HortScience 20(1): 127–128. 1985.

Interaction of Nitrogen Fertility and Plant Populations on Transplanted Broccoli and Cauliflower Yields

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Additional index words. *Brassica oleracea* 'Italica', *Brassica oleracea* 'Botrytis', cole, crucifer, cruciferae, nutrition, hollow stem

Abstract. **As broccoli populations increased from 24,000 to 72,000 plants/ha at N rates of 112, 168, or 224 kg/ha, head weight decreased linearly. Increasing the N rate from 56 to 224 kg/ha at any population linearly increased broccoli head weight and marketable yields, and decreased cull yields. Broccoli yields were highest at 72,000 plants/ha and 224 kg N/ha. No marketable cauliflower curds were produced at 56 kg N/ha at any population evaluated. As populations increased from 24,000 to 72,000 plants/ha with N rates held constant at either 112 or 224 kg/ha, marketable curd weight decreased linearly and cull production increased linearly. Increasing the N rate from 112 to 224 kg/ha did not increase marketable curd weight or yields at any population. Increasing the N rate to 112 kg/ha or higher reduced cull production at 24,000 plants/ha, but not at populations of 36,000 or higher. Cauliflower yields were optimized at 24,000 plants/ha and 112 kg N/ha based on reduced cull production, satisfactory curd weights, and transplant economy.**

Increasing plant population densities is a useful method to increase yield and profit potential in broccoli and cauliflower. Still, for high density cole crop production to be successful, N fertility inputs also should increase to compensate for increased nutrient utilization. High broccoli and cauliflower populations, however, have been reported to have some disadvantages. Broccoli yields per hectare increased with close plant spacing (4, 10); however, high plant populations decreased head size in broccoli (2, 4) and cauliflower (8, 11). Although high plant populations reduced head weight in broccoli, greater numbers of heads increased total yields (1, 4). High plant populations delayed cauliflower maturity (8) and reduced quality (12). Populations approaching 35,000 plants/ha were considered optimal for broccoli (1) and cauliflower (6) production.

The reduction in head weight with high plant populations may be moderated with higher N fertility. Letey et al. (9) and Arjona (1) found that broccoli head weight increased with N rates. The optimal N rates for high yields have been reported for broccoli at 90 kg N/ha (2), 112 kg N/ha (1), 168 kg N/ha (7) and for cauliflower from 112–224 kg N/ha (5), but high N rates also may alter head quality. Hollow stem in broccoli increased with N rates (3, 7, 13), but was ameliorated by close plant spacing (13, 14). Ideally, the reduction of head weight with close spacing may be offset by increasing the N rates; conversely, the incidence of hollow stem with high N rates may be reduced by close plant spacing.

The objectives of this study were to determine the effects of N and increasing plant populations on the yields of transplanted broccoli and cauliflower, and to identify N and population combinations which increase yield.

Broccoli and cauliflower transplants were grown by Speedling Inc., Sun City, Fla., using 100A cells and standard commercial practices. The 4-week-old transplants were shipped by air to Minnesota and, upon receipt, were acclimatized in a cold frame for 4 days prior to field planting. 'Southern Comet' broccoli and 'Snow Crown' cauliflower were hand planted at Becker, Minn., on 10 May 1983 on land cropped with barley the previous year. A soil test indicated 42 kg P/ha and 123 kg, K/ha on a Hubbard loamy sand (pH 6.2 and 2.6% OM). Prior to planting, 34 kg P/ha Trifluralin at 0.6 kg a.i./ha, and boron at 2.2 kg/ha were broadcasted and disked into the soil. About 200 ml of a transplant solution containing 54 mg N, 270 mg P, and 90 mg K/liter of H_2O, 600 ppm (formulation) S.T.E.M. (Soluble Trace Element Mixture), and 600 ppm (a.i.) Diazinon were poured into each planting hold at transplanting.

Plant populations of 24,000, 36,000, and 72,000 plants/ha were factorially combined with total N treatments of 56, 112, 168, and 224 kg/ha for broccoli and 56, 112, and 224 kg/ha for cauliflower. To achieve these populations, the plants were spaced 45, 30, and 15 cm apart within rows, respectively, using a standard 0.9 m row spacing. Nitrogen treatments, applied NH_4NO_3, were broadcasted and split applied, one-third of total at planting, one-third of total 2 weeks after planting and the last 3rd 4 weeks after planting. Nitrogen treatments were irrigated immediately with 2.5 cm water. Thereafter, the plots were sprinkler irrigated weekly with 2.5 cm water. The treatments were replicated 4 times and arranged in a split plot design with N rate as the main plot and plant population as the sub plot. The experimental plots included 4 parallel rows each containing 6 plants. A total of 6 plants were harvested from the center rows of each plot.

Broccoli heads were harvested at a 15 cm diameter with a 15 cm stem length (measured from the top of the head to stem butt). Cauliflower curds were cut at a 15 cm curd diameter with a 2.5 cm stem as measured from the base of the curd to stem end. Since maturity was uniform, each plot was harvested twice. Head quality was classified subjectively as "marketable" or "cull".

Broccoli. At all plant populations evaluated, increasing the N rate from 56 to 224 kg/ha linearly increased broccoli head weight (Table 1). Yet, as plant populations increased from 24,000 to 72,000 plants/ha with N rates (112 to 224 kg/ha) held constant, head weight decreased linearly. The incidence of hollow stem was negligible and not affected by any treatment. Early maturity was not affected by N or population treatments.

Despite a reduction of head weight with high plant populations, marketable yields increased simply due to increased numbers of heads (Table 1). Cutliffe (2, 4) reported similar responses. As N rate increased from 56 to 224 kg/ha at all plant populations, marketable yields increased linearly; however, cull production decreased linearly. Moreover, these increases in marketable yield did not level-off even at high populations and N rates. Thus, broccoli yields in this study were highest at populations of 72,000 plants/ha and 224 kg N/ha. It is probable that N rates higher than 224 kg/ha may increase head weight and yield.

Cauliflower. Cauliflower responded differently than broccoli to N and plant populations. The change in curd weight in response to an increase in N was nonlinear (Table 2). The application of 56 kg N/ha was inadequate for marketable curd production, since most of the curds were extremely loose and unuseable. There was no difference in curd weight between the 112 and 224 kg N/ha rates averaged over all populations. In the range of N rates between 56 and 112 kg/ha, apparently there existed a rate that would define a minimally acceptable yield response.

Increasing plant populations increased the competition among plants and subsequently reduced marketable yield. Curd weight decreased linearly as the populations increased from 24,000 to 72,000 plants/ha with N rates held constant at either 112 or 224 kg/ha. Thompson and Taylor (12) reported a similar response. N did not offset the apparent com-

Received for publication 21 May 1984. Journal article no. 13,960 of the Minnesota Agricultural Experiment Station. Financial assistance provided by the Governor's Council for Rural Development.The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Effects of N fertility and plant populations on 'Southern Comet' broccoli yield.

Plants/ha	N rate (kg/ha) 56	112	168	224	Significance[z]
	Marketable head wt (g/head)				
72,000	31.8	99.9	113.5	140.7	L**
36,000	45.4	131.7	177.1	217.9	L**
24,000	55.5	145.3	245.2	281.5	L**
Significance[y]	NS	L*	L**	L**	
N main effect: L**					
Population main effect: L**					
	Marketable yield (MT/ha)				
72,000	2.1	7.1	8.1	10.1	L**
36,000	1.2	4.8	6.0	7.6	L**
24,000	1.3	3.4	5.9	6.7	L**
Significance	NS	L**	L**	L**	
N main effect: L** Q**					
Population main effect: L*					
	Cull yield (MT/ha)				
72,000	4.2	1.8	1.8	0.6	L*
36,000	3.0	1.1	0.6	0	L*
24,000	2.5	1.2	0	0.4	L**
Significance	NS	NS	L*	NS	
N main effect: L**					
Population main effect: NS					

[z], NS, *, **Nonsignificant (NS) or significant at 5% (*) or 1% (**) level; linear (L) or quadratic (Q). Orthogonal comparisons of N rate effects with populations held constant.
[y]Orthogonal comparisons of population effects with N rate held constant.

petition among plants at these populations. Increasing the N rate from 112 to 224 kg/ha did not increase curd weight significantly at any specific plant population. Since the plants did not suffer water stress at any time, the competition between plants was caused by other unidentified factors rather than by a N deficiency.

Cauliflower marketable yields were not increased significantly by increasing the plant populations from 24,000 to 72,000 plants/ha at N rates of either 112 or 224 kg/ha (Table 2). The cull production increased linearly, however, as plant populations increased to 72,000 plants/ha. Increasing the N rate to 224 kg/ha at plant populations of 36,000 to 72,000 plants/ha did not reduce cull production significantly. At 24,000 plants/ha, increasing the N rates to 112 kg/ha reduced cull production.

Table 2. Effects of N fertility and plant populations on 'Snow Crown' cauliflower yield.

Plants/ha	N rate (kg/ha) 56	112	224	Significance[z]
	Marketable curd wt (g/curd)			
72,000	0	200	154	NS
36,000	0	372	327	L**Q**
24,000	0	504	590	L**Q**
Significance[y]	NS	L*	L**	
N main effect: L**Q*				
Population main effect: L**				
	Marketable yield (MT/ha)			
72,000	0	13.1	10.8	NS
36,000	0	12.8	11.7	L**Q**
24,000	0	11.9	11.7	L**Q**
Significance	NS	NS	NS	
N main effect: L**Q**				
Population main effect: NS				
	Cull yield (MT/ha)			
72,000	11.8	8.6	10.3	NS
36,000	8.9	5.4	5.4	NS
24,000	6.5	2.1	1.0	L**Q**
Significance	L**	L**	L*	
N main effect: L**Q**				
Population main effect: L**				

[z], NS, *, **Nonsignificant (NS) or significant at 5% (*) or 1% (**) levels; linear (L) or quadratic (Q). Orthogonal comparisons of N rate effects with population held constant.
[y]Orthogonal comparisons of population effects with N rate held constant.

Although marketable yields were equivalent among all plant populations evaluated at 112 to 224 kg N/ha, the additional cost of transplants at populations higher than 24,000 plants/ha was not warranted by yields obtained. More importantly, since cauliflower was harvested uniformly at a 15 cm curd diameter, increasing the populations to 36,000 plants/ha reduced curd weight undesirably. Cauliflower production, in this study, was best at the 24,000 plants/ha population, based on reduced cull production, transplant economy, and satisfactory curd weight. Since increasing N rates above 112 kg/ha did not increase curd weight or marketable yield, a minimum of 112 kg N/ha was adequate to produce satisfactory yields. On other soil types, these rates may have to be adjusted according to that soil's native fertility.

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