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CONTRACT REPORT
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CHINESE CABBAGE - AN EXAMINATION OF THE POSSIBLE CAUSES OF INTERNAL TIPBURN UNDERTAKEN FOR THE HDC

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CHINESE CABBAGE: AN EXAMINATION OF THE POSSIBLE CAUSES OF INTERNAL TIPBURN

Summary

Chinese cabbage, variety Kasumi was grown from three planting dates, 20 June, 8 July and 16 August in three separate trials. In each trial three fertiliser types, calcium nitrate all as base dressing and split between base and top dressings and ammonium sulphate applied with nitrification inhibitor (N Save) were applied at four rates, 150, 200 and 300kg/ha N and 300kg/ha N with extra irrigation and compared with an untreated control. Each fertiliser x rate treatment was grown with and without calcium nitrate sprays from the start of heart formation. Total yield in size grade was recorded and each marketable head was inspected internally for tipburn.

Fertiliser type and rate and additional irrigation had little effect on yield or percentage marketable heads over the three trials, although in the first trial the control produced lower yields.

Tipburn incidence was highest from the July planting (34%) with less from the June planting (14%) and no serious tipburn from the August planting, which was harvested in October.

The use of calcium sprays did not affect the level of tipburn. The control treatment had lower levels of tipburn than the fertilised treatments although with the reduction in yields this would not be advised as a means of reducing tipburn. Within the fertilised treatments, applying 300kg/ha N with no extra irrigation increased tipburn as did applying ammonium sulphate plus N Save. Over the three trials there was a positive relationship between maximum soil moisture deficit developed and tipburn levels. It was suggested that factors affecting water uptake including soil moisture deficit, weather conditions, soil conductivity in general and ammonium concentration in particular combined to increase the level of tipburn by disrupting calcium uptake and supply to the heart leaves of the Chinese cabbage plants. These results represent one year's work only and so should be treated with caution, the effects of water use and soil conductivity should be tested under different weather conditions.

Introduction

Maturing crops of Chinese cabbage are often susceptible to marginal leaf tissue breakdown which is thought to result from poor distribution of calcium. The problem is exacerbated by drying conditions - strong winds, sunshine, high temperatures - especially when these occur in combination with high levels of ammoniacal nitrogen and soluble salts in the soil.

Work at the Asian Vegetable Research and Development Centre (AVRDC), Taiwan showed that ammonium toxicity discouraged rooting and during times of rapid top growth, this exacerbated tipburns (Imai, Ma and Wu 1988).

Complementary work at the same centre showed that the more controlled early growth, resulting from split applications of N gave the heaviest heads without tipburn or internal rot. Workers at AVRDC determined that crops were most vulnerable to these disorders at the hearting stage (AVRDC 1987a, 1987b, 1987c).

Various calcium solutions have been used as sprays of calcium chloride, nitrate and citrate and proprietary brands containing calcium. A range of concentrations have also been used. Buitelaar working under glass in Holland greatly reduced tipburn in winter grown crops by spraying with $Ca(NO_3)_2$ solution (0.6-1.9%) 3 times per week for two weeks before harvest (1982, 1983, 1984). Marote et al (1986) also reduced tipburn under glass using a foliar calcium spray (Wuxal calcium) and at AVRDC (1987c) internal rot was reduced by spraying with calcium nitrate. Aloni (1986) was not able to reduce tipburn by irrigating with 10mM calcium nitrate or chloride solutions in pot-grown Chinese cabbage. Nor was van Berkel (1988) able to affect tipburn under glass using a 0.7% calcium nitrate spray. Johnson (1991) sprayed spring greens grown in the field with calcium nitrate and chloride solutions (4.8% and 2.2% respectively) weekly from 10 days from planting. Up to 49% of plants had tipburn but the calcium sprays had no effect on the incidence of tipburn.

Water stress has also been implicated in causing tipburn. Suh, Park and Kwon (1987a, 1987b) stated that plants grown under water stress were more likely to show symptoms of tipburn. Workers at AVRDC suggested that ammonium toxicity was due to reduced water uptake due to root damage and that careful management of soil water status could reduce tipburn (Imai 1987). Experimental work in solution culture has established that a minimum of 80 ppm calcium was needed for normal growth and tipburn symptoms developed at 20 ppm (Zhao, Xing and Li, 1982).

In this project it was decided to investigate the effects of calcium sprays, nitrogen source, eg ammonium versus nitrate, timing of nitrogen via split dressings and base dressings, rate of nitrogen and irrigation on tipburn in three successive sowings.

Materials and methods

Plant raising and culture

Seeds of variety Kasumi were sown on 30 May, 14 June and 23 July 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 $N:K_2O$ as necessary. Propamocarb hydrochloride (as Filex) 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 13 fertiliser treatments as main plot treatments and with or without calcium sprays as the two subplots. The fertiliser treatments were arranged as a three by four factorial design plus one control treatment, there were three fertiliser types and four rates used plus an untreated control.

Three fertiliser types were used:

Calcium nitrate - all as a base dressing

Calcium nitrate - split between a base and a top dressing

Ammonium sulphate applied with N Save at 10 kg/ha in a 2% solution

and four rates of application

300 kg/ha N plus extra irrigation 25 mm applied at 25 mm SMD

300 kg/ha N with no additional irrigation

200 kg/ha N with no additional irrigation

150 kg/ha N with no additional irrigation

and a control zero nitrogen with no additional irrigation

The trials were planted by hand on 20 June, 8 July and 16 August. The plant spacings were 300mm between rows and 350mm between plants for sowings 1 and 2 and 330mm between rows and 320mm between plants for sowing 3. Sowing 3 was planted on beds to improve access for spraying operations. At both plant spacings the overall population was 95,000 plants/ha (38,000 plants/ac). The crops were grown to a good commercial standard using treatments given in Appendix 1. Soil samples to three depths, 0-150mm, 150-300mm and 300-600mm were taken pre-planting.

Fertiliser treatments were applied by hand before planting, additional irrigation was applied via purpose made layflat irrigation grids to individual plots according to soil moisture deficit (SMD) 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). The whole trial was irrigated using an overhead irrigation boom with 25mm at SMD = 50mm.

Each fertiliser treatment was grown with and without calcium sprays. The calcium spray was applied as 20 g/l $Ca(NO_3)_2$ at 450 l/ha using an Oxford precision sprayer. Sprays were applied at intervals from approximately one week before head formation as shown below:-

	Sowing 1	Sowing 2	Sowing 3
Planted	20 June	8 July	16 Aug
Top dressed	17 July	8 Aug	9 Sept
Sprayed 22 July	√		
29 July	√	√	
7 Aug	(9 Aug cut)	√	
16 Aug		√	
27 Aug		√ (3 Sept trial cut)	
20 Sept			√
26 Sept			√
9 Oct			√ (24 Oct trial cut)

√ = timing of calcium spray

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. For sowing 1 only, those treatments with more than 50% mature heads were cut on 9 August when 18 plants per plot were cut, on 12 August 27 plants per plot were cut from all plots to give one common harvest. On 14 August the remainder of the plants on the plots not cut on 9 August were cut. The heads were trimmed for market and graded according to weight in size grades 600-700g, 700-800g, 800-900g, 900-1000g and >1000g. 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.

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

For sowing 2, all marketable-sized heads were cut on 3 September, they were graded into size grades; 600-800g, 800-1000g, 1000-1200g, 1200-1400g and >1400 g. Marketable heads were inspected for tipburn as before, but each size grade was scored separately. Sowing 3 was harvested on 24 October when 20 heads per plot were cut, and graded and scored as per sowing 2.

Statistical analysis

In sowings 1 and 2, each main plot consisted of nine rows of 19 plants, a picture frame of guard plants was used allowing seven rows of 17 plants. One guard row was left between each sub-plot thereby allowing three rows of 17 recordable plants in each side-by-side sub-plot. For sowing 3, five rows of 27 plants formed the main plots and three rows of 12 plants formed the recordable plants for each end-to-end sub-plot. 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

The different rates and types of fertiliser used and additional irrigation had little effect on the yield or percentage marketable heads over the three sowings. Only at sowing 1 was there an effect where the untreated control produced a lower yield and percentage marketable than the fertilised treatments (Table 1). The control produced more small and loose heads than fertilised treatments and fewer heads over 1kg in weight. At sowing 2, there was no overall effect of fertiliser treatment on yield, however 300 kg/ha nitrogen plus irrigation reduced the percentage of 600-800g heads and increased the percentage of over 1400g heads although not enough to affect the overall yield significantly.

Sowing 2 was badly affected by cabbage root fly with eggs being laid on the base of the plant and developing larvae burrowing into the midribs of the outer leaves causing rotting or complete death of the plant. Trichlorofon as Dipterex 80 was applied on 6 August and then weekly from 28 August (see Appendix 1). The first spray did not hold the attack and the main damage was done in mid August before weekly spraying was started. Plants from all fertiliser treatments were equally affected at about 30% of heads unmarketable, only the marketable heads were assessed for yield and tipburn. Calcium nitrate sprays reduced the percentage of cabbage root fly damaged plants from 34% to 28%. This spraying may have deterred egg laying by making the plants wet or by masking the brassica smell that attracts cabbage root fly or possibly by washing off some eggs (pers. comm. Lole). By reducing losses due to cabbage root fly, calcium nitrate sprays increased the percentage marketable and total yield pro rata. It is not thought that the calcium nitrate spray affected yield in any other way.

Sprays against cabbage root fly attack gave adequate protection of plants from sowing 3 and yields and percentage marketable were similar or slightly better than for sowing 1. There was no effect of fertiliser type or rate on total marketable yields or any other aspect of yield. Spraying with calcium nitrate increased the number of medium sized heads and reduced the number in the smallest size grade overall in this trial.

Table 1a Marketable yield - sowing 1

Treatment	Marketable % Marketable	Total yield t/ha	Percentages in size grades % 6-700g	% 7-800g	% 8-900g	% 9-1000g	% >1000g	% Small	Unmarketable % Rotten	% Loose
Main effect fertiliser type										
Control	49 (45)	43.4	6	8	11	7	18 (22)	13 (21)	15 (22)	19 (24)
Calcium nitrate (base)	64 (53)	59.7	6	10	11	10	27 (31)	12 (20)	12 (19)	9 (17)
Calcium nitrate (split)	69 (57)	67.6	4	8	10	11	37 (37)	7 (14)	16 (23)	6 (12)
Ammonium sulphate + N Save	63 (53)	61.5	4	7	9	12	31 (33)	9 (17)	17 (24)	7 (15)
LSD (5%)										
(a)	- (3.4)	7.0	-	-	-	-	- (5.2)	- (3.9)	- (3.3)	- (3.7)
(b)	- (5.4)	11.1	-	-	-	-	- (8.2)	- (6.2)	- (5.2)	- (5.8)
Main effect fertiliser rate										
Control	49 (45)	43.4	6	8	11	7	18 (22)	13 (21)	15 (22)	19 (24)
300 kg/ha + I	67 (53)	65.7	6	8	9	10	35 (35)	12 (19)	11 (19)	8 (15)
300 kg/ha	63 (53)	60.6	4	9	11	11	28 (32)	10 (18)	16 (23)	8 (16)
200 kg/ha	68 (56)	64.3	5	8	10	12	32 (34)	7 (14)	17 (24)	5 (12)
150 kg/ha	63 (53)	60.9	3	7	11	12	30 (33)	9 (16)	16 (23)	9 (16)
LSD (a)	- (4.0)	8.1	-	-	-	-	- (6.0)	- (4.5)	- (3.8)	- (4.3)
(b)	- (5.6)	11.5	-	-	-	-	- (8.5)	- (6.4)	- (5.4)	- (6.0)
Main effect calcium sprays										
Ca Spray	65 (54)	62.5	4	9	11	12	30 (32)	10 (17)	14 (22)	7 (14)
No spray	63 (53)	60.3	6	8	9	10	31 (33)	9 (16)	16 (23)	10 (17)
LSD (5%)	- (NS)	NS	-	-	-	-	- (NS)	- (NS)	- (NS)	- (2.5)

(b) to compare control with other fertiliser types or rates
(a) to compare fertiliser types or rates

Table 1b Marketable yield - sowing 2

Treatment	Marketable % Marketable	Total yield t/ha	Percentages in size grades % 6-800g	% 8-1000g	% 10-1200g	% 12-1400g	% >1400g	% Small	% Cabbage Root fly	Unmarketable % Loose
Main effect fertiliser type										
Control	35 (36)	31.3	8 (15)	14	10	3 (8)	0 (1)	8	31 (34)	20 (26)
Calcium nitrate (base)	34 (35)	33.9	6 (11)	11	8	5 (11)	4 (8)	7	31 (34)	17 (24)
Calcium nitrate (split)	34 (35)	32.3	6 (12)	11	9	5 (10)	3 (7)	8	31 (33)	16 (23)
Ammonium sulphate + N Save	36 (36)	35.1	5 (11)	12	11	5 (11)	3 (7)	8	31 (33)	16 (23)
LSD 5% (a)	- (5.5)	9.3	- (4.0)	-	-	- (4.6)	- (4.1)	-	- (5.8)	- (3.2)
(b)	- (8.8)	14.7	- (6.3)	-	-	- (7.3)	- (6.4)	-	- (9.2)	- (5.0)
Main effect fertiliser rate										
Control	35 (36)	31.3	8 (15)	14	10	3 (8)	0 (1)	8	31 (34)	20 (26)
300 kg/ha + I	37 (37)	39.5	4 (9)	9	11	7 (13)	7 (12)	7	28 (32)	17 (24)
300 kg/ha	36 (36)	35.2	5 (11)	12	10	6 (12)	3 (6)	8	32 (34)	14 (21)
200 kg/ha	34 (35)	32.9	4 (11)	12	10	5 (11)	2 (6)	7	28 (31)	21 (27)
150 kg/ha	31 (33)	27.5	8 (15)	12	8	2 (5)	1 (5)	8	37 (37)	15 (22)
LSD (5%)										
LSD (5%) (a)	- (6.4)	10.7	- (4.6)	-	-	- (5.4)	- (4.7)	-	-	- (3.6)
(b)	- (9.1)	15.2	- (6.5)	-	-	- (7.6)	- (6.6)	-	-	- (5.1)
Main effect calcium sprays										
Calcium spray	37 (37)	36.2	6 (12)	13	10	5 (10)	4 (8)	8	28 (32)	17 (24)
No spray	32 (34)	31.0	6 (12)	10	9	5 (11)	2 (6)	7	34 (35)	17 (23)
LSD (5%)	- (2.4)	3.7	- (3.0)	-	-	- (2.4)	- (2.6)	-	- (1.9)	- (2.6)

(a) to compare fertiliser types or rates
(b) to compare control with other fertiliser types or rates

Table 1c Marketable yield - sowing 3

Treatment	Marketable % Marketable	Total yield t/ha	Percentages in size grades % 6-800g	% 8-1000g	% 10-1200g	% 12-1400g	% >1400g	% Small	Unmarketable % Loose
Main effect fertiliser type									
Control	70 (57)	63.8	11	25	29	6	0	18	12
Calcium nitrate (base)	71 (59)	65.0	14	31	19	6	1	15	12
Calcium nitrate (split)	72 (60)	66.2	16	29	17	8	2	15	11
Ammonium sulphate + N Save	74 (61)	70.8	12	29	22	8	3	14	10
LSD (5%)									
(a)	- (7.1)	13.2	-	-	-	-	-	-	-
(b)	- (11.2)	20.9	-	-	-	-	-	-	-
Main effect fertiliser rate									
Control	70 (57)	63.8	11	25	28	6	0	18	12
300 kg/ha + I	72 (60)	68.9	11	28	22	9	3	14	12
300 kg/ha	74 (60)	67.5	15	28	22	8	1	15	10
200 kg/ha	70 (59)	63.1	15	31	17	6	1	18	10
150 kg/ha	75 (61)	69.6	16	33	18	6	2	12	12
LSD (5%) (a)	- (11.6)	15.3	-	-	-	-	-		
(b)	- (8.2)	21.6	-	-	-	-	-		
Calcium sprays									
Ca Spray	72 (60)	68.2	10 (17)	28	27 (27)	7	1	15	11
No spray	72 (60)	65.9	17 (23)	29	17 (24)	8	2	15	10
LSD (5%)	- (6.6)	8.8	- (4.8)	-	- (3.4)	-	-	-	-

(a) to compare fertiliser types or rates
(b) to compare control with other fertiliser types or rates

Tipburn

Most tipburn occurred in the second sowing harvested in mid September, with 34% of heads with a tipburn score of 2 or more (score 2+). There was less tipburn in the first sowing (13.5% score 2+) but there was however a large proportion of those heads with severe tipburn (score 4). In the third sowing harvested in late October no heads were recorded with score 2+ but 35% had slight tipburn score 1.

The percentage of heads with tipburn score 2 or more was analysed as many heads had slight speckling of the inner leaf margins. It was felt that this may or may not have developed into clearly visible symptoms of tipburn, ie browning and subsequent rotting of inner leaf margins, if left. The results from sowings 1 and 2 were combined but there were no score 2+ heads from sowing 3 so these were not included and were analysed separately as percentage of score 1 heads. (Table 2)

Table 2 Summary of tipburn scores at each harvest

	Tipburn score				
	% score 0	% score 2+	% score 4	% score 1+	Mean score
Sowing 1	69.7	13.5	5.7	30.5	0.572
Sowing 2	48.3	34.0	11.7	51.7	1.154
Sowing 3	65.4	0	0	34.6	0.347

The use of regular calcium nitrate sprays did not affect the level of tipburn in any of the three sowings (Tables 3 & 4). The use of fertiliser compared to no fertiliser (control) and the type and rate of application and the use of irrigation all affected tipburn.

The control treatment, no fertiliser applied, had lower levels of tipburn than the fertilised treatments. Within the fertilised treatments applying 300 kg/ha with no extra irrigation increased tipburn compared with the other rates applied, which were similar overall. Applying nitrogen as ammonium sulphate plus N Save increased tipburn compared with applying it as calcium nitrate all in the base dressing. In sowing 1, applying 300 kg/ha ammonium sulphate plus didin with no extra irrigation stood out as significantly worse for tipburn than the control and most other treatments. In sowing 2, only calcium nitrate all in the base at 200 or 150 kg/ha was not significantly different from the control, these two treatments also had low levels of tipburn in sowing 1 (Table 3).

Table 3 Tipburn scores, sowing 1 and 2 combined
Percentage of heads with score 2 or greater

Fertiliser type	Sowing	Fertiliser rate (kg/ha) Control	300 plus extra irrigation	300 no extra irrigation	200	150	Mean
Control	S1	3.3					} 7.4
	S2	11.5					}
Ca nitrate base	S1		4.4	13.1	18.5	7.0	} 21.0
	S2		27.2	49.1	24.9	23.4	}
Ca nitrate split	S1		2.0	17.8	7.1	27.7	} 24.1
	S2		36.3	45.1	30.9	26.2	}
Am. sulphate	S1		6.2	43.4	9.7	14.7	} 29.7
	S2		47.5	33.4	45.6	37.0	}
Mean		7.4	20.6	33.6	22.8	22.7	

LSD (5%) mean fertiliser rate 13.1
mean fertiliser types 12.7
for each sowing, rate x type interaction 22.7

Tipburn scores - the effect of calcium spray and fertiliser treatment, sowing 1 and 2 combined

Treatment	Control	Fertiliser	Mean
Calcium spray	6.3	24.8	23.4
No spray	8.6	25.1	23.8
Mean	7.5	24.9	23.6

LSD (5%) control v fertiliser 11.72
Ca spray 3.92

Sowing 3 analysed as percent score 1 was less variable than sowings 1 and 2. There was no difference between the control and fertilised treatments, unlike sowings 1 and 2. However, in agreement with sowings 1 and 2, applying 300 kg/ha nitrogen with no extra irrigation caused more tipburn than applying 150 kg/ha nitrogen. There was also a trend towards more tipburn when ammonium sulphate plus didin was applied (Table 4).

Table 4 Tipburn scores Sowing 3
Percentage of heads with score 1 or greater

Treatment type	Rate (kg/ha) Calcium spray	Control	300+ Extra irrigation	300- Irrigation	200	150	Mean
Control	+	31					)33.0
	-	35					)
Calcium nitrate (base)	+		38	35	28	31	)33.4
	-		25	27	52	31	)
Calcium nitrate (split)	+		30	44	30	32	)32.4
	-		37	36	24	26	)
Ammonium sulphate + N Save	+		48	54	27	29	)38.8
	-		33	55	41	23	)
Mean		33	35	42	34	29	
LSD (5%)		Mean fertiliser rate 10.0 Mean fertiliser type 8.7					

Tipburn scores - the effect of calcium spray and fertiliser treatment

Treatment	Control	Fertiliser	Mean
Ca spray	31	35	35
No spray	35	34	34
Mean	33	35	35
LSD (5%) Ca spray	16.11		
Fertiliser	12.73		

Growth rate

Chinese cabbage at sowing 1 and 2 grew at very similar rates in terms of fresh weight and leaf number (Fig 1). Plants from sowing 3 grew more slowly, reflecting the cooler growing conditions.

Fig 1a CHINESE CABBAGE

Increase in fresh weight from planting

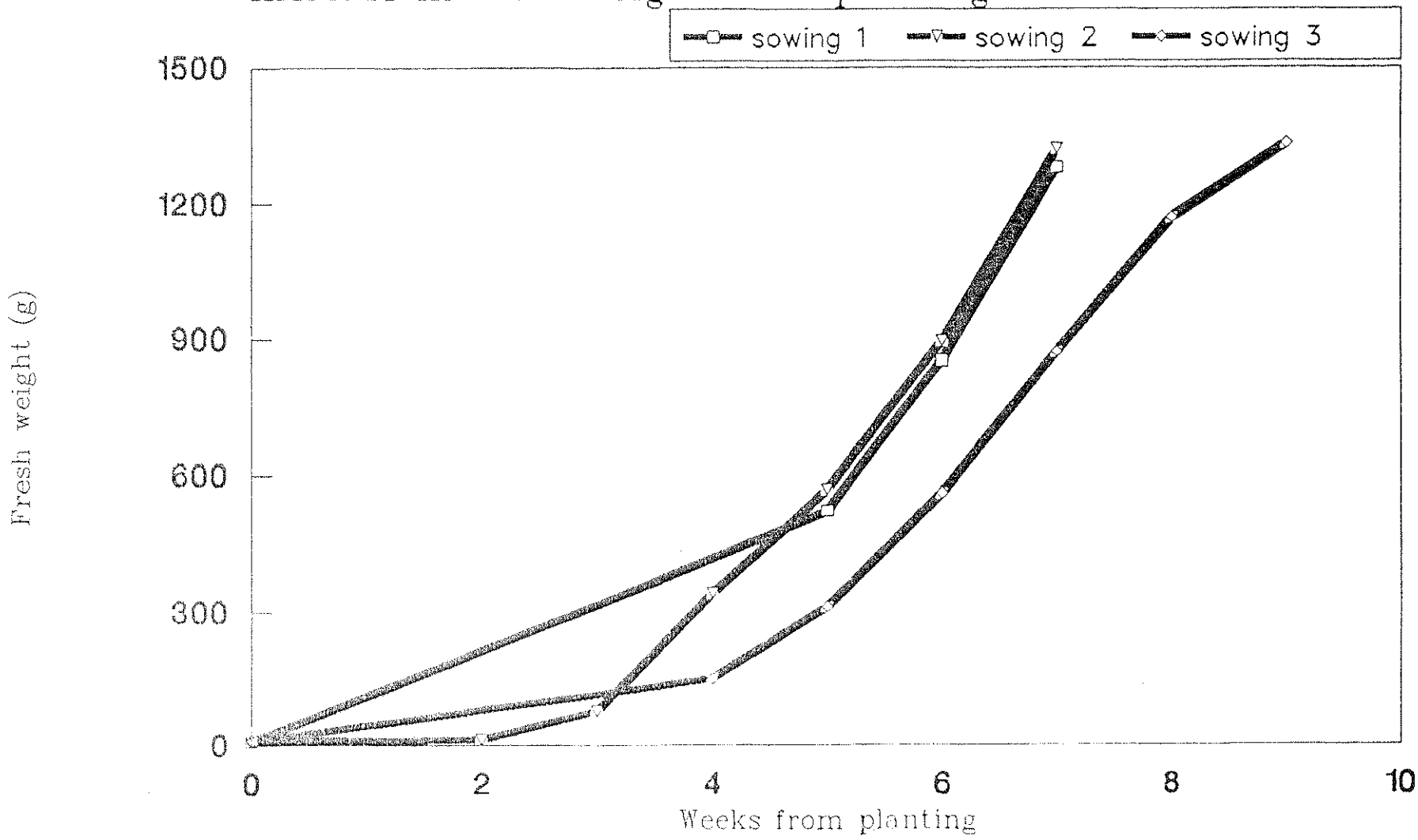
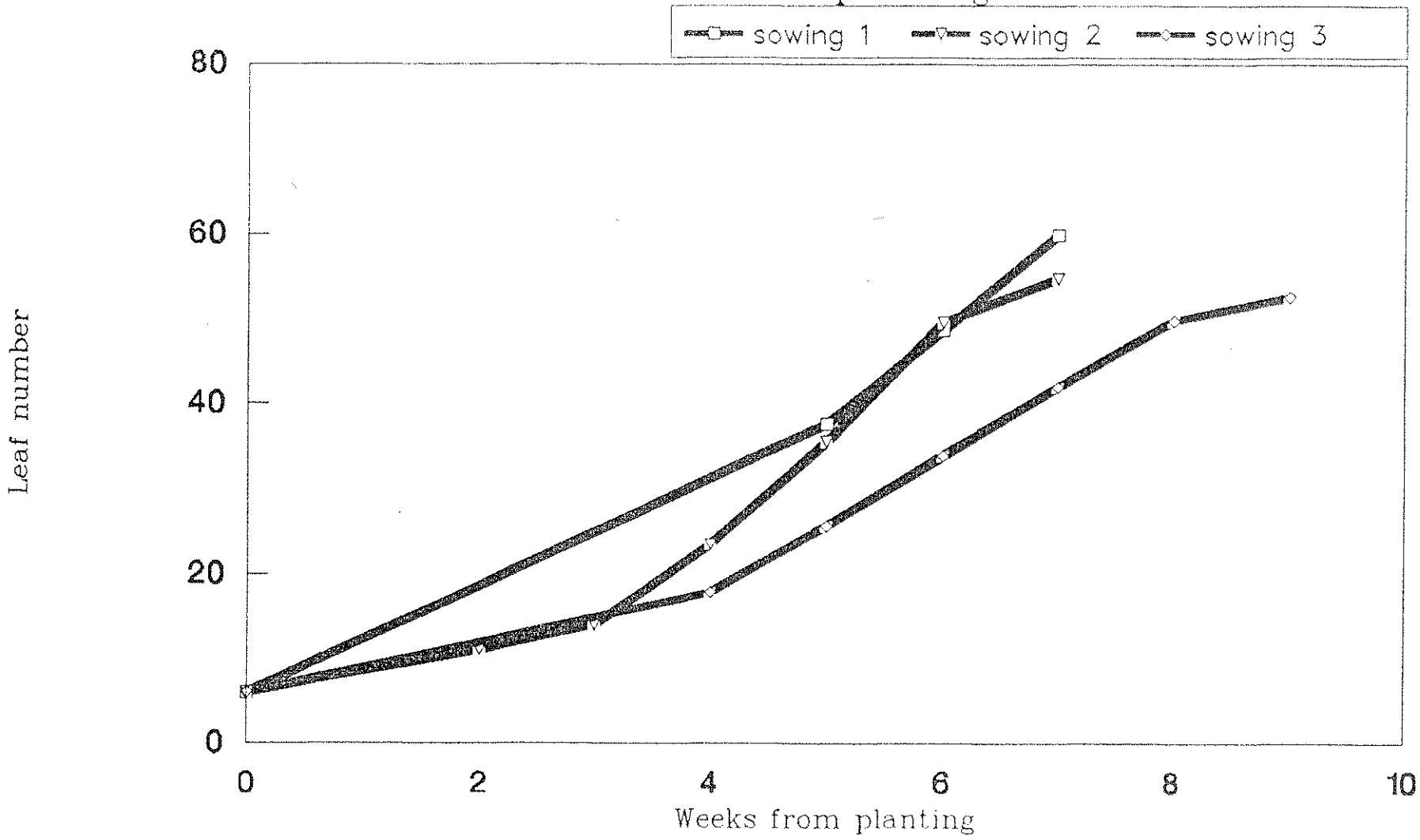


Fig 1b CHINESE CABBAGE

Increase in leaf number from planting



Discussion

In these trials planting date had a major effect on tipburn incidence in Chinese cabbage. The two earlier crops grown in the hot, dry conditions of July and August had more severe tipburn than that grown in the cooler conditions experienced in September and October. This indicates that weather conditions had a major effect on tipburn incidence most probably via the evapotranspiration demand of the plant and water supply. Under conditions of high transpiration demand the upward xylem flow containing calcium is directed almost entirely to the outer transpiring leaves, thereby restricting the calcium supply to the inner leaves. The reduced calcium supply to the inner leaves causes tipburn to develop.

In these trials irrigation was applied to the whole trial at an estimated soil moisture deficit (SMD) of 50mm approximately and additional irrigation was applied at SMD 25mm to some treatments receiving 300 kg/ha nitrogen. In sowings 1 and 2 additional irrigation reduced tipburn. Target SMDs were not always achieved in these trials producing a range of maximum SMDs experienced from 31 to 80mm, these plotted against tipburn scores for treatments receiving 300 kg/ha nitrogen show a strong relationship between increasing tipburn and max SMD experienced (Fig 2). It might be suggested that maintaining SMD below 30mm would prevent severe tipburn from developing.

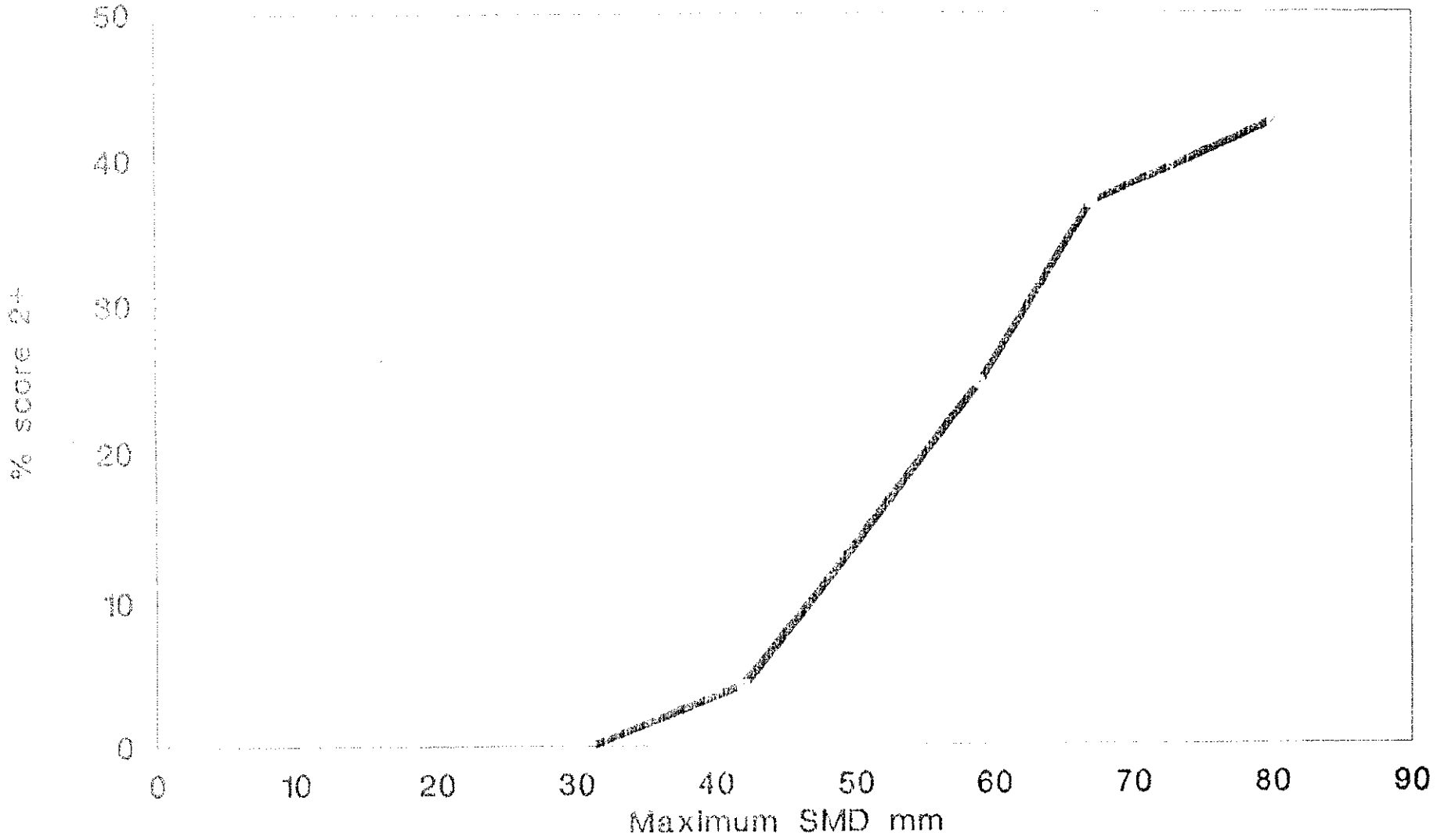
For sowing 1 and 2, applying any nitrogen fertiliser increased the incidence of tipburn. The mineral nitrogen content of the soil measured at planting was approximately 250 kg/ha N, adding between 150 and 300 kg/ha may have caused quite high soil conductivity, adding to the water stress experienced by the plant in dry conditions. Applying nitrogen did not increase yield for sowings 2 and 3 but did show an advantage for sowing 1. Although there was not a yield benefit, the higher rates of nitrogen tended to result in earlier harvest by two to three days in summer and seven days in autumn. It would not be advisable to cut nitrogen applications to zero in order to avoid tipburn as production schedules, head size and total yields would be affected.

Applying nitrogen as ammonium caused more tipburn than applying it as calcium nitrate. Ammonium-N (NH_4-N) is reported to increase calcium related disorders in other crops (Wilcox, Hoff and Jones 1973) as a result of competition between NH_4^+ and Ca^{2+} ions. The ammonium ion is also known to reduce water uptake (Quebedeaux and Ozbun 1973) and this may cause water-stress in plants when present in high concentrations.

In these trials, calcium nitrate sprays were applied weekly for two, three or four weeks before harvest as a 2% solution. There was no effect on the incidence of tipburn in any of the three trials. Previous work showing the benefits of calcium sprays was carried out under glass, Buitelaar (1982, 1983, 1984) which may have a large effect on the background levels of calcium in the plant tissue and the ability of the plant to take up foliar applied materials if leaves are softer. These sprays were also applied three times a week which was not considered practical in a field grown crop. Other calcium related disorders, eg tipburn in lettuce, internal browning in Brussels sprouts have not responded to calcium sprays (Shear 1975).

From the results reported here it seems most likely that tipburn in Chinese cabbage is caused by water stress induced by dry weather conditions, high nitrogen fertiliser applications and ammonium. Under conditions of high transpiration demand calcium-bearing xylem fluid is directed towards the outer, transpiring leaves, leaving the inner heart leaves without a calcium

Fig 2. Percentage tipburn score 2 or more at 300 kgN/ha fertilizer plotted against maximum estimated soil moisture deficit(SMD)
(Results of three sowings combined)



supply for new growth, inducing the tissue breakdown seen as tipburn. It is proposed that careful attention to soil moisture status and soil conductivity could alleviate tipburn in Chinese cabbage.

Recommendations

1. Calcium sprays did not reduce tipburn and should not be pursued further.

2. Repeat the comparison of nitrogen sources and rates and examine rates of irrigation, on 3 sowings.

Acknowledgements

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APPENDIX I Trial Crop Diary

Soil type:	Coarse silty alluvium
Previous cropping:	1990 Brassicas 1989 Minor bulbs
Soil analysis:	pH 7.1, P index 4, K index 2, Mg index 4, soil mineral N to 60 cm, 253 kg/ha June, 238 kg/ha July 5 t/ha lime applied January 1991
Cultivations:	Ploughed January 1991 Cultivated pre-planting using Lely roterra
Fertiliser:	N applied as treatments 275 kg/ha K, 35 kg/ha P applied pre-planting
Herbicide:	Propachlor as 9 l/ha Ramrod applied post-establishment
Insecticide:	Chlorpyrifos as Dursban 4 applied pre-planting
23 July	Demeton-S-methyl as 560 ml/ha Metasystox plus trichlorfon as 1.75 kg/ha Dipterex 80 applied to sowing 1
6 August	Trichlorfon as above applied tos owing 1 + 2
28 August	Trichlorofon as above applied to sowing 2 + 3
5 September	Trichlorofon as above applied to sowing 3
12 September	As per 23 July applied to sowing 3
20 September	As per 5 September
4 October	As per 5 September
Fungicide:	2 August Chlorothalonil as 3 l/ha Bravo applied to sowing 1 + 2
27 August	As per 2 August applied to sowing 2 + 3
12 September + 4 Oct	As per 2 August to sowing 3 only.
Irrigation:	
10 July	12mm applied sowing 2 at planting
17 July	25mm applied to sowing 1 SMD = 59mm
1 August	30mm applied to sowing 1 SMD = 57mm
16 August	15mm applied to sowing 3 at planting
20 August	15mm applied to sowing 3 for establishment
21 August	25mm applied to sowing 2 SMD = 73mm
29 August	15mm applied to sowing 3 SMD = 15mm

30 August	25mm applied to sowing 2 SMD = 80mm	
Plots receiving extra irrigation were irrigated as below:		
Sowing 1	24 July	SMD = 42mm
Sowing 2	6 + 16 August	SMD = 38, 44mm
Sowing 3	24 September	SMD = 31mm
Planting:	20 June sowing 1 (sown 30 May)	
	8 July sowing 2 (sown 14 June)	
	16 August sowing 3 (sown 23 July)	
Harvesting:	9-13 August	sowing 1
	3 September	sowing 2
	24 October	sowing 3

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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.

Carol Paterson
(Signature)

C D PATERSON

Date 9/3/92

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Date 9/3/92