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Chinese cabbage: An examination of the possible causes of internal tipburn.

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AUTHENTICATION

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

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(on behalf of Dr M R Shipway,
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Summary

Chinese cabbage, variety Kasumi was grown from three planting dates 8 and 30 June and 23 July in three separate trials. There were three main factors; irrigation, nitrogen (N) rate and type at three, four and two levels respectively. The three irrigation rates were 25 mm at 50 mm soil moisture deficit (SMD) (standard treatment), 25 mm at 25 mm SMD and 25 mm at 25 mm SMD plus overhead flash misting (applied as a fine spray) late afternoon to try to reduce high evapotranspiration conditions in the two weeks prior to harvest. The four rates of nitrogen were 250, 150, 100 and 0 kg/ha N, the highest rate was set using the HRI-nitrogen model following soil mineral N determination. For the second and third plantings the rates were 225, 135, 90 and 0 kg/ha. The two types of fertiliser N were calcium nitrate as a split dressing and ammonium sulphate as a base dressing with a nitrification inhibitor (N Save).

All three irrigation treatments were applied to the first planting, however the conditions during the second planting did not require any irrigation. The soil moisture deficit was low throughout the third planting, but dry sunny weather before harvest necessitated the application of the flash irrigation.

From all three plantings tipburn levels were low, and where present it was not severe. The three plantings were harvested on 30 July, 25 August and 17 September and the mean levels of tipburn were 4, 12 and 1% respectively. From planting 1, where flash irrigation was applied six times in the two weeks prior to harvest, tipburn was reduced by 60%, albeit from low levels. From the third planting, where flash irrigation was also applied, the overall level of tipburn was extremely low and no measurable effect was observed.

At both plantings 1 and 2, applications of calcium nitrate produced more tipburn than applications of ammonium sulphate, (contrary to the finding of other work). This was associated with faster growth with calcium nitrate, as head size and yield was increased. At planting 2, the highest rate of nitrogen also increased tipburn.

In 1991 factors affecting water uptake were identified as having a major influence on the level of tipburn observed. In 1992 where soil moisture deficits experienced and nitrogen levels were lower than in 1991, less tipburn was observed. Where flash misting was used it reduced tipburn as did slower growth rates associated with lower rates of nitrogen and ammonium sulphate fertiliser. These aspects should be investigated further under higher SMD's. The rainfall in July, August and September 1992 was 235, 202 and 159% of the 20 year average for Kirton.

Introduction

Maturing crops of Chinese cabbage often develop tipburn which is ultimately caused by a localised calcium deficiency. Tipburn is a common disorder of head-forming vegetables like lettuce, cabbage and Chinese cabbage, the main symptoms are necrotic plant tissue at the edge of leaves, brown veins resulting in soft tissue, and brown dots. All these symptoms occur in the inner leaves which have restricted calcium supply and are rapidly expanding. Environmental factors such as high temperatures, sunshine, strong winds and moisture availability are known to increase tipburn as are high levels of nitrogen (especially in the ammonium form) and soluble salts in the soil.

In the 1991 HDC-sponsored trials the effects of irrigation, nitrogen-rate, -timing, and -source, eg ammonium versus nitrate, and calcium sprays were investigated. No reduction in tipburn was observed with calcium sprays (Paterson 1992). The main effect observed was that of irrigation, over the three sowing dates tipburn was increased where high soil moisture deficits were experienced, and applying irrigation reduced tipburn in the trials. In 1991 high levels of soil mineral nitrogen were present in the soil and little response to nitrogen was observed in terms of yield. Tipburn however, was generally low in the unfertilised control treatments compared with fertilised treatments, showing the damaging effects of high nitrogen supply.

In 1992 it was decided to investigate further the effects of nitrogen -rate and -source and irrigation. In addition to the two standard overhead irrigation treatments applying 25 mm water at 25 mm or 50 mm SMD, an additional irrigation treatment of overhead watering ('misting') for 15-20 minutes in late afternoon in hot, windy conditions from heart formation was included. The three sowing dates for the trial were brought earlier and closer together to try to ensure that growth and maturity occurred during a period of more stressful conditions.

Materials and methods

Seeds of variety Kasumi were sown on 19 May, 8 June and 30 June in 228 cellular trays using Bulrush modular compost. The trays were placed directly in a heated Venlo glasshouse at 18°C min with ventilation at 21°C. The plants were given liquid feeds of 100:200 mg/l $N:K_20$ as necessary. Fosetyl-aluminium (as Aliette) against downy mildew (*Peronospora parasitica*) and damping-off (*Pythium* spp) was applied as a drench post-emergence. The plants were treated with a drench of chlorpyrifos (as half-rate Dursban 4) pre-planting.

Treatments

A three replicate, split plot design was used with three irrigation treatments as main plots and seven fertiliser treatments as subplots. The fertiliser treatments were arranged as a two by three factorial design plus one control treatment, there were two fertiliser types and three rates used plus an untreated control.

The three irrigation treatments used were:

R. 25 mm applied at 50 mm SMD
S. 25 mm applied at 25 mm SMD
T. 25 mm applied at 25 mm SMD plus flash misting

The irrigation was applied using an overhead irrigation boom. The flash irrigation was applied for 15 minutes in the late afternoon in hot, windy conditions from heart formation. A simple small-scale fixed sprinkler system producing a fine spray was set up on these plots after planting. Soil moisture deficit (SMD) was calculated using Penman's equation (MAFF

1981) using a crop factor for growth stage specifically for Chinese cabbage in use in Rhineland-Palatinate State, Germany (pers. comm A. Maync).

Two fertiliser types were used:

Calcium nitrate - split between a base and top dressing
Ammonium sulphate applied with N Save at 10 kg/ha in a 2% solution

and three rates of application which were adjusted according to pre-planting soil mineral nitrogen levels.

	Sowing 1	Sowing 2	Sowing 3
Pre-planting soil mineral-N	122	144	144
Fertiliser rates	250 kg/ha N	225 kg/ha N	225 kg/ha N
	150 kg/ha N	135 kg/ha N	135 kg/ha N
	100 kg/ha N	90 kg/ha N	90 kg/ha N
HRI N-Model optimum	250	225	225

Fertiliser treatments were applied by hand before planting. The N Save solution was sprayed on to the plots using an Oxford precision sprayer before the ammonium sulphate was spread.

The three trials were planted by hand on 9 June, 30 June and 23 July respectively. The plant spacings were 330 mm between rows and 320 mm between plants to give five rows per 1.83 m wide bed. There were 85 plants/plot at an overall population of 95,000 plants/ha (38,000 plants/ac). The crops were grown to a good commercial standard using treatments given in Appendix 1.

At four weeks and after harvest soil samples were taken at 0-30, 30-60 and 60-90 cm depths, NH_4-N and NO_3-N was measured (Appendix 2).

Irrigation treatments

	Sowing 1	Sowing 2	Sowing 3
25 mm at 50 mm SMD	SMD not reached	SMD not reached	SMD not reached
25 mm at 25 mm SMD	24 June	SMD not reached	SMD not reached
Flash irrigation	16/7,17/7,18/7, 19/7,24/7,26/7, 28/7	Conditions not suitable	8/9,11/9,12/9
Representative treatments harvested	R,S,T	R	R + T

Recording

Leaf number and fresh and dry weights on five plants per replicate were recorded weekly from the rosette stage. The trials were harvested when the heads were well filled and moderately firm to the touch. All plots were harvested on the same day. The heads were trimmed for market and graded according to weight in size grades 600-800 g, 800-1000 g, 1000-1200 g, 1200-1400 g and >1400 g. The number of unmarketable heads was recorded in each of the following categories; small, rotten, cabbage root fly damage, caterpillar damage, loose, alternaria and pepper spot. All marketable heads were sliced in half and scored for tipburn on a scale of 0-4. Each size grade was recorded separately.

0 = no tipburn
1 = slight speckling in a limited area
2 = slight speckling throughout head
3 = brown margins to internal leaves in a limited area
4 = brown margins to internal leaves throughout head

Twenty heads per sample plot were examined for tipburn five and eight days after the main harvest. Sample plots received ammonium sulphate at the high rate with the low rate of irrigation.

Statistical analysis

Yield, quality and tipburn scores were subject to analysis of variance using transformed (angular) data where appropriate. Differences discussed below are significant at $p \leq 0.05$.

Results

Yield and quality - Nitrogen fertiliser

Applying nitrogen fertiliser increased marketable yield at all three sowings. From sowing 1 calcium nitrate fertiliser produced higher yields than no nitrogen and ammonium sulphate fertiliser. This increase was due to heavier heads being produced rather than more marketable heads, calcium nitrate fertiliser produced more 1000-1200 g and 1200-1400 g heads than other treatments (Table 1). Although the numbers of unmarketable heads in total were similar from all treatments, calcium nitrate fertiliser produced more rotten heads and fewer loose and small heads than other treatments.

From sowing 2 the percentage of marketable heads was less with calcium nitrate fertiliser than other treatments due to a high percentage of rotten heads. However the total marketable yield was as high as from the ammonium sulphate treatment due to a larger proportion of 1200-1400 g and >1400 g heads. Both fertiliser treatments produced higher yields than the unfertilised plots. Nitrogen rate had little effect on total yield, however there was an interaction between nitrogen and fertiliser type for percentage marketable. With calcium nitrate fertiliser lower nitrogen produced a higher percentage of marketable heads, due to there being fewer rotten heads. With ammonium sulphate fertiliser the lowest nitrogen rate produced fewer marketable heads, due to there being more loose heads. A similar relationship was seen for total marketable yield but was not statistically significant (Table 2).

From sowing 3 there was no effect of fertiliser type so yield data is presented for fertiliser rates only (Table 3). Applying nitrogen increased marketable yield compared with the untreated control, but there was no significant effect of rate on total marketable yield. The percentage of marketable heads was not affected by nitrogen treatments. With nitrogen fertiliser application more 1000-1200 g and 1200-1400 g heads were produced than for the untreated control. Applying 225 kg/ha N increased the percentage of 1000-1200 g and 1200-1400 g heads compared with the lower rates of nitrogen.

Yield and quality - Irrigation treatments

The full range of three different irrigation treatments was applied to sowing 1 and the flash misting was applied to sowing 3, sowing 2 did not require extra irrigation. At sowing 1 flash misting applied seven times in the two weeks prior to harvest reduced total yield compared with the other two irrigation regimes, 25 mm at 25 mm and 50 mm SMD. There was no effect of flash misting on yields at sowing 3.

Yield and quality - Starter solution treatments

Observation plots treated with a starter solution were included at sowings 2 and 3. The starter solution used was 40 ml of a 3% solution of Kemira 10:52:17 applied to the planting hole first before the plant was planted, 225 kg/ha N as ammonium sulphate was also applied broadcast. Plants from sowing 2, with starter solution treatment, produced low yields due to high levels of rotting and cabbage root fly damage. From sowing 3 there was no reduction in yield with the starter solution and the results were similar to the 225 kg/ha N fertiliser rate.

Table 1 Marketable yield - Sowing 1 (Angular transformation in parenthesis)

Treatment	Marketable yield (t/ha)	Percentages in size grade (g) 6-800	8-1000	10-1200	12-1400	>1400	% Unmarketable Loose	Small	Rot	% Marketable
Main effect fertiliser										
Control	49.1	22	24	10 (16)	2	1	6 (12)	13 (20)	11 (19)	59 (50)
Calcium nitrate 100	59.1	8	22	23 (28)	12	1	5 (11)	2 (7)	18 (23)	66 (55)
150	57.1	6	19	24 (29)	12	0	3 (7)	1 (4)	24 (28)	61 (52)
250	70.2	5	18	25 (30)	16	5	2 (6)	2 (7)	8 (19)	68 (56)
Mean	62.1	6	20	24 (29)	13	2	3 (8)	2 (6)	17 (23)	65 (54)
Ammonium sulphate 100	50.2	25	27	8 (15)	2	1	6 (13)	12 (18)	6 (14)	63 (53)
150	47.6	27	25	7 (15)	1	0	6 (10)	14 (21)	10 (17)	60 (51)
250	42.0	31	15	7 (13)	1	0	10 (16)	10 (17)	9 (17)	55 (48)
Mean	46.6	19	22	7 (14)	1	0	7 (13)	12 (19)	8 (16)	59 (50)
LSD 5% Fertiliser type (a)	10.1 ***	-	-	- (5.8) ***	-	-	- (5.6) **	- (5.0) ***	- (5.6) ***	- (6.2) NS
Fertiliser type x rate	12.33 *	-	-	- (7.1) NS	-	-	- (6.8) NS	- (6.2) NS	- (6.8) NS	- (7.5) NS
Main effect irrigation										
25 mm @ 50 mm SMD	57.9	18	24	16 (23)	6	2	5 (11)	7 (12)	12 (19)	67 (55)
25 mm @ 25 mm SMD	56.7	14	23	17 (22)	7	1	3 (8)	9 (14)	12 (18)	63 (53)
25 mm @ 25 mm SMD + Flash	46.1	21	17	11 (17)	6	0	8 (13)	8 (15)	15 (22)	56 (48)
LSD 5%	9.0 *	-	-	- (9.7) NS	-	-	- (12.8) NS	- (11.5) NS	- (15.9) NS	- (7.9) NS

Significance levels:-

*	$p \leq 0.05$
**	$p \leq 0.01$
***	$p \leq 0.001$

(a) LSD Fertiliser type to be used to compare control with fertiliser means

Table 2 Marketable yield - Sowing 2 (Angular transformation in parenthesis)

Treatment		Marketable yield (t/ha)	Percentages in size grade (g) 6-800	8-1000	10-1200	12-1400	>1400	% Unmarketable Loose	Rot	CRF	% Marketable
Control		46.2	20 (26)	19 (26)	14 (20)	3 (5)	0 (0)	13 (17)	10 (19)	2 (4)	55 (48)
Calcium nitrate	90	62.0	10 (19)	19 (25)	21 (27)	12 (19)	2 (4)	1 (3)	21 (26)	3 (9)	64 (53)
	135	57.9	4 (12)	9 (18)	19 (26)	9 (18)	11 (18)	4 (12)	23 (28)	3 (8)	53 (47)
	225	57.0	0 (0)	9 (18)	17 (24)	12 (20)	11 (19)	4 (9)	32 (34)	2 (4)	50 (45)
Mean		59.0	5 (10)	12 (20)	19 (26)	11 (19)	8 (14)	3 (8)	25 (30)	3 (7)	56 (48)
Ammonium sulphate	90	50.4	18 (25)	22 (28)	18 (24)	1 (3)	0 (0)	16 (22)	10 (18)	4 (7)	59 (50)
	135	59.6	21 (27)	32 (35)	21 (25)	1 (3)	1 (3)	3 (8)	9 (19)	1 (3)	76 (58)
	225	54.8	30 (33)	30 (33)	8 (15)	2 (6)	0 (0)	7 (15)	7 (15)	0 (0)	69 (57)
Mean		54.9	28 (32)	28 (32)	16 (21)	1 (4)	0 (1)	9 (15)	9 (17)	2 (3)	68 (55)
Starter solution		45.6	9 (17)	26 (30)	9 (16)	6 (11)	1 (3)	15 (22)	15 (22)	11 (18)	50 (45)
LSD 5% Fertiliser type (a)		11.9 *	- (4.6) ***	- (8.8) ***	- (8.5) NS	- (9.6) *	- (7.5) ***	- (8.2) ***	- (8.2) ***	- (11.6) *	- (6.2) **
Fertiliser type x rate		14.6 NS	- (5.6) ***	- (10.7) NS	- (10.4) NS	- (11.8) NS	- (9.2) NS	- (10.0) NS	- (10.0) NS	- (14.2) NS	- (7.5) *

Significance levels:-

* $p \le 0.05$
** $p \le 0.01$
*** $p \le 0.001$

(a) LSD Fertiliser type to be used to compare control with fertiliser means

Table 3 Marketable yield - Sowing 3 (Angular transformation in parenthesis)

Treatment	Flash Irr[n]	Marketable yield (t/ha)	Percentages in size grades (g) 6-800	8-1000	10-1200	12-1400	>1400	% Unmarketable Loose	Small	Rot	% Marketable
Control	-	47.6	36	21 (28)	5 (10)	0 (0)	0	7	16 (23)	13 (19)	63 (53)
0 kg/ha N	+	56.1	43	31 (34)	2 (4)	0 (0)	0	0	16 (23)	6 (14)	76 (61)
	Mean	51.8	40	26 (31)	4 (7)	0 (0)	0	4	16 (23)	10 (17)	70 (57)
90 kg/ha N	-	63.2	16	39 (39)	17 (24)	1 (5)	0	3	6 (13)	14 (21)	74 (59)
	+	67.2	16	35 (36)	23 (29)	3 (6)	0	1	6 (13)	10 (18)	77 (61)
	Mean	65.2	16	37 (37)	28 (26)	2 (5)	0	2	6 (13)	12 (19)	75 (60)
135 kg/ha N	-	67.0	19	39 (38)	18 (25)	2 (4)	0	1	4 (10)	13 (21)	77 (62)
	+	66.9	16	38 (38)	21 (27)	1 (3)	0	1	2 (5)	16 (23)	76 (61)
	Mean	66.9	18	38 (38)	20 (26)	2 (4)	0	1	3 (8)	14 (22)	76 (61)
225 kg/ha N	-	74.9	12	25 (28)	26 (30)	5 (12)	0	2	8 (15)	13 (20)	69 (56)
	+	62.6	10	32 (34)	34 (35)	5 (12)	0	0	3 (10)	11 (18)	81 (64)
	Mean	68.7	11	28 (32)	30 (33)	5 (12)	0	1	6 (13)	12 (19)	75 (60)
Starter soln	-	68.3	16	40 (39)	19 (25)	4 (9)	0	2	8 (16)	4 (9)	79 (63)
+ 225 kg/ha N	+	70.1	19	27 (31)	26 (31)	7 (14)	0	4	2 (7)	9 (17)	78 (62)
	Mean	69.2	18	34 (35)	23 (28)	6 (11)	0	3	5 (12)	7 (13)	78 (62)
Mean	+	62.7	18	33 (35)	18 (24)	3 (7)	0	3	7 (15)	12 (19)	73 (59)
	-	68.0	19	34 (35)	23 (27)	3 (7)	0	1	5 (11)	11 (18)	77 (62)
LSD 5%	N rate	6.01 ***	-	- (5.3) **	- (5.3) **	- (5.1) ***	-	-	- (5.5) *	- (6.3) *	- (4.6) NS
	N rate x Irrg[n]	9.15 *	-	- (8.6) NS	- (8.1) NS	- (8.1) NS	-	-	- (7.6) NS	- (13.9) NS	- (7.3) *

Significance levels:-
* $p \leq 0.05$
** $p \leq 0.01$
*** $p \leq 0.001$

Tipburn

Low levels of tipburn were observed, means of 4%, 12% and 1% for the three sowings respectively. The symptoms observed were slight, only black dots were seen on the inner leaf margins, only in one head had these developed to marginal necrosis of tissue. The low levels of tipburn are attributed to low soil moisture stress, there was plentiful rainfall in July, August and September (235, 202 and 159% of the 20 year average at Kirton), and low total soil nitrogen supply compared with 1991.

From sowing 1, tipburn was highest with calcium nitrate fertiliser but there was no difference between the different rates used. Only low levels of tipburn (3% and 2%) were found with no fertiliser or ammonium sulphate fertiliser. Applying irrigation at the lower soil moisture deficit did not reduce the level of tipburn. However applying the flash misting, on seven occasions prior to harvest, reduced tipburn overall from 5% to 2% (Table 4).

No irrigation treatments were applied to sowing 2. Calcium nitrate fertiliser again produced higher levels of tipburn than ammonium sulphate fertiliser or the untreated control. There was also a significant effect of nitrogen rate, 225 kg/ha N applied increased tipburn compared with lower rates (Table 5).

During the growth of sowing 3, soil moisture deficit did not rise above 21 mm and so no standard irrigation treatments were applied. Following heart formation the conditions for flash irrigation occurred and this was applied three times although the soil moisture deficit was low at the time. Very few heads with tipburn were found at harvest so the results were not analysed (Table 6).

Table 4 Percentage of heads with tipburn - Sowing 1 (Angular transformation in parenthesis)

Fertiliser treatment (kg/ha)	Irrigation-25 mm applied at:- 50 mm SMD	25 mm SMD	25 mm SMD + flash irig	Mean (over irrig^n treats)
Control	2.8 (7.8)	5.9 (10.8)	0 (0)	2.9 (6.2)
Calcium nitrate				
100	5.6 (10.8)	2.6 (7.5)	4.4 (9.6)	4.2 (9.3)
150	10.9 (18.4)	3.0 (8.2)	3.8 (9.2)	5.9 (11.9)
250	10.8 (11.5)	8.7 (16.3)	4.3 (11.8)	7.9 (13.2)
Mean	9.1 (13.6)	4.8 (10.7)	4.2 (10.2)	6.0 (11.5)
Ammonium sulphate				
100	1.8 (6.3)	1.9 (4.5)	0.0 (0)	1.2 (3.6)
150	1.0 (3.3)	2.0 (4.7)	2.3 (5.1)	1.8 (4.4)
250	4.4 (9.9)	3.2 (10.3)	0.0 (0)	2.5 (6.7)
Mean	2.4 (6.5)	2.4 (6.5)	0.8 (1.7)	1.9 (4.9)
mean (over fert treats)	5.3 (9.7)	3.9 (8.9)	2.1 (5.1)	3.7 (7.9)
LSD 5% irrigation	(2.19)**	nitrogen type	(6.78) **	

Table 5 Tipburn score - percentage of heads with tipburn - Sowing 2 (Angular transformation in parenthesis)

N Rate (kg/ha)	Control	Calcium nitrate	Ammonium sulphate	Mean
Control 0	3 (7)	-	-	3 (7)
90	-	14 (22)	0 (0)	7 (11)
135	-	28 (31)	0 (0)	14 (16)
225	-	40 (39)	2 (7)	21 (23)
mean	-	27 (31)	1 (2)	
Starter solution	3 (7)	-	-	7 (12)
LSD N (a) type	- (10.0) *	NS	NS	
N rate (a)	- (9.0) ***	NS	NS	

(a) LSD to be used to compare control with means of fertiliser type or rate.

Table 6 Tipburn scores - percentage of heads with tipburn - Sowing 3

Fertiliser treatment (kg/ha)	Irrigation (25 mm applied)		
	at 50 mm SMD	Plus flash irrigation	mean
Control	0	0	0
Calcium nitrate			
90	0	0	0
135	2	1	1
225	0	4	2
Mean	1	2	1
Ammonium sulphate			
90	0	2	1
135	0	0	0
225	1	1	1
Mean	0	1	1
Starter solution + 225 kg/ha N	3	3	3
Mean (over fert treats)	1	1	1

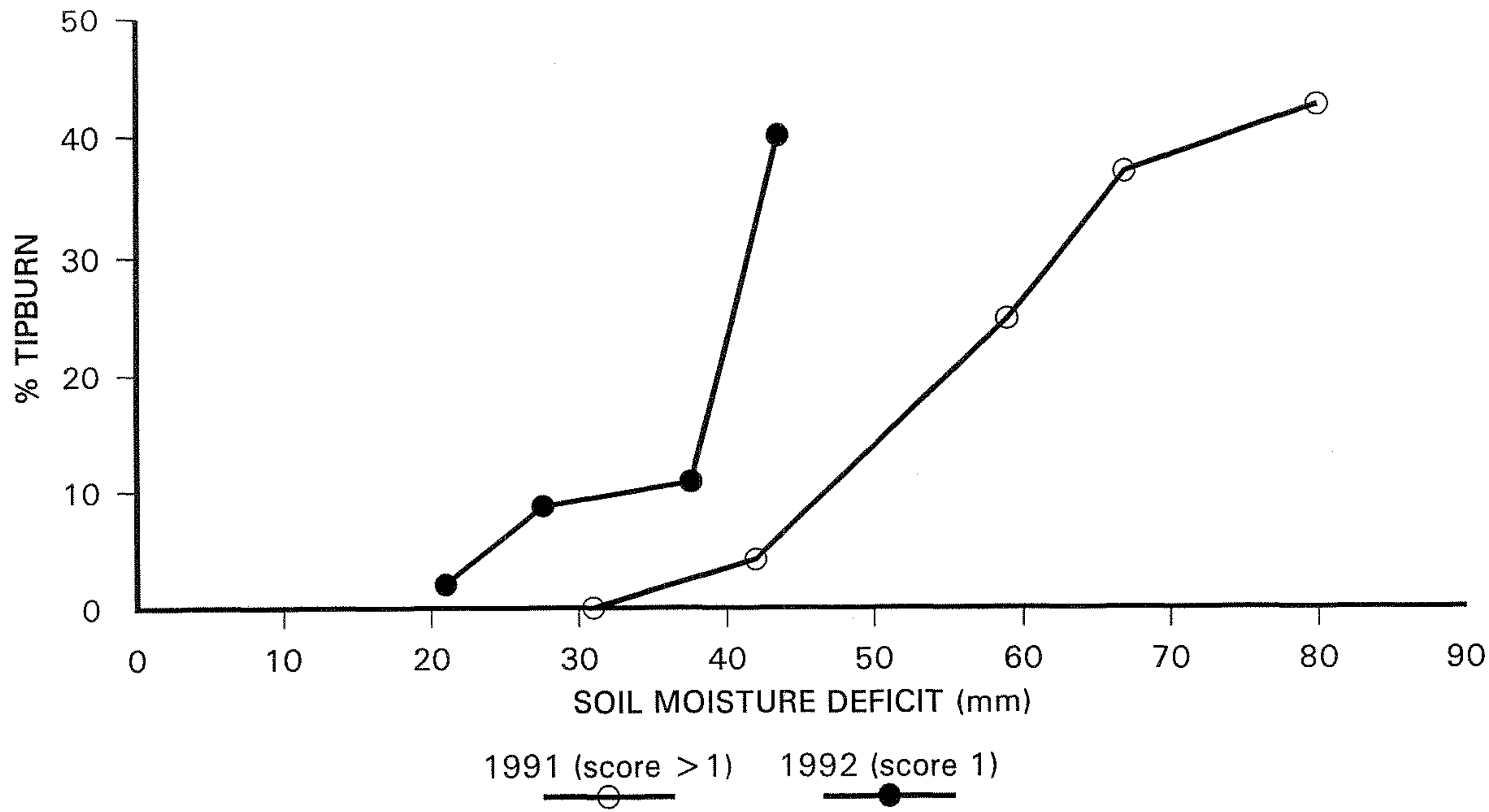
not analysed

Tipburn - Effect of soil moisture deficit

The difference in levels of tipburn between the three sowings can be explained to some extent by the soil moisture deficits experienced by the crops. Figure 1 shows maximum soil moisture deficit experience against percentage tipburn for 1992 and 1991. For 1991 the percentage tipburn greater than score 1 was plotted against maximum SMD developed. The points are mean percentages of tipburn from the highest fertiliser rate with and without additional irrigation. This produced five points from the three sowing dates, no additional irrigation was applied for the 3rd sowing. For 1992 the percentage tipburn from the highest rate of calcium nitrate fertiliser was plotted against SMD, from each sowing. There are four points as two levels of SMD developed on sowing 1 following application of irrigation treatments.

In 1991 high SMD's developed and high levels of moderately severe tipburn developed, in 1992 the SMD's were lower and the tipburn was less severe and at lower levels. In both years where maximum SMD experienced by the crop rose above 40 mm there was an increase in the level of tipburn.

Fig 1 Maximum soil moisture deficit and percent tipburn in 1991 (score >1) and 1992 (score 1) at highest rate of calcium nitrate fertiliser



Tipburn - Effect of nitrogen fertiliser

At sowings 1 and 2 there were significant treatment differences in yield and tipburn levels. These differences followed the same trends with calcium nitrate and high N treatments increasing yield, the proportion of larger heads and tipburn. Thus the effect of N supply on tipburn could be due to an increase in plant growth rate as well as a specific effect of nitrogen itself. Figs. 2 and 3 show the effect of head size on tipburn for sowings 1 and 2. As head size increased so did the percentage of heads in that size grade with tipburn. Sowing 2 produced more large heads, of which a higher proportion had tipburn, than sowing 1, possibly another contributory factor to the observed level of tipburn from sowing 2.

Head weight may be taken as a measure of growth rate as all plants were harvested on the same day. To distinguish between growth rate and a specific N effect the percentage of tipburn in heads of the same size was plotted against the nitrogen fertiliser applied for both sowings 1 and 2 (Figs. 4 and 5). From sowing 2 there is a clear relationship between nitrogen rate and level of tipburn particularly for the larger heads. For sowing 1, where less tipburn was observed, the relationship is less clear but levels of tipburn increase with increasing nitrogen overall.

These results show that both stimulation of growth and a specific N effect are implicated in the influence of N supply on tipburn of Chinese cabbage.

Fig 2 Percent of marketable heads in size grades and percent of heads with tipburn in each grade sowing 1

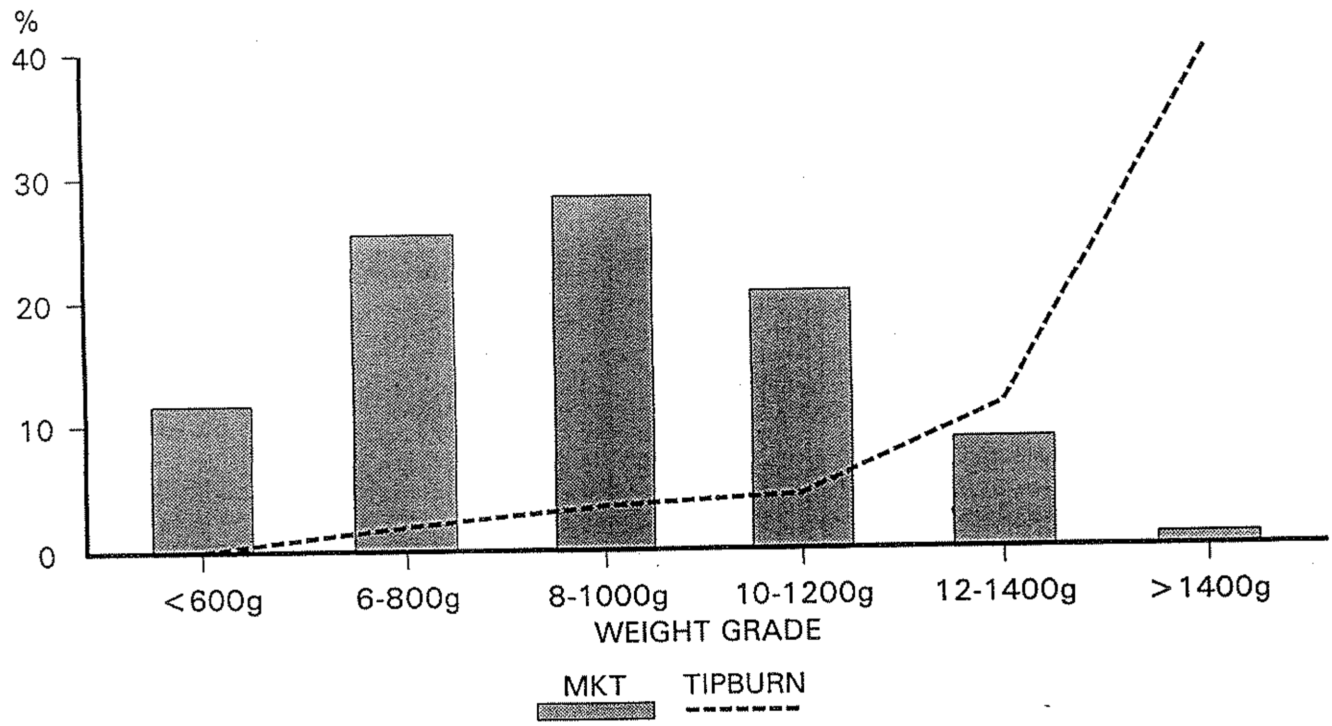


Fig 3 Percent of marketable heads in size grades and percent of heads with tipburn in each grade sowing 2

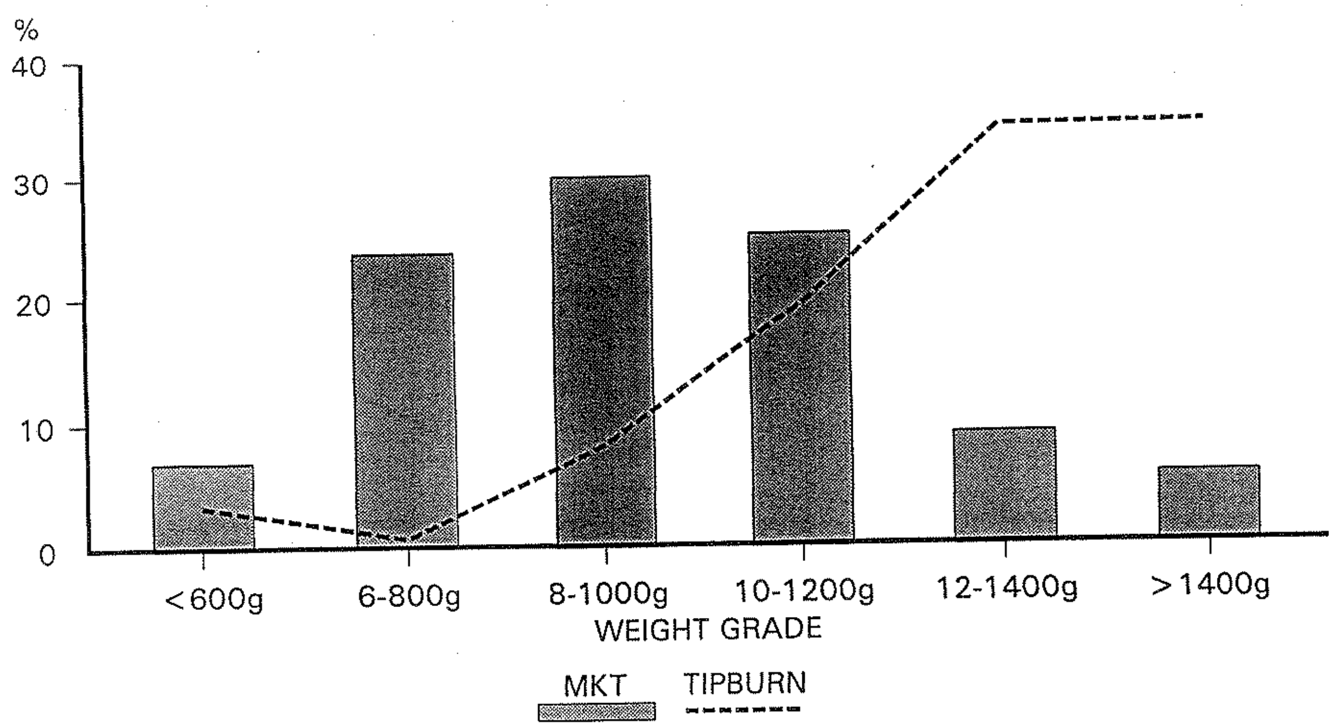


Fig 4 The influence of nitrogen rate on percent tipburn in different size grades - sowing 1

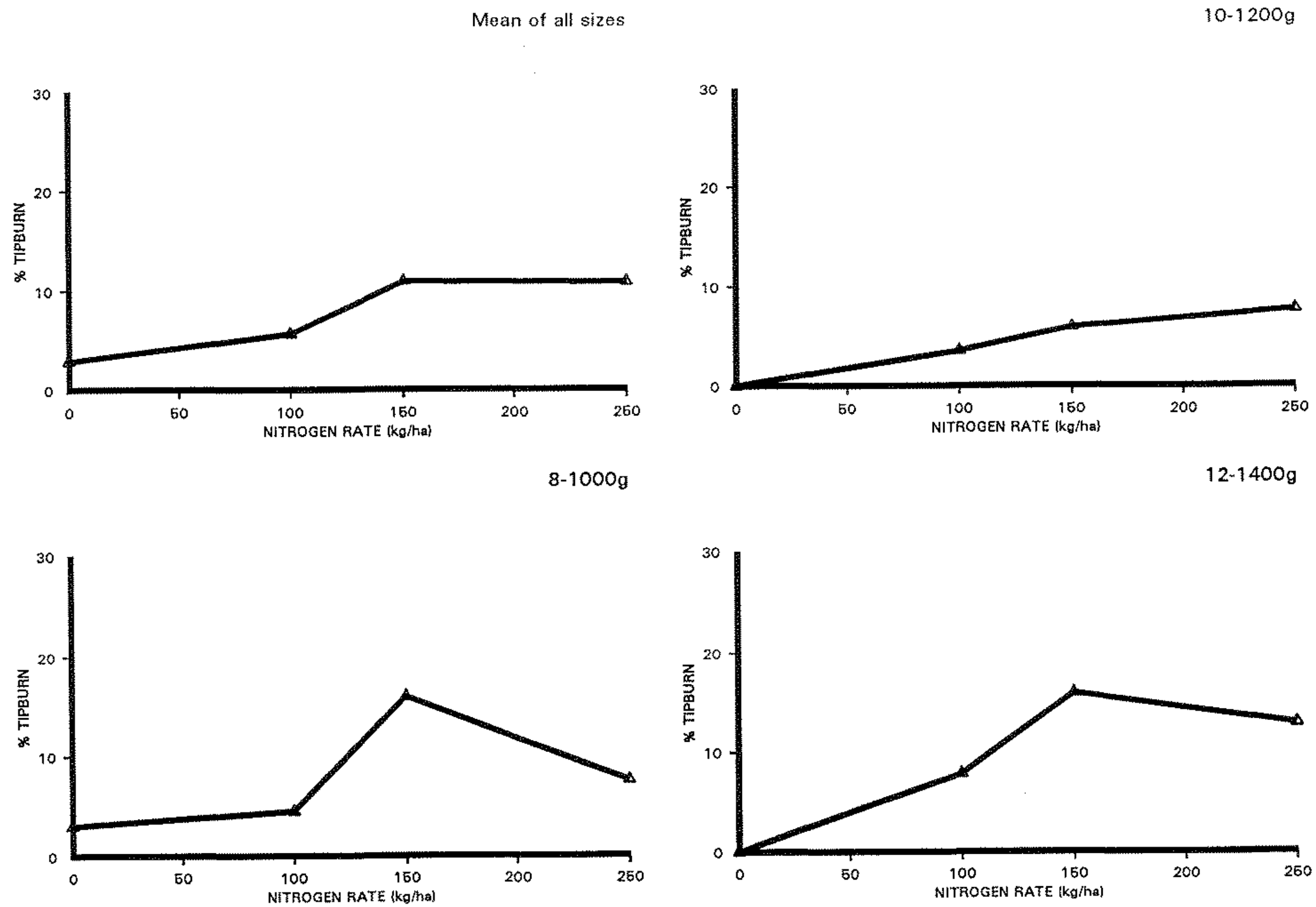
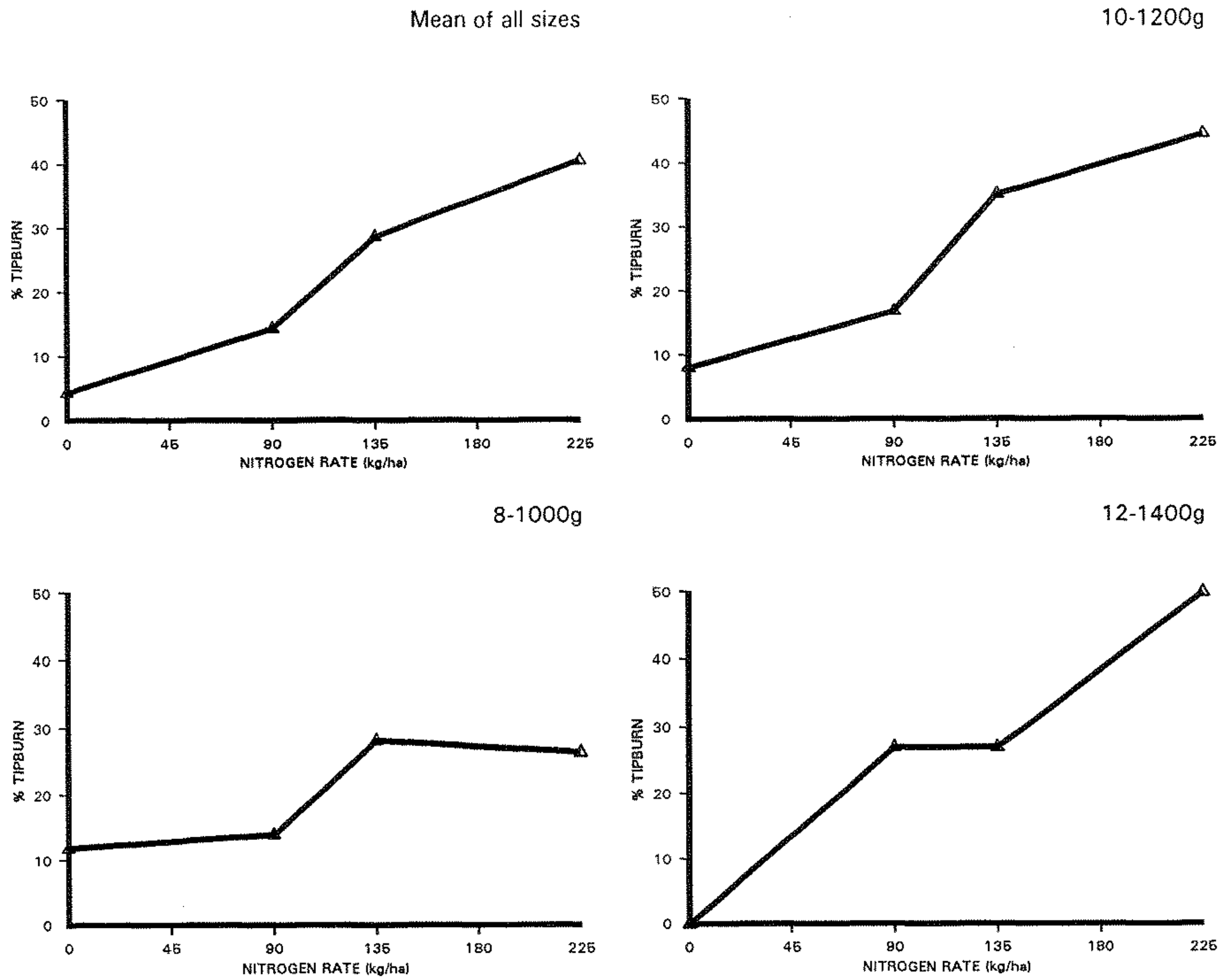


Fig 5 The influence of nitrogen rate on percent tipburn in different size grades - sowing 2



Tipburn - Effect of growth rate

The fresh and dry weight, and leaf number was measured weekly (Figs 6 and 7). Plants from all three sowings grew at very similar rates so differences in tipburn between sowing dates could not be attributed to growth rate overall.

Tipburn - Effect of maturity

The effect of maturity on tipburn was examined in additional sample plots. There was no increase in tipburn five or eight days after harvest but the treatment given had low levels of tipburn at harvest so differences would not have been picked up at the level of sampling carried out.

Conclusions and discussion

In the 1992 trials only low levels of tipburn were observed compared with 1991, this can be attributed to the cooler wetter growing conditions experienced in 1992. The intended irrigation treatments were not always applied due to high levels of rainfall, however there was a positive relationship between soil moisture deficit and tipburn, as there was in 1991. The soil moisture deficit above which tipburn increased noticeably was around 40 mm in both years (Paterson 1992).

Increased tipburn has been observed where irrigation application has been delayed (Runham 1990). The current practice is to give 25 mm of water at 35 mm SMD, which may be a slightly risky practice if timing is unreliable. A target of 25 mm SMD may be more reliable. The use of flash irrigation reduced tipburn at the first sowing but the total yield was reduced. The importance of good water supply management has been highlighted by other workers for Chinese cabbage (Suh, Park and Kwon 1987a, 1987b and Imai, Ma and Wu 1988).

Nitrogen application and fertiliser type affected tipburn levels in these trials, as in 1991. High rates of nitrogen increased tipburn however this effect was partially due to increased

Fig 6 Increase in fresh weight with time

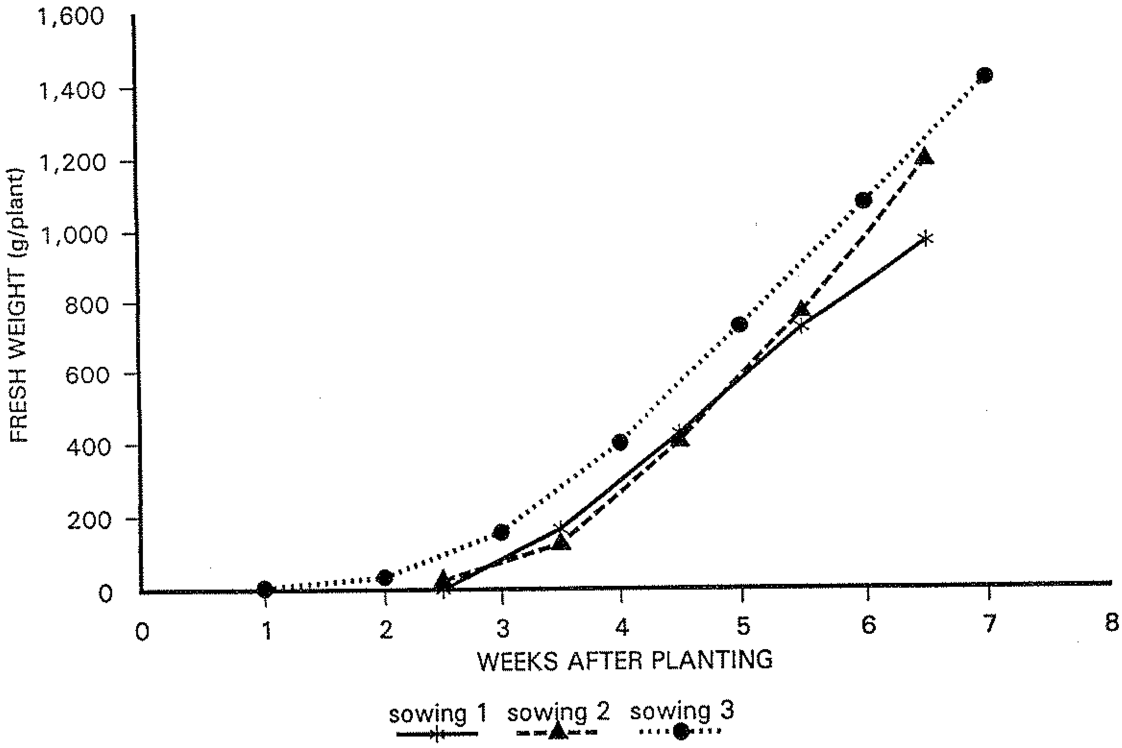
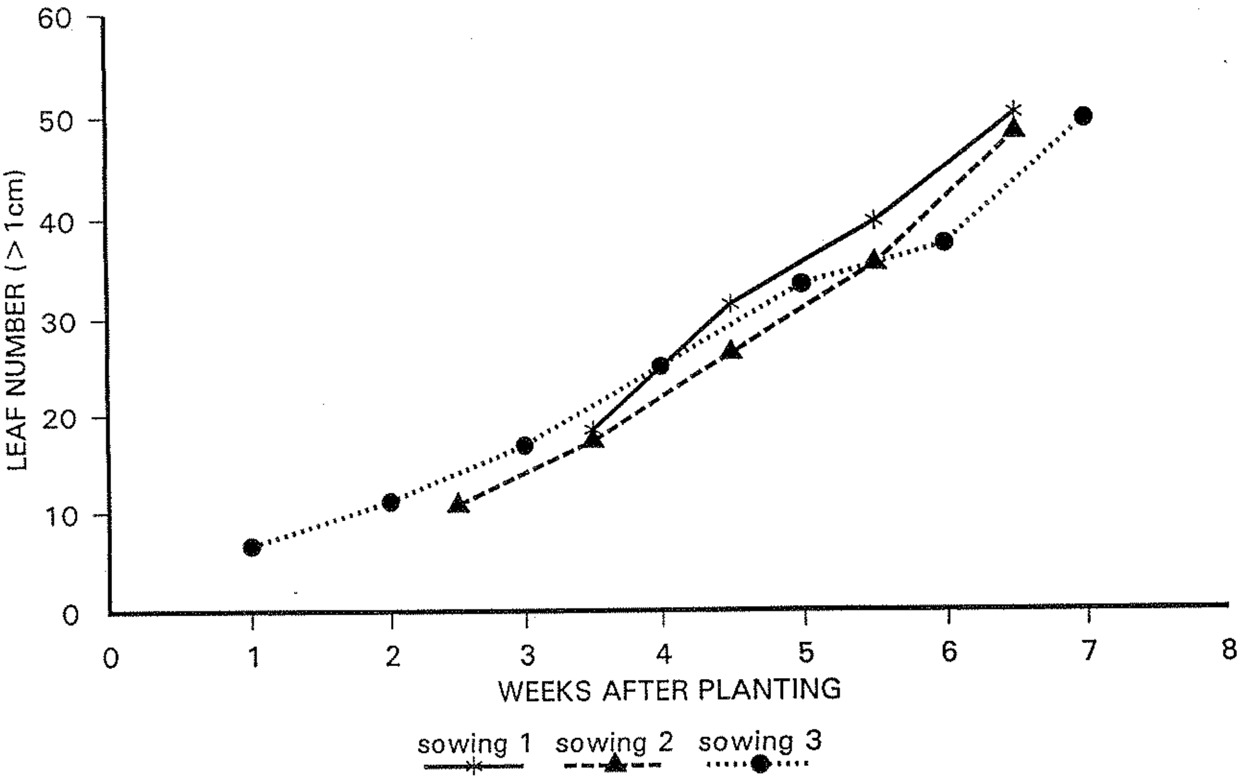


Fig 7 Increase in leaf number with time



growth rate. The effect of high growth rate on calcium deficiency disorders is generally recognised (Thibodeau and Minotti 1969, Bangerth 1979, Coleman 1982) and specifically for Chinese cabbage (Imai *et al* 1988). At high growth rates the calcium supply to the affected tissues is inadequate, and a localised and transient calcium deficiency can occur. Reducing the amount of nitrogen applied can control the growth rate and reduce the level of tipburn occurring.

A specific nitrogen effect on tipburn was also demonstrated in these trials, in addition to its effect on growth rate. This has recently been shown for lettuce (Bruum and Schenk 1993). They suggested that at higher nitrogen rates the root/shoot ratio is decreased and that calcium uptake is reduced by the restricted root growth. Aloni (1986) has shown for Chinese cabbage that reducing the root volume without causing water stress in pot experiments decreased the uptake of calcium. The effect of high nitrogen rates may also be due to increased soil conductivity and it's effect on water uptake.

In 1991 factors affecting water uptake were identified as having a major influence on the level of tipburn observed. The effects of nitrogen treatments were explained in terms of effects on water uptake ie, high soil conductivity and the effect of the ammonium ion on water uptake. In 1992 the soil moisture deficits experienced were lower as was the level of tipburn, in agreement with the 1991 results, however this did not allow a good test of the effect of irrigation as a means of tipburn control.

The results obtained in these trials demonstrate the effects of nitrogen fertiliser on tipburn. High levels of nitrogen stimulated more rapid growth and thereby increased tipburn. The current ADAS recommendations are too high (MAFF 1988), these are 300 kg/ha N at index 0 and 250 kg/ha N at index 1. The HRI-nitrogen model predicted optimum yields with 250 kg/ha and 225 kg/ha for soils that would be classified as index 1. These levels of nitrogen increase the amount of tipburn in the crop. Fertiliser recommendation in use in Germany suggest that high levels of nitrogen can lead to tipburn in Chinese cabbage (Lorenz *et al* 1989) and calculating nitrogen requirement using the KNS system suggests the application of 250 - soil mineral nitrogen kg/ha N ie, 128, 106 and 106 kg/ha N for the three sowings. Careful attention should be paid to nitrogen fertiliser use for this crop.

Recommendations

1. To avoid tipburn it is suggested that SMD is not allowed to go above 30 mm (25 mm would be a safer target.

2. This should be tested experimentally under conditions of high evapotranspiration demand as should the technique of flash 'misting'.

3. Nitrogen fertiliser application should be reduced so that growth rate is slowed, harvest may be delayed by a few days but this may be a necessary precaution which could be built into saving programmes.

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APPENDIX 2 Soil mineral nitrogen content at 4 weeks from planting and at harvest from Ammonium sulphate plus N Save treated plots at highest rate (kg/ha N).

Depth	0-15 cm		15-30 cm		30-60 cm		Total 0-60 cm		
	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	Total
Sowing 1									
At harvest	5.5	12.5	5.3	7.8	3.2	3.3	14.0	23.6	37.6
Sowing 2									
Planting + 4 weeks	1.8	29.1	0.9	65.8	2.0	48.0	4.7	142.9	147.6
At harvest	3.1	5.7	2.9	5.7	2.5	3.2	8.5	14.6	23.1
Sowing 3									
Planting + 4 weeks	186.9	73.7	5.3	49.5	19.7	82.9	211.9	206.1	418.0
At harvest	78.5	49.1	82.6	19.0	10.7	44.4	171.8	112.5	284.3

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