Optimum Nitrogen Fertilization of Summer Cabbage in Ontario

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Abstract

The recent introduction of nutrient management legislation in Ontario may force vegetable growers to reduce nitrogen (N) application. Experiments were conducted on mineral soil in Simcoe, Ontario in 2000 and 2001 to re-evaluate the N needs of cabbage. Nitrogen application rates of 0, 85, 170, 255, and 340 kg ha^{-1} were applied 75% preplant and 25% sidedress to Atlantis, a mid-season cultivar. Total yield, marketable yield, weight per head, head density, and head size were assessed at harvest. In 2001, total yield showed a peak at 265 kg N ha^{-1} while in 2001 no significant effect was recorded. Head size and weight per head increased with increasing N rate only in 2000, reflecting differences in yield. Cabbage density was generally unaffected by N rate. Days to maturity decreased with increasing N rate reaching a minimum at 245 and 226 kg ha^{-1} in 2000 and 2001, respectively. Nitrogen rates above current recommended levels are beneficial in maximizing cabbage yields in wet years and minimizing days to maturity.

INTRODUCTION

With the introduction of nutrient management legislation, Ontario vegetable growers may have to reduce nitrogen (N) application rates. There are unknown effects of altering N rates because minimal research has been conducted in Ontario over the past few decades to account for changes in production practices. Many changes to the cabbage cultivars grown have also occurred, and there have been few studies to account for the N requirements of introduced cultivars (Kretchman and Maddy, 1973). In addition, while the current Ontario recommendation is not specific for growth types, late storage cultivars, in general, appear to respond to much higher N application rates than midseason or early cultivars. Modern midseason cultivars require between 150 and 308 kg N ha^{-1} (Thomas et al., 1970; Bishop et al.,1975; White and Forbes; 1976; Csizinszky and Schuster, 1993; Sanderson and Ivany, 1999), while late storage cultivars respond to N rates up to 500 kg ha^{-1} (Zebarth et al., 1991). The N requirements of both growth types are often higher than the current Ontario recommended rate of 170 kg N ha^{-1} (OMAFRA, 2000).

While modern cultivars require high rates of N to maximize yield, harmful side effects can occur at these rates. High rates of N can delay maturity, decrease storage life, and increase the incidence of disorders (Peck, 1981; Berard, 1990; Locascio et al., 1984). In Ontario, research has focussed on maximizing yield rather than quality, and it is unknown whether current recommended rates maximize the marketable yield of the crop.

The objectives of this study were to: 1) re-evaluate the current N recommendations in Ontario and determine whether current recommendations maximize yield and quality, and 2) evaluate the effects of N rate on the days to maturity.

MATERIALS AND METHODS

Cabbage (*Brassica oleracea* var. *capitata* L.) was grown on mineral soil at the University of Guelph - Simcoe Campus (42^{o}51’N 80^{o}16’W), Simcoe, Ontario in 2000 and 2001. ‘Atlantis’ cabbage was seeded in 200 cell plastic plug trays on 10 May 2000 and 27

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April 2001, and transplanted into the field on 9 June 2000 and 30 May 2001. Plots consisted of four rows, spaced 0.75 m apart, 7 m (2000) and 9 m (2001) in length, and within row spacing of 0.45 m. The experiments were arranged in a randomized complete block design with four replications. The soil (pH 5.8-7.0), a grey brown luvisol, had organic matter content between 0.5 and 1.5% and thus low moisture and nutrient holding capacity. Temperature and rainfall records for 2000 and 2001 are presented in Table 1.

Nitrogen was applied at 0, 85, 170, 255, and 340 kg/ha, based on the current Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) recommendations, with 75% preplant incorporated and 25% sidedressed (OMAFRA, 2000). Calcium ammonium nitrate was used for all preplant N applications and potassium nitrate was used for sidedress applications.

Total yield was assessed at maturity from 4 m of the inside two rows of each replicate on 16 August, 30 August, and 11 September, 2000 and 17 August and 5 September, 2001, by weighing each head individually. Splits, rots, any disorders, and heads that were below 1.0 kg were noted as unmarketable. To assess quality, a maximum of 20 heads per treatment were measured for width and height and were split in half and rated for overall density (presence of air pockets between leaf layers: 5-leaves tightly pressed together, 4-small gaps between some layers, 3-moderate gaps between many layers, 2-large gaps between most layers, 1-heads loose with very large gaps between layers).

Data were analysed by linear and quadratic regression analysis. Peak values using quadratic regression equations were determined by setting the slope to zero and solving the first derivative of the regression equation. Data were analyzed using the Corr, GLM, and Univariate procedures of SAS version 8.0 (SAS Institute, Cary NC).

RESULTS

Both total and marketable yield were increased with increasing N rate in 2000 (Table 2). A quadratic relationship between N application rate and total yield, marketable yield, and weight per head (Table 2) was identified. The peak total yield in this plot occurred at an N application rate of 265 kg ha^{-1}, which was mainly due to the large head size at this rate. Visual differences among treatments were evident throughout the season. Cabbage that received the highest N application rates was larger and had a darker green colour compared to those that received no applied N. In 2001, no differences in total or marketable yields among treatments were detected (Table 2). The 2000 season was generally cool and wet, while the 2001 season was generally hot and dry, which may provide some explanation for the differences between the two years (Table 1).

Due to treatment induced uneven maturation, cabbage heads were harvested in three harvests, two weeks apart, in 2000 and two harvests, three weeks apart, in 2001. The relationship between N rate and days to maturity was quadratic in both years with a minimum at an N rate of 245 and 226 kg ha^{-1} for 2000 and 2001, respectively. Cabbage that received the highest N rates reached maturity up to four weeks earlier than those that received no or low N rates, with a mean difference between the lowest and highest days to maturity in 2000 and 2001 of 18 and 12 days, respectively (Table 3).

Head width and height increased with increasing N application in 2000 up to 255 kg N ha^{-1} (Table 4). A quadratic relationship existed between N application rate and head height and width in the 2000 plot (Table 4). In 2001, heads in the 255 kg N ha^{-1} treatment had a higher head width than the other N rates. However, the height of the heads was not affected by N rate in 2001, and no relationships between head size and N rate were observed. Head density ratings were lower in 2000 in cabbage that received the recommended N rate of 170 kg ha^{-1} compared to those that received 85 kg N ha^{-1}, but there were no differences among the other treatments (Table 4). There was no effect of N application rate on head density rating in 2001 (Table 4).

DISCUSSION

Total yield was affected by N application rate only in 2000. This suggests that more N is required in wet years. The reason for a lack of yield response to N rate in 2001 is not entirely known. Yields in 2001 were at the same levels achieved in 2000 at the higher N rates, and yields were higher than industry norms. The dry conditions in 2001 may have promoted a more extensive root system, which would have been capable of taking up higher quantities of nutrients. However, it would be expected in a hot year that cabbage growth would be stunted because it is a cool season crop. Grevesen (1998) showed that mean temperatures above 17°C stunted the growth of broccoli plants. This effect was not observed in this cabbage trial.

Low and high N rates in both years reduced the days to maturity by an average of 12 to 18 days. Reducing the days to maturity would be beneficial to growers because the crop could be marketed earlier in the season and crop management costs such as pesticide applications and irrigation could be reduced. Previous studies have shown a delay in maturity at high N rates (Berard, 1990), but low N has not been shown to delay cabbage maturity prior to this study. The effect of N on days to maturity should be factored into production recommendations because it is nearly as important as the effect of N on yield and quality.

Nitrogen application rate appeared to affect cabbage size without affecting quality as indicated by density of the head. Differences in head size reflected differences in yield. This is consistent with a previous study where extremely high N application rates had no effect on cabbage quality (Zebarth et al., 1991).

In a concurrent study we showed that N rate also has an effect on onion thrips (OT) damage in cabbage (Westerveld et al., in press). Cabbage in the 0 kg N ha^{-1} rate treatment in 2000 had higher OT damage than cabbage that received N rates at or above 170 kg N ha^{-1}. In 2001, cabbage that received 0 and 340 kg N ha^{-1} had higher OT damage than those receiving 255 kg N ha^{-1}. The differences in OT damage were attributed to differences in days to maturity. As the days to maturity increased, the OT damage also increased, which was most likely due to increased time for OT populations to develop (Westerveld et al., in press).

With the combined effect of N on yield, days to maturity, and OT damage, N rates between 220 and 260 kg ha^{-1} appear to be beneficial for summer cabbage in Ontario, which is much higher than the current recommended rate of 170 kg ha^{-1}. Consequently, a reduction in N application rates due to nutrient management legislation would have harmful effects to cabbage growers. Methods of reducing the environmental impact of high N application rates in cabbage should be investigated as an alternative to restricting N use.

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Literature Cited

Berard, L.S. 1990. Effects of nitrogen fertilization on stored cabbage. I. Development of physiological disorders on tolerant and susceptible cultivars. J. Hort. Sci. 65:289-296.

Bishop, R.F., Chipman, E.W. and MacEachern, C.R. 1975. Effect of nitrogen, phosphorus and potassium on yields and nutrient levels in cabbage grown on sphagnum peat. Commun. Soil Sci. Plant Anal. 6:479-488.

Csizinszky, A.A. and Schuster, D.J. 1993. Impact of insecticide schedule, N and K rates, and transplant container size on cabbage yield. HortScience 28:299-302.

Grevesen, K., 1998. Effects of average temperature on head growth of broccoli (*Brassica oleracea* Var *italica*); Parameter estimates for a predictive model. J. Hort. Sci. Biotech. 73:235 –244.

Kretchman, D.W. and Maddy, G.E. 1973. A nitrogen rate – spacing – cultivar study on cabbage for processing. Outdoor Vegetable Crops Research, Research Summary 65, Ohio Agricultural Research and Development Center, Wooster, Ohio, Jan. p.33-34.

Locascio, S.J., Wiltbank, W.J., Gull, D.D. and Maynard, D.N. 1984. Fruit and vegetable quality as affected by nitrogen nutrition, p. 617-26. In: R.D. Hauck (ed.). Nitrogen in crop production. Amer. Soc. Agron., Madison, Wisconsin.
Ontario Ministry of Agriculture, Food, and Rural Affairs. 2000. Vegetable production recommendations. Publ. 363. Queen's Printer for Ontario, Toronto.
Peck, N.H. 1981. Cabbage plant responses to nitrogen fertilization. Agron. J. 73:679-684.
Sanderson, K.R. and Ivany, J.A. 1999. Cole crop yield response to reduced nitrogen rates. Can. J. Plant Sci. 79:149-151.
Thomas, J.R., Namken, L.N. and Brown, R.G. 1970. Yield of cabbage in relation to nitrogen and water supply. J. Amer. Soc. Hort. Sci. 95:732-735.
Westerveld, S.M., McDonald, M.R., Scott-Dupree, C.D. and McKeown, A.W. The effect of nitrogen on insect and disease pests of onions, carrots, and cabbage. J. Veg. Crop Prod., in press.
White, J.M. and Forbes, R.B. 1976. Effect of spacing and fertilizer rates on cabbage yield and head weight. Proc. Fla. State Hort. Soc. 89:118-120.
Zebarth, B.J., Freyman, S. and Kowalenko, C.G. 1991. Influence of nitrogen fertilization on cabbage yield, head nitrogen content and extractable soil inorganic nitrogen at harvest. Can. J. Plant Sci. 71:1275-1280.

Tables

Table 1. Mean monthly air temperatures, monthly precipitation, and long-term averages (LTA) at the University of Guelph – Simcoe Campus in 2000 and 2001.

Month	Mean Air Temperature (°C)			Precipitation (mm)		
	2000	2001	LTA[1]	2000	2001	LTA[1]
May	14.4	14.7	12.6	103	109	74
June	18.5	19.3	17.8	181	63	82
July	19.8	20.7	20.4	146	11	77
August	19.7	21.8	19.5	81	105	80
September	15.8	15.9	15.5	99	37	89

[1] 30 year averages in Simcoe, Ontario.

Table 2. Effect of nitrogen (N) application rate on the total yield, marketable yield, and head weight of cabbage grown on mineral soil in 2000 and 2001.

Applied N	Total Yield ($t\ ha^{-1}$)		Marketable Yield ($t\ ha^{-1}$)		Weight per Head (kg)	
($kg\ ha^{-1}$)	2000	2001[1]	2000	2001[1]	2000	2001[1]
0	36.3	59.2	30.8	59.1	1.39	1.94
85	63.6	63.8	62.8	63.8	2.42	2.07
170	62.7	57.9	61.4	57.9	2.47	1.95
255	69.3	70.5	68.5	70.5	3.02	2.21
340	69.6	58.1	69.6	58.1	2.77	1.99
Intercept	39.16		34.28		1.446	
1st order	0.242		0.278		0.0109	
2nd order	-0.00046		-0.00053		-0.00002	
R^2	0.61		0.63		0.73	
P level	< 0.001		< 0.001		< 0.001	

[1] No effect was significant

Table 3. Effect of nitrogen (N) application rate on the days to maturity of cabbage grown on mineral soil in 2000 and 2001.

N rates	Mean Days to Maturity	
kg ha^{-1}	2000	2001
0	90.5	95.5
85	75.1	90.5
170	73.3	91.5
255	72.1	83.4
340	72.1	91.6
Intercept	89.1	95.9
1st order	-0.153	-0.093
2nd order	0.00031	0.00017
R^2	0.80	0.32
P level	< 0.001	0.039

Table 4. Effect of nitrogen (N) application rate on cabbage head width, height, and density rating in 2000 and 2001.

N rates	Head Width (cm)		Head Height (cm)		Density Rating[1]	
kg ha^{-1}	2000	2001[2]	2000	2001[2]	2000[2]	2001[2]
0	15.6	14.3	14.4	15.3	3.4	4.2
85	17.6	15.2	16.7	16.0	3.6	4.1
170	18.6	14.9	17.4	16.0	3.0	4.1
255	19.7	16.5	18.4	17.2	3.2	3.4
340	18.6	14.8	18.2	15.8	3.3	4.2
Intercept	15.40		14.33			
1st order	0.0327		0.0283			
2nd order	-0.000068		-0.000050			
R^2	0.66		0.82			
P level	< 0.001		< 0.001			

[1] Density Rating: presence of air pockets between leaf layers: 5-leaves tightly pressed together, 4-small gaps between some layers, 3-moderate gaps between many layers, 2-large gaps between most layers, 1-heads loose.
[2] No effect was significant.