Impact of Insecticide Schedule, N and K Rates, and Transplant Container Size on Cabbage Yield

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Abstract. The impact of two insecticide spray application schedules (weekly or on demand), three N and K rates [1x, 1.5x, and 2x; 1x = (kg·ha⁻¹) 130N-149K], and two transplant container cell sizes [small, 21 mm wide × 51 mm deep (7.5 cm³), and large, 38 mm wide × 70 mm deep (33.7 cm³)] on 'Market Prize' cabbage (*Brassica oleracea* L. Capitata group) yield was investigated in Fall and Winter 1982-83 and Spring 1983. Fenvalerate was sprayed at 0.112 kg·ha⁻¹. For the weekly schedule, 10 sprays were applied in fall and winter and nine in spring; for the on-demand schedule, two sprays were applied in both seasons. There were more insect-damaged heads in both seasons in the plots sprayed on demand than in those sprayed weekly. In fall and winter, the combination of a weekly schedule with 1.5x and 2x N and K rates increased marketable yields over those of the on-demand schedule. Marketable yields at the 1.5x and 2x N and K rates were similar for plants in small or large transplant container cells, but the 1x N and K rate applied to plants in small cells reduced yields. In spring, both application schedules produced similar yields, but yield increased with increasing N and K rates and large transplant container cells. Insecticide application schedule and cell size did not affect leaf nutrient concentration significantly, but increasing N and K rates resulted in higher N, P, and K leaf concentrations. Concentrations of N and K in the soil at 42 days after transplanting (DAT) were higher with increasing N and K rates. At harvest (86 DAT), only K concentrations had increased with N and K rates. Chemical name used: cyano (3-phenoxyphenyl) methyl 1-4 chloro-alpha-(1-methylethyl benzeneacetate) (fenvalerate).

Florida is an important producer of fresh-market cabbage during winter and spring. High day and night temperatures in early fall, rapidly increasing temperatures in spring, and high insect populations in both seasons often adversely affect yields. Because of the potentially damaging number of insects, cabbage is sprayed with insecticides every 3 to 7 days, regardless of pest status (Schuster et al., 1984). The frequent use of insecticides increases production costs and the resistance of insects to insecticides, and may eliminate the natural enemies of insect pests (Davis and Kuhn, 1974). Consequently, economic considerations and pest resistance to chemicals created a need for integrated pest management. Researchers established visual damage thresholds for insect management on cabbage. Insecticides were applied only when damage to the crop or the density of pest population equaled or exceeded a certain threshold (Schuster et al., 1984; Shelton et al., 1983). For example, in Florida

and Georgia, using a damage threshold of 0.5 lepidopterous larval feeding injuries per plant reduced spray applications from 11 to two without reducing marketable yields (Csizinszky and Schuster, 1985; Schuster et al., 1984).

High fertilizer rates are applied to cabbage in Florida. In a nonmulched production system, yields increased when N rates were increased from 140 to 380 kg·ha⁻¹ (White and Forbes, 1976). Researchers in other areas also have found a similar relationship between increasing N rates and higher cabbage yields (Hara and Sonoda, 1982; Knael and Herron, 1981; Peck, 1981). However, Kowal and Barker (1981) found no significant increase in yield per plant with increasing N rates for several straight and savoy-leaved cabbage

cultivars. Increasing K rates from 110 to 675 kg·ha⁻¹ increased total cabbage yields, but the proportion of burst heads increased from 8% to 45% (Peck et al., 1987). In a polyethylene-mulched production system, the effect of fertilizer rate depended on season (Csizinszky and Schuster, 1985). In spring (February to April), early and total marketable yields doubled when nutrients were increased from (kg·ha⁻¹) 152N-53P-139K to 257N-99P-261K. In fall (October to December), yields were similar with low and high nutrient rates.

Transplant container cell size influences plant growth, early and total yields, and vegetable production costs. Dufault and Waters (1985) found little or no significant effect of transplant container cell size on yields of broccoli (*Brassica oleracea* L. Italica group) and cauliflower (*Brassica oleracea* L. Botrytis group). In other studies, marketable yields of cabbage in Florida (White, 1980) and Chinese cabbage [*Brassica rapa* L. ssp. Pekinensis group (Lour) Olsson] in Hawaii (Kratky et al., 1982) increased with increasing transplant container cell size. In England, large cauliflower transplant container cells gave higher early but reduced total yields compared with small cells (Whitwell and Crofts, 1972). Seedlings raised in 38-mm-diameter cells (33.7 cm³) cost twice as much as seedlings raised in 21-mm-diameter cells (7.5 cm³). Therefore, using small transplant container cells should reduce production costs, if the cell size does not limit yield and quality.

The objective of this study was to determine the effect of insecticide spray application schedule, N and K rates, and transplant container cell size on cabbage yield.

Experiments were conducted at the Gulf Coast Research and Education Center, Bradenton, Fla., in fall and winter (October to January) and spring (March to May) on EauGallie fine sand (sandy siliceous hyperthermic Alfic haplaquod). The design was a split-split plot arranged in three randomized complete blocks. Main plots, each 13.7 m long × 4.2 m wide with 1.5 m between plots, were two insecticide spray application schedules. The pyrethrin insecticide fenvalerate was applied at 0.112 kg·ha⁻¹ either weekly or on demand. Plots were sampled weekly for insect infestation and the on-demand plots were sprayed when a threshold of an average of 0.5 feeding holes or "windows" (feeding sites on the undersides of the leaves leaving the upper

Table 1. Average monthly maximum and minimum temperatures and rainfall during Fall and Winter 1982-83 and Spring 1983 and 30-year averages at the Gulf Coast Research and Education Center, Bradenton, Fla.

Month	Temp, actual (°C)		Rainfall (mm)	Temp, 30-yr avg (°C)		Rainfall (mm)
	Max	Min		Max	Min	
Fall and Winter 1982–83						
Oct. (7–31)	28.9	16.7	25	29.4	17.8	71
Nov.	27.8	15.6	30	25.5	13.9	48
Dec.	25.6	13.3	27	22.8	11.1	61
Jan.(1–12)	22.2	11.7	7	21.7	9.4	65
Spring 1983						
Mar. (8–31)	22.2	11.1	214	25.0	12.8	80
Apr.	27.2	13.9	61	27.8	15.6	41
May. (1–24)	30.0	17.2	5	30.6	17.8	81

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cuticle intact) on the head plus four wrapper leaves of 20 plants was met or exceeded. Fungicides approved for cabbage were applied weekly to all plots in both seasons.

Main plots were divided into three N and K rates/subplots: low [$1x=(kg\cdot ha^{-1})$ 130N-149K], medium (1.5x), and high (2x). Each subplot treatment consisted of one bed, 13.7 m long $\times$ 76 cm wide $\times$ 23 cm high on 1.4-m centers. Nitrogen and K were derived from an 18N-0P-20.8K-1.2Mg (%) fertilizer. Each of the three N and K subplots received ($kg\cdot ha^{-1}$) 37P-269Ca-1.92B from 20% superphosphate, $CaCO_3$, and borax, respectively. The superphosphate also contained micronutrients (F503 oxide) at $40\ kg\cdot t^{-1}$. About 10% of the N, K, and Mg and all of the P, Ca, and micronutrients were incorporated in the soil along the full width of the bed. The remaining N and K was applied in a 4- to 5-cm-deep, 5-cm-wide furrow in the bed's center. Soil was treated with a broad-spectrum fumigant [66% methyl-bromide, 33% nitrochloroform (chloropicrin)] at $166\ kg\cdot ha^{-1}$. The entire bed was covered with a 0.32-mm-thick polyethylene film, white in fall and black in spring. Subplots were divided into two transplant container cell size (small and large) sub-subplots, each 6.1 m long $\times$ 1.4 m wide. A commercial company raised the seedlings in inverted pyramid-shaped cells in container flats. Small cells were 21 mm wide $\times$ 55 mm deep ($7.5\ cm^3$), and large cells were 38 mm wide $\times$ 70 mm deep ($33.7\ cm^3$). 'Market Prize' cabbage seedlings were planted 31 cm between rows and 31 cm within rows in double rows (32 plants per sub-subplot) on 7 Oct. 1982 and 8 Mar. 1983. Irrigation was provided by the seepage (modified furrow) system.

Soil samples from 0 to 23 cm deep were taken from each sub-subplot midseason [45 days after transplanting (DAT)], and at the end of the season. Soil was extracted by the saturated paste method (U.S. Salinity Laboratory Staff, 1954) and the Mehlich I extractant (Reference Soil Test Methods for the Southern Region of the United States, 1983). The saturated paste extract was used to determine pH with a pH meter and N by a modified Kjeldahl method [Association of Official Agricultural Chemists (AOAC), 1980]. On the double-acid extracts, P was determined by the ammonium molybdate-ascorbic acid calorimetric method, and K and Ca by atomic absorption spectrophotometry. Nitrogen, P, and K concentrations and dry-matter content were determined on wrapper leaf samples at 45 DAT and harvest by AOAC methods (AOAC, 1980).

Plant height, plant width, and area covered by the plant were measured at 28 and 42 DAT on six plants from each sub-subplot in spring. Cabbage heads were harvested on 22 Dec. and 12 Jan. in fall and winter and 17 and 24 May in spring. Marketable heads 1 kg or heavier (U.S. Dept. of Agriculture, 1981) and four wrapper leaves from a 3.6-m-long center section in each sub-subplot were cut. Insect feeding damage was rated by a system of 1 to 6 in which marketable heads received a score of 3 or lower (Greene et al., 1969). Data were tested by analysis of variance. Where appropriate,

Table 2. Effect of insecticide spray application schedule, N and K rate, and transplant container cell size on 'Market Prize' cabbage, Fall and Winter 1982-83.

Treatment	Insect-damaged	Plants with	Marketable		Avg wt	
	heads	heads	Early	Total	Early	Total
	(%)	(%)	(t·ha ⁻¹)		(kg)	
Application schedule (I) ²						
Weekly	3.6	85	10.4	44.0	1.30	1.41
Demand	13.2	70	10.0	35.7	1.36	1.36
F value	*	*	NS	NS	NS	NS
N and K rate (F) ^y						
1x	6.6	75	6.7	35.9	1.28	1.36
1.5x	7.3	76	10.0	42.1	1.34	1.39
2x	11.2	81	13.9	41.3	1.37	1.40
L	*	**	**	*	*	*
Q	NS	NS	*	NS	NS	*
Cell size (C) ^x						
Small	8.3	76	10.4	38.3	1.32	1.37
Large	8.4	78	10.1	41.3	1.34	1.40
F value	NS	NS	NS	*	NS	NS
Interactions						
I × F	NS	*	*	*	NS	NS
I × C	NS	NS	NS	NS	NS	NS
F × C	NS	*	NS	*	NS	*
I × F × C	NS	NS	NS	NS	NS	NS

²Each entry is an average of three replications $\times$ three N and K rates $\times$ two transplant container cell sizes.

³Each entry is an average of three replications $\times$ two application schedules $\times$ two transplant container cell sizes; 1x N and K rate = ($kg\cdot ha^{-1}$) 130N-149K.

⁴Each entry is an average of three replications $\times$ two application schedules $\times$ 3 N and K rates; small = 21 mm wide $\times$ 50 mm deep; large = 38 mm wide $\times$ 70 mm deep.

NS,*,**Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Effect of insecticide spray application schedule, N and K rate, and transplant container cell size on 'Market Prize' cabbage, Spring 1983.

Treatment	Insect-damaged	Plants with	Marketable		Avg wt	
	heads	heads	yield		per head	
	(%)	(%)	Early	Total	Early	Total
			(t·ha ⁻¹)		(kg)	
Application schedule (I) ²						
Weekly	0.0	72	23.8	35.6	1.46	1.36
Demand	6.8	66	22.8	32.8	1.43	1.37
F value	*	NS	NS	NS	NS	NS
N and K rate (F) ^y						
1x	3.2	56	14.8	25.6	1.35	1.27
1.5x	2.7	75	23.5	35.4	1.42	1.35
2x	4.4	77	31.6	41.6	1.56	1.49
L	NS	**	**	**	*	*
Q	NS	**	NS	**	NS	NS
Cell size (C) ^x						
Small	3.8	66	19.4	31.3	1.36	1.31
Large	3.0	72	27.2	37.1	1.52	1.42
F value	NS	*	*	**	**	*
Interactions						
I × F	NS	NS	NS	NS	NS	NS
I × C	NS	NS	NS	NS	NS	*
F × C	NS	NS	NS	NS	NS	NS
I × F × C	NS	NS	NS	NS	NS	*

²Each entry is an average of three replications $\times$ three N and K rates $\times$ two transplant container cell sizes.

³Each entry is an average of three replications $\times$ two application schedules $\times$ two transplant container cell sizes; 1x N and K rate = ($kg\cdot ha^{-1}$) 130N-149K.

⁴Each entry is an average of three replications $\times$ two application schedules $\times$ three N and K rates; small = 21 mm wide $\times$ 50 mm deep; large = 38 mm wide $\times$ 70 mm deep.

NS,*,**Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

regression analyses were performed to test the effect of N and K concentrations.

Average maximum and minimum temperatures in fall and winter were above and rainfall was below the 30-year average (Table 1). In spring, temperatures were below the 30-year average (Stanley, 1985), with heavy rains in March.

In fall and spring, cabbage on the demand

insecticide application schedule received two and that on the weekly schedule ten and nine applications, respectively, for the two seasons. In both seasons, the proportion of insect-damaged heads was significantly higher ($P \leq 0.05$) with the on-demand than with the weekly schedule (Tables 2 and 3). Insect damage ratings also were lower ($P \leq 0.05$) in the plots sprayed weekly (1.14 fall and 1.00 spring)

Table 4. Interaction of insecticide spray application schedule and N and K rate on 'Market Prize' cabbage, Fall and Winter 1982-83.

Application schedule	N and K rate ²		
	1x	1.5x	2x
<i>Proportion of plants with marketable heads (%)</i>			
Weekly	81	83	90
Demand	69	69	73
LSD _{0.05}	2.9		
<i>Early marketable yield (t·ha⁻¹)</i>			
Weekly	7.5	7.8	16.0
Demand	6.0	12.3	11.8
LSD _{0.05}	6.0		
<i>Marketable yield, total harvest (t·ha⁻¹)</i>			
Weekly	39.4	46.9	45.6
Demand	32.5	37.1	36.0
LSD _{0.05}	7.4		

¹1x N and K rate = (kg·ha⁻¹) 130N-149K.

than in those sprayed on demand (1.59 fall, 1.40 spring).

In spite of higher insect damage to heads sprayed on demand, differences in early and total marketable yields and average head size were nonsignificant with both application schedules (Tables 2 and 3). The results of these experiments support our previous findings on the effect of insecticide application schedule on cabbage (Csizinszky and Schuster, 1985) and cauliflower yields (Csizinszky and Schuster, 1988).

The proportion of insect-damaged heads in fall and winter increased linearly with increasing N and K rates (Table 2); however, in spring, the proportion of insect-damaged heads was similar with all N and K rates (Table 3). Early and total marketable yields increased with increasing N and K rates in both seasons (Tables 2 and 3). Yield increases were due to a larger proportion of plants with marketable heads and to a higher average weight per head with increasing N and K rates. The yield increase was especially large in the early season. The increase in marketable cabbage yield with increasing N and K rates agrees with previously reported results for broccoli (Csizinszky and Stanley, 1984), cauliflower (Csizinszky and Schuster, 1985), and cabbage (Csizinszky and Schuster, 1988) from this research center and with published results of others on fertilizer rate effects on cole crop yields under various environmental and cultural conditions (Knavel and Herron, 1981; White and Forbes, 1976).

Transplant container cell size affected plant growth early in the season and total marketable yield in fall and winter. At 28 DAT, plants raised in large cells had a larger leaf area (825 cm²) than plants raised in small cells (612 cm²) ($P \leq 0.05$). Plant height, plant width, and area covered by the plant did not differ significantly with application schedule and N and K rate (data not presented here). Total marketable yield in fall and winter also was higher for plants in large (41.3 t·ha⁻¹) than in small cells (38.3 t·ha⁻¹) (Table 2). In spring, the proportion of plants with marketable heads, early and total marketable yields, and average head weight were higher for plants in large than in small cells (Table 3).

Table 5. Interaction of N and K rate and transplant container cell size on 'Market Prize' cabbage, Fall and Winter 1982-83.

Cell size ²	N and K rate ²		
	1x	1.5x	2x
<i>Proportion of plants with marketable heads (%)</i>			
Small	71	75	83
Large	80	77	79
LSD _{0.05}	1.7		
<i>Total marketable yield (t·ha⁻¹)</i>			
Small	33.9	41.5	39.2
Large	38.1	42.5	42.4
LSD _{0.05}	4.4		
<i>Average weight per head (kg)</i>			
Small	1.31	1.43	1.38
Large	1.42	1.36	1.43
LSD _{0.05}	0.02		

¹1x N and K rate = (kg·ha⁻¹) 130N-149K.

²Small = 21 mm wide × 50 mm deep; large = 38 mm wide × 70 mm deep.

Application schedule × N and K rate interaction in fall and winter affected the proportion of plants with marketable heads and total marketable yields (Table 4). At the 1x N and K rate, fertilizer, not application schedule, limited cabbage yields. At the 1.5x and 2x N and K rates, however, the on-demand schedule was the yield-limiting factor.

The N and K rate × cell size interaction in fall and winter (Table 5) also reveals that cell size limited total marketable yield only at the 1x N and K rate. At the 1.5x and 2x N and K rates, yields were similar for seedlings from both cell sizes. The proportion of plants with marketable heads and average weight per head were also lowest at the 1x N and K rate and small cell size (Table 5).

In spring, the application schedule × cell size and application schedule × N and K rate × cell size interactions affected average head weight (Tables 3 and 6). Heaviest heads were recorded with the weekly schedule at the 2x N and K rate and large or small cells, and the on-

Table 6. Interaction of insecticide spray application schedule, N and K rate, and transplant container cell size on average weight of marketable 'Market Prize' cabbage heads, Spring 1983.

N and K rate ²	Transplant container cell size ²	Avg wt of marketable head (kg) ³
1x	Weekly	
	Small	1.26 de
	Large	1.36 cd
1.5x	Small	1.28 c-e
	Large	1.32 c-e
2x	Small	1.41 b-d
	Large	1.55 ab
1x	On demand	
	Small	1.20 e
	Large	1.25 de
1.5x	Small	1.35 c-e
	Large	1.43 bc
2x	Small	1.36 cd
	Large	1.63 a

¹1x N and K rate = (kg·ha⁻¹) 130N-149K.

²Small = 21 mm wide × 50 mm deep; large = 38 mm wide × 70 mm deep.

³Mean separation by Duncan's multiple range test, $P \leq 0.05$.

demand schedule with 2x N and K rate and large cells.

Nutrient concentrations in leaves were similar with all N and K rates in fall (data not presented here), but N, P, and K concentrations increased with increasing N and K rates in spring (Table 7). At the 1x N and K rate, at which leaf N concentration was 1.76%, N deficiency symptoms were apparent on the plants. Application schedule and cell size did not affect leaf nutrient concentrations significantly (data not presented).

In the soil, N and K rates affected nutrient concentrations only at midseason. Concentrations of NO₃⁻, NH₄⁺, and K increased with increasing N and K rates (Table 8). Postharvest nutrient concentrations in the soil were similar with all N and K rates. Residual K concentrations, however, were high, and K rates for optimum cabbage yields on light sandy soils should be investigated to reduce the amount of residual K in the soil. Application schedule and cell size did not affect soil nutrient concentrations (data not presented).

Based on one test during each season, we conclude that cabbage may require different management methods in fall than in spring. The reason for the different management methods between the two seasons presumably is the difference in weather. In early fall, high day and night temperatures are favorable for insects, and their populations may reach damaging levels. In spring, day and night temperatures are low and insect populations also are reduced. Therefore, in fall, a combination of preventive weekly insecticide applications and (kg·ha⁻¹) 210N-224K likely will be required for good marketable yields. At adequate N and K rates, costs can be reduced by using seedlings raised in small transplant container cells. In spring, insecticides may be applied on demand, provided plants are inspected weekly for signs of insect feeding and insect population thresholds. Marketable yields, especially early marketable yields, will be maximized from (kg·ha⁻¹) 210N-224K to 280N-298K with plants raised in large cells.

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Table 7. Effect of N and K rates on elemental concentrations in cabbage leaves, Spring 1983.

N and K rates	N (%)	P (%)	K (%)
1x ²	1.76	0.28	2.83
1.5x	2.20	0.32	3.31
2x	2.66	0.33	3.50
Significance	L***	L**Q**	L***

¹1x N and K rate = (kg·ha⁻¹) 130N-149K.

***Significant at $P \leq 0.01$ or 0.001, respectively; L = linear, Q = quadratic.

Table 8. Effect of N and K rates on pH and ionic or elemental concentration in soil, Fall and Winter 1982-83.

N and K rate ^z	pH		NO ₃		NH ₄		P		K	
	M ^y	H	M	H	M	H	M	H	M	H
1x	6.75	6.82	100	3.2	30	11.0	9.6	11.2	260	195
1.5x	6.48	6.50	161	7.9	78	17.0	11.1	12.0	490	430
2x	6.55	6.80	364	25.3	200	22.9	16.4	11.6	1270	530
Significance	NS	NS	L*	NS	L*	NS	NS	NS	L**	NS

²1x N and K rate = (kg·ha⁻¹) 130N–149K.

^yM = mid-season; H = harvest.

NS, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively; L = linear.

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