AVAILABILITY OF MINERAL PHOSPHATES FOR PLANT NUTRITION, VOL. VI, NO. 13, JUNE 26, 1916, PP. 485-514

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649194698

Availability of mineral phosphates for plant nutrition, Vol. VI, No. 13, June 26, 1916, pp. 485-514 by William Leonidas Burlison

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

www.triestepublishing.com

WILLIAM LEONIDAS BURLISON

AVAILABILITY OF MINERAL PHOSPHATES FOR PLANT NUTRITION, VOL. VI, NO. 13, JUNE 26, 1916, PP. 485-514

Trieste

AVAILABILITY OF MINERAL PHOSPHATES FOR PLANT NUTRITION

BY

WILLIAM LEONIDAS BURLISON

B.S. Agricultural and Mechanical College
of Oklahoma 1905

M.S. University of Illinois 1908

THESIS

Submitted in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

IN AGRONOMY

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1915

CONTENTS

AVAILABILITY OF MINERAL PHOSPHATES FOR PLANT NUTRITION [1]

By W. L. BURLISON,

Associate Professor, Crop Production, Agricultural College, and Associate Chief, Crop Production, Illinois Agricultural Experiment Station [2]

INTRODUCTION

Phosphorus is the key to permanent systems of agriculture for a large portion of the common soils of the corn belt. These soils contain, as an average, 5,000 pounds of nitrogen, 1,200 pounds of phosphorus, and 35,000 pounds of potassium for the surface soil to the depth of 6⅔ inches. If the land were producing corn at the rate of 100 bushels per acre, the nitrogen would be sufficient for 50 crops, the phosphorus for 70 crops, and the potassium for about 1,842 crops. The nitrogen supply can be maintained by the growth and judicious management of leguminous crops. Potassium is present in quantities adequate for many years. With phosphorus the problem is different. This element can not be gathered from the soil air by legumes; nor is it one of unlimited supply. When once removed, phosphorus must be returned to the land in crop residues, in farm manures, or in commercial fertilizers which contain phosphorus.

Since the introduction of commercial fertilizers, more or less discussion has been carried on concerning the value of insoluble mineral phosphates as a source of phosphorus for the nutrition of plants. In Europe (28, p. 329)[3] the highest authorities on agricultural problems have discouraged the use of insoluble phosphates, while in America scientists and practical men have disagreed. Investigations which have been conducted on the use of insoluble minerals are by no means conclusive. Therefore it is the purpose of the work reported in the following pages to throw more light on this question, which is of so great economic importance and scientific significance. The subject matter will be presented according to the following divisions:

I. Review of literature regarding the availability of phosphate minerals.

II. The availability of phosphorus in Tennessee brown rock phosphate for wheat (*Triticum vulgare*), oats (*Avena sativa*), rye (*Secale cereale*), barley (*Hordeum sativum hexastichon*), cowpeas (*Vigna catjang*), soybeans (*Glycine hispida*), timothy (*Phleum pratense*), red clover (*Trifolium pratense*), and alfalfa (*Medicago sativa*).

---

[1] This paper is submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Agronomy in the Graduate School of the University of Illinois, 1915.

[2] The author wishes to express his appreciation for the suggestions and encouragement tendered by Dr. C. G. Hopkins and Dr. A. L. Whiting, of the Illinois Experiment Station.

[3] Reference is made by number to "Literature cited," p. 513-514.

Journal of Agricultural Research, Dept. of Agriculture, Washington, D. C.
af

Vol. VI, No. 13
June 26, 1916
Ill.—1

III. A comparative study of the productive powers of six mineral phosphates for farm crops.

IV. The influence of fermenting dextrose and crop residues on the availability of phosphorus in finely ground rock phosphate.

V. The influence of the size of particles on the availability of phosphorus in mineral phosphates.

REVIEW OF LITERATURE

The availability of mineral phosphates for plant nutrition has been under investigation at various institutions for more than half a century. Among the earlier scientists who attempted to determine the availability of the phosphorus in mineral phosphates was Dyer (4), who found that undissolved phosphate produced better returns than dissolved phosphate for swedes and oats. Frear (5) studied the comparative value of various phosphorus carriers for farm crops. Finely ground bone and reverted phosphate produced the largest number of mature stalks of corn, and finely ground bone, the highest yield of ears. Superphosphate and certain mineral or raw phosphates were put in field trials by Johnson (9), and for corn, dissolved bone black was superior to others tested. Bishop (1) grew soybeans in pot cultures and concluded that concentrated phosphate and acid phosphate were more desirable than Florida soft rock and iron and aluminum phosphate. Equivalent amounts of different carriers of phosphate were employed by Hess (7) in a 4-year rotation of corn, oats, wheat, and grass. Finely ground bone gave the highest yields of wheat, with raw rock second. Ground bone was most effective for corn, while for oats insoluble ground bone seemed to be satisfactory. South Carolina rock was very useful for clover. Jordan (10) conducted two experiments at the Maine Station with different forms of phosphate. In the first experiment the minerals were applied in equal quantities. For the first two years the acid phosphate gave the highest returns, but later bone meal took the lead. Raw rock was only about half as productive as the other two. In the second trial equal money values of phosphates were applied; and the author points out that, with but one exception, the raw rock gave larger returns than acid phosphate. The work of Jordan, previously mentioned, was continued by Merrill (15), who used pure sand cultures in the greenhouse. Two facts are clear from Merrill's work. First, plants differ widely in their power to assimilate phosphorus from different phosphates. Second, turnips and rutabagas gave almost as good results with raw rock phosphate as with acid phosphate. Later, at the New York Station, Jordan (11) continued the work which he had begun at the Maine Station. His results are in accord with the work previously reported by himself and Merrill.

In 1890 Goessman (2) outlined what has since become a most extensive investigation, concerning the availability of phosphate minerals. In reporting on this work Brooks says (3, p. 104) that—

> It is possible to produce profitable crops of most kinds by liberal use of natural phosphates, and in a long series of years there might be a considerable money saving in depending, at least in part, upon these rather than upon the higher-priced dissolved phosphates.

Results from a second series of experiments begun in Massachusetts in 1897, along the same line as that outlined by Goessman, indicate that phosphatic slag was "exceedingly available for crops, but the Florida soft phosphate was very inferior. For certain crops, South Carolina rock gave surprisingly good returns * * *."

Prianishnikov (20) states that lupins and peas have a very marked ability to obtain phosphorus from natural phosphate, while wheat and oats must be assisted by the solvent powers of the soil or they can not produce normal crops. Schloessing (22) concludes from his experiments that it is not necessary that phosphate should be in a state of solution, since the roots of plants are able to dissolve the phosphorus compounds without the intervention of water.

Patterson (18) reports results, based on a study of various phosphates, which indicate that reverted phosphate gave the highest average yield for corn, wheat, and hay. South Carolina rock phosphate produced slightly better yields than bone black, and Florida soft rock phosphate was quite available for wheat. Wheeler and Adams (30, 31, 32) found raw phosphate profitable for peas, oats, crimson clover, and Japanese millet when used on unlimed land; but for flat turnips, beets, and cabbage it gave poor yields. They are of the opinion that rock phosphate is likely to be most useful when applied to moist soils rich in organic matter, where legumes, corn, and "possibly wheat and oats are to be grown."

Thorne (24, 25), of Ohio, in 1897 inaugurated a very extensive study of the comparative value of raw rock phosphate and acid phosphate used in conjunction with manure. Where, in computing the yields of corn, wheat, and clover, he took the average of all the unfertilized plots as a basis for comparison, he reports (24, p. 18)—

> By this method of calculation the average increase on Plots 2 [floats plus yard manure] and 3 [floats plus stall manure] combined is found to be practically the same as that on Plots 5 [acid phosphate plus yard manure] and 6 [acid phosphate plus stall manure] combined, but when the larger cost of the acid phosphate is deducted the net gain is a little greater on Plots 2 and 3 [with raw phosphate].

By another method of computing the increase he obtains results less favorable to raw phosphate.

Truog (27) has demonstrated rather clearly that farm crops are variable in their ability to secure phosphorus from different sources. Nine of the ten crops tested by him made a better growth on aluminum phosphate than on calcium phosphate, and "six made better growth on iron phosphate than on calcium phosphate."

Under the direction of Hopkins (8), the Illinois Experiment Station is conducting probably the most extensive investigation of any in the world on the use of rock phosphate. Some of the most interesting results were obtained from a field near Galesburg, Knox County, Ill., on brown silt loam prairie soil.

> Phosphorus applied in fine-ground natural rock phosphate in part as top dressing, and with no adequate provision for decaying organic matter, paid only 47 per cent on the investment as an average of the first three years. But it should be kept in mind that the word *investment* is here used in its proper sense, for the phosphorus that was removed in the increase produced was less than 2 per cent of the amount applied, and that removed in the total crops less than one-third. During the last six years, however, the phosphorus has paid 130 per cent on the investment, even though two-thirds of the application remains to positively enrich the soil (8, p. 15).

Newman (16) investigated the use of floats with and without cottonseed meal. He found a marked increase in availability where organic matter was used in conjunction with the mineral phosphate. Later experiments by Newman and Clayton (17) confirmed the above results. Lupton (13) continued the work of Newman, but used acid phosphate as a check on the raw rock phosphate, both with and without organic matter. His results are also in accord with Newman's earlier experiments. Where floats were mixed with cottonseed meal and allowed to ferment, the data seemed to show that the fermentation of the material had very little, if any, influence on the availability of the phosphate. Pfeiffer and Thurman (19) found no beneficial results from composting raw rock phosphate with decaying organic matter. In Canada (23) fermenting manures were found to have only slightly solvent action on composted rock phosphate.

Hartwell and Pember (6) mixed fresh cow manure and floats and allowed them to ferment. They feel that there was practically no increase in the availability of phosphorus in the floats. McDowell (14) also found no increase in the availability of phosphate in finely ground rock phosphate by composting the mineral with cow and horse manure. Tottingham and Hoffmann (26), following the same line of investigation as that which McDowell observed, actually found a decrease in water-soluble phosphorus, but the results were similar with acid phosphate.

Krober (12) was unable to find any increase in availability of mineral phosphates by composting with sawdust and allowing fermentation to proceed. Truog (27) believes that fermented manure has a slightly solvent action on crude phosphate. He also points out that a uniform distribution of the phosphate in the soil will give much better results than that poorly distributed.

Krober (12) shows that the acid-forming bacteria and yeasts are of great value in rendering some of the phosphorus in insoluble phosphate available. He makes the statement that carbon dioxid was more active than other acids in this respect.

The degree of fineness plays an important part in the availability of the crude phosphates. Jordan (11) proves this quite conclusively. He procured better results from the phosphates which were ground to an impalpable powder. Analysis of the plants showed an increase in the proportion of dry matter to phosphorus as the size of the particles decreased. Voelcker (29) in some of the earliest work says that the efficiency of insoluble calcium phosphate depends upon the minuteness of division; the finer the particles the more energetic will be its action.

EXPERIMENTAL WORK

MEDIUM FOR PLANT GROWTH

Pure white sand was used throughout these experiments as a medium for plant growth. For most of the work this material was leached with a dilute solution of hydrochloric acid for three days to insure the removal of plant food. The sand was then washed with distilled water until there was no trace of acid in the drainage solution. Next it was placed on clean paper until dry, when it was sifted, in order that foreign particles might be removed. Samples were collected for a phosphorus determination from each lot of sand washed, but in no case during the progress of the study was the slightest trace of phosphorus detected.

POTS

Two sizes of pots were used in this investigation. When it was necessary to grow the crop to maturity, the small glass battery jars, approximately 6 inches in diameter and 8 inches in height, proved very satisfactory; but when a grain crop was desired, the 4-gallon stone pots were more suitable. All jars were supplied with adequate drainage.

For the cultures grown in the winter the pots were covered with a coat of black paint, but for the summer series a white coat was placed over the black. The black paint prevented the growth of algæ and the white had a tendency to keep the temperature from becoming excessive within the jars. This precaution was clearly justified, for upon several occasions there was a difference of 5° to 10° in temperature between the black and white pots.

KINDS OF CROPS GROWN

Wheat, oats, rye, barley, timothy, cowpeas, soybeans, clover, and alfalfa—nine common crops that are cultivated on Illinois farms—were grown under various treatments for this investigation. High-grade seed from the previous season's crop was selected for planting, and in all cases the grains were treated with a solution of formalin to prevent smut.