EFFECT OF APOLLO 16 LUNAR FINES AND TERRESTRIAL SOILS ON THE GROWTH OF CORN PLANTS. F. J. Shay, R. R. Baker, W. L. Lindsay, and P. L. G. Vlek. Colorado State University, Fort Collins, Colorado 80521.

Several authors (1, 2, 3, 4) report that lunar material added to a hydroponic culture increases plant growth, yet no unusual element or microbe has been discovered to which this response can be ascribed. The minerals identified in lunar rocks and soils are to a large extent those found in abundance on earth.

Walkinshaw and Johnson (2) reported the elemental composition of vegetable seedlings (broccoli, brussel sprouts, cabbage, carrot, lettuce, and radish) grown on a hydroponic solution (Hoagland) to which Apollo 14 Lunar fines, terrestrial fines, or no solid phase were added. Differences were found in the Al, Fe, and Ti content of the tissues between the pure hydroponic and soil treated cultures. Other elements such as K, Ca, Na, Mg, B, Cu, Zn, Ni, and Co were not significantly different from the control.

Weete and Walkinshaw (4) reported increased pigmentation (21-35%) of tobacco tissue cultures grown on White's medium when lunar (Apollo 12) or terrestrial material was added. Silverman _et al_. (1) demonstrated that pigment formation in _Serratia marcesens_ and _Pseudomonas aeruginosa_ was increased by the addition of lunar material to various agar media, but the effect of terrestrial material was not determined. The addition of mono-salt solutions of either Fe(II) or Fe(III) gave similar effects.

The importance of Fe, Zn, Mn, Cu, and Mg in the formation of chlorophyll is well known. For this reason studies were done to compare the release of available nutrients from lunar and terrestrial fines of similar mineral composition. Other studies attempted to duplicate the reported growth response of plants exposed to lunar soil and to compare that response with the response of plants exposed to terrestrial soils or pure hydroponic solutions.

Corn plants (_Zea mays_ L. var. Japonica) were surface sterilized and grown in complete Hoagland solution plus minor elements with 3×10^{-5}M FeEDTA as the iron source. After germination the plants were asceptically transferred to sterile gnotobiotic isolators and grown in the nutrient solution for 2 weeks. Plants were then selected for uniformity and transferred to individual jars of sterile nutrient solution (200 ml/jar) and treated. The treated plants were grown for two weeks then harvested, weighed, and analyzed for Fe, Zn, Mn, and Cu uptake. The treatments consisted of pure hydroponic solution, solution plus lunar fines (67011.3), solution plus Hawaiian Basalt [simulated lunar fines, (2)], or solution plus Iowa soil. Two dose levels were used for the soil amended solutions. One set of replicates received 0.2g of soil/plant which was the level used by other investigators previously mentioned and a second set received 0.4g/plant to determine if dose level had any affect of the plant response. The soils were added to the growth solutions at the time of plant transfer.

The effects of the addition of the terrestrial soils and lunar fine on plant growth and the uptake of Fe, Zn, Mn, and Cu are presented in Table 1. After treatment with 0.2g/plant of either Lunar, Iowa, or Hawaiian Basalt no significant effect on shoot or root dry weight was observed. This is in conflict with the data reported by previous investigators (2, 3). At the

EFFECT OF LUNAR FINES ON PLANT GROWTH

Shay, F. J. et al.

0.4g/plant treatment level the addition of terrestrial soils or lunar fines caused a significant increase in the dry weight of both the shoots and roots when compared to plants grown in pure hydroponic solutions. The increase in dry weight was not significantly different between the terrestrial and lunar soils. Thus the response of the plants to lunar soil was similar to the response of the plants to terrestrial soils which is also in conflict with the implied conclusions of several authors (2, 3). Along with the dry weight increase at the 0.4g/plant treatment level, an increase in the uptake of Fe, Zn, and Mn was noted. On this basis we concluded that the response of the plants to both the terrestrial and lunar fines was due to the soils serving as a mineral nutrient supplement for the hydroponic solution. We believe that the conflict in our data and the data previously reported can also be resolved on the basis of the soil acting to supplement the nutrient solutions.

It is not possible to determine from the papers of Walkinshaw and his co-workers (2, 3) whether trace elements were used in their nutrient solutions. If left out, the 0.2g lunar sample/plant treatment could have partially supplied these essential trace elements increasing growth over non-treated controls. One report (2) stated that increased plant weight and height occurred in plants treated with lunar soils yet an examination of the data reveals that the greatest growth occurred in the non-treated plants for two of the six species studied.

We believe that trace nutrient elements are released by lunar and terrestrial soils and that at the higher soil dose levels sufficient quantities of Fe, Zn, and Mn and possibly several other elements are released to supplement the nutrient solution and cause an increase in plant growth. The effect then is one of mineral nutrient supplementation which occurs when either lunar or terrestrial soils are added to hydroponic solutions. This indicates that the hydroponic solutions were not nutritionally optimal for plant growth. The fact that Hoagland's solution is not an optimum solution for the growth of all plant species is well documented in the literature. The differences in the nutrient requirements for each species and the adequacy of Hoagland's solution in supplying these nutrients at the proper quantity would dictate the type and level of growth response observed after the addition of soil to the solution. This would explain the fact that the type and degree of growth response of plants after addition of lunar soil was different depending upon the species exposed to the soil (2, 3). This viewpoint of mineral nutrient supplementation by the soils is supported by the work of Silverman (1) in which the response of bacteria to lunar soil was duplicated by the addition of mono-salts of Fe(II) and Fe(III) to the culture media.

EFFECT OF LUNAR FINES ON PLANT GROWTH

Shay, F. J. et al.

Table 1.
Effect of Lunar Fines, Hawaiian Basalt, and Iowa Soil in complete sterile nutrient solutions for the growth of corn.

Treatment	Dry weight (mg) Shoot	Dry weight (mg) Root	Fe Uptake ug/plant	Zn Uptake ug/plant	Mn Uptake ug/plant	Cu Uptake ug/plant
No Soil	201a*	63a	18.9	20.5	21.5	3.4
Basalt						
0.2g	217a	66a	22.6	20.4	21.0	2.8
0.4g	260b	100b	21.6	27.8	26.3	3.4
Iowa						
0.2g	203a	78a	22.5	19.7	26.2	2.8
0.4g	240b	98b	28.1	25.4	36.7	2.9
Lunar						
0.2g	200a	78a	22.2	17.8	20.4	2.6
0.4g	292b	118b	27.2	23.1	28.6	2.9

*/ Average of five replicates. Dry weights followed by different lowercase letters are significant at the 90% probability.

REFERENCES

1. Silverman, M. P., E. F. Munoz and V. I. Oyama. 1971. Effect of Apollo 11 lunar samples on terrestrial organisms. Nature, 230:169-170.
2. Walkinshaw, H. C., and P. H. Johnson. 1971. Analysis of vegetable seedlings grown in contact with Apollo 14 lunar surface fines. Hort Sci. 6:5320535.
3. Walkinshaw, C. H., H. C. Sweet, S. Venketeswaran, and W. H. Horne. 1971. Results of Apollo 11 and 12 quarantine studies on plants. Biosci. 20:1297-1302.
4. Weete, J. D. and C. H. Walkinshaw. 1972. Apollo 12 lunar material: effects on plant pigments. Can. J. Bot. 50:101-104.