Organic Growing Media

Research Into Use of Compost for Potting Mix Nutrition

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Abstract: A variety of commercial soil-less growing media were examined for nutrient content and growth effects, and compared to some model organic blends. Peats are shown to be desireable growing substrates provided they are limed. Tests of commercial blends indicate variable and sometimes very high nutrient content, in particular soluble nitrogen. High levels of nitrate in mixes correlated significantly with plant nitrate. Growing media containing more than 200 mg/l NO_3-N lead to excessive plant nitrate levels with effects discernable up to 60 days after planting. Organic mixes containing compost and seaweed as nutrient sources give average growth with lettuce, wheat, broccoli and radish and superior growth with tomatoes.

1. Introduction

Modern advances in seedling management have made the use soilless growing media increasingly practical. These media consist principally of peats blended with inert natural or artificial bulkers, to which are added varying amounts of inorganic nutrients and non-ionic surfactants.

The reasons for abandoning traditional soil-based growing media in favor of loamless types were lack of uniformity and uneconomic weight, phytotoxic effects arising from sterilization [1] and proneness to water-logging with subsequent increased disease susceptibility (e.g. Pythium, Fusarium root rot)[2]. However, many growers still prefer the old mixes for their simplicity of preparation and the fact that they contain intrinsic nutrients which are generally adequate for growth.

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Peat, a natural resource in plentiful supply in some regions of the world [3] [4], provides an excellent matrix but contains little available minerals[5] Thus, seedling nutrition must derive from added nutrients. For this reason, growing media have been almost exclusively based on inorganic chemical salts designed for plant nutrition[6] [7].

Commercial organic produce growers feel the need to use non-organic growing media to get the rapid early-season growth of vegetables crucial for successful market positioning.

For organic production, however, there may be trade-offs in using the commercial blends. Firstly, synthesized non-ionic surfactants have unknown toxicological properties and have been shown to disrupt normal cellular membrane activity and suppress rootlet development [8] [9]. Secondly, the nutrients added to growing media may be the same ones not permitted elsewhere in the organic production system

Thirdly, comparative studies of conventional growing media have indicated widely varying nutrient contents from low to very-high [10] [11] so that growers may not necessarily gain the control they expect. Finally, the possibility exists that high nutrient levels early in the season may prompt elevated nitrates in plant tissue [12].

In field culture, significantly increased early growth rates can be accomplished with soluble nutrients from either organic or inorganic sources, though at some cost to nitrate levels found in crops and residual levels in soil[13]. There is increasing concern about excessive nitrates in green leafy vegetables, not only due to risks of infant methemoglobinemia [14] but owing to the likelihood of nitrosamine formation via nitration of amines normally present in cellular solutions [15] [16] [17]. However, it has not been known to what extent nitrogen contained in growing media may contribute to elevated nitrates in early vegetables.

Regulations drafted by the Organic Crop Improvement Association (OCIA) [18] specifically prescribe growing media to be employed for organic production. We expect other certification programs to do the same. However, we know of very few commercial growing media which claim to be organic.

Our objective was to research growing media with particular reference to achieving acceptable growth rates with nutrients provided from organic sources. We present data on composition of a variety of commercially available growing media and perform seedling trials comparing their performance against that of a model organic medium developed in the course of the research.

2. Materials and Methods

2.1 **Samples:** Commercial potting mixes were randomly purchased at market places in New England or shipped from Europe and are listed in Table 1. Samples of black peat (Terre Noire) and sphagnum were acquired through Fafard (Springfield,MA) or Agway (Syracuse, NY). Materials used to prepare model potting mixes included dried kelp meal*, sieved, dried compost**, fresh farmyard compost (Woods End Laboratory) and Lee dolomitic limestone (from Lee, Mass).

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* Sea Min Dried Seaweed, Organic Sea Products, San Francisco, CA

** Erth-Rite from Zook and Ranck Co., Gap PA

2.2 **Comparative Analyses:** Samples of commercial potting mixes are analyzed for physicial and nutrient traits. Bulk density was determined for fresh (as-is) and dried, ground samples. pH was measured in fresh samples in a 1:2 sample:water ratio. Conductivity was measured on a saturation paste. Dried samples were ground in a Wiley mill and extracted by shaking 20 minutes in neutral N/10 LiAc and analysed for nutrient ions by high-performance liquid chromatography (Wescan Instruments, Santa Clara, Ca).

2.3 **Sample Trials:** In order to assess nitrogen influences on growing seedlings we took potting mixes of varying available nitrogen content and performed replicated growing trials with 6 cultivars (wheat, lettuce, kale, brocolli, spinach, tomato) over a period of 15-60 days after planting. All trials were conducted by placing the growing medium into Speedlings (type #72) or preformed soil-blocks [19] having a volume of 70-80cc. The volume of a peat-nutrient plug will significantly affect plant tissue values and was held relatively constant. We investigated traits of basic peat admixtures with similar growing trials of black and white peats with and without limestone and added compost and seaweed. Finally, we performed a comparative growing trial of the commercial growing media tested here using wheat, bib lettuce and broccoli.

3. RESULTS

3.1 **Sample Analyses:** In Tables 1 and 2 we present analytical data on the commercial potting mixes we evaluated. There was considerable variation in most attributes. Initial moisture ranged from 10-80% and significantly affected wettability (r^2= .55**). pH did not vary appreciably, but values of 5.2-5.3 are considered low for starting seedlings. We observed a significant negative correlation of pH to nitrate (r= -0.77**), probably indicative of addition of the acid nitrate salt. The bulk densities varied by 30 to 50% between 0.1 to 0.5 g/cc (6-30 lb/bu) for both wet and dry materials. Samples consisting principally of sphagnum and/or perlite gave the lower values.

Conductivity (salt) levels are within tolerance although our experimental blend with seaweed is high. Conductivity levels correlate with sodium and potassium (r=0.86*** and r=0.85**, resp.) and potassium with chloride (r=0.81**) probably owing to KCl additions to the peats. However, conductivity levels of 0.5 or less, encountered in two samples, may indicate lack of sufficient nutrients for rapid early growth.

With regard to available nutrient levels (Table 2) there is tremendous variation between the different samples. Nitrate-N levels range between 12 and 3100 ppm and ammonium-N between 1 and 1750 ppm. In atleast half the samples the ratio of potassium to available-N (NO_3-N + NH_4-N) is low and may lead to legginess and reduced stem strength. In soils, ratios less than 1.0 would be regarded as extremely unusual.

Nutrient levels based on weight (ppm) in potting mixes can not be directly compared with soil values due to density/weight differences. However, presenting nutrient values in terms of weight per unit volume (e.g., mg/liter) is roughly comparable to soil ppm values (mg/kg). In Table 3 we added a column for total available-N in terms of mg/liter, yielding a variation between 6 and 711 mg/l. Values over 200mg/l N are probably unecessarily high, and levels over 350 mg/l are considered excessive for all crops grown in peat-based media [20]. The widely recognized Cornell Peat-Lite mixes are based on achieving soluble N levels of around 120 mg/l [21].

A seedling transplanted in a peat-block containing high levels of nutrients will continue to grow on them until the level of nutrients in the plug are equal to or less than that in the surrounding soil. Therefore, plant nitrate concentration may be high even after transplanting to the field. It depends on a variety of factors, notably size of peat block, moisture regime and age at harvest.

3.2 **Correlations between Potting Mix and Plant Nitrate** We attempted to correlate plant nitrate levels for varying cultivars raised in potting-mixes at four levels of soluble nitrogen concentrations (25-95-600-1000ppm). Simple correlation analysis of pooled plant-nitrate levels at 30 days of growth with potting mix nitrate content gave a correlation of $r^2=0.72^{***}$. The regression slope indicated that for each 100 ppm increase in potting-medium nitrate plant nitrate increased by approximately 1000 ppm (see Figure 1.) Since plant nitrate concentrations decrease as dry matter accumulates, we correlated nitrate with age with significant results (pooling cultivar data gave $r= -0.50^{***}$). A multiple regression for all cultivars of plant nitrate on soil nitrate and age therefore gave a highly significant correlation of $r=0.81^{***}$:

$$y[\text{plant } NO_3\text{-N,ppm}] = 7X_i - 136X_{ii} + 488 \qquad [1]$$

where: X_i is soil NO_3-N (ppm dm) and X_{ii} is age in days

Thus we calculate that for each day of growth between 15 and 60 days, all other factors being equal, mean tissue nitrate concentration falls by 140-190 ppm.

However, potting mixes containing nitrate-N concentrations greater than 1000 ppm (about 200 mg/l) gave on the average excessive plant nitrate levels (>2500 ppm Nitrate (NO_3-) on a fresh weight basis) up to and beyond 60 days of growth at which point some leafy crops are ready for market. The level of 2500 ppm nitrate fresh weight (565 ppm expressed as NO_3-N) has been selected as a maximum permissable safe level for foodstuffs in Austria and Switzerland [22]. A nitrate tolerance limit for foodstuffs is currently not recognized in the United States.

3.3 **Peat Trials:** In order to appraise intrinsic nutrient contributions, we evaluated seedling behaviour in sphagnum and black sedge peats without and with additions of lime.

Growth in the unlimed peats was unsatisfactory owing to poor root formation, most likely due to direct inhibition from the acidity. The average growth response to liming is of the order of 41%, with the actual variation per cultivar ranging from 42 to 53% (see Fig. 2). Dry yields ranged from 60-85% of that observed with full fertilization, an impressive showing.

Nutrient effects stemming from this trial are described in Table 3. The tissue analyses indicate a positive nitrate, phosphate and potassium effect stemming from the liming. The nitrate effects are much more pronounced with regard to lettuce than with radish, but there are no significant variety differences with other nutrients. The fact that nitrate is more than twice as high where lime was used clearly indicates a biological effect in the peat from raising the pH. Incubation trials performed in the laboratory gave relative carbon releases of 0.4 and 1.0mg CO_2-C gC^{-1} dy^{-1}, respectively for black and sphagnum peats. This corresponds to a nitrogen release of about 6.5-9.3mg kg^{-1} dy^{-1}, or about 180-279 mg/kg (22-53 mg/l) respectively over 30 days if a constant rate is assumed. The values represent about one-quarter the estimated nitrogen requirement and are therefore not inconsiderable. Incubation estimations of nitrogen release from peats are rarely borne out in actual field data, however[5].

The pronounced potassium effect observed in the limed peat is particularly noteworthy and may be attributed to diminished competition from exchangeable hydrogen. There is little or no exchangeable aluminum in peat.

3.4 **Organic vs Inorganic Peat Mediums:** We prepared two model organic growing media by adding portions of aged compost to limed black and white peats to yield available nitrate levels of 30 and 100 ppm and exchangeable ammonium of 500 and 1000 ppm (OrgLo, OrgHi). These were compared in seedling behaviour with two commercial growing mediums containing significantly greater amounts of nitrates and lesser ammonium-N (see Tables 1 & 2, samples #4 ConvLo and #7 ConvHi). Growth effects for five cultivars are shown in terms dry matter and nutrate content in Figure 3 and Figure 4, respectively.

There were significant cultivar-by-treatment interactions in regard to dry matter yields (see Fig. 3). For example, the higher analysis organic mix did not yield significantly less than the conventional mixes in the lettuce and brassica trials. However, the low organic treatment performed the same as the high organic for wheat and radish, and significantly less than the conventional. With tomatoes the organic mix with extra potash in the form of seaweed significantly out-yielded all others.

There were highly significant differences in nitrate content of plants between treatments, the commercial blends containing several times more nitrate than did the organic mixes (see Fig. 4).

Correlations of nitrate content in the growing medium with that of yields were significant for radish, rape and wheat but not for lettuce or tomatoes. In fact, seedling tomato yields correlated significantly with growing-medium potassium. Visual ranking of tomato seedling quality by a panel of judges correlated very significantly with tissue potassium (r^2=0.73***). By subsequent correlation with growing-medium potassium, we calculated that best tomato growth is achieved where potassium levels are in the range 4000-6000ppm (800-1200 mg/l) in the potting mix. This is higher than what is normally found in most potting mixes (see Table 2).

3.5 **Commercial Mix Trial:** The samples shown in Tables 1-4 were trialed with three cultivars and measures of plant height and plant survivability taken at 12 days after planting. In Figure 5 we show plant height in relation to the mixes (in order #1-#11) and, in Figure 6, per cent surviving seedling (this value integrates germination and damping-off effects).

There were significant differences in seedling behaviour between the mixes. Since our observations were limited we will focus only on the most apparent effects.

Growing medium #3 containing the least nitrogen gave significantly less height gain in lettuce and wheat, and significantly slower germination in lettuce. Two mixes, #9 and #10 gave significant damping-off for lettuce and some for brocolli (the effect is observable in figure 7) but damping off was also observed in #6 for lettuce and #8 for broccolli. We can not rule put the possibility that fungal infection spread by contact across the Speedling or soil-blocks, as eventually lettuce samples in media #6-#10 had succumbed seriously to damping-off. However, despite close proximity to these other media no damping off was observed in our organic mix (GRT,#11), which is not sterilized. Compost materials can confer infection resistance upon growing media [23].

Many of the growing media gave excessively leggy growth for lettuce and broccoli, so that height measures alone are unfairly biased. A more moderate growth effect may be what growers select for. Towards this interpretation, lines indicating averages are drawn through the figures. Thus, samples falling close to, or considering the high mean, slightly below the line would be considered acceptable. The organic mix falls in the average to slightly below average category. Thus, it seems possible to achieve fairly good growth in organic mixes of lesser nitrogen status than many commercial blends.

4. Organic Materials as source of nutrients

We gathered pertinent data from these studies to arrive at estimated ideal levels of nitrates, ammonium and potassium. Clearly, however, natural materials such as compost and seaweeds do not carry one nutrient to the exclusion of others, thus the task of providing desired nutrient levels is made more difficult.

Using a spreadsheet analysis scheme we are able to perform projections for potting-mix bulk density, conductivity and soluble nutrient levels based on any combination of ingredients. This method has served to indicate problems in formulating organic blends.

For example, compost generally could not be added to give enough nitrate or potassium without contributing too much in undesired salts (sodium, ammonium). By the same token, most composts gave too much ammonium in relation to nitrate, the latter being hard to find in any quantity in microbilogically active organic materials. Similarly, we found we could improve wettability by addition of sand or basalt meal, but undesired density changes outweighed the favorable effects. Finally, many powdered seaweeds could not be added as a potash source without providing too much sodium and chloride.

In Table 4 we summarize our findings by indicating a variable, its desired level in the mix, and a probable source. Specific mix ratios must be determined at the moment based on actual analysis of each ingredient.

5. Discussion

A narrative on this process of developing a natural growing medium has been presented elsewhere [24]. The research trials here with a variety of commercial blends have indicated that admixtures of peat and compost and other natural ingredients can give reasonable growth for a number of cultivars. Correlations of yields and nitrate-content with that of mix composition have indicated a reasonable range principally for nitrogen and potassium, and it is possible to achieve this with ripened composts and seaweed powder.

Difficulties inherent in preparing organic mixes consist in lack of control of nutrient content in source ingredients. Ripened compost can be viewed as a soluble nitrogen source, provided it has been kept well aerated, and some other additive (e.g. seaweed meal) sought as a potassium source. Ample phosphorus is present in any the above ingredients. White and black peats should be blended since black peats, though more expensive, are not as hydrophobic as sphagnums. It is felt that addition of small amounts of soils, sand or rock powder are unnecessary though probably not harmful. Finally, we have experienced no problems with damping-off provided compost of known aerobic history is selected.

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Table 1. Selected Potting-Mix Attributes

ID #	sample name	Principal Composition	scale of wetting	initial Moisture	density g/cc	salts-mmhos/cm
1	Peter's	Sp, Vm, Cx	(3)	64.7	0.18	1.2
2	Baccto	BP, Wd, Pt, Sn	(4)	55.2	0.48	0.5
3	Jungle	Cp, Wd, St	(6)	42.0	0.44	0.4
4	Levington	BP, Sp	(4)	56.7	0.31	1.8
5	ASB	Sp	(1)	79.1	0.12	1.3
6	Fafard	Sp, Vm, Pt	(4)	10.7	0.14	0.8
7	Shamrock	BP, Sp	(5)	44.5	0.21	2.1
8	Pro-Mix	Sp, Vm, Pt	(6)	20.7	0.19	0.5
9	Canada Pro	Sp	(2)	73.1	0.15	1.0
10	Magic Soil	Sp, Pt	(3)	66.2	0.17	1.1
11	Green River	Bp, Sp, Cp	(6)	40.0	0.25	3.3

KEY:
wetting scale (1-6): 1=fastest; 6=slowest
Ingredient codes:
Sp- Sphagnum
BP- Black sedge peat
Cp- Compost
Vm- Vermiculite
Pt- Perlite
Wd- wood chips
Cx- charcoal
St- styrofoam

Table 2. Potting Mix Nutrient Analysis

Sample Name	pH	ppm NO3-N	ppm NH4-N	mg/l avail-N	ppm Cl	ppm P	ppm K	ppm Ca	ppm Mg	ppm Na	ratio K/N
Peters	6.2	201	575	139	347	99	1270	3000	865	181	1.6
Baccto	5.7	370	60	206	346	72	380	1753	506	42	0.8
Jungle	6.0	12	1	6	485	56	942	1021	295	157	68.8
Leving	5.3	2268	27	711	595	396	1660	3740	1080	203	0.7
ASB	5.2	2677	250	351	1797	297	3046	5790	1672	372	1.0
Fafard	5.5	1409	87	209	277	96	440	2365	683	194	0.2
Shamroc	5.5	3102	136	680	456	705	2140	3615	1044	420	0.6
Promix	5.8	875	270	217	248	317	480	2250	651	250	0.4
CanPro	5.7	1046	1250	344	1511	341	1880	2230	644	286	0.8
MagicS	5.6	1149	1750	492	1916	223	3500	2125	614	250	1.2
GRT	6.3	781	221	360	1953	144	7200	2651	766	1546	7.1
MIN:	5.2	12	1	6	248	56	380	1021	295	42	0.2
MAX:	6.3	3102	1750	711	1953	705	7200	5790	1672	1546	68.8
MEAN:	5.71	1263	421	338	903	250	2085	2776	802	355	7.6
SD:	0.35	1017	568	219	722	193	1987	1268	366	408	20.4

-Woods End Laboratory data

Table 3. Plant nutrient levels as influenced by peat treatment

	ppm dry basis			
Variety/	Nitrate-N	Amine-N*	Phosphate(P)	Potassium (K)
Radish:				
1. Sphagnum	186	2988	9873	5763
2. Black	183	3307	7559	4291
3. wh + bl	210	3443	10411	5844
4. (3) Limed	256	1955	12760	33124
Lettuce:				
1. Sphagnum	150	1758	8413	7410
2. Black	108	1641	11176	5546
3. wh + bl	129	1630	10716	6693
4. (3) Limed	510	1541	18366	37623
MEAN EFFECTS AND SIGNIFICANCE:				
1. SPHAGNUM	168 b#	2373 a	9143 c	6587 b
2. BLACK	146 b	2474 a	9368 c	4919 c
3. WH + BL	170 b	2537 a	10564 b	6268 b
4. LIMED	383 a	1748 a	15563 a	35374 a

* Amine-N = soluble tissue NH_2-N + NH_3-N

\# values followed by the same letter do not differ at the $p<=0.05$ level.

Table 4. Recommended Nutrient Levels and Sources for Organic Media

Variable	desired	source-comments
density	.15-.25g/cc	Black + White peat & compost
pH	6.0-6.2	Dolomitic lime @ ca. 2-3% peat weight
nitrate	100-150mg/l	well-oxidized compost or black-dirt
ammonium	200-250mg/l	compost, dried manure
potassium	800-1000mg/l	seaweed & compost
wetting	-	compost, black dirt, Valeriana officianalis extract[24]

Fig. 1. Tissue vs Potting Mix Nitrate

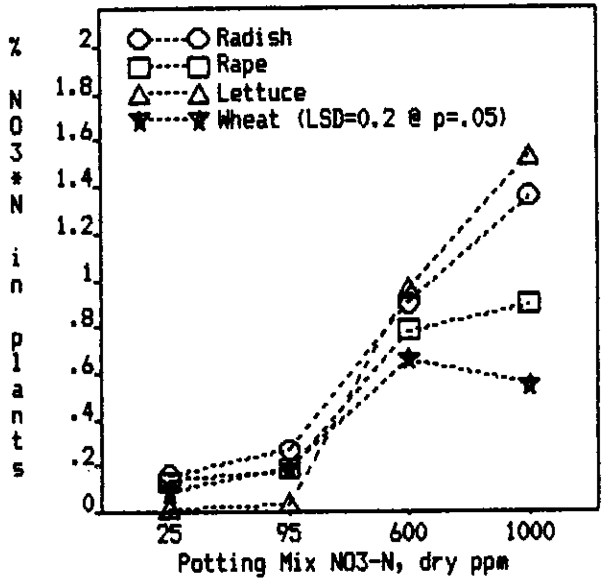

Fig. 2. PEAT EFFECTS ON SEEDLINGS

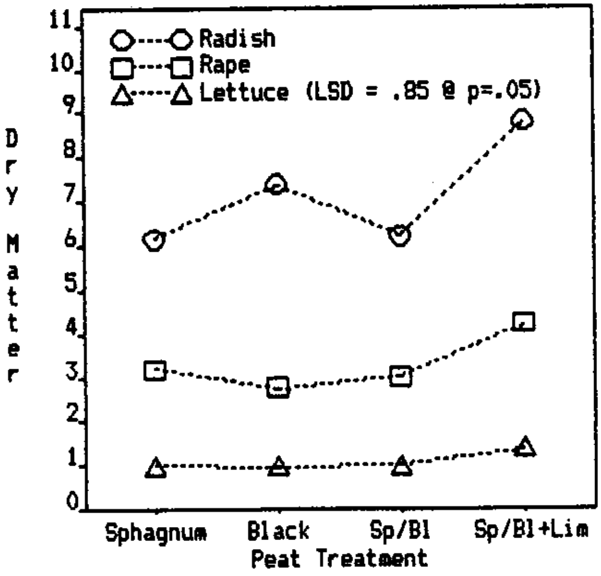

Fig. 3. POTTING MIX EFFECTS ON SEEDLINGS

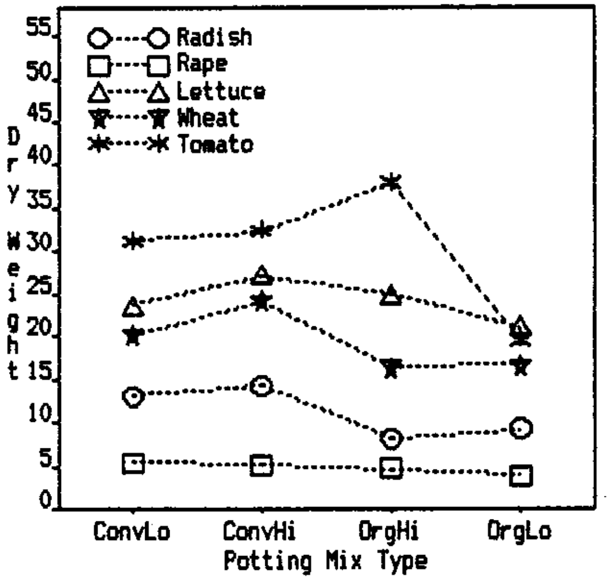

Fig. 4. POTTING MIX EFFECTS ON NITRATE

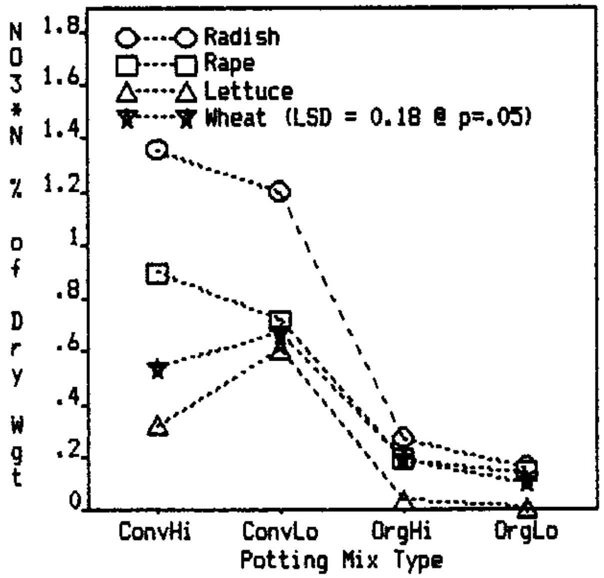

Fig. 5. Effects of Mix on Seedling Growth

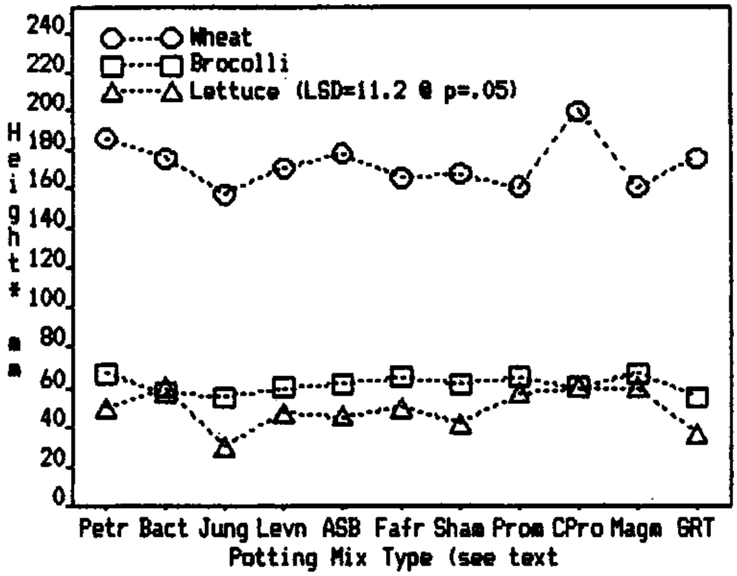

Fig. 6. Effects of Mix on Seedling Germination

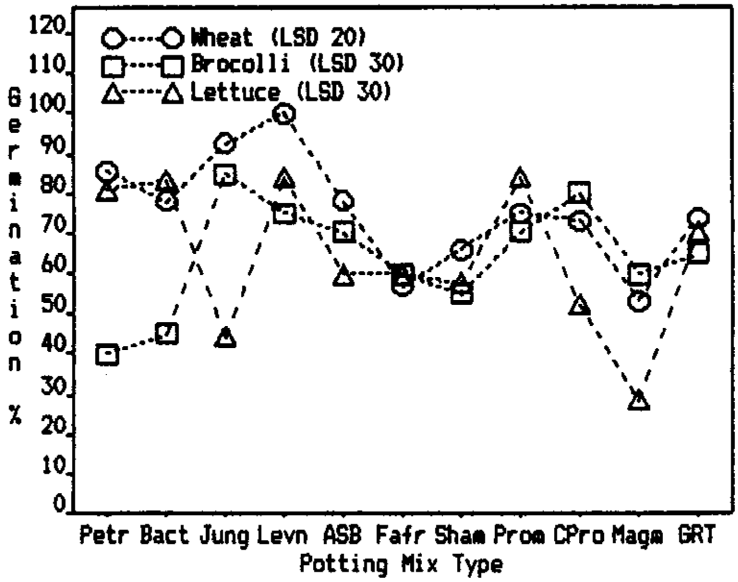

Fig. 7. Effects of Mix on Seedling Germination