Artificial Root Media

and Fertilizations for

Container-Grown Chrysanthemums

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NEW HAVEN

SUMMARY

The effects of various fertilizations and root media on the development and flowering of chrysanthemums grown in containers in the greenhouse are reported in this publication.

Adding relatively high amounts of magnesium ammonium phosphate (MagAmp)®, 10 pounds per cubic yard, as a preplant, once-a-crop, slow-release fertilization caused initial leaf injury and reduced growth. In the peat-sand-vermiculite media, likely to be free of microorganisms, the conversion of the ammonium released from the MagAmp fertilizer into nitrates was slow initially, thus causing concentrations of ammonium detrimental to the growth of the chrysanthemums.

Leaf injury was reduced and the growth and flowering were improved by replacing the medium granules of MagAmp by coarse granules of MagAmp, while the addition of ammonium nitrate further improved the effectiveness of the MagAmp, coarse granule.

Best results were obtained by an ample preplanting addition of ammonium nitrate, supplemented later in the growing period by liquid feeding based on soil testing. The water-soluble ammonium nitrate supplied a reliable and satisfactory level of nitrate nitrogen at and directly after planting, while the ammonium nitrogen did not exceed medium levels, which decreased rapidly as the growing period progressed.

During the growing period the following visual observations were made on structure and drainage of the media. The only soil-based mixture slaked and rapidly lost its surface structure and this compacted surface layer, when wet, may have reduced the aeration of the mix throughout the plastic pot. Such slaking was not observed in the soilless peat-sand-vermiculite mixes. The peat-sand-sludge mix, however, showed the best infiltration of irrigation water and its granulated surface remained highly open-structured throughout the growing season.

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The production of plants in containers holding artificial soil-based mixtures is an expanding industry. Many growing mixtures have been tried and are now in widespread use by greenhouse and nursery operators. These plant producers sell the soil with their plants and therefore require a continuing supply of soil to stay in business.

The unavailability of good topsoil, variations in soils, and the incidence of soil-borne pests, which makes soil pasteurization a necessity, presented the problem of getting sufficient quantities of good soilless growing mixtures. Most of these mixtures use sphagnum peat moss or muck (native or bog peat, often called humus by growers), in combination with either sand and/or perlite, and some vermiculite. These mixes are amended with the required amounts of lime, gypsum, and superphosphate, and fertilized with a standard fertilizer mix. Since these artificial root media are composed of a mixture of well-defined ingredients they can be made with a minimum of variation. Furthermore, they normally are free of pests and offer a number of other advantages over soil (2).

At the Valley Laboratory in Windsor a greenhouse experiment gave information on artificial media and methods and levels of fertilization for growing chrysanthemums in pots.

Materials and Methods. Commercially produced rooted cuttings of *Chrysanthemum morifolium* cv. "Hunter Moon" were planted in different mixes contained in the standard 1-gallon plastic containers on 1 September, 1971.

Nine plants, one in each pot, were used per treatment and the 6 treatments were replicated 4 times in a randomized block experiment. Two to three weeks after planting the rooted cuttings, the terminal buds were pinched out to induce branching.

The mixes used, their amendments and fertilizations are shown in Table 1.

Mixture SoPG or mix 6 is typical for commercial production and was used as the control for this experiment. The soil used in this experiment was a Merrimac fine sandy loam, a soil type common in the Connecticut Valley. This soil was taken from tobacco land, relatively free of weeds and pests, and was therefore not pasteurized for use in mix 6; soil pasteurization is otherwise a standard practice. The pre- and post-planting fertilization of this mix, guided by soil tests[1], is comparable to those used under practical conditions.

The other artificial root media are mainly made up of such commonly used ingredients as peat moss and sand. Mixes 1 to 4 inclusive are enriched with a small volume (10%) of vermiculite and mix 5 contains 20% municipal digested sewage sludge.

The vermiculite contributes some slowly available potash (approximately 2.5% K_2O) and magnesium (20 to 24% MgO); furthermore, it increases the base or cation exchange capacity[2] of the root medium and absorbs relatively large amounts of moisture.

The sludge was derived from material accumulated over the past 35 years by the Metropolitan District at its sewage treatment plant in Hartford, and about 2 years ago trucked to and piled in various fields of a local nursery. The sludge was dug from such a pile, shredded, and used within a few days. Freshly dug, the unweathered sewage sludge tested extremely high (EH) in ammonium, raising the pH to about 8. After shredding and exposing the sludge to the air, its ammonium content and pH dropped, while its nitrate nitrogen levels increased from 0 or very low (VL) to very high (VH). The pH dropped to around 5 (4.9-5.2). The phosphorus contents averaged around medium high (MH), while the potassium was normally VL.

The use of the sludge was based on principles developed by Lunt (5, 6). Sludge can have severe adverse effects on plants and must be employed with caution. "Usually such toxicity, which is due to copper or zinc, or both, and probably to iron deficiency induced by these metals, can be avoided by liming the soil to pH 6.0 or higher." Furthermore, Lunt's experiments demonstrated that "digested sewage sludge as produced in Connecticut treatment plants improves the physical condition of the soil and has a more lasting effect than does manure."

The fertilization treatments of the various media were set up to answer the following questions. First, we wanted to test the use of magnesium ammonium phosphate (MagAmp, 7-40-6) as a long-lasting, non-burning fertilizer source of nitrogen (N), phosphorus (P) and potassium (K) for the production of container-grown chrysanthemums. Under commercial conditions 10 to 12 lbs. of medium granules (m) of MagAmp applied to a cubic yard (cu. yd.) of soil mix had often given poor results, probably due to root burn. As indicated in Table 1, mix 1 tested the rate of 10 lbs. of MagAmp (m) per cu. yd., as applied to a PSV medium. As a possible corrective measure for burn, in mix 2 medium MagAmp (m) was exchanged for coarse granules (c) of MagAmp. We did not lower the rate of 10 lbs. of MagAmp (m) per cu. yd. of mix,

[1] Morgan's Soil test (4) L–low; M–medium; H–high; V–very; E–extremely.

[2] The ability of a soil to hold and exchange cations, chiefly calcium, potassium, and magnesium.

TABLE 1.

	Treatment–Mix	*No.*	*1*	*2*	*3*	*4*	*5*	*6*
		Code	PSV	PSV	PSV	PSV	PSSe	SoPG
Materials								
% by volume	Peat Moss	P	45	45	45	45	40	25
	Sand	S	45	45	45	45	40	
	Vermiculite	V	10	10	10	10		
	Sewage Sludge	Se					20	
	Soil	So						50
	Perlite	G						25
Fertilizers		Formula						
lbs./cu. yd.	MagAmp[1]	7-40-6	10m	10c	10c			
	Amm. nitrate	33-0-0			.5	.5		
	Superphosphate	0-20-0				2.5	.25	.25
	Potassium sulf.[2]	0-0-50				.44	.25	.25
	Limestone, dol.		10	10	10	10	10	6
ozs./cu. yd.	F.T.E. 519[3]		2	2	2	2	2	2
	Versinol[4]		6	6	6	6		6
	Liquid feed		No	No	No	Yes	Yes	Yes

[1] Magnesium ammonium phosphate (MagAmp)
m = medium granule, c = coarse granule

[2] In treatment 4 applied in solution 10 days after potting

[3] Fritted potash (29% K_2O) and trace elements

[4] 5% iron chelate on vermiculite

(The use of these chemicals does not imply approval of these products to the exclusion of others that may be suitable.)

because this amount is already considerably less than the 15 to 20 lbs. suggested by the manufacturer of MagAmp as a one-time application for the production of chrysanthemums. In mix 3 the application of 10 lbs. of MagAmp (c) per cu. yd. of PSV mix was supplemented with 0.5 lb. of readily soluble and available ammonium nitrate. This addition of ammonium nitrate was intended as a starter to counteract the possibility that the release of N from the coarse MagAmp would be too slow for the fast growing chrysanthemums, particularly in freshly made growing mixtures.

The MagAmp fertilizations of mixes 1, 2, and 3 were planned as "once-a-crop fertilizations," i.e., as single pre-planting applications of fertilizer that would provide all the nutrients needed by the plants for their full development. On the other hand, plants grown in mixes 4, 5, and 6 were topdressed with liquid fertilizer, which will be discussed below.

The pre-plant or base-fertilization of the growing media 4, 5, and 6 was partially based on soil test results. Mix 4 received N in the form of 0.5 lb. ammonium nitrate per cu. yd. of mix, while mixes 5 and 6 showed sufficient N levels at planting time to warrant no preplant application. The N in mix 5 was supplied by the sewage sludge, which usually contains 1 to 3% N (5). Mix 6, 50 percent of which consisted of well managed Merrimac sandy loam rich in residual N, also showed a satisfactory level of N at planting time. All three treatments received P in the form of 20% superphosphate; mix 4 showing the need for a full application of 2.5 lb. per cu. yd. Potassium was applied in the form of potassium sulfate; mixes 5 and 6 received 0.25 lb. per cu. yd. at mixing time a few days before planting. Mix 4 was topdressed with a solution of potassium sulfate (.44 lb. per cu. yd.) when after 10 days (day 10) a soil test indicated the K level to be VL or deficient; apparently the supply of K by the vermiculite in the mix did not suffice.

Finally, Table 1 shows that mix 1 to 5 inclusive were amended with 10 lbs. of dolomitic limestone. A soil test indicated that mix 6 needed about 6 lbs. of lime to reach the optium pH range for the development of chrysanthemums. Nearly all treatments received a preplant application of 2 ozs./cu. yd. of fritted potash with trace elements (F.T.E. 519) and 6 ozs./cu. yd. of chelated iron on vermiculite. The only exception, mix 5, did not get any chelated iron, because this medium, holding sewage sludge, contained plenty of iron; in the treatment plant the digested sludge had been subjected to an application of ferric chloride and tested MH in iron.

The postplant fertilizations or topdressings with fertilizer of mix 4, 5, and 6 were applied as solutions. The need for and amount of liquid feeding was based on soil tests, which were made of all mixes at regular intervals of mostly 10 to 15 days. A soil auger was used to sample the media from the top to the bottom of the pot. A general feeding took place 3 weeks after planting day (day 21) and 4 weeks later (day 51). Both feedings were applied as Hoagland's solution (3); this complete nutrient solution has a N-P_2O_5-K_2O ratio of 3-1-4 and was added at a relatively low rate of 10 to 15 lbs. of N and K_2O per acre.

Liquid feedings later in the season consisted of solutions of fertilizer materials supplying a single nutrient. About 9 weeks after planting the soil tests showed that mix 5 and 6 needed additional K and N, respectively. Thus, on day 64 all plants growing in mix 5 received potassium sulfate at the rate of 200 lbs. of K_2O per acre and those in mix 6 received ammonium nitrate at the rate of 66 lbs. of N per acre.

The effect of the various media and fertilizations on the chrysanthemums was evaluated on the basis of average appearance and size, i.e., quantity and quality of foliage, and number and size of flowers per plant. The evaluations were made during the growth period until most plants were mature. Foliage quality or in fact leaf damage, apparently caused mainly by ammonium toxicity, was rated on day 8; rating of growth and general appearance of the plants was done on day 35 and 72. The latter ratings were based on an arbitrary scale of 1 to 6; lower numbers were assigned to plant loss and stunting, severe leaf damage or fair growth with none or few flowers; high numbers were given to well developed plants showing good colored, undamaged foliage, with emphasis on the number and size of the flowers. At about midseason, on day 42, average width and height of each plant was measured, while the final evaluation took place on day 94, 3 December 1971. On day 94 the flowers, including the well developed buds, were counted, harvested, and immediately weighed, followed by cutting off the shoots at the soil line so as to determine their fresh weights.

Results and Discussion: About one week after planting leaf damage became apparent on most plants. Some of the injuries were similar to the symptoms caused by salt injury in most plant species, i.e., marginal leaf burn and leaf scorch. These symptoms were observed particularly in mix 1, and sparsely among the plants of mix 3 and 6. The main injury, however, was a yellowish-grey spotting of the leaves, probably caused by ammonium toxicity (8). On day 8 the treatments were rated by counting the number of plants affected by the blemishes just described. The percentage of plants damaged in mix 1 to 6 inclusive was as follows:

TABLE 2. *Mixture No.*	*1*	*2*	*3*	*4*	*5*	*6*
Percent of plants showing leaf injury on day 8	92	85	66	64	0	91

A soil test on day 10 did not indicate that excess salts were a factor, but in most treatments where the damage was serious, ammonium was present in substantial amounts. Figure 1 clearly shows that in the mixes with MagAmp, mix 1, 2, and 3, the ammonium contents were H to EH. In mix 1 and 2 ammonium was the sole or predominant source of N, while mix 3 showed a H nitrate-N content derived from the ammonium nitrate supplement. Subsequent soil tests showed that MagAmp (m) of mix 1 released its ammonium at a rate faster than that of MagAmp (c) in mix 2 and 3. The smaller the granule size, the greater is the effective surface of the MagAmp granules. In mix 1 EH ammonium levels were reached from day 35 through 49, while in mix 2 and 3 the VH to H ammonium levels dropped continuously after day 35. The leaf damage followed the same pattern. The plants of mix 1 showed the worst leaf damage; an injury which they never outgrew and which reduced the final vegetative growth and flowering (Table 3). The plants of mix 2 and 3 initially showed less injury (Table 2), which they eventually overcame, particularly in mix 3, as shown in Table 3. The initial presence of nitrate-N of the ammonium nitrate fertilizer in mix 3 seemed to be beneficial; it lowered the average percentage of injured plants observed on day 8 from 85 in mix 2 to 66 in mix 3.

The ammonium of the ammonium nitrate supplied in mix 4 never reached high or toxic levels in our soil tests and was converted into nitrate-N in about 6 weeks; and yet, about 64 percent of the plants showed injury (Table 2). The very high number of plants damaged in mix 6 is difficult to explain on the basis of these soil tests. However, the following observations, indicating a lack of aeration just around the roots of the transplanted cuttings could offer an explanation. On day 13

TABLE 3.

Effect of the media and fertilizations on growth and flowering of chrysanthemum plants.

Treatment–Mix	*No.*	*1*	*2*	*3*	*4*	*5*	*6*	*LSD (0.05)*
Growth evaluation								
Day 35–Rating		2.1	2.6	3.1	3.5	4.4	3.0	1.2
Day 42–Plant height–	cm	6.6	7.6	9.2	9.6	9.5	8.0	ns
Plant width–	cm	10.5	11.6	13.0	12.7	12.2	11.1	1.7
Day 73–Rating		2.6	3.0	3.4	4.4	4.5	3.2	0.9
Day 94–Flowers	no.	2.7	4.0	5.3	5.5	4.3	2.5	ns
Flowers weight	g	3.3	5.0	6.6	7.5	5.9	4.2	ns
Shoot weight	g	17.4	20.7	27.2	28.2	25.1	21.5	ns

LSD (0.05) = least significant difference at the 5% level.
ns = non-significant at 5%.

a few of the seriously damaged and stunted plants were carefully removed from their pots. We noticed that in each case the roots were still confined to the little ball of peat with which the cuttings were pulled from the beds and packed for delivery. Since the cuttings were transplanted with as much peat as would hang onto the roots, it is clear that in many instances this rootball stayed intact, fully surrounding the root after transplanting into the experimental mixes. Since this peat or muck clinging to the roots was very fine textured, it may have resulted in poor aeration in this original rootball, particularly after undergoing some compaction in the transplanting operation. This poor aeration hampered nitrification, and a buildup of ammonium in the fine textured peat surrounding the roots may have been the result. This, in turn, brought about the leaf injury comparable to the one observed in the treatments with high ammonium levels throughout the whole container.

The plants of mix 5 were the only ones that did not show any leaf injury. Medium 5, containing 20% sewage sludge, did not receive any N in its base-fertilization, since soil tests of this particular sludge had shown it to be rich in ammonium-N. The soil tests on day 10 showed satisfactory levels of nitrate-N and no ammonium-N and this situation lasted throughout the growing period (Figure 1). Nitrification apparently benefited from the structural condition of mix 5, as created by the addition of the sludge. Sludge is known to improve the physical properties of soil (5, 6), which in this container experiment mix 5 showed an excellent penetrability for irrigation water, indicating an open structure needed for good aeration.

Although the plants in mix 5 did not show any of the leaf injuries mentioned above, they were not without imperfections. In the early stages of development, the upper leaves and growing tip looked yellowish instead of showing a normal light green and the growth appeared

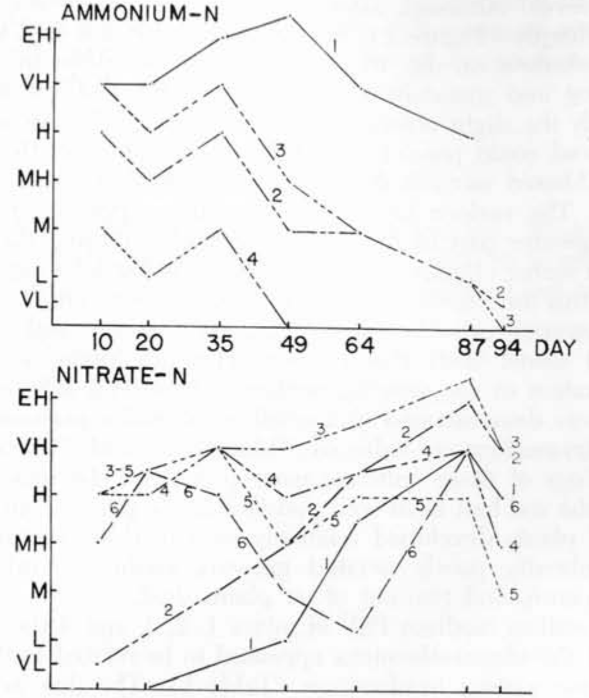

Figure 1. Changes in ammonium and nitrate nitrogen levels with time (days after planting) in the various growing mixtures.

to be slightly retarded, although the tops were dense. Since the liming of mix 5 did not raise its pH above 5.2 until day 21, it was very likely that the high levels of zinc and copper of the sludge induced an incipient iron deficiency (5), causing the yellowing of the growing tips. However, the plants never exhibited interveinal chlorosis, an intermediate degree of iron deficiency (7), and actually outgrew the discoloring, although the pH of the medium never raised above 5.6 during the growing period.

The slight retardation in early development demonstrates itself in the pinching out of the terminal bud. On day 13 we counted that 39, 31, 40, 42, and 28 percent of the plants growing in the mixes 1, 2, 3, 4, and 6 respectively, had already been pinched, while only 19 percent of those growing in mix 5 had sufficiently developed to be topped. On day 35, however, according to our subjective rating shown in Table 3, this apparent growth retardation of the plants in mix 5 was no longer evident. Although on day 42 the plant width and height measurements favored slightly mixes 4 and 3 respectively, on day 73 the plants in mix 5 were again ranked first. At maturity, on day 94, the plants in mix 4 showed best growth and flower production, followed by those in mix 3, but none of the observed differences were statistically significant at the 5 percent probability level. Although after day 87 the nitrate-N content of mix 5 dropped sharply (Figure 1), it is not likely that this had an effect on the final evaluation on day 94. Adding more limestone in the original mix, to bring and maintain its pH between 6.5 and 7.0, should very likely remedy the slight chlorosis observed in the early part of the growing period and could possibly correct this apparent growth retardation.

The soil-based mix, no. 6, produced the smallest number of flowers on day 94. The surface layer of this medium appeared to be slaked during the greater part of the growing period, retarding the infiltration of irrigation water. Under such conditions it is logical to speculate that aeration of this mix in the plastic pots was less than satisfactory, reducing the vegetative growth and flowering of the chrysanthemums. Furthermore, it seems likely that cultivar "Hunter's Moon" is sensitive to reduced aeration in the growing medium. A varietal difference in such sensitivity was demonstrated in a small additional experiment with two different chrysanthemum cultivars, "Showtime" and "Martian." Well-rooted cuttings of these cultivars were potted in Merrimac fine sandy loam after the soil had been well puddled in the plastic containers. The "Showtime" plants developed relatively well in this structureless, compact, undoubtedly poorly aerated growing medium, while "Martian" plants did poorly and two out of six plants died.

In the soilless medium PSV of mixes 1, 2, 3, and 4 the growth and flowering of the chrysanthemums appeared to be related to the type and amount of the various fertilizations (Table 1). The slow release, once-a-crop fertilization of 10 lbs. of MagAmp per cu. yd. reduced the growth and blooms, particularly when supplied in the form of medium sized granules of mix 1. Mixes 2 and 3 using the coarse granulated MagAmp (c) with less effective surface area exposed to the growing medium, caused less excessive or toxic amounts of ammonium in the PSV medium than did mix 1. As shown in Figure 1, the initial H to VH levels of ammonium in mix 2 and 3 lasted for about 5 weeks and then decreased continuously. The preplanting addition of nitrate-N in the form of ammonium nitrate, seemed to improve the performance of MagAmp (c), as mix 3 gave consistently better results in chrysanthemum production than did mix 2. Mix 4, however, appeared to form the best mix among the PSV media. The fertilization of mix 4 did not include any MagAmp and ammonium nitrate formed the sole nitrogen source at planting time, supplying an initial M level of ammonium-N and a H to VH concentration of nitrates. According to our visual inspection on day 73, which evaluated quality as well as quantity of foliage and bloom, mix 4 produced much better growth and flowering than the MagAmp mixes 1, 2, and 3. The exact measurements and countings on day 94 also showed mix 4 to be more productive than all other treatments, but unfortunately these differences were not statistically significant and did not reflect the superiority of mix 4 that was obvious by our subjective scoring.

In conclusion, the fertilization aspects of these experimental results indicate that a high or once-a-crop application of MagAmp should be used with caution in artificial root media. Such media likely lack sufficient nitrifying bacteria for a satisfactory conversion of ammonium into nitrates. As a result high concentrations of ammonium are formed, causing injury on the chrysanthemum plants.

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