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HortScience 18(2):196–197. 1983.

Accumulation and Partitioning of Nitrogen and Dry Matter during the Growth of Chrysanthemum

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Additional index words. *Chrysanthemum* X *morifolium*, plant nutrition

Abstract. **Changes in dry weights, total N, nitrate N, and reduced N in the aboveground parts of *Chrysanthemum* X *morifolium* Ramat. 'Gt.#4 Indianapolis White' were determined at intervals from planting of rooted cuttings until inflorescence maturity. Plant dry matter accumulation rate (mg/day) increased in the combined aboveground tissues with each successive harvest, while N accumulation rate (mg N/day) peaked early in the plants' growth and decreased after the 6th week of growth. Continued dry matter accumulation in the leaves during inflorescence development suggested that photosynthetic capacity was in excess of the inflorescences' needs. In contrast, a loss of N from the vegetative portions, and primarily the stems plus petioles, indicated that newly absorbed N was inadequate to meet the demands of the developing inflorescence. The partitioning of N between NO_3 and reduced N indicated that enzymatic reduction of NO_3 did not limit the availability of reduced N during inflorescence development.**

The standard disbudded chrysanthemum is grown commercially for its large terminal inflorescence. Lunt and Kofranek (6) reported that at maturity a crop of 'Albatross' and 'Good News' chrysanthemums contained as much as 23% of the total aboveground dry weight in the inflorescence. Working with 'Bright Golden Anne', Cockshull and Hughes (2) found that the accumulation of dry matter in the inflorescence occurred partially at the expense of the vegetative portions of the plant. Furthermore, they found that the removal of the inflorescence early in its development resulted in continued dry matter accumulation in the vegetative tissues. These data indicate that the developing chrysanthemum inflorescence becomes a substantial "sink" for assimilates.

The importance of N fertilization in the production of quality chrysanthemums is well-known (4, 6). Lunt and Kofranek (6) reported that maintaining high N levels early in the growth of chrysanthemums was essential since deficiencies suffered during this stage of growth could not be overcome by later N fertilization. Kofranek (5) suggested that N accumulated in the leaves during early stages of growth is possibly retranslocated to the developing inflorescence. Boodley and Meyer (1) reported that the N concentration of the median leaves of 'Bonnaffon Deluxe' chrysanthemums increased rapidly during the first 4 weeks of growth, then remained relatively constant through flowering. However, these data do not give a clear indication of N accumulation since they were based on selected leaves and expressed as concentration rather than content. Little information is available on the accumulation and distribution of N in various tissues during the growth of chrysanthemum.

Our objectives were to: (a) follow the changes in the dry matter and N content of the aboveground vegetative tissues and the inflorescence during chrysanthemum development; (b) determine the partitioning of accumulated N between storage as free NO_3 and reduced N; and (c) estimate from this information the capacity of the vegetation to meet the demands for dry matter and N by the developing inflorescence.

Unrooted cuttings of 'Gt.#4 Indianapolis White' chrysanthemum were obtained from Yoder Brothers (Barberton, Ohio) and rooted under intermittent mist. Rooted cuttings were planted, one per 15-cm standard plastic pot, on April 26. Plants were grown in a 1 sphagnum moss:1 vermiculite (v/v) medium amended with 3.0 kg m^{-3} dolomite, 1.8 kg m^{-3} superphosphate, 2.4 kg m^{-3} esmigran, and wetting agent. Plants were fertilized at each watering with 200 mg $liter^{-1}$ N and K derived from $Ca(NO_3)_2$ and KNO_3.

This experiment was conducted in a glass covered greenhouse in Ithaca, N.Y. Night temperature was maintained at 18°C. Day temperature was 24°, with slightly higher temperatures experienced towards the end of the experiment. During the rooting of cuttings and the first 2 weeks of growth, plants were exposed to noninductive long days by interrupting the night period between 2200 and 0200 hr with incandescent lamps. Plants were then exposed to inductive short-day conditions by covering with black cloth from 1700 to 0800 HR until final harvest. Plants were grown single stem with all lateral shoots and buds removed, resulting in the development of only the terminal inflorescence.

Four replicate plants were harvested after 0 (rooted cuttings), 2, 4, 6, 8, and 9 weeks of growth and separated into leaf blades, stems plus petioles, and inflorescence. Tissue was dried in a forced-air oven at 75°C for 48 hr. Dried tissue was ground in a small Wiley mill to pass a 20-mesh screen. Total N was determined by a micro-Kjeldahl procedure which included a salicylic acid predigestion phase and subsequent digestion with sodium thiosulfate prior to addition of catalyst to reduce NO_3 (3). Nitrate N was determined using an ion-specific NO_3 electrode (model 93-07, Orion Research, Inc., Cambridge, MA 02139). Tissue was extracted with distilled water (NO_3-N free) and the extracts analyzed for NO_3-N after adding 2 N $(NH_4)_2SO_4$ as an ionic strength adjustor. Reduced N was estimated by the difference between total N and NO_3-N. Nitrogen content is reported as mg N per plant part.

Dry matter continued to accumulate in the combined aboveground tissues of chrysanthemum at increasingly rapid rates with each successive harvest through inflorescence maturity (Table 1). The rate of dry matter accumulation in the leaves and stems plus petioles was most rapid between the 4th and 6th weeks of growth. Leaves continued to accumulate a significant amount of dry matter, and at a high rate, through inflorescence maturity. In contrast, stems plus petioles attained their maximum dry weight 8 weeks after planting. Of the 4.7 g of dry matter accumulated in the aboveground tissues between the 8th and 9th weeks of growth, 3.0 g or 64% was accumulated in the inflorescence. This represents the most rapid rate of dry matter accumulation in any of the aboveground plant parts between harvests and underscores the potential "sink" capacity of the developing inflorescence. At maturity the inflorescence contained 21% of the total

Received for publication Aug. 23, 1982. Appreciation is expressed to Yoder Brothers, Inc., Barberton, OH 44203 for donation of plant material. 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. Accumulation of dry matter in the aboveground tissues of chrysanthemum.

Weeks after planting	Dry wt (g)				Dry wt gain (mg/day/plant)			
	Total	Leaves	Stems	Inflor.	Total	Leaves	Stems	Inflor.
0	1.2[z]	0.9	0.3					
2	2.5	1.8	0.7		92.9[y]	64.3	28.6	
4	6.0	3.9	2.1		250.0	150.0	100.0	
6	13.1	7.8	5.1	0.2	507.1	271.6	214.3	
8	20.3	11.4	6.6	2.3	514.3	257.1	107.1	135.7
9	25.0	13.1	6.6	5.3	671.4	242.9	0.0	428.6
LSD 5%	0.7	0.5	0.4	0.4				

[z]Means of 4 replicates.
[y]Daily rates of dry matter accumulation as calculated from the mean dry wt of successive harvests.

Table 2. Accumulation of N in the aboveground tissues of chrysanthemum.

Weeks after planting	Total N (mg)				N gain or loss (mg N/day/plant)			
	Total	Leaves	Stems	Inflor.	Total	Leaves	Stems	Inflor.
0	27.5[z]	24.0	3.5					
2	98.1	82.5	15.5		5.0[y]	4.2	0.9	
4	245.9	201.4	42.1		10.6	8.5	1.9	
6	403.6	319.7	76.9	7.0	11.3	8.5	2.5	
8	509.8	385.9	66.0	58.0	7.6	4.7	−0.8	3.6
9	540.4	384.9	62.2	93.3	4.4	−0.1	−0.5	5.0
LSD 5%	27.5	24.6	5.9	5.2				

[z]Means of 4 replicates.
[y]Daily rates of N accumulation or loss as calculated from the mean N contents of successive harvests.

Table 3. Partitioning of N between free NO_3 and reduced N in the aboveground tissues of chrysanthemum.

Weeks after planting	N partitioning (mg N/plant part)					
	Leaves		Stems		Inflorescence	
	NO_3-N	Red-N[z]	NO_3-N	Red-N	NO_3-N	Red-N
0	0.5[y]	23.6	0.2	3.2		
2	11.8	72.4	3.6	11.7		
4	32.4	168.9	13.3	28.7		
6	48.3	271.5	11.6	65.2	0.1	6.9
8	49.8	336.1	6.4	59.2	1.0	57.0
9	49.5	335.4	8.7	53.5	1.9	91.4
LSD 5%	3.5	22.4	1.7	5.1	0.2	5.1

[z]Reduced N estimated by subtracting NO_3-N from total N.
[y]Means of 4 replicates.

aboveground dry matter. As judged by the continued accumulation of dry matter in the leaves during inflorescence development, photosynthetic capacity exceeded "sinks'" demands. Our results differ from those previously reported for 'Bright Golden Anne' (2), where a cessation of dry matter accumulation in the vegetative portions of the plant occurred concomitant with inflorescence development.

The pattern of N accumulation in chrysanthemum differed from that of dry matter (Table 2). Early stages of growth were marked by high rates of N accumulation in the combined aboveground tissues. A decrease in the rate of N accumulation after the 6th week of growth indicates a decrease in the overall N requirement of chrysanthemum. A significant amount of N was lost from the stems plus petioles between the 6th and 9th weeks of growth, indicating a net remobilization of N to other N-accumulating tissues, such as the leaves and inflorescence. During the final week of growth, the developing inflorescence accounted for all of the N accumulated in the aboveground plant. At maturity the inflorescence contained 17% of the total N present in the aboveground tissues.

The partitioning of N between storage as NO_3 and reduced N varied with tissue and plant age (Table 3). Leaves contained only a small portion of their total N as free NO_3, and the ratio of NO_3-N to reduced N remained relatively constant during plant development. In contrast, stems plus petioles contained as much as 32% of their total N as free NO_3 by the 4th week of growth. Between the 4th and 6th weeks of growth free NO_3 in the stems plus petioles decreased, while a concomitant increase in reduced N was seen. These data would suggest that the rate of enzymatic reduction of NO_3 was not limiting the amount of reduced N available for the developing inflorescence. Free NO_3 was a relatively minor constituent of the inflorescences' total N.

Our data indicates that the early stages of chrysanthemum growth are critical periods with respect to N availability. These results are in agreement with those of Lunt and Kofranek (6), which emphasized the importance of early N fertilization. These data show that the photosynthetic capacity, as judged by dry matter accumulation, was in excess of the developing inflorescences' demands, whereas the availability of newly absorbed and reduced N was inadequate for the inflorescences' needs since a net loss of N from the vegetative tissues was seen during inflorescence development. Since N fertilization was carried out at a consistently high rate throughout crop development, the decrease in N accumulation during the later stages of growth is likely the result of a decrease in the plants' inherent N requirement and/or a decrease in the plants' capacity to absorb available N.

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