temperature and is greatest for a poor blanket and a high room temperature, as the rate of flow of heat into the refrigerator is then the greatest and the compressor has to work most often.

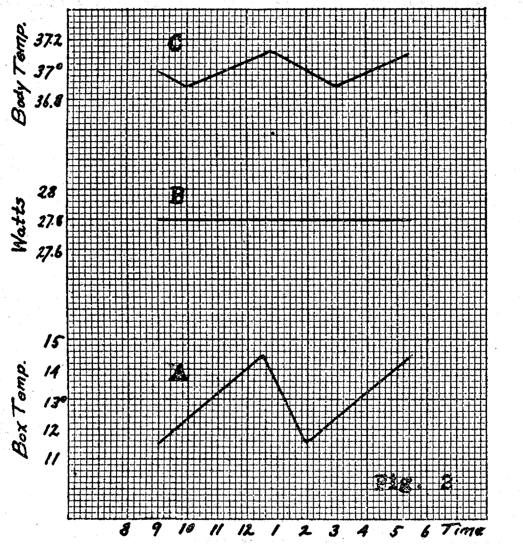

Fig. 2

Fig. 2 shows plots of readings obtained in the test of a good cotton blanket. Curve A shows the variation of the box temperature with time; curve B the power supplied to the body, and curve C the resulting temperatures of the body. The power in watts supplied to the body when its average temperature is 37° while the average temperature of the box is 13° is a measure of the heat-insulating property of the blanket under test. It may be mentioned here that the power supplied to the stirring device is insignificantly small.

Inasmuch as the number of watts which have to be supplied to the body is least for the best blanket it seemed desirable to obtain a measure which was numerically greater for the better insulator. This was done by determining the watts needed when the body was covered with only a cotton sheet in place of a blanket and using as the measure the difference between this value and that for a given blanket. This difference, of course, is greatest for the best blanket.

Knowing the area of the covering and the power supplied, it is possible to compute the energy in B. T. U. which passes through ten square feet of any blanket in eight hours. This I have adopted as my unit in blanket testing. An interesting result obtained was that a single thickness of heavily napped cotton blanket gave 2,730 of these units, which corresponds to the heat value of about two thirds of a pound of lean beef.

M. F. Weinrich

Department of Physics,
Columbia University

SPECIAL ARTICLES

THE EFFECT OF COLLOIDAL SILICA ON THE ABSORPTION OF PHOSPHORIC ACID BY PLANTS

Replying to a criticism of Fisher[1] concerning the interpretation of the effect of sodium silicate in increasing the assimilation of phosphoric acid by barley in the Rothamsted field experiments, Hall[2] suggests that an explanation of the phenomenon may be sought in the colloidal behavior of the sodium silicate in accordance with the theory advanced by Comber.[3] The latter maintains that the soil colloids play an important rôle by being directly absorbed by plants through the formation of a one phase system between the colloidal coating of the plant root hairs and the colloidal coating of the soil particles. This proposed modification[3] of present views by Comber,[3] however, has been critically discussed by the writer,[4] who has shown that the weight of existing evidence does not support the theory of the absorption of colloids by plants.

There is ample evidence,[5,6,7,8] moreover, to disprove the view that silica may act as a substitute for phosphoric acid in the metabolic processes—it is not "phosphorsäuresparend"; nor can the view[9] that the observed effect is due to the improvement in the physical condition of the soil withstand critical investigation.[10] Relative to the alternative explanations presented by Hall and Morison,[7] certain authorities[1,6,8] have concluded from the increased quantity of phosphoric acid per dry weight of the crop that the beneficial effect of silica is due to the increased availability resulting from an increase in the quan-

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[1] R. A. Fisher, *Jour. Agr. Sci.*, 19: 132–139, 1929.

[2] A. D. Hall, *Jour. Agr. Sci.*, 19: 586–588, 1929.

[3] Norman M. Comber, *Jour. Agr. Sci.*, 12: 363–369, 1922.

[4] Walter Thomas, *Soil Sci.*, 27: 249–270, 1929.

[5] Wl. S. Butkewitsch and W. W. Butkewitsch, *Biochem. Ztschr.*, 161: 468–487, 1925.

[6] P. L. Gile and J. G. Smith, *Jour. Agr. Res.*, 31: 247–260, 1925.

[7] A. D. Hall and C. G. T. Morison, *Proc. Roy. Soc.*, B-77: 455–477, 1906.

[8] O. Lemmermann, H. Wiessmann and K. Sammet, *Ztschr. Pflanzenernähr. u. Düngung*, 4A: 265–315, 1925.

[9] Fr. Duchon, *Ztschr. Pflanzenernähr. u. Düngung*, 4A: 316–325, 1925.

[10] O. Lemmermann, *Ztschr. Pflanzenernähr. u. Düngung*, 4A: 326–330, 1925.

tity of phosphoric acid in the soil solution. Gile and Smith[6] and also Lemmermann[8] concluded that this action is a solvent one on the soil phosphates. The former[6] substantiate their conclusions from experiments (albeit *in vitro*) which showed a greater solubility of rock phosphate in the presence of silica gel, whereas the latter[8] recognizes that the explanation just advanced is incomplete. The fact, however, that plants can thrive in extremely dilute solutions of phosphate ion if the supply is maintained[11,12] even as low as 0.25 p.p.m.[13] proves that the solvent effect of silica on soil phosphates, as suggested by these investigators, is a negligible factor compared with the other more powerful solvent forces present.

The seat of action ultimately must be in the plant itself,[7] for the absorption of ions by the plant is conditioned by the equilibrium conditions prevailing in the interface of the system composed of the ions in the plasma membrane of the root hairs and the ions of the soil solution. Now, in a system containing a non-diffusible ion—$SiO_3^=$ in the case under discussion—a marked effect is exerted on the distribution of diffusible ions on either side of the cell membrane. A non-diffusible electro-negative ion, such as a colloid micelle,[4] will produce a greater concentration of diffusible electro-negative ions and a lower concentration of electro-positive ions on its own side of the membrane than on the other. A non-diffusible electro-positive ion will produce the opposite effect. According to the Gibbs-Donnan distribution law[14,15] at equilibrium the product of the concentrations of each pair of oppositely charged diffusible ions is the same on both sides of the membrane. Hence, in the system under consideration if x and y represent the molar concentrations of the diffusible H and PO_4 ions, respectively, on each side of the interface considered, and z the concentration of the non-diffusible SiO_3 ions, then, according to the Donnan principle, displacement of the diffusible ions takes place in such a way that at equilibrium $x = y(y + z)$. It follows that the greater the concentration of non-diffusible anions ($SiO_3^=$) present, the greater must be the absorption of diffusible anions ($PO_4^{\equiv}$) into the cell. The equation also shows that x and y are equal only when $z = 0$. Practically, there is a limit to the amount of silica that might be added, because of the coating of the root hairs and other factors.[5] Obviously, the Donnan effect will be restricted by the presence of diffusible $xSiO_2 \cdot yH_2O$ ions, some of which will be present in the solution.[4]

The experiments of Butkewitsch and Butkewitsch[5] with collodion membranes and also with maize plants grown in Pfeiffer's nutrient solution with and without phosphoric acid to which different amounts of silicic acid were added afford the first experimental evidence in support of the interpretation just submitted.

It is realized that the Gibbs-Donnan distribution law may not suffice to explain all the facts connected with the absorption of ions from the soil solution by the plasma membrane of the root hairs of plants, for the Donnan principle applies to free ions only. From Wright's investigations[16] on the secretion of the high amounts of calcium in milk from the relatively low concentrations of this element in the blood plasma, it is apparent that the degree of dissociation of the protein salts must be taken into consideration also, since these ions are present in the cell in addition to those which entered to satisfy the product equation. The plant cell is a polyphase system; from this starting-point Briggs and Petrie[17] have deduced that the apparent internal ionic product resulting from the collective effect of all the phases within the tissue in this polyphase system must have a higher value than that of the external medium. It must be kept in mind, however, that deductions from experiments[17,18,19] in isolated tissues or cells of plants, although supplying valuable information, may not necessarily conform to the behavior of the plant as a whole. Herein, from the plant physiology standpoint, lies the value of the type of experiments carried out by Butkewitsch and Butkewitsch.[5]

It remains only to be pointed out that in the Rothamsted experiments sodium silicate, a salt showing a strong tendency to hydrolyze, was used, whereas in the other experiments cited in this paper the silica was added in the form of silicic acid gel. The effect, therefore, of hydrogen-ion concentration on the mobility of ionic pairs must also be considered.[20,21]

WALTER THOMAS

DEPARTMENT OF AGRICULTURAL
AND BIOLOGICAL CHEMISTRY,
PENNSYLVANIA STATE COLLEGE

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