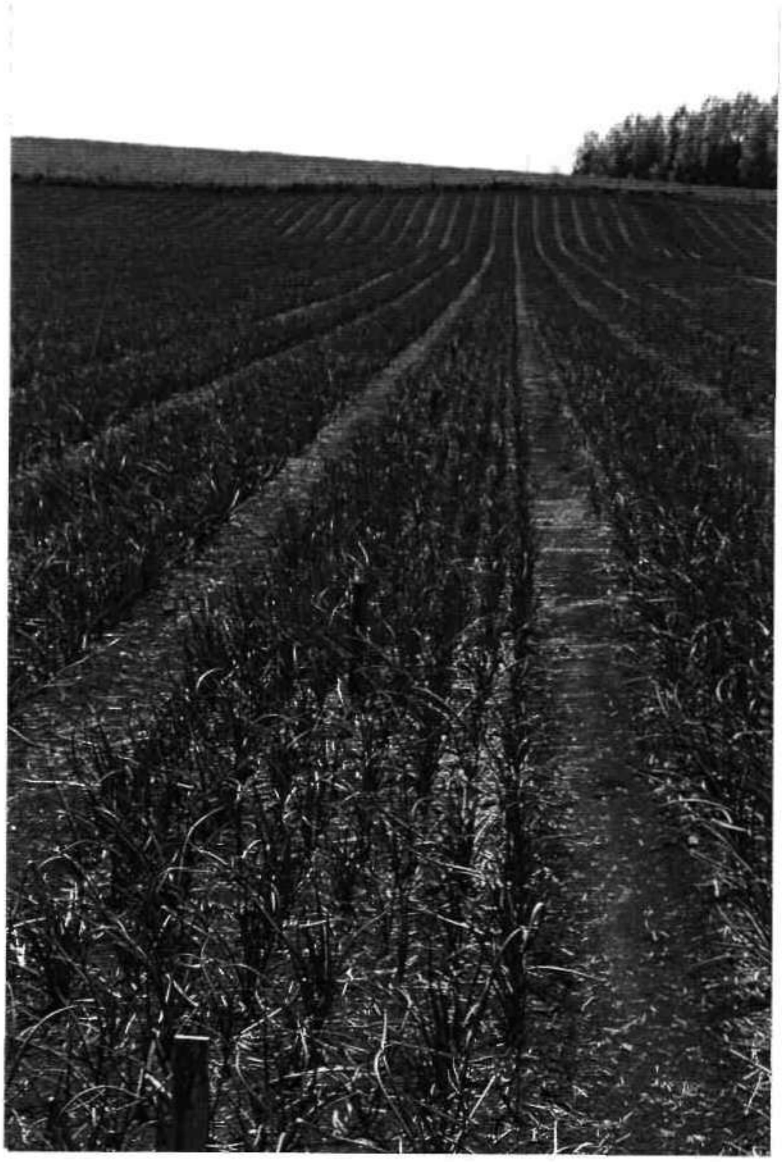

Plate 3 - D. Hill trial 16th November 1995
Foreground - Plot 1 (2 x Calcium Nitrate); Background - Plot 5 (Untreated). Notice the chlorosis in the untreated plot due to nitrogen deficiency.

Plate 4 - D. Hill trials early bulbing (c. December 1995)
Visual symptoms from varying levels of nitrogen application

Plate 5 - D. Hill trial - early bulbing (c. December 1995)
Foreground - Plot 7 (Untreated); Background - Plot 13 (4 x 125 kg/ha Nitram). Notice the chlorosis of the untreated plot due to nitrogen deficiency

Plate 6 - D. Hill trial early bulbing (c. December 1995)
LHS - Plot 24 (5 x 125 kg/ha Nitram); RHS - Plot 18 (Untreated)
Notice the chlorosis in the untreated plot due to nitrogen deficiency.

Plate 7 - D. Hill trial early bulbing (c. December 1995)
The chlorotic plot (plot 18) is untreated with Plots 12 and 24 on either end of it having recieved 5 applications of 125 kg/ha Nitram.