Longwood Program

CONTAINER PLANTS: A COMPARISON OF ORGANIC AND INORGANIC FERTILIZERS

BY

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CONTENTS

LIST OF TABLES AND FIGURES

ABSTRACT

This study was initiated to determine if herbaceous ornamentals would have differences in growth when fertilized with commercially available organic fertilizers and commercially available inorganic fertilizers applied at label rates and at equal nitrogen rates. Four comparisons were made: (1) commercially available organic fertilizer at label rate--nutrient solution at equal analysis and rate, (2) commercially available organic fertilizer at label rate--commercially available inorganic fertilizer at label rate, (3) commercially available organic fertilizer at 285 mg nitrogen per month--commercially available inorganic fertilizer at 285 mg of nitrogen per month, and (4) a comparison of commercially available organic fertilizer applied at label rate to a soil mix and to a soilless mix.

The study was conducted at Longwood Gardens' experimental greenhouses and at the University of Delaware from January to April 1976. The plants studied were <u>Coleus blumei</u> 'Glory of Luxembourg', and geranium, <u>Pelargonium</u> ×

hortorum 'Cherie'. Fertilizers studied were cow manure (2-1-2), fish emulsion (5-1-1), a mixture of organic fertilizers (4-5-2), a dry chemical fertilizer (8-8-8), a liquid chemical fertilizer (15-30-15), and a slow release fertilizer (12-6-6).

Commercially available inorganic fertilizers applied as directed on the label were found to produce plants with more vigorous growth, more attractive appearance and greater dry weights than commercially available organic fertilizers applied as directed. The inorganic fertilizers also produced more growth when the fertilizer label rates were increased to equal nitrogen levels.

The inorganic fertilizers seemed to have analysis ratios that were better suited for promoting abundant plant growth. Increasing the "potted plant" label rate of both organic and inorganic fertilizers resulted in improved growth and greater dry weights.

INTRODUCTION

Plants have been grown in containers for thousands of years. Gothein (1966) explains that Queen Hatshepsut (ca. 1503-1482 B.C.) had special walled pits, which served as planters, set into the terraces of her temple at Dier-el-Bakhari. Reliefs on this temple depict an Egyptian expedition to Punt bringing back large trees placed in round-bottomed containers for the journey.

Queen Hatshepsut's use of containers to grow and transport plants is the earliest recorded example of plants grown in this manner. However, the use of containers to grow plants for home adornment most likely had its beginnings in the Festival of Adonis, which was celebrated by Athenian women (Gothein 1966). For this observance earthen pots were filled with soil and sown with fennel, lettuce, wheat and barley. The pots were then placed on the roof around a figure of Adonis. After germinating and growing for a short time the plants withered and died. This represented the fate of all vegetation and symbolized the early death of the youth Adonis.

"Adonis gardens," as they came to be known, had begun as a part of a short festival practiced by Greek women. Gradually this practice expanded, and it eventually became a custom over a wide geographical area to decorate roofs and balconies with potted plants and flowers throughout the entire year.

Rome and Assyria were referred to as being places where potted plants were set on the roofs of pillared courts for decoration. When Appolonius of Tyana visited the Palatine he found the emperor in the court of Adonis. "This court was adorned with flowers just as the Assyrians plant them on the roofs in honour of Adonis" (Gothein 1966). In Pompeii excavations uncovered remains of balcony gardens. Here also containers were used, "so that tall plants could grow there, flowers, shrubs, vines and even trees" (Gothein 1966).

Containers, whether used for religious observances, household adornment or propagation (Thompson 1963), have had an integral part in the history of man's association with plants. Gardening in containers is becoming increasingly popular today. Garden design and color effects can be varied since plants in containers are very mobile. Containers allow for the addition of plant forms and color to roofs, walls, windowsills and balconies. And probably most important, container gardening minimizes the problems associated with lack of space. Containers, large or small, square or round, indoors or outdoors, allow those who enjoy green foliage and colored blossoms the opportunity to grow plants.

All plants need a continuous supply of nutrients for optimum growth. This is especially important for container grown plants since the volume of the growing medium is limited and the nutrients available are usually less than are required by the final plant.

Plants absorb nearly all of the major nutrients that commonly limit growth from the soil solution. This supply of nutrients is leached out with the regular waterings required by container grown plants. Once the nutrients have been leached from the root zone they are no longer available to the plant and must be reintroduced. This introduction of more nutrients to the growth medium and root zone is called fertilization.

The forms or types of fertilizers which are on the market today fall into two main groups. These are: (1) organic fertilizers, consisting mainly of plant or animal wastes or by-products, and (2) inorganic or mineral fertilizers, consisting of chemicals manufactured by industrial processes from non-organic sources. It has been generally believed that organic fertilizers improve soil structure and are a slowly available source of nutrients. Inorganic fertilizers are thought to have nutrients that are more readily available to plants and to be subject to more rapid loss from the soil. A program utilizing these two types of fertilizers is often recommended. However, differences of opinion regarding these fertilizers have arisen. There are proponents of organic fertilizers and proponents of inorganic fertilizers. At the extremes, proponents of each claim their type to be better or more appropriate than the other type.

Statements from the advocates of organic fertilizers compared to those of the advocates of inorganic fertilizers immediately show the difference of opinion between the two. Robert Rodale, editor of Organic Gardening, writes: ". . . stop using artificial fertilizers and pesticides and use old-fashioned natural methods in their place" (Organic Gardening 1972). He also says, ". . . use the energy of the sun and the fertility of the soil . . . without expecting the aid of powerful chemicals which cause pollution" (Organic Gardening 1971). In response to such statements Robert L. Carolus wrote an editorial in HortScience (1971): "Organic gardeners practice medieval alchemy . . . . They show an alarming anti-intellectualism in repudiating the findings reported by crop physiologists and soil scientists . . . ."

Findings from the experiments that Carolus here refers to almost always show that ". . . yields with mineral fertilizers have been as high or higher than the manure plots when equal amounts of nutrients have been applied to the soil" (Wiggans 1972). Peavy and Greig (1972) found that inorganic, or mineral, fertilizers gave increased leaf tissue yields of spinach when compared to organically fertilized plants that received an equal amount of nutrients. These results were contrary to

Hinkle (1925) who reported that farmyard manure generally gave equivalent or better yields with other crops (Peavy and Greig 1972).

Svec et al. (1975) established small garden plots and grew several vegetables under both organic and inorganic fertilizer regimes. Measurements and statistical comparison of two seasons' growth produced results that led to the conclusion that both methods of fertilization gave crops of nearly equal yield. The inorganic fertilizers produced slightly greater yield.

Experimentation using herbaceous horticultural crops to compare organic and inorganic fertilizers has been limited. Work on this type of crop (Criley and Carlson 1970, Johnson 1973, Kofranek 1969, and Tsurushima and Date 1971) has consisted primarily in establishing standard and critical fertility levels. The levels in these works are commonly referred to by commercial growers for use in their fertilizer application schedules.

On the other hand, information presented to the public concerning fertilizers is in no way limited. The beneficial effects of a variety of organic and inorganic fertilizers are lauded in many popular gardening magazines. Claims of "super", "magic" and "unbelievable" results are often seen in reference to the effect of a particular fertilizer. The result is that the gardening public, aware of the organic-inorganic argument, often purchases fertilizer on the basis of the emotional appeal of the advertisement.

This experiment was undertaken in response to this situation. It is an attempt to determine if there are differences in plant response between several organic and inorganic fertilizers applied as recommended by their manufacturer. The results are interpreted for container plants grown outdoors under conditions of adequate light and moisture.

The six fertilizers chosen for the experiment were selected on the basis of ready availability to the public. All of these fertilizers are popular among gardeners and commercial growers and can be obtained in most garden centers. (See Appendix).

Coleus, Coleus blumei, and geranium, Pelargonium × hortorum, were chosen as the test plants. The reason for the selection of these two particular plants is their rapid growth, easy culture and popularity for use in containers. *Coleus blumei* is referred to by Ball (1972) as being ". . . one of the most useful of all colored foliage plants, especially for combination boxes and pots." He says that *Pelargonium* × *hortorum* ". . . is the sixth most important flower crop in the United States today. In many areas it is the No. 1 pot plant."

METHODS AND MATERIALS

The experiment was designed to make the following comparisons:

1. Organic fertilizer at label rate--nutrient solution at equal analysis and rate
2. Organic fertilizer at label rate--inorganic fertilizer at label rate
3. Organic fertilizer at 285 mg N per month--inorganic fertilizer at 285 mg N per month
4. Organic fertilizer at label rate applied to a soil mix--organic fertilizer at label rate applied to a soilless mix.

In addition there was an optimum fertilization treatment determined from standard industry rates. There were a total of twenty treatments. These are listed in Table 1. Table 2 lists the fertilizers, their analyses and the amount of nutrients applied in each treatment.

TABLE 1

TWENTY TREATMENTS IN THE ORGANIC FERTILIZER--
INORGANIC FERTILIZER EXPERIMENT

Fertilizer	Analysis	Application Rate	Growth Medium
Organic mix	4-5-2	label	soil mix
Nutrient solution	4-5-2	equal to label	soil mix
Organic mix	4-5-2	285 mg N/month	soil mix
Organic mix	4-5-2	label	soilless mix
Cow manure	2-1-2	label	soil mix
Nutrient solution	2-1-2	equal to label	soil mix
Cow manure	2-1-2	285 mg N/month	soil mix
Cow manure	2-1-2	label	soilless mix
Fish emulsion	5-1-1	label	soil mix
Nutrient solution	5-1-1	equal to label	soil mix
Fish emulsion	5-1-1	285 mg N/month	soil mix
Fish emulsion	5-1-1	label	soilless mix
Dry chemical	8-8-8	label	soil mix
Dry chemical	8-8-8	285 mg N/month	soil mix
Liquid chemical	15-30-15	label	soil mix
Liquid chemical	15-30-15	285 mg N/month	soil mix
Slow release	12-6-6	label	soil mix
Slow release	12-6-6	285 mg N/month	soil mix
Optimum	20-20-20	285 mg N/month	soil mix
Control	. . .	. . .	soil mix

TABLE 2

NITROGEN, PHOSPHOROUS AND POTASSIUM APPLIED PER PLANT AT TWO RATES

Label Rate				
Fertilizer	Analysis	Nutrients Applied (mg)		
		N	P	K
Organic mix	4-5-2	60.80	33.44	25.23[a]
Cow manure	2-1-2	60.80	13.38	50.46[b]
Fish emulsion	5-1-1	37.65	3.31	6.25[c]
Dry chemical	8-8-8	90.18	39.68	74.85
Liquid chemical	15-30-15	42.75	37.92	35.48
Slow release	12-6-6	303.99	66.88	126.16

285 mg N per month				
Fertilizer	Analysis	Nutrients Applied (mg)		
		N	P	K
Organic mix	4-5-2	285.00	156.75	118.27
Cow manure	2-1-2	285.00	62.70	236.55
Fish emulsion	5-1-1	285.00	25.08	47.31
Dry chemical	8-8-8	285.00	125.40	236.55
Liquid chemical	15-30-15	285.00	250.78	236.53
Slow release	12-6-6	285.00	62.79	118.27
Optimum	20-20-20	285.00	125.40	236.55

Fertilizers and Application

Three organic and three inorganic fertilizers were used in this experiment. Cow manure (2-1-2), a mix of organic fertilizers (4-5-2), and fish emulsion (5-1-1) were the organic fertilizers. A liquid chemical (15-30-15), a dry chemical (8-8-8), and a slow release (12-6-6) were the inorganic fertilizers.

Nutrient solutions were made from reagent grade calcium nitrate, calcium phosphate and potassium chloride. Each of the nutrient solutions was made up to equal the analysis of one of the organic fertilizers. A standard industry rate (Ball 1972, White 1971) of a liquid chemical fertilizer (20-20-20) was applied at the rate of 2½ pounds per 100 gallons every 2 weeks. This fertilization rate (285 mg N per plant per month) was used as a standard for the optimum response.

The organic and inorganic fertilizers were applied at two rates: (1) the label rate for "house" or potted plants, and (2) a rate at which nitrogen in the fertilizer was applied at 285 mg N per plant per month. This second rate is similar in nitrogen application to the industry rate used for the optimum fertilization treatment.

The amount of each nutrient solution applied was determined by using the label analysis of N-P-K at the recommended rate for each of the organic fertilizers. The total applied was divided into weekly allotments to approximate the expected availability of the organic fertilizers that they equalled in nutrient application.

The organic fertilizers at the label rate were also applied to a potting mix which contained no soil. These treatments were to determine if any differences in growth occured as a result of interaction between soil microorganisms and the organic fertilizers.

Plants

Coleus

Two hundred coleus, *Coleus blumei* 'Glory of Luxembourg', cuttings were taken on 13 December 1975 and rooted under mist in vermiculite and charcoal at Longwood Gardens in the experimental greenhouses. On 17 January 1976 one hundred plants, selected for uniformity, were potted into five-inch plastic pots. Eighty-five plants were potted into an aerated steam-sterilized soil mix, a standard practice for controlling soil pathogens. This soil mix consisted of a Manor Silt Loam, peat and perlite in a 1:1:1 ratio. Fifteen plants were potted in a soilless mix consisting of sand, peat and perlite in a 2:2:1 ratio. Fertilizer treatments were begun at the time of potting.

There were twenty treatments including the unfertilized control. Each was replicated five times. The pots were set out in a randomized complete block design. Watering was done through plastic tubing turned on manually when necessary. Each replicate received 250 ml of water per watering. The treatment having cow manure applied at the rate of 285 mg of N per month retained water in the pots and did not drain properly. Consequently this treatment was not watered as often as the rest.

The treatments were fertilized according to the specified rates until 10 April 1976 when the top growth was harvested. The plants were individually dried, weighed and ground in a Wiley mill using a 40 mesh screen. The nitrogen content was determined from a colormetric response to Nessler's reagent (Vaneslow 1940) after digesting the tissue in sulfuric acid and oxidizing the organic matter with hydrogen peroxide. Phosphorus and potassium content were determined from procedures given by Steckel and Flannery (1971).

Geranium

One hundred and twenty geraniums, *Pelargonium* × *hortorum* 'Cherie', in one inch pots, were purchased from a commercial grower. They were selected for uniformity at the time they were purchased.

On 9 March 1976 these plants were transplanted into five-inch plastic pots. The commercial grower's soil was lightly shaken from the roots before repotting. Eighty-five were transplanted into an aerated steam-sterilized soil mix consisting of a Manor Silt Loam, peat and perlite in a 1:1:1 ratio. Fifteen plants were potted into a soilless potting mix consisting of sand, peat and perlite in a 2:2:1 ratio. After repotting, all plants were treated with a fungicide to control soil pathogens (see Appendix). The remaining twenty plants were not used in the experiment.

The fertilizer treatments were applied on 16 March 1976. The fertilizer treatments were the same as the coleus treatments. There were twenty treatments including an unfertilized control. Each was replicated five times. The pots were set out in a randomized complete block design. Watering was done through plastic tubing turned on manually when necessary. The treatment of cow manure with the fertilizer applied at a rate of 285 mg N tended to retain water in the pots. These replicates were not watered as often as the rest.

During the last weeks of growth the plants with the best growth required more water. Therefore water was not applied equally to all plants. Equal amounts would have caused wilting in some treatments and overwatering in others. Watering was kept equal until growth differences became marked.

The inflorescences from each geranium were removed as they began to open. The timing of removal allowed for inflorescence development and ensured that the nutrients would be used primarily for vegetative growth. The number of florets in each inflorescence was recorded. Statistical relationships between the treatments were not determined for the floret count. A comparison between this count and the nutrient uptake and the dry weight of each treatment was drawn.

Top growth of the plants was harvested on 18 May 1976. This was dried, weighed and then ground in a Wiley mill using a 40 mesh screen. After digestion with sulfuric acid and oxidation of organic matter with hydrogen peroxide, nitrogen content was measured colormetrically using Nessler's reagent (Vaneslow 1940). Phosphorus and potassium content was determined according to the procedures of Steckel and Flannery (1971).

Analysis of the Data

The results of this experiment were evaluated using Duncan's multiple range test. The data used for this statistical test were the dry weights of the top growth of each plant. Stepwise linear regressions were used to determine the functional relationships of nitrogen, phosphorus and potassium. This statistical procedure was necessary to find these relationships since the experiment was designed to measure differences in fertilizer programs, not the influence of individual nutrients.

RESULTS

Coleus

Organic Fertilizer at Label Rate--
Nutrient Solution at Equal Analysis and Rate

The dry weights of each coleus treatment are shown in Figure 1. Duncan's multiple range test of the coleus treatments (Table 3) indicated that there was no significant difference between dry weights of the organic fertilizer treatments and the treatments which received nutrient solutions at similar analyses. The organic mix (4-5-2) and nutrient solution (4-5-2) treatments were similar to each other in dry weight and also similar to the cow manure (2-1-2) and nutrient solution (2-1-2) treatments. The dry weights of the 4-5-2 and 2-1-2 analysis treatments were greater than those of treatments receiving fish emulsion (5-1-1) and the nutrient solution (5-1-1).

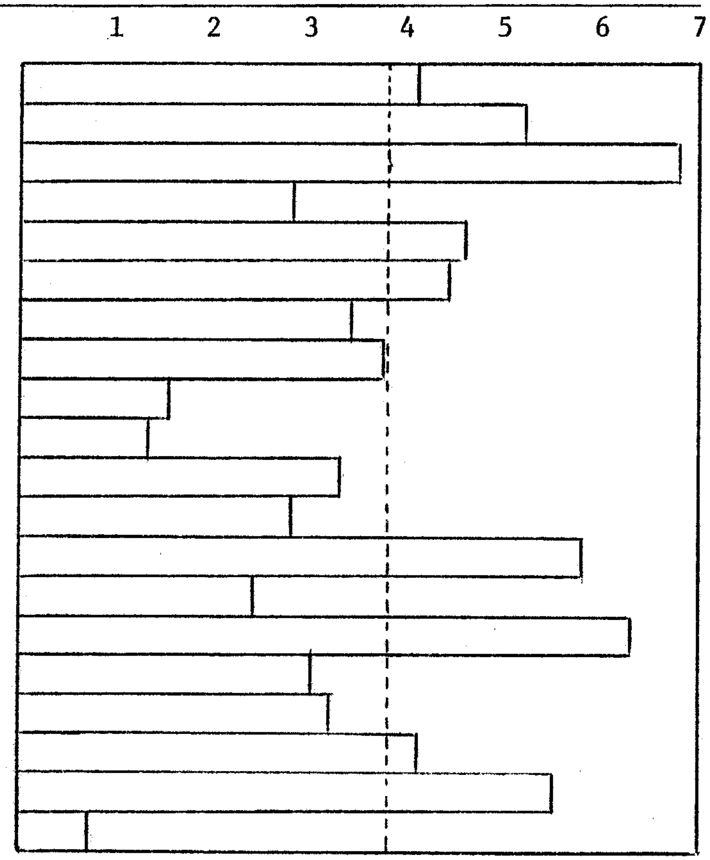
Organic Fertilizer at Label Rate--
Inorganic Fertilizer at Label Rate

The treatments receiving dry chemical and liquid

FIGURE 1

DRY WEIGHTS OF EACH Coleus blumei
'Glory of Luxembourg'
FERTILIZER TREATMENT

Treatment | Dry Weight (g/plant)



Organic mix--label rate (4-5-2)
Nutrient solution (4-5-2)
Organic mix--285 mg N/month (4-5-2)
Organic mix--soilless mix (4-5-2)
Cow manure--label rate (2-1-2)
Nutrient solution (2-1-2)
Cow manure--285 mg N/month (2-1-2)
Cow manure--soilless mix (2-1-2)
Fish emulsion--label rate (5-1-1)
Nutrient solution (5-1-1)
Fish emulsion--285 mg N/month (5-1-1)
Fish emulsion--soilless mix (5-1-1)
Dry chemical--label rate (8-8-8)
Dry chemical--285 mg N/month (8-8-8)
Liquid chemical--label rate (15-30-15)
Liquid chemical--285 mg N/month (15-30-15)
Slow release--label rate (12-6-6)
Slow release--285 mg N/month (12-6-6)
Optimum--285 mg N/month (20-20-20)
Control--unfertilized

Dotted line indicates mean of all treatments.

TABLE 3

DRY WEIGHT MEANS OF EACH *Coleus blumei* 'Glory of Luxembourg' TREATMENT

Fertilizer Treatment	Dry Weight (g/plant)
Organic mix--285 mg N/mo (4-5-2)	6.83
Liquid chemical--label rate (15-30-15)	6.29
Dry chemical--label rate (8-8-8)	5.77
Optimum--285 mg N/month (20-20-20)	5.52
Nutrient solution (4-5-2)	5.22
Cow manure--label rate (2-1-2)	4.55
Nutrient solution (2-1-2)	4.42
Slow release--285 mg N/mo (12-6-6)	4.13
Organic mix--label rate (4-5-2)	4.04
Cow manure--soilless mix (2-1-2)	3.76
Fish emulsion--285 mg N/mo (5-1-5)	3.28
Slow release--label rate (12-6-6)	3.18
Cow manure--285 mg N/month (2-1-2)	3.04
Liquid chemical--285 mg N/mo (15-30-15)	2.99
Organic mix--soilless mix (4-5-2)	2.83
Fish emulsion--soilless mix (5-1-1)	2.79
Dry chemical--285 mg N/mo (8-8-8)	2.40
Fish emulsion--label rate (5-1-1)	1.57
Nutrient solution (5-1-1)	1.34
Control--unfertilized	0.74

Treatments not connected by a common line differ at the 5% level by Duncan's multiple range test.

chemical inorganic fertilizers at the label rate had greater dry weights than the treatments receiving organic fertilizers applied at the label rate. There were exceptions to this general rule. The treatment receiving cow manure at the label rate had a dry weight that was greater than the treatment receiving slow release fertilizer applied at the label rate. The slow release fertilizer treatment had a dry weight similar to the treatment receiving the organic mix and a greater dry weight than the treatment receiving fish emulsion at the label rate.

Organic Fertilizer at 285 mg Nitrogen Per Month--Inorganic Fertilizer at 285 mg Nitrogen Per Month

The organic mix treatment in which the fertilizer rate was increased so that 285 mg of nitrogen were applied per month had a dry weight that was greater than all other treatments. The treatments which received fish emulsion (285 mg N/mo) and the slow release fertilizer (285 mg N/mo) had dry weights that were similar to each other and greater than the dry weights of the treatments which received cow manure (285 mg N/mo), liquid chemical (285 mg N/mo) and dry chemical (285 mg N/mo) fertilizers. The latter three treatments had dry weights that were similar.

The dry chemical and liquid chemical inorganic fertilizers applied at the rate of 285 mg of nitrogen per month resulted in a high mortality rate among the replicates. Four plants in the treatment fertilized with the dry chemical died and two of the plants in the liquid chemical treatment died. The treatments receiving organic fertilizers applied at a similar rate of 285 mg of nitrogen per month had no deaths.

Organic Fertilizer at Label Rate Applied to a Soil Mix--Organic Fertilizer at Label Rate Applied to a Soilless Mix

The treatments that had the organic mix and cow manure applied to a soil mix had dry weights that were similar to the dry weights of treatments that had the organic mix and cow manure applied to a soilless mix. The treatment with fish emulsion applied to a soilless mix had a greater dry weight than the treatment that had fish emulsion applied to a soil mix.

Optimum Treatment (Standard Rate)

The optimum treatment which received 285 mg of nitrogen (20-20-20) per month had a dry weight that was similar to the treatments which received liquid chemical and dry chemical fertilizers at the label rate. This standard, commercial grower rate did not produce results better than those of inorganic fertilizers applied at the "homeowner" rate given on the label of each fertilizer.

Fish Emulsion (5-1-1)

No significant difference was indicated in the dry weights of the treatment receiving fish emulsion (5-1-1), the treatment receiving a nutrient solution applied at the 5-1-1 analysis, and the unfertilized control. These three treatments produced the lowest dry weights of all treatments.

Regression Analysis

Stepwise linear regression results were determined from relationships between the dry weight yield and nitrogen, phosphorus and potassium concentration and uptake of each treatment (Table 4). These results (Table 5) indicated that an increase in potassium uptake was the factor having the most influence on the increase in dry weight of the treatments receiving organic fertilizers. It was indicated among the inorganically fertilized

TABLE 4

NUTRIENT CONCENTRATION AND UPTAKE OF *Coleus blumei* 'Glory of Luxembourg' GROWN UNDER TWENTY FERTILIZER TREATMENTS

Treatment	Nutrient Concentration as a % of Dry Weight/Plant			Nutrient Uptake (mg/plant)		
	N	P	K	N	P	K
Organic mix--label rate (4-5-2)	1.71	0.18	3.26	70.09	7.48	132.32
Nutrient solution (4-5-2)	2.86	0.38	2.53	146.59	19.78	143.86
Organic mix--285 mg N/mo (4-5-2)	3.43	0.37	4.53	232.36	24.70	305.92
Organic mix--soilless mix (4-5-2)	1.66	0.49	2.50	46.44	13.60	70.65
Cow manure--label rate (2-1-2)	2.52	0.28	2.78	92.62	12.81	126.40
Nutrient solution (2-1-2)	2.80	0.31	2.95	123.73	13.63	130.36
Cow manure--285 mg N/mo (2-1-2)	4.75	0.61	4.42	142.58	18.61	134.52
Cow manure--soilless mix (2-1-2)	2.66	0.60	2.77	98.23	21.98	103.48
Fish emulsion--label rate (5-1-1)	3.30	0.12	2.52	51.97	1.86	39.98
Nutrient solution (5-1-1)	2.92	0.12	2.22	39.18	1.55	29.68
Fish emulsion--285 mg N/mo (5-1-1)	4.16	0.34	3.28	134.12	11.04	104.42
Fish emulsion--soilless mix (5-1-1)	2.16	0.21	1.40	59.89	5.71	38.85
Dry chemical--label rate (8-8-8)	2.50	0.31	3.71	144.16	17.73	213.87
Dry chemical--285 mg N/mo (8-8-8)	4.60	0.47	5.56	110.40	11.28	133.44
Liquid chem.--label rate (15-30-15)	2.39	0.35	2.92	155.14	22.36	184.96
Liquid chem.--285 mg N/mo (15-30-15)	4.81	0.77	3.92	114.25	19.00	116.99
Slow release--label rate (12-6-6)	4.97	0.32	3.68	158.89	10.24	121.93
Slow release--285 mg N/mo (12-6-6)	4.51	0.54	3.36	184.70	22.56	138.74
Optimum--285 mg N/month (20-20-20)	4.17	0.78	4.14	230.08	43.08	228.40
Control--unfertilized	1.58	0.09	2.53	11.03	0.67	19.05

TABLE 5

PARTIAL CORRELATION COEFFICIENTS OF *Coleus blumei* 'Glory of Luxembourg' FROM STEPWISE LINEAR REGRESSION

Independent Variable[a]	Dependent Variable[b]	Partial Correlation Coefficient
Total Ferilizer Treatments[c]		
Nitrogen concentration	yield	-0.15
Nitrogen uptake	yield	0.14
Phosphorous concentration	yield	0.21
Phosphorous uptake	yield	-0.12
Potassium concentration	yield	-0.63
Potassium uptake	yield	0.76
Organic Fertilizer Treatments Only[d]		
Nitrogen concentration	yield	-0.46
Nitrogen uptake	yield	0.04
Phosphorous concentration	yield	0.58
Phosphorous uptake	yield	-0.34
Potassium concentration	yield	-0.77
Potassium uptake	yield	0.82
Inorganic Fertilizer Treatments Only[e]		
Nitrogen concentration	yield	-0.70
Nitrogen uptake	yield	0.63
Phosphorous concentration	yield	0.43
Phosphorous uptake	yield	-0.41
Potassium concentration	yield	-0.40
Potassium uptake	yield	0.45

[a] All other independent variables held constant.
[b] The yield is dry weight per plant.
[c] Significance of correlation coefficients at 5% is .2111.
[d] Significance of correlation coefficients at 5% is .3125.
[e] Significance of correlation coefficients at 5% is .3976.

treatments that the dry weight was most influenced by nitrogen concentration. However, nitrogen uptake was indicated as having practically equal influence on the increase in dry weight.

Geranium

Organic Fertilizer at Label Rate--Nutrient Solution at Equal Analysis and Rate

The dry weights of each geranium treatment are shown in Figure 2. Duncan's multiple range test of the geranium treatments (Table 6) indicated that there was no significant difference between the dry weights of the treatment receiving cow manure (2-1-2) and the treatment receiving a nutrient solution (2-1-2). The dry weights of the treatment receiving fish emulsion (5-1-1) and the treatment receiving a nutrient solution (5-1-1) were also similar. Statistical analysis did indicate that the treatment receiving a nutrient solution (4-5-2) had a greater yield than the treatment receiving the organic mix (4-5-2).

Organic Fertilizer at Label Rate--Inorganic Fertilizer at Label Rate

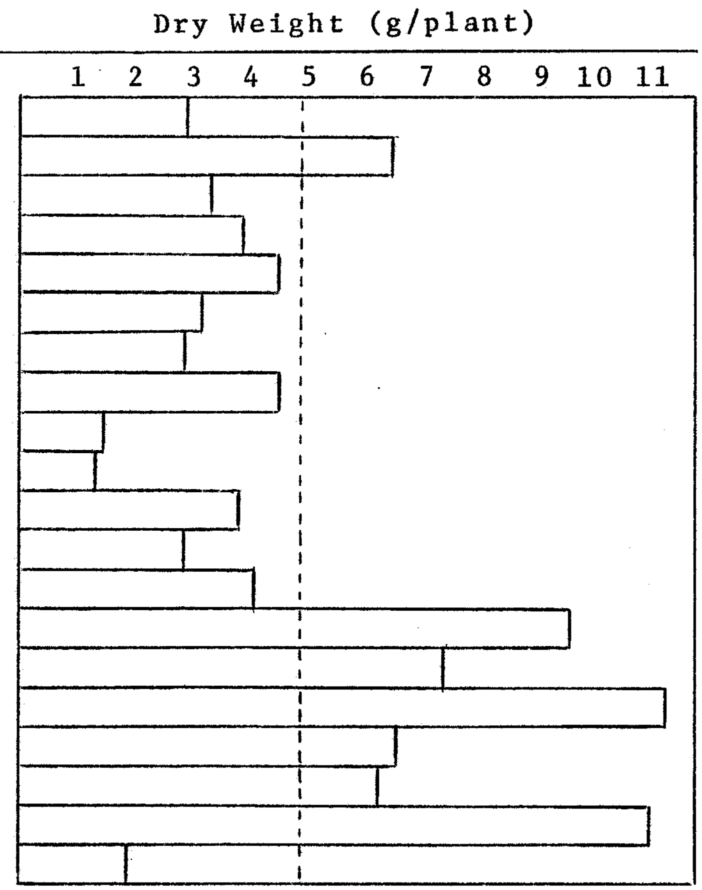
The dry weights of treatments receiving liquid chemical and slow release inorganic fertilizers applied

FIGURE 2

DRY WEIGHTS OF EACH GERANIUM
Pelargonium × hortorum
'Cherie' FERTILIZER
TREATMENT

Treatment

Organic mix--label rate (4-5-2)
Nutrient solution (4-5-2)
Organic mix--285 mg N/month (4-5-2)
Organic mix--soilless mix (4-5-2)
Cow manure--label rate (2-1-2)
Nutrient solution (2-1-2)
Cow manure--285 mg N/month (2-1-2)
Cow manure--soilless mix (2-1-2)
Fish emulsion--label rate (5-1-1)
Nutrient solution (5-1-1)
Fish emulsion--285 mg N/month (5-1-1)
Fish emulsion--soilless mix (5-1-1)
Dry chemical--label rate (8-8-8)
Dry chemical--285 mg N/month (8-8-8)
Liquid chemical--label rate (15-30-15)
Liquid chemical--285 mg N/month (15-30-15)
Slow release--label rate (12-6-6)
Slow release--285 mg N/month (12-6-6)
Optimum--285 mg N/month (20-20-20)
Control--unfertilized



Dotted line indicates mean of all treatments.

TABLE 6

DRY WEIGHT MEANS OF EACH GERANIUM
Pelargonium × *hortorum*
'Cherie' TREATMENT

Fertilizer Treatment	Dry Weight (g/plant)
Liquid chemical--285 mg N/month (15-30-15)	11.18
Optimum--285 mg N/month (20-20-20)	10.82
Dry chemical--285 mg N/month (8-8-8)	9.46
Liquid chemical--label rate (15-30-15)	7.27
Slow release--label rate (8-8-8)	6.62
Nutrient solution (4-5-2)	6.41
Slow release--285 mg N/month (12-6-6)	6.23
Cow manure--soilless mix (2-1-2)	4.50
Cow manure--label rate (2-1-2)	4.46
Dry chemical--label rate (8-8-8)	4.06
Organic mix--soilless mix (4-5-2)	3.88
Fish emulsion--285 mg N/month (5-1-1)	3.83
Organic mix--285 mg N/month (4-5-2)	3.23
Nutrient solution (2-1-2)	3.19
Organic mix--label rate (4-5-2)	2.86
Fish emulsion--soilless mix (5-1-1)	2.83
Cow manure--285 mg N/month (2-1-2)	2.80
Control--unfertilized	1.80
Fish emulsion--label rate (5-1-1)	1.44
Nutrient solution (5-1-1)	1.38

Treatments not connected by a common line differ at the 5% level according to Duncan's multiple range test.

at the label rate were greater than the dry weights of the treatments receiving organic fertilizers applied at the label rate. The treatment receiving dry chemical inorganic fertilizer had a dry weight that was similar to the dry weight of the treatments receiving cow manure and the organic mix at the label rate.

Organic Fertilizer at 285 mg Nitrogen Per Month--Inorganic Fertilizer at 285 mg Nitrogen Per Month

The treatments that had the label rates of liquid chemical and dry chemical inorganic fertilizer increased so that 285 mg of nitrogen were applied per month had dry weights that were greater than all other treatments, except the optimum treatment. The treatment which received slow release inorganic fertilizer (285 mg N/mo) had a greater dry weight than the treatments which received fish emulsion (285 mg N/mo), cow manure (285 mg N/mo), and the organic mix (285 mg N/mo). The latter three fertilizer treatments had dry weights which were similar.

Organic Fertilizer at Label Rate Applied to a Soil Mix--Organic Fertilizer at Label Rate Applied to a Soilless Mix

The three organic fertilizer treatments in soil mixes had dry weights that were similar to corresponding fertilizer treatments in soilless mixes. However, the treatment which received fish emulsion applied to the soilless mix, although statistically similar, actually had a dry weight that was twice that of the treatment which received fish emulsion in a soil mix.

Optimum Treatment (Standard Rate)

The optimum treatment which received 285 mg of nitrogen per month (20-20-20) resulted in a dry weight that was similar to the dry weights of the liquid chemical and dry chemical inorganic fertilizer treatments which received 285 mg of nitrogen per month. These three treatments had dry weights that were greater than the dry weights of all other treatments.

Fish Emulsion (5-1-1)

There was no significant difference indicated between the dry weight of the treatment receiving fish emulsion (5-1-1), the treatment receiving a nutrient solution (5-1-1), and the unfertilized control. These three treatments had lower dry weights than all other treatments.

Floret Count

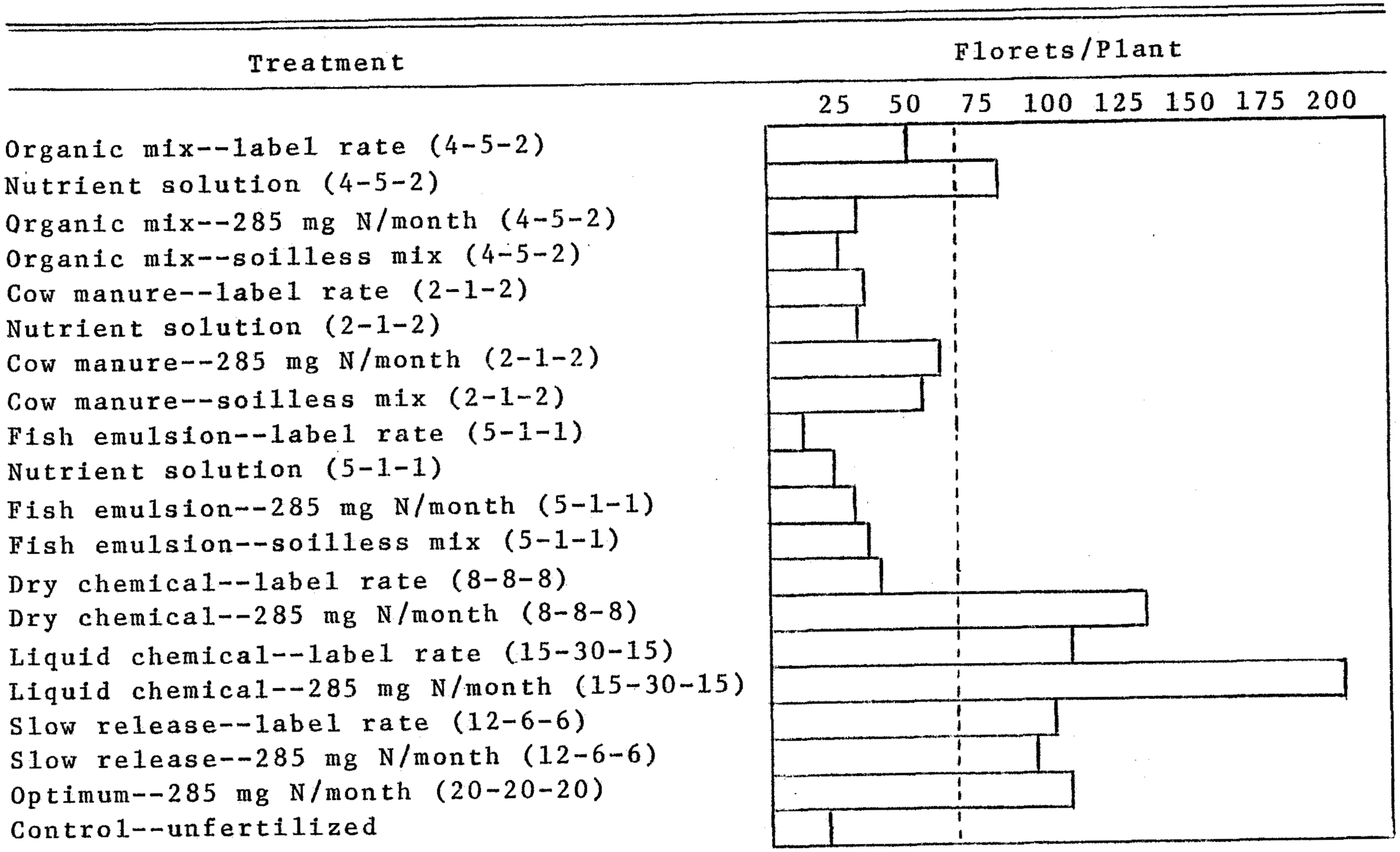
The inorganic liquid chemical and dry chemical fertilizer treatments at the 285 mg of nitrogen per month rate had the highest floret counts (Figure 3). The optimum treatment, both slow release treatments and the liquid chemical treatment at the label rate also had high floret counts. With the exception of the nutrient solution (4-5-2), all other treatments had considerably lower floret counts.

Regression Analysis

Stepwise linear regression results were determined from relationships between the dry weight yield and nitrogen, phosphorus and potassium concentration and uptake (Table 7). These results (Table 8) indicated that increasing nitrogen uptake was the most influential factor in increasing the dry weights of the plants. This was the case in all the treatments.

FIGURE 3

FLORET COUNT OF EACH GERANIUM
Pelargonium × _hortorum_
'Cherie' FERTILIZER
TREATMENT



Dotted line indicates mean of all treatments.

TABLE 7

NUTRIENT CONCENTRATION AND UPTAKE OF GERANIUM
Pelargonium × *hortorum* 'Cherie' GROWN
UNDER TWENTY FERTILIZER
TREATMENTS

Treatment	Nutrient Concentration as a % of Dry Weight/Plant			Nutrient Uptake (mg/plant)		
	N	P	K	N	P	K
Organic mix--label rate (4-5-2)	1.60	0.07	1.42	44.05	1.90	41.44
Nutrient solution (4-5-2)	1.42	0.10	0.91	90.67	6.41	57.98
Organic mix--285 mg N/mo (4-5-2)	2.13	0.12	2.33	70.07	4.00	78.88
Organic mix--soilless mix (4-5-2)	1.01	0.16	0.84	39.01	6.02	31.86
Cow manure--label rate (2-1-2)	1.67	0.11	1.65	73.60	5.14	75.26
Nutrient solution (2-1-2)	1.73	0.07	1.00	55.66	2.18	32.65
Cow manure--285 mg N/mo (2-1-2)	2.12	0.11	2.45	59.98	3.12	68.19
Cow manure--soilless mix (2-1-2)	1.19	0.19	0.99	53.11	8.51	45.33
Fish emulsion--label rate (5-1-1)	1.53	0.07	1.09	21.55	0.94	17.48
Nutrient solution (5-1-1)	1.62	0.09	0.92	21.42	1.20	12.61
Fish emulsion--285 mg N/mo (5-1-1)	1.89	0.12	1.19	72.77	4.83	49.54
Fish emulsion--soilless mix (5-1-1)	0.94	0.10	0.40	26.89	2.89	11.43
Dry chemical--label rate (8-8-8)	1.76	0.13	1.49	63.86	5.55	69.31
Dry chemical--285 mg N/mo (8-8-8)	2.18	0.23	2.33	206.91	22.00	220.28
Liquid chem.--label rate (15-30-15)	1.11	0.11	1.06	80.99	8.30	76.82
Liquid chem.--285 mg N/mo (15-30-15)	2.91	0.53	2.04	325.48	60.26	227.49
Slow release--label rate (12-6-6)	2.54	0.24	2.16	164.92	15.51	139.94
Slow release--285 mg N/mo (12-6-6)	2.22	0.19	1.99	135.65	11.92	122.34
Optimum--285 mg N/mo (20-20-20)	2.12	0.34	2.27	219.33	36.78	237.88
Control--unfertilized	1.12	0.08	1.04	18.59	1.37	19.27

TABLE 8

PARTIAL CORRELATION COEFFICIENTS OF GERANIUM *Pelargonium* × *hortorum* 'Cherie' FROM STEPWISE LINEAR REGRESSION

Independent Variable[a]	Dependent Variable[b]	Partial Correlation Coefficient
Total Fertilizer Treatments[c]		
Nitrogen concentration	yield	-0.63
Nitrogen uptake	yield	0.61
Phosphorous concentration	yield	-0.04
Phosphorous uptake	yield	-0.19
Potassium concentration	yield	-0.22
Potassium uptake	yield	0.48
Organic Fertilizer Treatments Only[d]		
Nitrogen concentration	yield	-0.77
Nitrogen uptake	yield	0.84
Phosphorous concentration	yield	0.21
Phosphorous uptake	yield	-0.14
Potassium concentration	yield	0.01
Potassium uptake	yield	0.06
Inorganic Fertilizer Treatments Only[e]		
Nitrogen concentration	yield	-0.72
Nitrogen uptake	yield	0.73
Phosphorous concentration	yield	0.19
Phosphorous uptake	yield	-0.24
Potassium concentration	yield	-0.39
Potassium uptake	yield	0.59

[a]All other independent variables held constant.
[b]The yield is dry weight per plant.
[c]Significance of correlation coefficients at 5% is .2048.
[d]Significance of correlation coefficients at 5% is .3125.
[e]Significance of correlation coefficients at 5% is .3783.

DISCUSSION

Organic Fertilizer at Label Rate--Nutrient Solution at Equal Analysis and Rate

Cooke (1972) has stated that plants take up nutrients from the soil solution as inorganic ions. The processes by which this occurs have been extensively discussed by Sutcliffe (1962). The treatments of organic fertilizers applied at label rate and the nutrient solutions of equal analyses and rate were compared to determine if differences in the source of the nutrients would cause differences in plant growth. With one exception, the results of the coleus and geranium treatments showed that the dry weight yields of treatments receiving organic fertilizers were statistically similar to the dry weight yields of the treatments receiving nutrient solutions of equal nutrient content. These results indicate that the origin of ions, whether organic or inorganic, is not the determining factor in plant growth.

It was observed in both *Coleus blumei* 'Glory of Luxembourg' and *Pelargonium* × *hortorum* 'Cherie' that the treatments which received a nutrient solution (4-5-2) equal to the amount of nutrients applied to the treatments receiving the organic mix (4-5-2) had greater dry weight yields. However, only in the case of geraniums was the yield statistically different. These results are not consistent with the results of the treatments receiving cow manure and fish emulsion when compared with treatments receiving nutrient solution applications equal to those organic fertilizers. The reason for this difference is unclear and requires further testing for adequate discussion.

Organic Fertilizer at Label Rate--Inorganic Fertilizer at Label Rate

The overall results showed that both coleus and geranium treatments receiving commercially available inorganic fertilizers applied as recommended produced statistically higher yields than the treatments receiving commercially available organic fertilizers applied as recommended.

These results seem to indicate that the nutrients of the inorganic fertilizers (8-8-8, 15-30-15, 12-6-6) are in a more desirable ratio than are the nutrients of the organic fertilizers (4-5-2, 2-1-2, 5-1-1). There were comparisons supporting this which showed the treatment yields of organic fertilizers and comparable nutrient solutions to be statistically similar. The similarity of treatment yields of organic fertilizers and treatment yields of comparable nutrient solutions tend to preclude the attribution of differences between organic fertilizer and inorganic fertilizer treatments to either ion source or rate of availability.

It is important to realize that inorganic fertilizers are manufactured for the express purpose of promoting plant growth. The analysis ratio and often availability of individual nutrients is derived from information based on plant growth studies. This is not necessarily the case with organic fertilizers. Organic fertilizers may or may not have a nutrient balance that is favorable for optimum plant growth.

It is commonly accepted that nutrients in organic fertilizers become only slowly available. Allison (1973) states that the slow availability of nitrogen from high grade organic fertilizers is largely a myth. He states that the nitrogen in organic fertilizers often becomes quite readily available. This apparent ready availability of nitrogen in certain organic fertilizers and the yield similarities of the organic fertilizer and nutrient solution treatments tend to indicate that yield differences between the organic and inorganic fertilizers may be accounted for by inadequacies in the N-P-K analysis ratios of the organic fertilizers.

Organic Fertilizer at 285 mg Nitrogen Per Month--Inorganic Fertilizer at 285 mg Nitrogen Per Month

The Ball Red Book (1972) and White (1971) recommend a rate of 285 mg of nitrogen per plant per month for the commercial production of bedding plants which include coleus and geranium. Each of the six fertilizers being tested was applied so that 285 mg of nitrogen per month would be applied to the treatments. In these treatments phosphorus and potassium varied in direct proportion to label analysis with the change in nitrogen.

This increased fertilizer (decreased in the case of slow release) was applied to the coleus at the time the rooted cuttings were potted. The mortality rate, 60 per cent within 21 days, in the treatments receiving the liquid chemical and dry chemical inorganic fertilizers was attributed to the high salt concentration and resultant root burn.

The deaths which occurred in the inorganic liquid chemical and dry chemical (285 mg N/month) treatments were significant since no deaths occurred in the treatments of organic fertilizers at a similar rate. Although nitrogen may be released quite readily from some organic fertilizers (Allison 1973), the nutrients seem to be released at a rate which is not rapid enough to cause root damage. The deaths in the inorganically fertilized treatments illustrate the need for care in the timing and application of these fertilizers.

The occurrence of differences between the organic and inorganic fertilizers because of burn was not anticipated in the experimental design. The study was intended to measure yield of the various fertilizer programs.

Therefore, the geraniums were allowed to become established before the fertilizers were applied. The deaths which occurred in the coleus were of definite interest but it was not desired to have them repeated in the geranium study.

The results from the geranium treatments were quite different from those of the coleus. The geranium treatments receiving the higher amounts of liquid chemical and dry chemical fertilizer had much higher dry weights than the other treatments. The floret count was also much higher. These results reflect the vigorous growth desired by commercial flower growers who must produce marketable plants that are attractive and healthy.

The poor response of the treatments receiving the organic fertilizers at the increased rate cannot be accounted for fully.

The treatments receiving cow manure at the increased rate had a tendancy to become waterlogged. The large amount of fertilizer needed to obtain the 285 mg of nitrogen per month rate was utilized for experimental purposes but under ordinary conditions would be highly impractical.

The slow release fertilizer rate was actually reduced from that of the label rate in order that 285 mg of nitrogen per month be applied. Of the fertilizers tested, the slow release was the only one that had nutrients applied by label directions at a rate somewhat similar to commercial recommendations. Despite this fact the treatments that received the slow release fertilizer did not produce the expected higher dry weight yields. This is probably because the nutrients were not released at a rate rapid enough for optimum plant use.

Organic Fertilizer at Label Rate Applied to a Soil Mix--Organic Fertilizer at Label Rate Applied to a Soilless Mix

The statistical similarities between the treatments grown in a soil mix and the soilless mix indicate that either growing medium can be used with similar growth results. The hypothesis that microbial activity either restricted or increased the availability of the nutrients is not supported by this study.

It is not known why the treatments in the soilless mix receiving fish emulsion, in both coleus and geranium, had greater actual yields than the treatments in soil mix. It may derive from the fact that phosphorus, which forms insoluble compounds in soil (Furuta 1974), remains soluble and available to the plants in the soilless mix.

Optimum Treatment (Standard Rate)

This treatment was essentially a check using a 20-20-20 fertilizer applied at the commercially recommended rate. At this rate, 285 mg of nitrogen were applied per month to serve as a standard treatment to which the other treatments could be compared.

It is unknown why this treatment did not experience as severe a response to root burn in the coleus treatment as those receiving liquid chemical and dry chemical inorganic fertilizers at a similar application rate. Some damage does appear to have occurred since this treatment, while not significantly different at the 5% level, has a dry weight yield that is less than the treatments receiving liquid chemical and dry chemical inorganic fertilizers at the label rate.

In the geranium experiment this optimum treatment is statistically similar to the treatments that received liquid chemical and dry chemical inorganic fertilizers applied at the similar 285 mg of nitrogen per month rate. This indicates that the higher rate of nutrients which were applied did promote better plant growth.

Fish Emulsion (5-1-1)

Both the coleus and geraniums that received nutrient solution (5-1-1) and fish emulsion at the label rate had very low dry weights. This may be due to improper nutrient balance. The importance of proper nutrient balance has been emphasized by Cook (1950) in studies with flowering crops.

The concentration and uptake of phosphorus by the plants in the 5-1-1 label rate applications of both fish emulsion and the nutrient solution are very low. Cook (1950), in his experiments with flowering crops, found that when phosphorus was omitted from fertilizer applications response to nitrogen was greatly lessened. Fish emulsion, even with a five per cent nitrogen content, may have inadequate phosphorus for proper growth. The low phosphorus content of this fertilizer may be further compounded by the conversion of phosphorus to insoluble forms in the soil (Furuta 1971).

Another factor which may have had an influence on the low dry weights of the fish emulsion and nutrient solution (5-1-1) treatments was the rate at which they were applied. The label gave two rates: (1) a rate for house plants, and (2) a rate for outdoor plants. The house plant rate was used since "house plant" is often equated with "potted plant". This may have been an incorrect procedure with the consequence of biased results.

The label rate that was applied was one-fourth that of the suggested "outdoor" rate. The "outdoor" rate was in turn approximately one-half the 285 mg of nitrogen per month rate that was applied. Both the coleus and geranium treatments that received 285 mg of nitrogen per month of fish emulsion did have dry weights which were significantly greater than the dry weights of the label rate fish emulsion treatments. It is not known if the "outdoor" label rate which was not applied would also have produced higher dry weights.

Floret Count

The floret count of the geranium treatments receiving inorganic fertilizers was directly related to the amount of fertilizer applied. The higher fertilization rates resulted in increased floret counts. This was generally true of the organic treatments also but the increase in floret count was not as pronounced as in the inorganic treatments. The low floret count of the organic treatments parallels the generally low dry weight yield of those treatments. This illustrates that plants lacking vigor and healthy vegetative growth do not flower well.

However, the number of florets appears to be dependent upon more than just strong vegetative growth. Comparing the floret count with the amount of nutrients applied indicates that nutrient balance is also important. The nutrient analysis ratio of the inorganic liquid chemical seemed the most beneficial for floret production. The N-P-K analysis ratio of the liquid chemical was 1:2:1. The optimum response treatment, with an N-P-K analysis ratio of 1:1:1, produced a statistically similar dry weight yield but only half as many florets as the liquid chemical treatment (285 mg N/month). This was true despite the fact that the nitrogen levels were equal. Even with nitrogen levels varying greatly, the optimum treatment and the label rate liquid chemical treatment had floret counts that were quite similar.

Regression Analysis

The partial correlation coefficients statistically measure the correlation between the dry weight yields and the independent variables--concentration and uptake of nitrogen, phosphorus and potassium. This coefficient gives indication as to which independent variable has the most influence on the variation in dry weight. The higher the absolute value of a partial correlation coefficient associated with a particular independent variable the greater the contribution of that variable to the variation in dry weight.

These data indicate that the uptake of nitrogen has influenced dry weight yield in most instances. The reason for potassium uptake being indicated as the most influential variable in the case of two coleus regression analyses is unknown. This information may indicate an artifact and not a true representation of nutrient relationships. To determine if these particular independent variables are actually the most influential factors further testing is necessary.

Label Recommendations

Fertilization rates recommended on the label must convey to the user a specific amount of fertilizer for a particular plant in a particular situation. Manufacturers accomplish this by grouping plants into two general categories. These are either outdoor, garden plants or indoor, house plants. An amount of fertilizer is then recommended for each of these groupings.

Manufacturers base the groupings and label rates on presupposed levels of growth, light intensities and watering rates. Little allowance is made for instances in which rapid, "garden" type growth is desired from a potted plant.

A potted geranium grown in a living room most likely has light as the major limiting factor of growth. That same plant, adequately watered, in a sunny location on a patio would probably have its growth limited by the amount of nutrients it absorbs. Therefore, the indoor, house plant group should have two rates of fertilization listed. (1) A rate which would maintain plant growth and allow for gradual maturation. This rate would be mainly for plants grown in low light situations. (2) A rate promoting rapid and abundant plant growth. This rate would be for plants grown in full sun much of the day. Present label rates do not adequately encompass these two situations.

The cow manure and organic mix labels gave a rate for pot plants and window boxes which was helpful. The fish emulsion label listed application rates for many plants and was the most informative label. However, rates which take into account different types of growth within the outdoor, garden and indoor, house plant groupings are not available. It is generally unclear from the labels of the fertilizers studied how much fertilizer should be applied to a potted coleus or geranium grown in a sunny location on a patio.

CONCLUSIONS

Commercially available inorganic fertilizers applied at the recommended label rate produce plants with greater dry weight and in the case of florists' geraniums, a larger floret count than do commercially available organic fertilizers applied at their recommended rate. This is also the case when the nitrogen in the label rate of the inorganic and organic fertilizers is increased to an equal amount. This conclusion is limited to plants receiving adequate sunlight and moisture. It would apply to rapidly growing plants in window boxes, hanging baskets and patio containers. It is not meant to include indoor house plants.

A balanced nutrient ratio in fertilizers is important for good plant growth. The organic fertilizers tested appear to have less than optimum analysis ratios. In addition, the type of growth produced, whether vegetative or reproductive, may be dependent upon that ratio.

Fertilizers with equal amounts of nitrogen, phosphorus and potassium, whether of organic or inorganic origin, produce plants with similar dry weight yields.

Fertilizer manufacturers should consider a fertilizer application rate on the label that would be specifically for rapidly growing plants in outdoor containers such as window boxes, hanging baskets and patio planters. This rate would take into account increased light and moisture often received by these container plants. This rate would be based on the fact that more abundant growth is usually expected from outdoor container plants.

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APPENDIX

COMMERCIAL PRODUCTS USED AND RATE OF APPLICATION

Fertilizer	Analysis	Application Rate g/5" pot/mo
Hoffman Super Manure	4-5-2	1.52
Hoffman Cow Manure	2-1-2	3.04
Atlas Fish Emulsion	5-1-1	0.75
Ortho General Purpose Plant Food	8-8-8	1.13
Miracle Grow	15-30-15	0.29
Precise	12-6-6	2.53

Fungicide	Application Rate (Soil Drench)
Benlate	4 oz/100 gal
Dexon	8 oz/100 gal