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Effect of Water and Nitrogen on Chinese Cabbage

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ABSTRACT

Three experiments were carried out on Chinese cabbage. The late hybrid " Elephant " commercial cultivar was grown during summer of 1986, and the early hybrid ASVEG # 1 cultivar was grown during the late cool season and summer season of 1987. Three rates of water application--50%, 75% and 100% of potential evapotranspiration (PET), and four rates of ammonium sulfate side-dressing--30, 60, 90 and 120 kg/rai were studied. The results indicated that ASVEG # 1 grown in late cool season performed the best with the overall averaged head yield of 4.1 t/rai. The yields of Chinese cabbage grown in summer were 1.58 t/rai for " Elephant " brand and 1.17 t/rai for ASVEG # 1. Water had direct effect on the head yield and tipburn incidence. Increasing the irrigation rate from 50% to 100% of PET could increase the yield by 36%, while side-dressing with more ammonium sulfate from 30 to 120 kg/rai increased the yield by only 12%. At the same time, the increase in water application rate reduced the tipburn rate to 46%, but the tipburn rate was slightly increased by the NH_4-N side-dressing. Calcium content of the head leaves was found to increase with the water application rate and inversely correlated to the rate of tipburn. Water management was considered to be a more practical way of alleviating tipburn damage than that of applying calcium to correct the calcium status in the plant.

High production inputs are necessary to assure satisfactory yield of short duration crop. Chinese cabbage, the early cultivar ASVEG # 1 in particular, can be harvested 35-40 days after transplant. The crop will absorb nutrient in a linearly increasing amount every day from the beginning of head formation to harvesting time, so a steady and sufficient supply of nutrients, especially nitrogen and potassium is necessary until harvest (Takahashi, 1981). Water requirement, on the other hand, is less studied. Water is normally applied in an excessive amount. But in summer season, water is not always available. There is a need to understand the response of vegetable to both water and nutrient. This investigation was set up to study Chinese cabbage production during the summer season as effected by water and NH_4-N side-dressing requirement.

MATERIALS AND METHODS

The study comprised 3 experiments on Chinese cabbage. First experiment employed a commercial late hybrid cultivar, " Elephant " brand, which was planted during summer season of 1986 with the spacing of $75 \times 40\ cm^2$. The other two experiments involved an early hybrid cultivar, ASVEG # 1, which was planted during late cool and summer seasons of 1987 and with the spacing of $60 \times 40\ cm^2$. The growing period and climatic data for the three experiments are shown in Table 1. The experiments were carried out in the TOP/AVRDC field, which comprised the Kamphaeng Saen soil series (Typic Haplustalfs). The soil has silt loam to sandy loam tex-

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ture, the upper 30 cm of which has pH of 6.0-7.5 and high levels of phosphorus (42 - 96 ppm by Bray No 2), potassium (128 - 370 ppm by ammonium acetate extract) and calcium (2 - 9 meq/100g) (Yingjajaval, 1988).

All experiments followed a split - plot design with 3 levels of water application rate as main plot factor and 4 levels of nitrogen fertilizer as sub - plot factor. Four blocks were included, and each treatment was made up of a 20 - plant bed. The irrigation levels were equivalent to 50%, 75% and 100% of mean potential evapotranspiration (PET) rate during the growing period. The mean potential evapotranspiration rate was calculated from the 10-year averaged climatic data of Kamphaeng Saen based on Blaney and Criddle method (Akratanakul, 1987). The irrigation rate of 100% of PET was equal to 5.1, 5.8, 6.3 and 3.6 mm/day for the months of February, March, April and May, respectively. Irrigation interval was kept twice a week. The amount and rate of water applied and the actual potential evapotranspiration and precipitation during the growing period are shown in Table 1.

Table 1 Climatic data and cultural practice for Chinese cabbage of the three experiments.

	Exp 1	Exp 2	Exp 3
1. Cultivation			
cultivar	Elephant	ASVEG # 1	ASVEG # 1
transplanting date	21-3-86	3-2-87	8-4-87
first harvesting date	6-5-86	10-3-87	12-5-87
growing period, days	45	35	34
2. Climatic data			
max.temp., C	36.9	33.1	36.4
min.temp., C	24.5	20.3	23.9
mean temp., C	30.7	26.7	30.2
mean RH,%	68.4	69.9	71.4
pan evaporation, mm/day	6.65	4.78	6.07
3. Irrigation scheme			
starting date	27-3-86	9-2-87	14-4-87
end date	2-5-86	3-3-87	8-5-87
period, days	37	23	25
number of irr.	10	6	6
amount applied at 100% mean PET[1]			
total, mm	208.9	111.1	98.1
daily average, mm/day	5.65	4.83	3.92
rainfall, mm	53.0	1.7	21.0
days with rainfall	4	3	1
actual PET[2]			
total, mm	175.4	89.9	104.5
daily average, mm/day	4.74	3.91	4.18

[1] potential evapotranspiration as calculated by Blaney and Criddle method from the 10-year mean climatic data.
[2] potential evapotranspiration as calculated by Blaney and Criddle method for the actual growing periods of the experiments.

At transplanting time, all plots were irrigated excessively by furrow and received 30 kg/rai (6.25 rai = 1 hectare) of 15-15-15 basal fertilizer. Afterwards, water was applied by sprinkler according to the specified rates. The subplot treatment, varying with respect to the amount of ammonium sulfate as side - dressing, included 4 rates of application at 30, 60, 90 and 120 kg/rai. Ammonium sulfate was applied weekly on the 7th, 14th, 21th and 28th days after transplanting. Each application amounted to 30 kg/rai for the plot. In this way, the first treatment received the side - dressing fertilizer only once on the 7th day after transplanting, the second treatment twice, the third and the fourth treatments three and four times, respectively. The yields, the total stand and the number of tipburn incidence of each treatment were recorded. One plant was then sampled from each treatment in each block (a total of 48 plants for each experiment) for the analysis of the whole head nutrient contents, namely, N and P by auto - analyzer, K and Ca by atomic absorption spectrophotometry. Statistical analysis was performed for each experiment and for the combined data of the three experiments. (Gomez and Gomez, 1984)

RESULTS AND DISCUSSION

Water had the most significant impact on the marketable yield and the tipburn incidence of Chinese cabbage. The results are shown in Figures 1 and 2. It was clear that increasing the irrigation rate from 50% to 100% of PET dramatically increased the yield, while reducing the tipburn symptom. Not only the marketable yield, but other yield components as shown in Table 2 were also improved by the higher rate of water application. On the other hand, the effect of side - dressing of ammonium sulfate was not so clear - cut. This may be due to the fact that although the experimental plots are used on a rotation basis, the entire field has been fertilized conti-

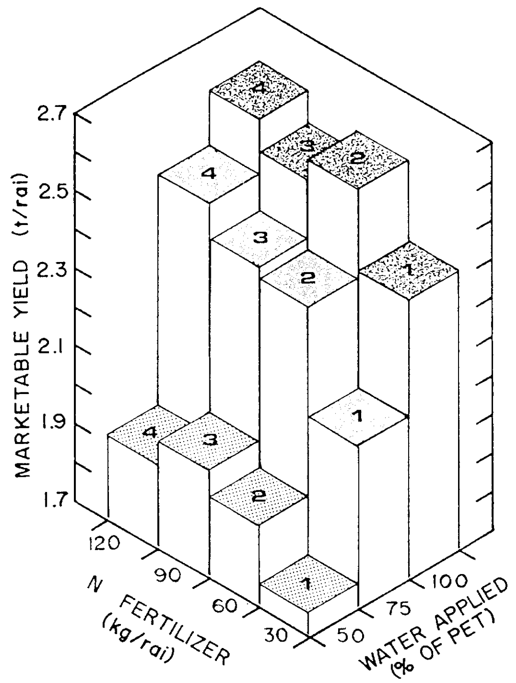

Figure 1. **Yield of Chinese cabbage as effected by the rates of water and ammonium sulfate side-dressing application.**

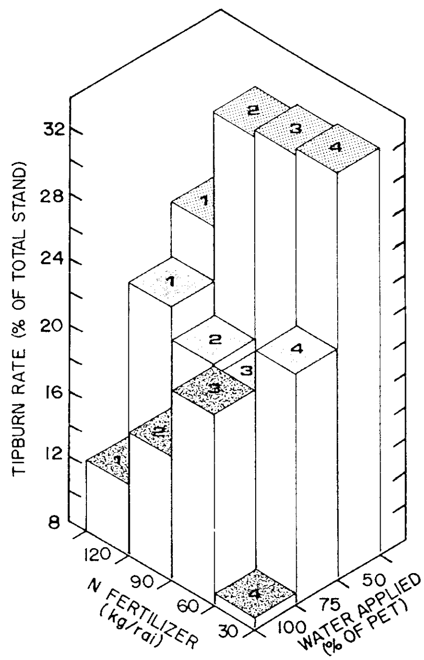

Figure 2. **Effect of rates of water and ammonium sulfate side-dressing application on the rate of tipburn incidence in Chinese cabbage.**

Table 2 Main plot × sub-plot matrix on yield components of Chinese cabbage.

Water application rate, % of PET	Ammonium sulfate side-dressing rate, kg/rai				Mean
	30	60	90	120	
1. whole plant yield, kg/rai					
50	5 079	5 239	5 528	5 326	5 293
75	5 769	6 199	6 317	6 549	6 208
100	6 048	6 720	6 311	6 612	6 423
mean	5 632	6 052	6 052	6 162	5 975
2. marketable yield, kg/rai					
50	1 766	1 913	1 977	1 918	1 893
75	2 173	2 406	2 435	2 523	2 384
100	2 424	2 627	2 582	2 656	2 572
mean	2 121	2 315	2 331	2 366	2 283
3. averaged head weight, g					
50	402	440	462	421	431
75	481	510	512	529	508
100	505	537	527	529	525
mean	463	496	500	493	488
4. harvesting index					
50	0.288	0.323	0.328	0.323	0.315
75	0.360	0.361	0.363	0.371	0.363
100	0.373	0.375	0.373	0.383	0.376
mean	0.340	0.353	0.355	0.359	0.352
5. harvesting rate, % of total stand					
50	64.5	68.3	72.2	73.5	69.6
75	79.1	75.3	80.1	80.6	78.8
100	80.6	81.2	79.1	83.3	81.1
mean	74.7	74.9	77.1	79.1	76.5
6. tipburn rate, % of total stand					
50	24.9	31.8	32.3	32.6	30.4
75	21.6	19.6	18.9	21.9	20.5
100	12.3	15.5	19.5	8.6	14.0
mean	19.6	22.3	23.6	21.0	21.6

nuously throughout the few years of the research activities. This practice is likely to leave organic matter and nitrogen residue in the soil.

As for plant nutrients, the results in Table 3 showed that calcium responded most clearly to the rate of water application. With easier available water, calcium moved more readily into the plant. For other nutrients, nitrogen content did not differ under different water application rate, although it increased slightly from 4.52% to 4.71% of dry matter, which was not statistically significant, with the higher application rate of ammonium sulfate fertilizer. Water also improved the availability of phosphorus to the head leaves. Doubling the water application rate increased the phosphorus content from 0.69% to 0.71% of dry matter.

For better comparison, the overall average values of plant parameters for each experiment were shown in Table 4 and the relative values showing the effects of treatments were summarized in Table 5.

Within the three experiments, ASVEG # 1 cultivar grown in cool season gave the best performance, with marketable yield averaged up to 4.1 t/rai. When the performance of ASVEG # 1 in cool season (Exp 2) was set as 100% (Table 5), the relative yield of ASVEG # 1 grown in summer (Exp 3) was only 29% (1.17 t/rai), while the yield of " Elephant " brand (Exp 1) was 39% (1.58 t/rai). In terms of whole plant yield, the relative values for crops grown in summer season were 46% for ASVEG # 1 and 80% for " Elephant " brand cultivar.

Although the " Elephant " brand cultivar accumulated a large quantity of whole plant yield even in summer season, the marketable yield was poor. Its harvesting index, which is the ratio of the marketable yield to the whole plant yield, for the overall experiment amounted to only 0.236 (Table 4). As high as 0.515 was accomplished by ASVEG # 1 cultivar grown in cool season and 0.304 in summer. The harvesting index could be increased by water application rate. Increasing water rate from 50% to 100% of PET raised the averaged harvesting index by 20% from 0.315 to 0.376 (Table 2).

After transplanting, many seedlings succumbed to salt damage--some to severe tipburn and some to soft rot. The total stand was highest for ASVEG # 1 grown in cool season and lowest for the commercial cultivar grown in summer season. ASVEG # 1 reached 97% harvesting rate (ratio of harvested head number to total stand) in cool season but only 62% when grown in summer, while the " Elephant " brand cultivar gave 71% harvesting rate in summer (Table 4). Increasing the water application rate increased the harvesting rate whereas the side - dressing of NH_4-N fertilizer had little effect (Table 5).

The incidence of tipburn was most severe in the " Elephant " commercial cultivar grown in summer season (Table 4). The averages rate of tipburn damage for the whole experiment was 52% of the total stand for " Elephant " brand, but only 3.2% for ASVEG # 1 grown in cool season and 10.4% for ASVEG # 1 grown in summer. The tipburn damage was significantly reduced by the increasing rate of water application. Water application rate of 100% of PET reduced the damage down to 46% of that occurred when water application rate was only 50% of PET (Table 5). The severity of tipburn corresponded closely to the low concentration of calcium of the head leaves. ASVEG # 1 in cool season accumulated calcium on the average up to 1.28% of dry matter (Table 4), but down to 0.84% in summer season. " Elephant " brand cultivar contained only 0.25%. The calcium content rose from 0.751% under water application rate at 50% of PET to 0.845% under 100% of PET application rate (Table 3). Increasing application rate of ammonium sulfate, on the other hand, had the tendency to induce more tipburn, but of no statistically significant. Weekly side - dressing for three times caused 20% more tipburn than side - dressing only once

Table 3 Main plot × sub-plot matrix on nutrient contents of the head leaves.

Water application rate, % of PET	Ammonium sulfate side-dressing rate, kg/rai				Mean
	30	60	90	120	
1. N content, % dry matter					
50	4.69	4.65	4.39	4.89	4.66
75	4.31	4.54	4.75	4.60	4.55
100	4.57	4.52	4.71	4.64	4.61
mean	4.52	4.57	4.62	4.71	4.61
2. P content, % dry matter					
50	0.708	0.654	0.654	0.701	0.692
75	0.697	0.722	0.719	0.699	0.709
100	0.704	0.694	0.739	0.715	0.713
mean	0.703	0.690	0.704	0.705	0.705
3. K content, % dry matter					
50	4.98	5.07	5.08	5.11	5.06
75	4.79	5.24	5.16	4.97	5.04
100	4.93	5.06	5.11	5.10	5.05
mean	4.90	5.12	5.12	5.06	5.05
4. Ca content, % dry matter					
50	0.667	0.792	0.783	0.761	0.751
75	0.748	0.801	0.843	0.715	0.777
100	0.795	0.877	0.762	0.947	0.845
mean	0.737	0.823	0.796	0.808	0.791
5. Ca/N ratio					
50	0.144	0.173	0.178	0.155	0.163
75	0.178	0.185	0.176	0.158	0.174
100	0.176	0.199	0.165	0.206	0.187
mean	0.166	0.186	0.173	0.173	0.175

Table 4 The overall average values of plant parameters for the three experiments.

plant parameters	Exp 1	Exp 2	Exp 3	Mean
1. whole plant yield, kg/rai	6 344	7 927	3 653	5 975
2. marketable yield, kg/rai	1 582	4 099	1 169	2 283
3. average head weight, g	525	639	298	487
4. harvesting index	0.236	0.515	0.304	0.352
5. harvesting rate, % of total stand	70.8	96.6	61.9	76.4
6. tipburn rate, % of total stand	52.0	3.2	10.4	21.9
7. N content, % dry matter	4.65	4.45	4.71	4.60
8. P content, % dry matter	0.94	0.77	0.40	0.71
9. K content, % dry matter	4.28	6.17	4.69	5.05
10. Ca content, % dry matter	0.25	1.28	0.84	0.79
11. Ca/N ratio	0.054	0.290	0.180	0.175

Table 5 Relative values of plant parameters showing the effects of rates of water and ammonium sulfate side-dressing application and experimental conditions on the yield and nutrient status of Chinese cabbage.

Plant parameters	Relative Percentage: Water rate, % of PET			NH$_4$-N side-dressing rate, kg/rai				Experiment		
	50	75	100	30	60	90	120	1	2	3
1. Whole plant yield	100	117	121 **[1]	100	107	107	109 **	80	100	46 **
2. Marketable yield	100	126	136 **	100	109	110	112 *	39	100	29 **
3. Average head wt.	100	118	122 **	100	107	108	106 **	82	100	47 **
4. Harvesting index	100	115	119 **	100	104	104	105 ns	46	100	59 **
5. Harvesting rate	100	113	117 *	100	100	103	106 ns	73	100	64 **
6. Tiphurn rate	100	67	46 **	100	114	120	107 ns	1 625	100	325 **
7. N content	100	98	99 ns	100	101	102	104 ns	104	100	106 ns
8. P content	100	102	103 *	100	101	110	100 ns	123	100	52 **
9. K content	100	100	100 ns	100	104	104	103 *	69	100	76 **
10. Ca content	100	103	113 **	100	112	108	110 ns	19	100	66 **
11. Ca/N	100	107	115 **	100	112	104	104 ns	19	100	62 **

[1] Statistical test on the combined data of all 3 experiments.

* F test, significant difference at 5% level.

** F test, significant difference at 1% level.

ns F test, no significant difference.

(Table 5). The result seemed to agree with AVRDC's study that NH_4-N fertilizer, especially at head initiation time had the greatest effect in predisposing the plant to tipburn damage. (AVRDC, 1985)

As tipburn incidence correlated well with the water application rate, and calcium concentration also increased with water availability, the tipburn incidence could be shown to be related to calcium content of the plant. Figure 3 showed the relationship between the overall average values of calcium content in the head leaves (Table 3) with the rate of tipburn damage (Table 2). The correlation seemed to fall in a linear pattern with a negative slope. The four points, which were way off the line belonged to the high incidence of tipburn (> 25% of total stand) when plant received the lowest rate of water application (50% of PET). Apparently, the rate of water application at 50% of PET was so limited to Ca absorption during rapid plant growth that the severe tipburn incidence, developed in the late stage of growth, showed no correlation with the Ca content already accumulated in the early stage of growth. When these four points were not considered, a linear relationship between the tipburn rate (TR) and calcium content (%Ca) of the whole head could be obtained as TR = 58.26 - 50.58 (%Ca). Consequently, the tipburn incidence, which has long been shown to correlate to low calcium concentration in the plant (Takahashi, 1981 ; Aloni, 1986), could be further connected to the availability of water for plant transpiration. (Barta and Tibbits 1986). Other study had shown that when root pressure flow was induced to occur during the dark period, adequate amounts of

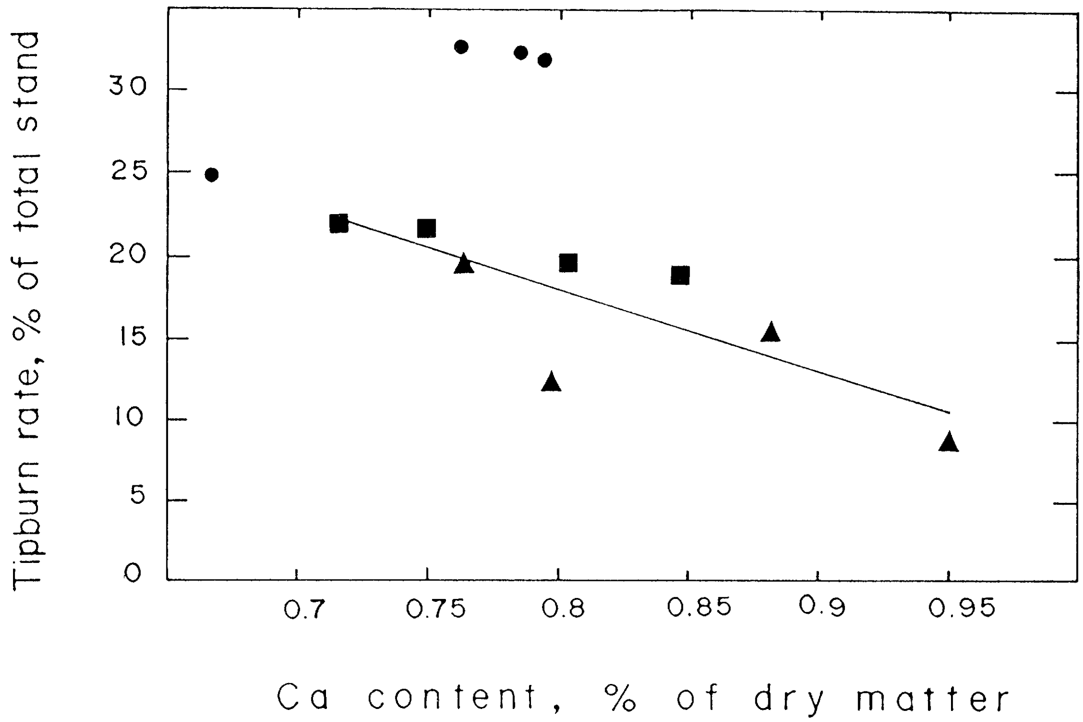

Figure 3. Rate of tipburn incidence in Chinese cabbage as a function of calcium content in the head leaves. Different symbols represent tipburn rates of plant receiving different water application rates, ● = 50%, ■ = 75% and ▲ = 100% of potential evapotranspiration. The straight line relationship of TR = 58.26 - 50.58 (%Ca), r = .81°, was obtained with the exclusion of the data of the 50% of PET water rate.

calcium could be moved to the head leaves of cabbage to prevent tipburn (Palzkill *et al,* 1976). Since the adding of calcium to the soil or the initial high calcium content in the soil alone was ineffective in preventing the tipburn development, this study demonstrated that management of water regime of the field, especially during summer season is a more practical way to reduce the tipburn damage in Chinese cabbage.

CONCLUSION

The rate of water application had the most impact on the yield and yield components of Chinese cabbage. With exception of nitrogen and potassium contents in the head leaves, all other plant parameters and nutrient contents were significantly effected by the rate of water application. Increasing rate of water application not only improved the yield, but also increased the calcium content in the head leaves and reduced the rate of tipburn disorder. On the other hand, the side - dressing of NH_4-N fertilizer had less effect on the yield and no effects on the calcium content and the rate of tipburn incidence.

The severity of tipburn incidence corresponded well with the calcium content of the plant. Chinese cabbage grown during summer period, not only yielded less than crop grown in cool season, but also showed high degree of susceptibility to tipburn disorder. Water management was recommended for alleviating the degree of tipburn damage in Chinese cabbage during summer season.

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