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Response of Chinese Cabbage to Nitrogen Rate and Source in Sequential Plantings

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Abstract. **'Tropical Quick' Chinese cabbage *(Brassica rapa* L., Pekinensis Group) was planted three times at 2-week intervals in Spring 1991 (direct-seeded) and two times in Fall 1991 (transplanted) in double rows on polyethylene-mulched beds to evaluate N source and rates. Calcium nitrate, ammonium nitrate, urea, urea-ammonium nitrate solution (Uran), and urea-calcium solution (Nitro-Pius) were applied preplant at 67,112, and 157 kg N/ha. The two later spring planting dates, compared with the earliest date, resulted in greater head fresh weights and higher insect damage incidence, but lower tipburn and flowering incidence. The earlier fall planting resulted in greater head fresh weight but a much higher flowering incidence than the later planting. Irrespective of planting date, head fresh weight increased quadratically, and tipburn and flowering incidence decreased linearly with increasing N rate. Although N source affected head fresh weight and tipbum incidence, differences were too small to be of practical value.**

Chinese cabbage production area in Florida, Texas, and California is increasing due to greater consumer consumption in the United States and Canada. More than 1600 ha of Chinese vegetables are grown in Florida alone (Vavrina, 1991). These crops include the napa and chihili Chinese cabbage types, Bok choy *(Brassica rapa* L., Chinensis Group), Chinese mustard *(Brassica juncea* L.), and Chinese broccoli *(Brassica alboglabra* L.)

Nitrogen fertilization and close plant spacing (20 cm) optimize yield in broccoli *(Brassica oleracea* L., Italica Group), cauliflower *(Brassica oleracea L.,*Botrytis Group) (Chung, 1985; Dufault and Waters, 1985), and Chinese vegetables (Hill, 1990). Fresh market head weight of Bok choy increased with increasing N up to 200 $kg\cdot ha^{-1}$ (Hill, 1990). Increasing N from 0 to 168 $kg\cdot ha^{-1}$ increased Chinese cabbage dry matter, while as little as 56 kg N/ha produced 95% of the dry matter produced with 224 kg N/ha (Guillard and Allison, 1988). The literature on nitrogen source for Chinese cabbage culture is minimal. The objective of this study was to evaluate N sources and rates and planting dates for Chinese cabbage in sequential plantings.

'Tropical Quick' Chinese cabbage is a small, napa-type, tight-headed Chinese cabbage resembling head lettuce and requiring an average of 35 days from transplanting to harvest (Sakata Seed America, Morgan Hill, Calif.). In Winter 1991, 'Tropical Quick' seeds were sown in Metro-Mix (Verlite, Tampa, Fla.) in multiple-cell (30.7 cm^3) polystyrene containerized flats (Todd, Plant City, Fla.) at 2-week intervals (31 Jan., 14 Feb., and 28 Feb.). Three weeks after sowing, seedlings were transplanted to the field. Transplanting dates were 22 Feb. and 8 and 22 Mar. 1991. Resets were replaced up to 14 days after initial transplanting as needed.

The fall experiment was direct-seeded on 24 Oct. and 8 and 22 Nov. 1991. The third planting was lost due to *Pythium* spp. Florida commercial growers generally direct-seed Chinese cabbage for fall production since transplants are difficult to establish in the greenhouse due to excessive summer soil and air temperatures.

Polyethylene mulch culture (0.3-mm-thick black mulch in spring, white mulch in fall) with subsurface irrigation was placed on Immokalee tine sand (sandy, siliceous, hypothermic, Arenic, Haplaquods). Soil pH was 7.0; Bray Pi-extractable P was 17 $mg\cdot kg^{-1}$; and neutral ammonium acetate-extractable Ca, Mg, and K levels were 620,74, and 4 $mg\cdot kg^{-1}$, respectively. Fumigant (metham sodium) was applied at 374 $kg\cdot ha^{-1}$ immediately before mulching. Beds (20 cm high, 91 cm wide) were on 1.8-m centers. Transplants and seed were placed in double rows (31 cm apart) with an in-row spacing of 36 cm.

Preplant N sources, applied manually at 67, 112, and 157 $kg\cdot ha^{-1}$, included ammonium nitrate, $Ca(NO_3)_2$, urea, a urea–Ca liquid (Nitro-Plus; Stoner Chemical Co., Houston), and a solution of 50% NH_4NO_3 and 50% urea (Kachelman, 1989). These fertilizers were banded 8 cm below the soil surface in the center and 36 cm to either side of the bed center (i.e., three bands) of 4-m-long plots. Seedlings and seed were placed 18 cm from the fertilizer bands. Concentrated superphosphate at 67 kg P/ha (determined by soil test) and potassium-magnesium sulfate at 45 kg K/ha were incorporated in the bed. An additional 134 kg K/ha as potassium-magnesium sulfate was banded in all N treatments to meet soil test requirements. Standard commercial cultural practices for Chinese cabbage were used (Vavrina, 1991). Subsurface seepage irrigation and pesticides were applied as needed.

Once-over harvests were on 1, 15, and 25 Apr. for the transplanted crops and on 12 and 30 Dec. 1991 for the direct-seeded crops. Ten random, mature heads were hand-harvested from the plot center for analysis of head fresh weight and the percentage of heads exhibiting insect damage, tipburn, or flower stalks.

The 5 (N source) × 3 (N rate) factorial for each plant type (direct-seeded vs. transplanted)

Table 1. Effects of plant type (PT), planting date (PD), and N source (S) and rate (R) on Chinese cabbage yield and quality.[z]

Plant type	Harvest date	Head fresh wt (g)	Insect (%)	Tipburn i%)	Flower ('%)
Direct-seeded	1 Apr.	490 b	56 b	68a	100 a
	15 Apr.	640 a	94a	47 b	74 b
	25 Apr.	560 ab	94a	15 c	51 c
Transplanted	12 Dec.	630 a	16 C	34 be	95 ab
	30 Dec.	540 b	23 C	17 c	64c
F test significances					
PT[y]		NS	NS	NS	NS
PD (within PT)[x]		***	**	**	***
S		**	NS	*	NS
R		***	NS	**	*
S × R		NS	NS	NS	NS
PT× S		NS	NS	NS	NS
PT × R		NS	NS	NS	NS
PT × S×R		NS	NS	NS	NS

[z]Mean separation within columns by Tukey's HSD ($P \le 0.05$). Percentages were not arcsin-transformed due to homogeneity of variance.
[y]Plant type, i.e., direct-seeded or transplanted, was tested against planting date within plant type.
[x]Harvest within plant type was tested against blocks within plant type by planting date.
NS, *, **, *** Nonsignificant or significant at $P \le$ 0.05,0.01, or 0.001, respectively.

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was arranged in a randomized complete block design with four replications. The data from the spring transplant and the fall directed-seeded experiments were combined to test the effects of plant types within season. Data were subjected to analysis of variance, and means separation was performed using Tukey's HSD procedure. Responses to fertilizer rates were tested by fitting linear and quadratic regression equations.

Sequential planting date. None of the tests on plant type or plant type interactions with N source and/or N rate was significant (Table 1). Planting date affected Chinese cabbage head weight. When marketable head fresh weight was pooled for all N rates and sources, the earliest spring and latest fall planting dates resulted in lower head fresh weights (Table 1). Florida's coldest air temperatures (mid-December through March) coincided with these two harvest dates and possibly contributed to slower growth and reduced head weight. Insect damage was greatest in late spring.

Tipburn incidence, often associated with Ca deficiency, abnormally high fertilizer rates, and improper water management (Collier and Tibbits, 1982), was lowest during late spring and fall, possibly as a result of a greater transpirational demand during these periods and, consequently, greater Ca uptake. Water management was adequate to overcome tipburn. Restricted root growth, also associated with tipburn (Aloni, 1986), was not evident. 'Tropical Quick' may be prone to tipburn, since it is tight-headed (Imai, 1990; Vavrina and Armbrester, 1991).

Flowering incidence decreased with later spring plantings (Table 1); higher temperatures lessened the effect of vernalization. The higher percentage of flower stalks in the early fall than late-fall crop may have been either a photoperiodic (Moe and Guttormsen, 1985) or a day/night temperature response (Guttormsen and Moe, 1985). Market acceptance of flower stalk elongation is tolerated, provided it is minimal (U.S. Dept. of Agriculture, 1981). However, even the lowest flowering incidence (51%) in our study was unacceptably high.

Nitrogen rate. As N rate increased, head fresh weight increased quadratically (Table 2). Head weight increased 14.2% as N was increased from 67 to 112 $kg\cdot ha^{-1}$, but only 5.0% as N was increased from 112 to 157 $kg\cdot ha^{-1}$. Our results agree with those of Guillard and Allison (1988) who reported increased total dry matter in Chinese cabbage as N was increased up to 168 $kg\cdot ha^{-1}$.

Percent incidence of tipburn and heads with flower stalk formation decreased linearly as N rate increased (Table 2). Tipburn incidence at 112 and 157 kg N/ha was 66% and 51%, respectively, that at 67 kg N/ha. Decreasing tipburn incidence with increasing N was reported in radicchio *(Cichorium intybus* L.) (Grevsen, 1992) and crisphead lettuce (J.N. Sorensen, personal communication). Insect damage was unaffected by N rate.

Nitrogen source. Head weight was 7% higher with $Ca(NO_3)_2$ or Uran than with urea or Nitro-Plus; ammonium nitrate resulted in intermediate head weight (Table 3). Such small increases in head weight maybe of little practical significance.

Tipburn was common in all plantings and was affected by N source (Table 3). Urea and Uran reduced tipburn more than ammonium nitrate. Excess NH_4-N in Chinese cabbage has increased tipburn (Imai, 1990). Goring and Laskowski (1982) reported that metham sodium can inhibit vitrification, thereby increasing NH_4 accumulation, but apparently the metham sodium used in this study did not induce NH_4-N toxicity. The additional Ca supplied by $Ca(NO_3)_2$ (112 to 263 $kg\cdot ha^{-1}$) or Nitro-Plus (26 to 61 $kg\cdot ha^{-1}$) did not affect tipburn incidence (Table 3). Preplanning soil Ca levels were adequate for Chinese cabbage production. Percentages of insect damage and flowering were unaffected by N source.

These results indicated that N rate and source can alter the physiological development of Chinese cabbage. Using >112 kg N/ha was unnecessary to generate acceptable yields but suppressed tipburn and flowering incidence slightly. Urea and urea-ammonium nitrate reduced tipburn incidence relative to $Ca(NO_3)_2$. Further research is needed, however, to assess the effect of N source and rate on tipburn incidence and to determine cultivar susceptibility to this disorder.

Table 2. Effect of N rate on Chinese cabbage yield and quality.[z]

	N rate ($kg\cdot ha^{-1}$)				
Variable	67	112	157	Linear	Quadratic
Head wt (g)	510	590	620	**	*
Tipburn (%)	50	33	25	**	NS
Flower(%)	80	76	74	*	NS
Insect (%)	54	55	53	NS	NS

[z]Percentages were not arcsin-transformed due to homogeneity of variance.
NS,*,** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Effect of N source on Chinese cabbage yield and quality.[z]

	N source[y]				
Variable	NH_4NO_3	$Ca(NO_3)_2$	Urea	Uran	Nitro-Plus
Head wt (g)	570 ab[x]	590 a	550 b	590 a	550 b
Tipburn (%)	41 a[x]	34 ab	32 b	32 b	39 ab
Flower (%)	81 a	78 a	74 a	75 a	76 a
Insect (%)	54 a	53 a	55 a	56 a	50 a

[z]Percentages were not arcsin-transformed due to homogeneity of variance.
[y]Uran = urea-ammonium nitrate; Nitro-Plus = urea–Ca solution.
[x]Mean separation within rows by Tukey's HSD ($P \leq 0.05$).

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