TECHNICAL PAPERS

Essentiality of Calcium in the Nutrition of Fungi

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Much of the data on the calcium and other mineral requirements of the fungi are, as is well known, of doubtful value. Compounds of unknown purity in nutrient solutions of haphazard and unstudied proportions and concentrations are the rule and not the exception. Conclusions concerning indispensability of chemical elements, based on growth levels well within the range of extreme starvation, have been made and even generally accepted. Nevertheless, it would appear certain that one fungus, *Aspergillus niger* van Tiegh., can attain maximum growth and development with a minimal salt solution containing only very faint spectroscopic traces of calcium (*1, 3*).

TABLE 1
Effect of Omission of Calcium on Growth of Fungi

Fungus	Control (mg)	Yield without calcium (%)
Aspergillus niger van Tiegh.	1,250.0	100.0
Rhizoctonia solani Kuehn	1,215.1	14.3
Sclerotium rolfsii Sacc.	1,082.3	49.5
Cercospora nicotianae Ell. & Ev.	1,380.2	90.1*
Fusarium oxysporum Schlecht var. *nicotianae* J. Johnson	823.3	100.0
Pythium irregulare Buis.	459.0	60.1*
Thielaviopsis basicola (Berk. & Br.) Ferr.	364.2	82.0*

* Asparagine of unknown purity.

Studies by the writer on the nutrient requirements of the fungi pathogenic to the tobacco plant have been under way for some time under conditions identical with those employed with *Aspergillus*. The experimental technique includes the exclusive use of quartzware, triply distilled water, sucrose of 0.00087% ash, and either selected reagent grade or spectroscopically pure salts and spectroscopically pure micronutrients. All salts (NH_4NO_3, K_2HPO_4, $MgSO_4 \cdot 7H_2O$, asparagine) were used in minimal quantities sufficient for maximum yields with 50 ml of a 5% sucrose solution. The macronutrients therefore included were C, H, O, N, K, P, Mg, and S. Micronutrients comprised Fe, Zn, Cu, Mn, Mo, and Ga, also in minimal quantity sufficient for maximum yield.

Since subsidiary problems that have arisen and other factors may delay publication perhaps indefinitely, it was considered desirable to make a preliminary report of the results so far obtained with calcium. These are briefly summarized in Table 1.

Omission of calcium from the solution caused maximum decreases in yield with *Rhizoctonia*. Of a total of 15 trace elements investigated, none could replace calcium in the nutrition of *Rhizoctonia*. In addition, only strontium, but not barium, gave partial replacement (*4*) of calcium sufficing for approximately 50% growth. The otherwise spectroscopically pure strontium chloride used contained a very slight trace of calcium.

The quantities of calcium required for maximum yields with these fungi ranged from 2 to 6 ppm, whereas the minimum quantity of magnesium needed (*Rhizoctonia*) was 14 ppm. Calcium, therefore, might be considered a micronutrient instead of a macronutrient in the nutrition of fungi, except that it would appear more logical to continue to limit use of "micronutrient" only to those trace elements discovered to be biologically essential for growth.

According to these data, the causes for pathogenicity would appear to be dissociated from mineral requirements. *Rhizoctonia* and *Fusarium* are plant parasites of widespread occurrence, but the former appears to require calcium, whereas the latter does not. *Aspergillus*, a typical saprophyte, behaves like *Fusarium* in this respect. In other respects the mineral requirements of these fungi are almost identical.

As will be noted four of these fungi gave yields (dry weight, 103—5° C) ranging from about 50 to 55% of the sucrose supplied. This is also the approximate percentage yield of yeast in aerated culture. It is probable, therefore, that utilization factors of this magnitude are indicative of optimum nutrition, and lower values, of starvation and possible abnormality.

Since it is generally accepted that cellular nutrition is basically quite similar in all types of organisms, these results again lend emphasis to a question of fundamental importance. Can the protoplasm of organisms able to dispense with calcium, cobalt, molybdenum, chlorine, iodine, or boron carry out all basic biochemical reactions identically? That is, are these "optional" indispensable chemical elements employed only for the purpose of supplementing the generally required essential elements in the fundamental reactions of protoplasm, or are these particular elements associated with new biochemical reactions? It is not impossible, however, that a marked increase (*i.e.* to 1 part per billion) in the present level of purity in nutrition studies will reveal a greater degree of uniformity (*2*) in mineral requirements for all organisms.

References

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