THE INFLUENCE OF PLANT AGE AND NITROGEN RATE ON NUTRIENT REMOVAL FROM THE CONTAINER MEDIUM SOLUTION

by

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(ABSTRACT)

Adequate nutrient supply to the medium solution of container-grown crops is a major concern to container plant production practices. The extent to which nutrients are removed by the plant from the medium solution of a container, however, has never been demonstrated. Mariogold, Tagetes erecta 'Inca' seed were glasshouse-grown in 500 cc plastic pots containing 1 peat: 1 perlite (v/v) medium and fertilized daily with 200 ppm N as ammonium nitrate. Thirty, 35, 40, 45 and 50 day old plants were subjected to either 20, 50, 80 or 110 ppm N. Medium solutions were tested at hour 0 and 6, and analyzed for N, P and K. Nitrogen removal from the medium solution was greatest by 45 and 50 day old plants at the higher N treatments. Phosphorous and K removal also increased with plant age. Medium solutions were tested and analyzed again, 10 days later. Nitrogen removal, 10 days later, was greatest for 50, 55 and 60 day old plants at the higher N treatments. Phosphorous removal was greatest by 55 and 60 day old plants whereas K removal increased up to day 60 through all age groups. Total N, P and K in the tissue reflected nutrient removal rates; however, no differences in dry weight due to N treatment were detected. In a second experiment, to determine the age at which dry weight is affected by N treatment, plants of one age group were treated with either 10, 30, 50 or 70 ppm N. Shoot dry weights did not differ until day 27 when plants grown at 10 ppm were smaller than for other treatments. As plants aged, higher levels of N were required to prevent growth reduction. These results indicate that age influences the N removal rate from the medium solution of container-grown plants. This relationship affects the amount of N applied to the medium solution to satisfy plant N requirement.

Dedication

I would like to dedicate this thesis to Johnny Randall for his support and patience throughout all stages of my degree.

Acknowledgements

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Sincere appreciation goes to Dr. Alex Niemiera and Dr. Robert Wright for their formal training, for their constant challenges and critical eyes and above all for providing me with the self-confidence to accept them. I thank my committee members Dr. Richard Johnson and Dr. Stephen Donohue for their time, expertise and warm support. I would also like to thank my friends for their strength, generous help, and encouragement. Thanks goes as well to Ms. Janet Dean for her help in this research. Utmost gratitude is extended to John and Helen Randall who have been faithfully supportive in all aspects of my education. Once again, a special thank you is given to Alex, who made the hard times seem easy and the good times better.

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INTRODUCTION

A plant's demand for nutrients increases as plant age increases and therefore the supply of nutrients must also be increased to prevent reduction in plant growth (6). This is a well established concept that has been demonstrated with plants growing in recirculating solution culture systems (1,2,7,8,9). Absorbed nutrients could be easily resupplied to the solution to compensate for plant removal or demands. Under field conditions, plants may compensate for an increased nutrient demand by increasing root volume commensurate with shoot growth. However, for plants growing in containers where medium volume and root proliferation are limited, nutrient supply must be increased by either increasing the frequency of nutrient applications or the application rate (6,22). Both approaches have been used in a nutrient flow system (3) where either the solution concentration or the solution flow rate throughout the system was increased.

With the production of container-grown greenhouse and nursery crops, little attention has been given to matching plant nutrient requirements with fertilizer application rates. Plants are commonly fertilized throughout most of a production cycle at one application rate with no regard for plant size or age. This practice is common regardless of whether controlled release or liquid feed systems are used. For example, manufacturer's recommendations for controlled release fertilizers for woody nursery crops specify that the same amount of fertilizer be applied to a plant the first year of production compared to the second. With liquid feed systems, levels of N, P, K, Ca and

Mg in the irrigation water have been established for rooted cuttings of container-grown Ilex crenata 'Helleri' (14,17,25). Results of these experiments, however, may not necessarily be extrapolated to fertilizing larger plants since nutrient requirements for larger plants may be greater.

Floriculture crops (11) and bedding plants (12) are usually fertilized 2 to 3 times a week, at 150 to 200 ppm N, in the irrigation water. These recommendations are made without mention of plant age in relation to nutrient requirements. As a result plants may be over-fertilized during early vegetative stages of growth and development, resulting in wasteful leaching of nutrients from the container. Nutrient supply may be limited during subsequent vegetative stages of plant development when exponential growth is occurring and nutrient demands are greater.

Therefore, the purpose of this research was to determine the influence of plant age on nutrient removal from a container medium solution supplied with different N application rates.

MATERIALS AND METHODS

Experiment 1. Tagetes erecta 'Inca' (Marigold) seed were sown under intermittent mist at 5 day intervals starting on 3 September, 1985 and ending on 28 September, thus establishing 5 age groups. Seeds were sown in plastic pots (500 cc) containing a medium of 1 peat:1 perlite (v/v) which was preplant amended with 1 kg Micromax (Sierra Chemical Co., Milpitas,CA.) m&sup-3. and 6 kg dolomitic lime m&sup-3.. Germination occurred in 3-4 days and plants were glasshouse-grown with day/night temperatures of 24°/18°C. Plants were placed on raised benches and arranged in a randomized complete block design with a sufficient number of plants (80) per age group in each of 5 blocks to fulfill the objective of the experiment. Plants were irrigated with 200 ml of a nutrient solution containing 200 ppm N as NH_4NO_3, 25 ppm P as H_3PO_4 and 150 ppm K as K_2SO_4. After every 2 nutrient solution irrigations, plants were irrigated with 200 ml tap water to prevent excessive salt accumulation in the medium. The frequency of irrigation was dependent upon plant need for water. All flower buds were removed when visible, which occurred at 30 days.

On 28 October, 1985, there were 5 plant age groups, 30, 35, 40, 45 and 50 days from seedling emergence from which 40 plants were selected from each age group for each block. At 2200 hr the 40 plants were treated with 1000 mls of either 20, 50, 80 or 110 ppm N to equilibrate the medium solution with the applied solution. On 29 October, at 0700 hr, the treatment was repeated. One hr later medium solutions were extracted from 5 plants per N treatment per age using the pour-through technique (24) in which 45 ml of distilled water was applied to the surface of the medium and the leachate collected. Medium solutions were tested again on a different group of 5 plants per N treatment per age at 1400 hr. This testing date was designated Pour-through (PT) 1. Uniform moisture levels of all treatments was maintained to prevent moisture influence on nutrient extraction from the container (23). To accomplish this containers were wrapped in Saran to decrease water lost by evaporation. Every 15-30 min, containers were weighed and any water lost via transpiration was reapplied as distilled water. Thus, moisture levels were maintained at container capacity and at the same levels each time the extraction was made. Leachates were analyzed for NH_4-N and NO_3-N using ion selective electrodes, P using a colormetric procedure (20) and K by atomic absorption spectrophotometry.

Medium solution N, P and K concentrations measured at 0800 and 1400 hr were multiplied by the volume of medium solution (200 ml) to express the amount of nutrient removed from the medium solution on an absolute basis. Volume of medium solution was calculated as the difference between wet weight of a saturated container and an oven dried container.

Nutrient extraction at 0800 and 1400 hr was repeated 10 days later (PT 2) using the same group of plants. During this 10 day interim period, plants of each group were fertilized daily with the respective 20, 50, 80 and 110 ppm N treatments.

At PT 1 and PT 2 plant shoots of each age group and N treatment were harvested, rinsed in distilled water, dried for 48 hr at 70°C, weighed and analyzed for total N using the micro-Kjeldahl technique (16). Shoot tissue was also rinsed in distilled water, dried, weighed, ashed in a muffle furnace at 450°C for 4 hr, then analyzed for total P and K as described above.

Controls were established to determine if the medium either adsorbed or desorbed nutrients. Two days before PT 1, 2 plants per block per N treatment for the 30 and 50 day old plants were cut at medium level. On 29 October, these containers were subjected to the PT procedure along with the other plants as described previously.

Experiment 2. Tagetes erecta 'Inca' seed were propagated on 5 March, 1986 as previously described. Seedlings emerged in 3 to 4 days and were glasshouse-grown. Plants were treated with either 10, 30, 50 or 70 ppm N in a nutrient solution with the same P and K concentrations, frequency of application and experimental design as in Expt. 1.

RESULTS AND DISCUSSION

The amount of N removed from the medium solution supplied with 20 or 50 ppm N was not influenced by plant age except for a slight increase between 30 and 35 day old plants (Fig. 1). However, for plants treated with 80 or 110 ppm N there was an increase in the amount of N absorbed from the medium solution as plant age increased (Fig. 1). In contrast to the lower N treatments, 80 and 110 ppm N in the medium solution were sufficient to supply plant nutrient needs for a longer portion of the growth period. Figure 2 confirms this since at 110 ppm N, the level of N in the medium solution was depleted only with the 45 and 50 day old plants. But, at low N levels (20 ppm) most of the available N was removed from the medium solution regardless of age. It is possible that the 110 ppm N treatment may have limited the growth of 45 and 50 day old plants since most of the available N (88 and 98% respectively) was removed from the medium solution by these plants (Fig. 2). The fact that there was no difference in N absorption between the 50 day old plants and 45 day old plants (Fig. 1) lends further support to this observation.

Data from controls (containers from which plants had been excised) demonstrated a consistent increase of 0.9 mg of NO_3 and a decrease of 0.6 mg of NH_4 across all N treatments for both age groups (data not shown). Thus, N sorbtion or transformations did not interfere with interpretations for N removal data during a 6 hr period. The increase in NO_3 accompanied by a decrease

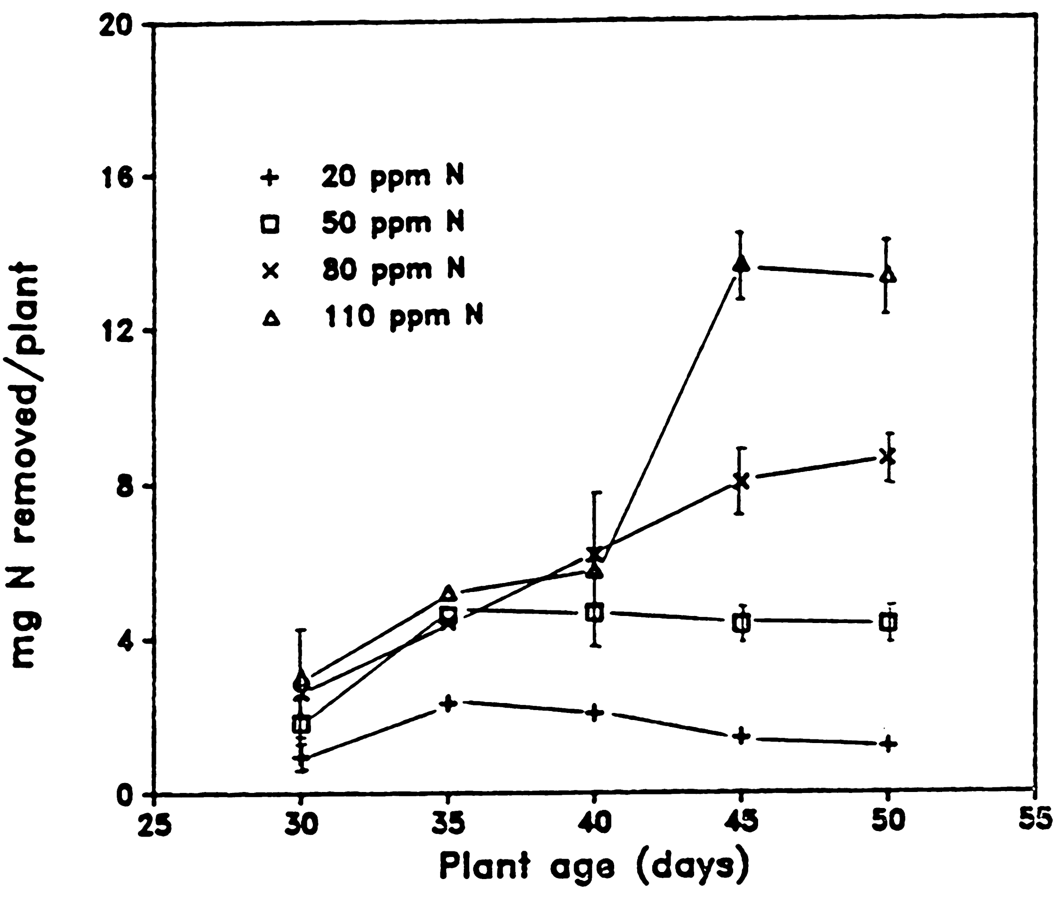

Figure 1. Influence of N treatment and plant age on amount of N removed from the media solution in 6 hr (PT 1). Brackets indicate ± SD. SD < 0.5 not shown.

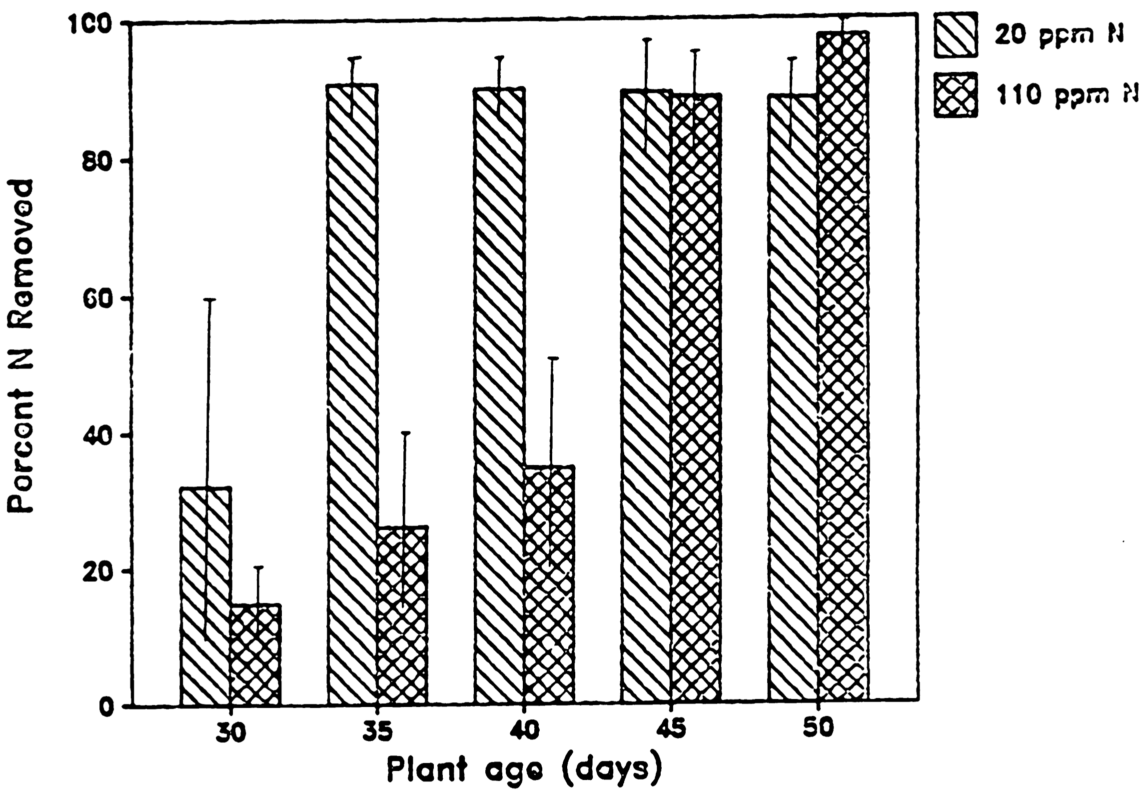

Figure 2. Influence of plant age on percent available N removed from media solution at 20 and 110 ppm N (PT 1). Brackets indicate ± SD. SD < 0.5 not shown.

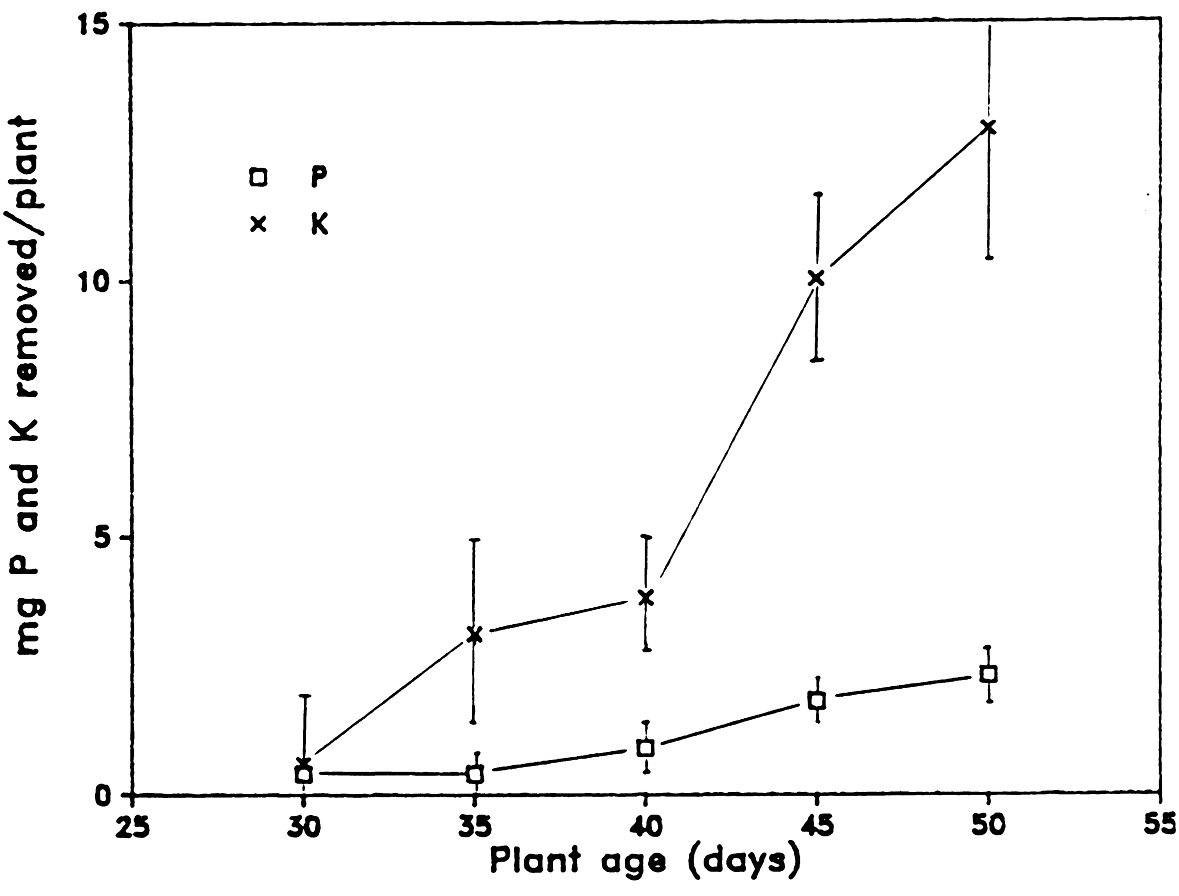

Figure 3. Influence of plant age on amount of P and K removed from media solution in 6 hr averaged over all N levels (PT 1). Brackets indicate ± SD.

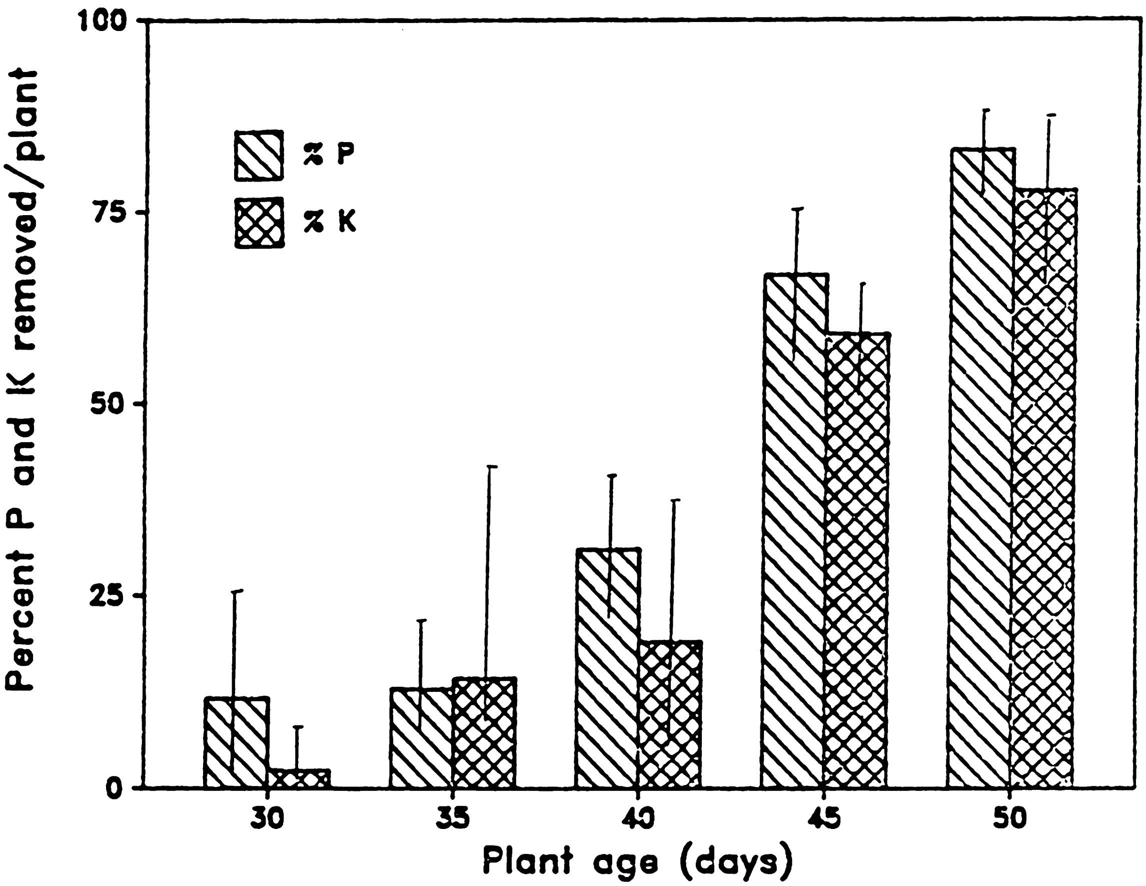

Figure 4. Influence of plant age on percent P and K removed from the media solution averaged at 20 and 110 ppm N (PT 2). Brackets indicate ± SD.

in NH_4 could be the result of nitrification, which has been known to occur in organic substrates (15).

The amounts of P and K removed within a 6 hour period increased as plant age increased (Fig. 3). The level of P and K removed was not influenced by the level of N applied (data not shown). Data also suggested that neither the level of P nor K in the medium solution likely limited uptake since only 80 to 85% of each were removed from the medium solution (Fig. 4). As with N removal, these data demonstrate that nutrient demand is dependent upon plant age and lower levels of P and K in the medium solution during early stages of development would not have limited growth. As long as nutrient supply is not limiting, nutrient uptake will increase commensurate with plant age or size.

In general the same nutrient removal trend was observed at PT 2, 10 days later, as at PT 1 (Fig. 5). Nitrogen levels appeared to be limiting, with the exception of 110 ppm N for the youngest (40 day old) plants. Nitrogen removal in response to age did not increase with the 50, 55 and 60 day old plants as with the 50 day old plants at PT 1. Of interest is the fact that N removal values, and plant dry weight values for a particular age plant, are approximately the same at either PT (Fig. 6). The lack of increase in N removal with 50, 55 and 60 day old plants could be related to a limitation in N supply since much of the N at 110 ppm had been removed from the medium solution by the larger plants (Fig. 2 and 7). However, it may also be related to a decrease in plant demand for N as the plant approaches maturity and flowering. This response to N removal with plant age is similar to that found by Edwards and Barber (1,2) in solution culture experiments with corn roots. Similar decreases in N removal from solution cultures and field research have been found with other plants (5,8,9,10,18,19). Daily nitrogen uptake for chrysanthemum (21) has also been characterized by a decreased demand for N as plants approach flowering. Consistent with our data this demonstrates a reduced demand for N beyond a certain age or stage of development even though dry weight increases continue.

As with PT 1 there was an increase in P and K uptake with increasing plant age (Fig. 8). Based on percent P and K removed from solution, it appeared that supply of these nutrients was not limiting (Fig. 9).

The pattern of total shoot N accumulation during the 10 days between PT 1 and PT 2 at 110 ppm N reflects the solution N removal data for each plant age group (Table 1). The rate of accumulation (mg N/day/shoot) increased with plant age with the exception of the oldest plants where N accumulation rate declined. Rapid increase in dry weight reflected high rates of N accumulation in the combined aboveground tissues. A decrease in the rate of N accumulation between 45 and 55 days implies a decreased demand for N beyond a certain age. A greater amount of N was accumulated in the tissue per day for each age group than shown for N removal data, indicating that N was also removed during the remaining unsampled hours of the day.

Ten days at either 20, 50, 80 and 110 ppm N treatments produced no dry weight differences between N treatments for all age groups (data not shown). High tissue N as a result of applications of 200 ppm N prior to the 10 day N treatment period may have masked the influence of N treatment (4,13,18). Plant accumulation of N may have been sufficient to prevent growth differences for 10 days.

Experiment 2. Another experiment was conducted to determine the age at which growth responses would occur when plants were subjected to different N levels. Differences in dry weight as affected by N treatment were not apparent at 22 days after seedling emergence (Fig. 10). Lack of dry weight difference indicates that 10 ppm N was sufficient to supply plant nutrient needs early in their life span. However, dry weight differences were manifested at day 27 when plants at 10 ppm were smaller than for other treatments. In keeping with this trend, as plant age increased, a higher N rate concentration was required to avoid growth limitation. These data support the nutrient removal data which demonstrated that smaller plants in comparison to larger ones did not deplete the nutrients in the medium solution, and thus had sufficient N available for maximum growth.

In summary, this work has indicated that plant nutrient removal from the container medium solution is a function of plant age. Plant N application rate commensurate with plant growth will result in fertilizer efficiency without sacrificing plant growth. Thus, the fertilization of an N related to the plant N removal rate will 1) increase fertilizer efficiency, 2) insure adequate N supply at all stages of growth and 3) decrease N leaching from containers thus reducing surface and ground water pollution. This confirms previous research (1,2,6,7,8,9).

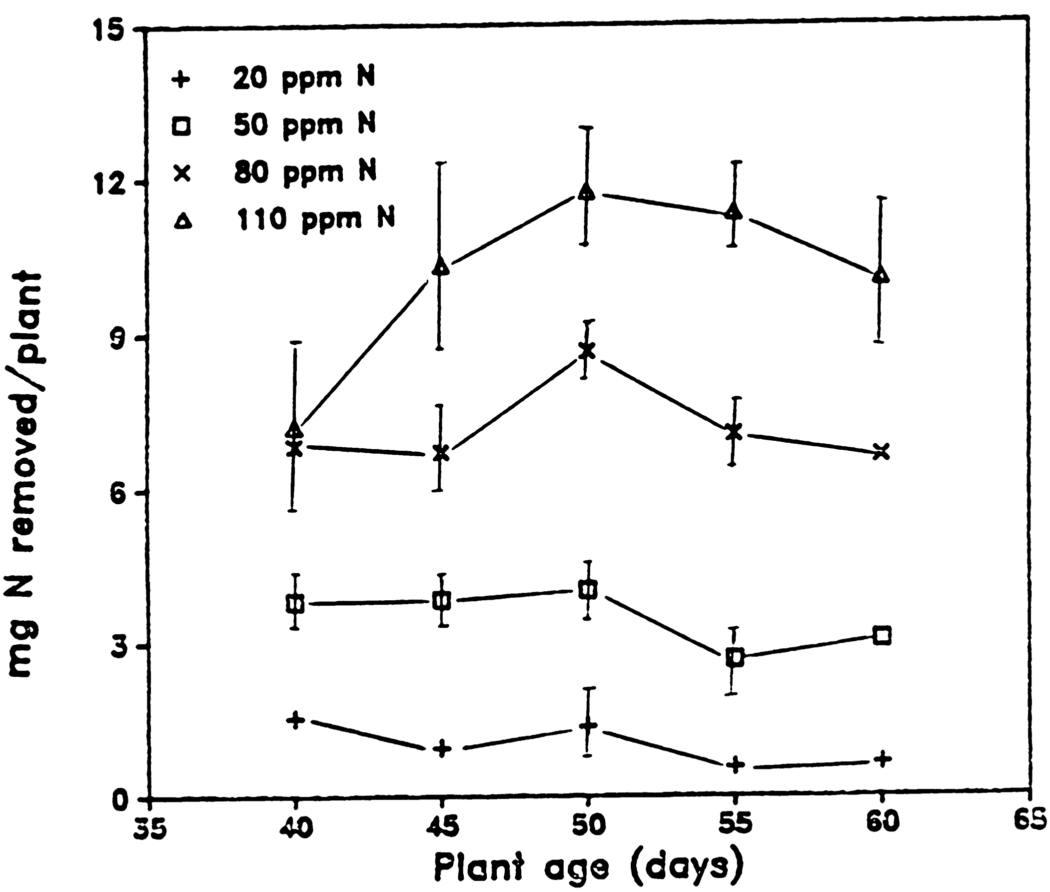

Figure 5. Influence of N treatment and plant age on amount of N removed from media solution in 6 hr (PT 2). Brackets indicate ± SD. SD < 0.5 not shown.

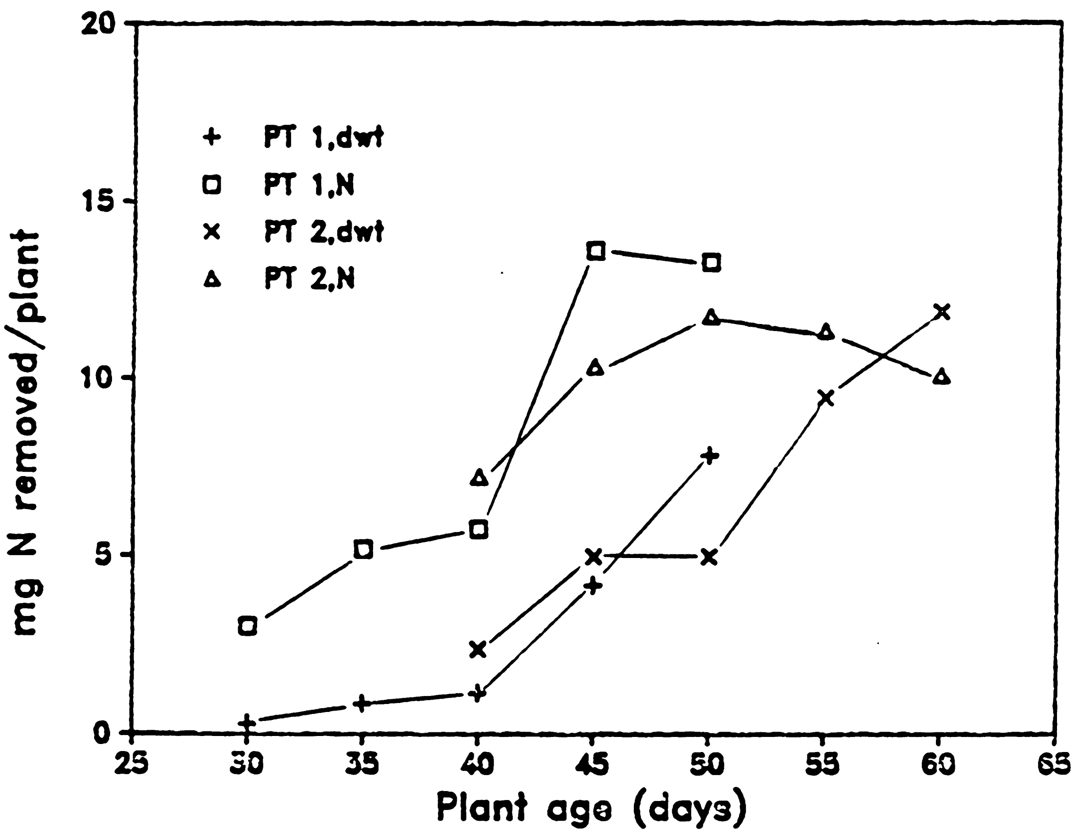

Figure 6. Influence of plant age on amount of N removed from the media solution and plant dry weight (PT 1 and PT 2).

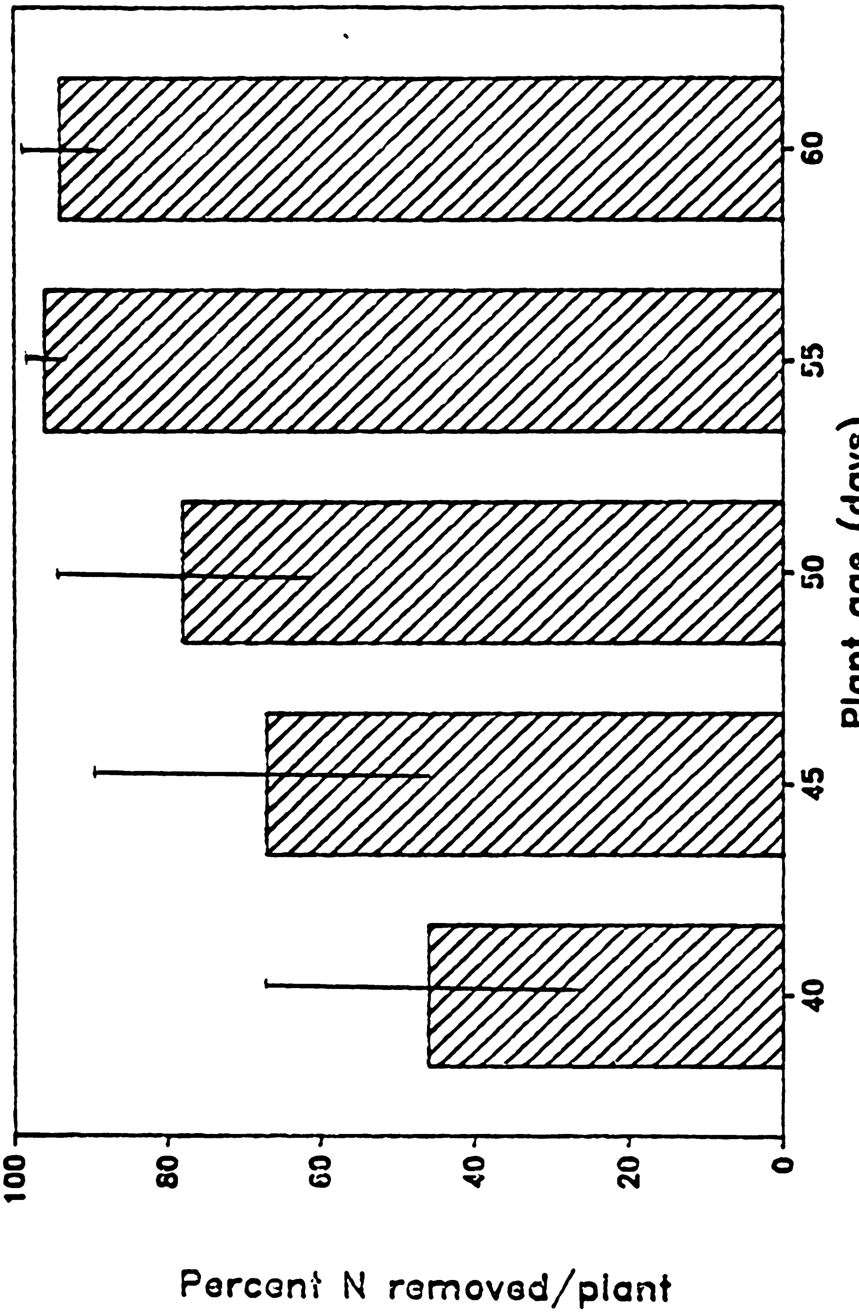

Figure 7. Influence of plant age on percent of availabl N removed from the media solution at 110 ppm N (PT 2). Brackets indicate ± SD.

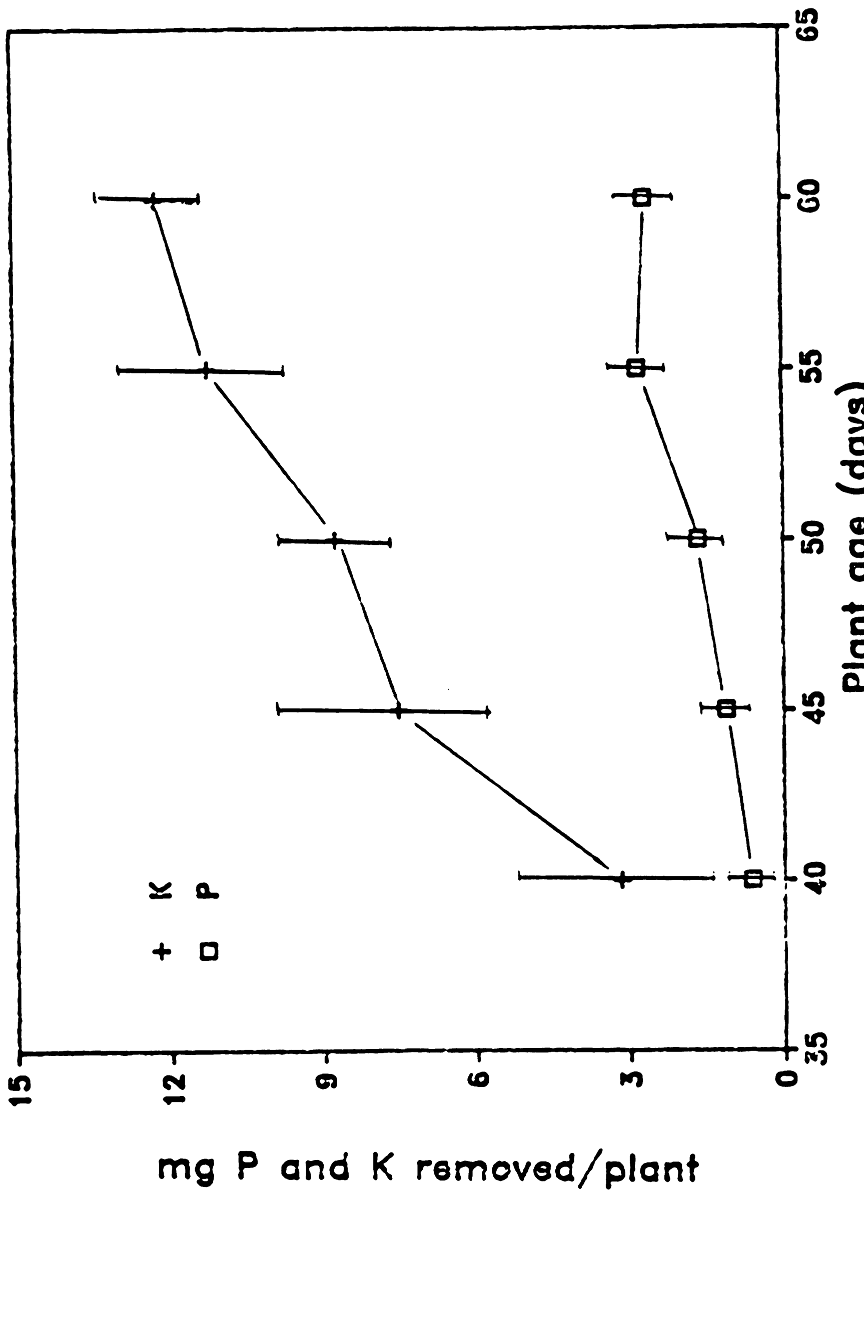

Figure 8. Influence of plant age on amount of P and K removed from the media solution in 6 hr averaged over all N levels (PT 2). Brackets indicate ± SD.

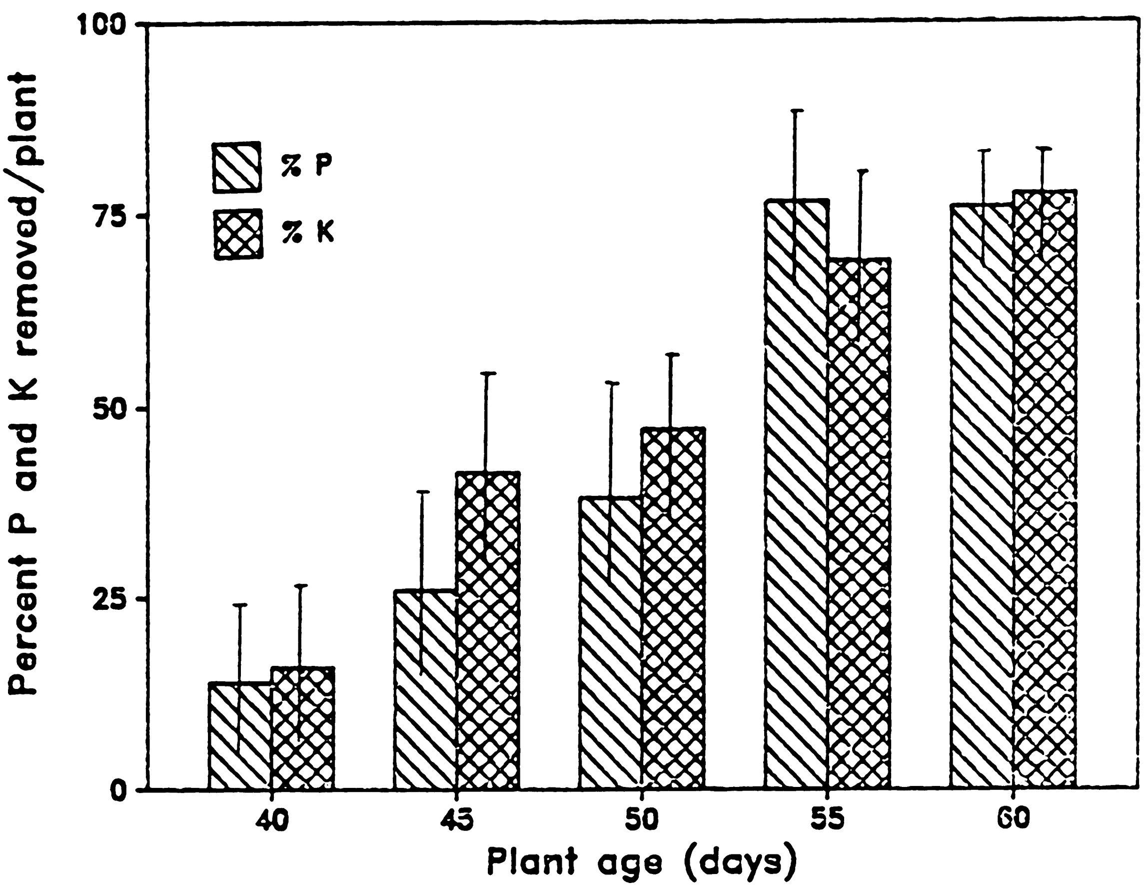

Figure 9. Influence of plant age on percent P and K removed from the media solution at 110 ppm N (PT 2). Brackets indicate ± SD. SD < 0.5 not shown.

Table 1. Influence of plant age on shoot dry weight and total N at PT 1 and PT 2 (10 days later), for 110 ppm N.

Table 1: Influence of plant age on shoot dry weight and total N at PT 1 and PT 2 (10 days later) for 110 ppm N.

Age (days) (PT 1 & 2)	Dry wt (g) (PT 1)	Total N (mg) (PT 1)	Dry wt (g) (PT 2)	Total N (mg) (PT 2)	Total N increase (mg N/day/shoot)
30-40	.3	14.1	3.2	147.2	13.3
35-45	.8	42.4	5.1	219.3	17.7
40-50	1.1	52.8	5.2	223.6	17.1
45-55	4.2	193.2	10.0	450.0	25.7
50-60	7.8	366.6	12.8	550.4	18.4
Significance					
Linear fit	***	***	***	***	***
Quadratic fit	NS	NS	**	*	***

zNs,*,**,***,Nonsignificant,significant at $\alpha = .05$, $\alpha = .01$, $\alpha = .001$.

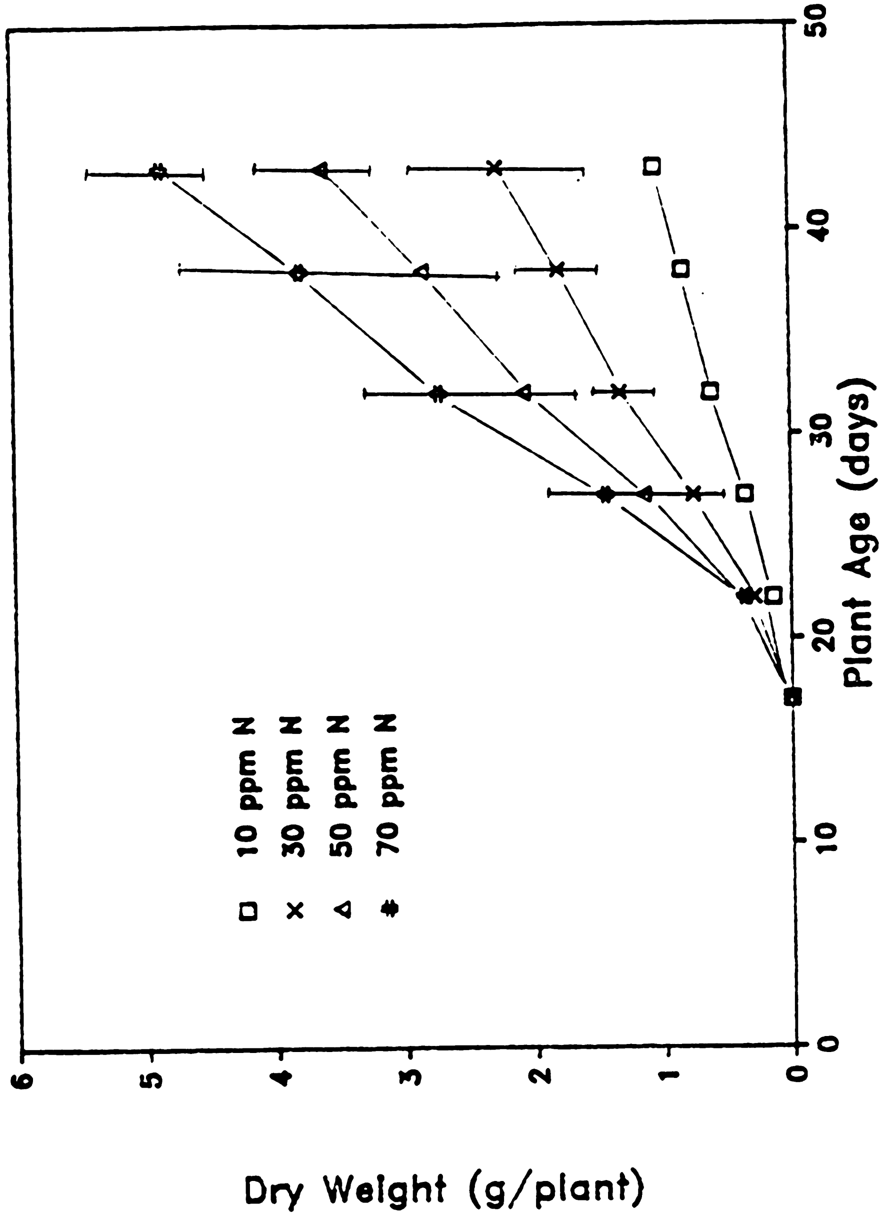

Figure 10. Influence of plant age and N application rate on plant dry weight (Expt. 2). Brackets indicate ± SD. SD < 0.5 not shown.

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