Nitrogen Rate, Cultivar, and Within-row Spacing Affect Collard Yield and Leaf Nutrient Concentration

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Abstract. Collards (*Brassica oleracea* L. Acephala Group) were grown in spring and fall to evaluate the effects of N fertilizer rate (0, 56, 112, 168, and 224 kg-ha⁻¹), cultivar (Blue Max and Vates), and within-row spacing (15, 23, and 30 cm) on yield and leaf mineral nutrient concentrations. Season, cultivar, and N rate interacted in their effects on yield. In spring, 'Blue Max' yield increased linearly with N rate to 10.4 t-ha⁻¹, whereas the highest 'Vates' yield (7.0 t-ha⁻¹) was obtained with 112 kg N/ha, and yield remained similar with additional N. In fall, 'Blue Max' and 'Vates' yields were highest (14.5 and 9.9 t-ha⁻¹, respectively) with 112 kg N/ha. Leaf N and P concentrations increased quadratically and linearly, respectively, in response to N rate. Maximum yields were obtained with the 15-cm within-row spacing. Leaf N concentration increased linearly with increased plant population. The adequacy of the present sufficiency range for leaf Ca concentrations of field-grown collards is discussed.

High plant population densities and N fertilizer rates are used to increase crucifer yields. High cabbage (*Brassica oleracea* L. Capitata Group) populations have produced higher yields but lower head weights (Csizinszky and Shuster, 1985; Knavel and Heron, 1981; Stofella and Fleming, 1990; White and Forbes, 1976) and increased variation in whole-plant, root, and head weights (Stofella and Fleming, 1990) compared to low plant populations. A positive response to N application up to 370 kg-ha⁻¹ has been reported (Knavel and Heron, 1981). The response of broccoli (*B. oleracea* L. Botrytis Group) to plant spacing (Cutcliffe, 1975; Massey et al., 1962; Palevitch, 1970) or fertilizer rate (Beverly et al., 1986; Kowalenko and Hall, 1987; Letey et al., 1983) has been documented. Linear increases in marketable broccoli yields and head weights were obtained with up to 224 kg N/ha and 72,000 plants/ha (Dufault and Waters, 1985).

The response of Chinese vegetables to N rates and within-row spacing has been reported (Hill, 1990). High yields of Chinese kale (*B. oleracea* L. Alboglabra Group) occurred at the closest spacing used (10 × 30 cm), and yields increased with the highest rate used—400 kg N/ha. At lower plant densities, maximum yields were produced at 200 kg N/ha. Low head weights were obtained with close within-row spacings. The positive yield response of false pak choi (*B. parachinensis* L.H. Bailey) to close within-row spacings was

more pronounced at all N rates than that of kai lan, but the effect of N rates was not as great. Tsoi sum (false pak choi) yields increased at 200 kg N/ha, then remained constant. Similar high yields of pak choi (*B. rapa* L. Chinensis Group) were obtained at the 10- or 20-cm within-row spacings with 200 kg N/ha; however, plant weights at 10 cm were much lower than at the other spacings. Applying additional N increased the incidence of soft rot and reduced yields.

Unlike most crucifers, turnips (*B. rapa* L. Rapifera Group) (Kahn, 1990) and collards (Johnson, 1991a) grown for fresh market and processing are usually established by direct seeding in the field. Because of the increased cost of hybrid seed and the convenience of obtaining quality transplants, collard establishment has shifted to using transplants (Olson and Stofella, 1989). The effects of within-row spacing and N rate on collard production, however, have not been addressed. The objective of this work, therefore, was to examine the seasonal effects of cultivar, fertilizer N rate, and within-row spacing on collard yields and leaf mineral nutrient concentrations.

Field experiments were conducted in Spring and Fall 1990 on a Norfolk-Orangeburg loamy sand association (fine, loamy, siliceous, thermic Typic Kandiodults) at the E.V. Smith Research Station near Shorter, Ala. Selected characteristics of the study site soils (0 to 15 cm deep) were pH, 6.3; organic matter, 1.4%; and cation-exchange capacity, 4.7 meq/100 g (Perkins, 1987). Melich I-extractable nutrients (in mg-liter⁻¹) were P, 55; K, 69; Ca, 158; and Mg, 54 (Hue and Evans, 1986). Treatments were factorial combinations of N rate (0, 56, 112, 168, and 224 kg-ha⁻¹ as NH₄NO₃), collard cultivar ('Blue Max' and 'Vates'), and within-row spacing (15, 23, and 30 cm) within a split-plot design. Nitrogen rates were assigned to main plots; within-row spacing and

cultivar combinations were subplots. Treatments were replicated four times in one-row plots 9.1 m long spaced 1.2 m apart.

Phosphorus (concentrated superphosphate) and K (KCl) were broadcast and incorporated at rates of (in kg-ha⁻¹) 29P-56K and 10P-19K in spring and fall, respectively. One-half of the N was broadcast and incorporated at planting; the remainder was band-applied 30 days after planting. a,a,a-Trifluoro-2,6-dinitro-N,N-dipropyl -p-toluidine (trifluralin) (0.473 liters-ha⁻¹) and O-ethyl S,S-dipropyl phosphodithionate (ethoprop) (0.486 liters-ha⁻¹) were broadcast and incorporated for weed and nematode control.

'Blue Max' (Abbott and Cobb, Feasterville, Pa.) and 'Vates' collard transplants (150-size TODD planter flats, Speedling, Sun City, Fla.) were planted on 28 Mar. and 12 Sept. 1990, 15, 23, and 30 cm apart in rows spaced 1.2 m to provide populations of 55,600, 36,200, and 27,800 plants/ha, respectively. Total rainfall and overhead irrigation during spring and fall were 220 and 190 mm, respectively. The fungicide tetrachloroisophthalonitrile (chlorothalonil) (0.42 liters-ha⁻¹) and the insecticide *Bacillus thuringiensis* var. *kurstaki* (0.560 kg-ha⁻¹) were applied weekly for disease and insect control, respectively.

Plants were harvested once at the 21-leaf stage on 18 May and 13 Nov. 1990. Before harvest, recently mature whole leaves were collected for nutrient analyses. Tissue was dried in a forced-air drier at 70C and ground to <0.6 mm. Tissue N concentrations were determined by dry combustion with an analyzer (model CHN-600; LECO Corp., St. Joseph, Minn.). Total P, K, Ca, and Mg concentrations were analyzed by inductively coupled plasma spectroscopy (Hue and Evans, 1986).

Data were subjected to analysis of variance procedures. The main effects of N rate and within-row spacing and their interactions were partitioned using single-degree-of-freedom contrasts.

Higher collard yields were obtained in fall than in spring (Table 1); however, season, N rate, and cultivar interacted in their effects on yield (Table 2). In spring, 'Blue Max' yield increased linearly, but 'Vates' yield increased quadratically, with the highest yields at 112 kg N/ha. In fall, both cultivar yields responded quadratically, with the highest yields at 112 kg N/ha. The superiority of 'Blue Max' was evident at 0 kg N/ha; its yield was ≈100% higher than that of 'Vates'. Higher biomass production by 'Blue Max' than 'Vates' has been reported in field, nutrient solution, and sand culture experiments (Johnson, 1991a; Olson and Stofella, 1989); the former attributed 'Blue Max' productivity to its large root system.

In addition to higher yields, higher leaf nutrient concentrations (except Ca) were obtained in fall than in spring (Table 1). Season and cultivar interacted only in their effects on leaf N concentrations (Table 3). Although higher yields were obtained for 'Blue Max' than 'Vates' in both seasons, similar leaf N concentrations were obtained for both cultivars in fall; but, in spring, N concentration was higher for 'Vates' than 'Blue Max'. In both

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Table 1. Effects of season, N rate, cultivar, and within-row plant spacing on collard yield and leaf nutrient concentrations.

	Yield (t·ha ⁻¹)	Nutrient concn (%)				
		N	P	K	Ca	Mg
Season (S)						
Spring	6.3	4.22	0.51	3.27	1.50	0.35
Fall	10.3	5.58	0.61	4.20	1.66	0.40
Significance	***	***	*	***	NS	*
N rate (N) (kg·ha ⁻¹)						
0	4.2	3.82	0.52	3.68	1.66	0.38
56	7.9	4.68	0.53	3.77	1.56	0.37
112	9.6	4.93	0.56	3.83	1.52	0.36
168	9.9	5.45	0.60	3.69	1.51	0.38
224	9.8	5.61	0.59	3.70	1.62	0.39
Significance	Q***	Q**	L***	NS	NS	NS
Cultivar (C)						
Blue Max	9.8	4.78	0.56	3.85	1.41	0.34
Vates	6.9	5.01	0.56	3.61	1.74	0.41
Significance	***	***	NS	***	***	***
Interaction ²						
Y × C	**	***	NS	NS	NS	NS
S × N × C	**	NS	NS	NS	NS	NS
Spacing (cm)						
15	8.9	4.77	0.55	3.75	1.6	0.39
23	8.0	4.90	0.56	3.74	1.6	0.38
30	7.9	5.02	0.57	3.71	1.5	0.36
Significance	Q*	L*	NS	NS	NS	NS

²No other interactions were significant.

NS, *, **, ***Nonsignificant or significant at $P = 0.05$, 0.01 , or 0.001 , respectively; L = linear, Q = quadratic.

Table 2. Interaction of season, cultivar, and N rate on collard yield.

Cultivar	Yield (t·ha ⁻¹)					Significance
	N rate (kg·ha ⁻¹)					
	0	56	112	168	224	
	<i>Spring</i>					
Blue Max	2.8	6.2	6.9	8.6	10.4	L***
Vates	2.2	4.6	7.0	7.1	7.0	Q***
	<i>Fall</i>					
Blue Max	8.1	12.8	14.5	14.8	12.9	Q***
Vates	3.9	8.2	9.9	9.0	9.0	Q***

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

Table 3. Interaction of season and cultivar on leaf N concentration.

Season	Leaf N concn (%)	
	Cultivar	
	Blue Max	Vates
Spring	4.02 b ^a	4.41 a
Fall	5.54 a	5.62 a

^aMeans compared within season at $P \leq 0.05$.

seasons, leaf N concentration of both cultivars responded quadratically to N rate, but leaf N concentration increased minimally with >168 kg N/ha (Table 1). Leaf P concentration increased linearly with N rate. The P concentrations were, however, within the sufficiency range for collards (Jones et al., 1991). Other leaf nutrient concentrations were not affected by N rate. 'Blue Max' leaf mineral nutrient concentrations, therefore, were not consistently higher than those of 'Vates', despite differences in greens production.

Except for Ca, leaf mineral nutrient concentrations reported in these experiments were within sufficiency ranges for collards (Jones et al., 1991). The mean Ca concentrations obtained for 'Blue Max' and 'Vates' were 1.41% and 1.74%, respectively (Table 1). Higher Ca concentrations have been reported for 'Vates'

than 'Blue Max' grown in the field, sand culture, and nutrient solution (Johnson, 1991a, 1991b). The highest Ca concentration (1.59%) reported in a field study for old 'Vates' leaves is about the same as values reported in our experiments. These values, however, are considerably lower than the sufficiency range of 3% to 4% provided by Jones et al. (1991). The results of our experiments question the current sufficiency range for this nutrient.

The quadratic decrease in yield obtained for 'Blue Max' with increased within-row spacing was similar to that obtained for 'Vates' (Table 1). This yield response agrees with the decreased crucifer yields obtained with increased spacing of cabbage (Csizinszky and Schuster, 1985; Knavel and Heron, 1981; Stofella and Fleming, 1990; White and Forbes, 1976), broccoli (Cutcliffe, 1975; Dufault and Waters, 1985; Massey et al., 1962; Palevitch, 1970), cauliflower (Dufault and Waters, 1985), and Chinese vegetables (Hill, 1990). Leaf N concentrations increased linearly with increasing within-row spacing and decreasing interplant competition. Concentrations of other mineral nutrients were not affected by within-row spacing.

Higher collard yields were obtained in fall than in spring. The results of these studies

confirm the superior yield potential of 'Blue Max', a hybrid, compared to 'Vates', an open-pollinated cultivar. 'Blue Max', but not 'Vates', responded to the addition of >112 kg N/ha in spring. In fall, yield differences between 'Blue Max' and 'Vates' at the 0 kg N/ha rate further substantiate the superior yield potential of 'Blue Max'. This impressive response may indicate the capacity of 'Blue Max' to produce high yields when planted as a double crop, without additional fertilizer, as is a common practice among collard growers. Yields were consistently higher for 'Blue Max' than 'Vates' at the other N rates. We found no evidence that its high yield resulted from improved mineral nutrition. The productivity of 'Blue Max' may be due to its extensive rooting system (Johnson, 1991 b). The reduced yield with increased within-row spacing confirms the results of experiments with other crucifers and suggests that the response to within-row spacing is the same for hybrid and open-pollinated collard cultivars. In conclusion, the results of these studies confirm the high yield potential of 'Blue Max' collards, establish a benchmark for an N application rate of 112 kg·ha⁻¹ for collards grown in single rows from transplants, and suggest that high yields of standard and hybrid collard cultivars may be obtained at 15-cm within-row spacings and a 1.2-m row spacing.

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